CONSERVATION OF LEATHER
AND TEXTILES FROM THE DEFENCE

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ABSTRACT—The article provides case studies for the conservation of water-logged archaeological leather and textiles. The materials described had been recovered from the underwater archaeological site of the DEFENCE (an American privateer sunk in 1779). Modifications of existing conservation treatments for these materials are described, including the use of oxalic acid to reduce metallic encrustations, the support of leather disruptions, and the use of freeze-drying in the conservation of particularly fragile textiles.

1 INTRODUCTION

THE USE OF FREEZE-DRYING in the preservation of archaeological materials is a technology still being developed. Newly modified treatments have been used with initial success at the Maine State Museum Regional Conservation Center (MSMRCC) for a variety of organic materials recovered from the underwater site of an American privateer, the DEFENCE. Among the materials being treated are wood, leather, and textiles. Some wood is being stabilized using a freeze-drying treatment proposed by Ambrose. Leather and textile treatments also use freeze-drying and some methods and materials proposed by Rosenquist and Geijer. The treatments for leather and textiles now in use at the MSMRCC are outlined here, and in each instance, case studies are presented.

2 A CONSERVATION TREATMENT FOR LEATHER FROM THE DEFENCE

AT THE TIME of recovery from this site, the leather was often soft and flexible; or stiff and inflexible when encrusted with metallic deposits (principally iron). The surface of the leather varied in appearance from smooth and well preserved to worn and disrupted. When severely deteriorated, the leather's surface had been reduced to very fine particles which were powdery when dry. The objective of the conservation treatment presented below was to stabilize and consolidate the leather without sacrificing its natural softness and flexibility, and to restore these qualities to leather which had been encrusted with metallic salts.

3 A CASE STUDY: A SHOE RECOVERED IN NON-ASSEMBLED ASSOCIATED FRAGMENTS

AMONG THE ARTIFACTS recovered during the 1977 DEFENCE field
season was a shoe (ca. 24 cm. long). Even in the cold, thick mud at the wreck site, thread which had originally secured the various shoe parts deteriorated, and the artifact was retrieved in sections.

The “upper” was made from leather comparable in weight (ca. 2 mm. thick) to that found in a modern shoe. Several layers of leather ranging in thickness from 2 to 4 mm. were sewn together into a sole and heel.

Iron staining could be seen on the surface of the leather, and when a section prepared with a freezing microtome (thickness ca. 5 microns) was viewed under magnification (100×), the intrusion of foreign matter into its structure was obvious. In this case, however, the accumulation of metal salts had not become thick enough to severely embrittle the leather.

Before treatment, the shoe parts and their identification numbers (embossed on a Teflon tape or written on a strip of Tyvek) were sewn between two pieces of fine nylon net. This encasement secured the leather fragments and their registration numbers so that they would not be confused or misplaced during treatment. The leather was kept in water at all times prior to treatment. Mold growth was curtailed by recirculating cold water (directly from the tap) through the leather holding tanks on a regularly (daily) basis.

3.1 Treatment of the Shoe

TREATMENT BEGINS by washing in de-ionized water to remove soluble salts. After removing these salts, leather which had been stained or encrusted with metallic salts was placed in a 5% (w/v) solution of oxalic acid in de-ionized water until the stain or encrustation dissipated. The leather was then thoroughly washed with tap water for several days. This procedure for removing encrustations was proposed by Tilbrooke and Pearson. Their treatment was designed for textiles, but in this case it was found useful when applied to leather.

A freeze-drying process for leather developed by Rosenquist makes use of polyethylene glycol 400, but does not mention surface treatment or consolidation. At the MSMRCC, a modified freeze-drying treatment uses PEG 1500. The process includes the following steps in sequence: impregnation, drying and surface treatment, followed by consolidation, support, and reconstruction when necessary.

Impregnation: The nylon-encased shoe parts were immersed at room temperature for six weeks (sufficient time for penetration) in a 10% (w/v) solution of PEG 1500 in de-ionized water. The volume of the solution was four to six times the volume of the leather.

A. E. A. Werner, as abstracted by B. Muhlenthaler, used PEG 1500 at an elevated temperature of 40°C. Initially, this method was attempted, but the
leather from the DEFENCE became hard and brittle. Further research showed that this method may be undesirable under any circumstances because elevated temperatures may have an adverse effect on leather. An aqueous solution of PEG 1500 at room temperature proved an effective impregnation treatment for waterlogged leather.

Drying: On removal from the impregnation solution, the leather was frozen at −18°C, and transferred to the freeze-drier (Fig. 1). Drying required from two to four weeks; its progress was monitored by the amount of water deposited in the freeze-drier's condensing chamber. The vacuum schedule used: day 1–2000 microns; day 2–300 microns; day 3–100 microns.

This schedule allowed the leather and the frozen water within an opportunity to acclimate to lowered pressures. From empirical observations, a gradual reduction in pressure minimizes the amount of surface disruptions in the leather. After three days, the pressure of the drying chamber was reduced to the limits of the unit (ca. 5 microns). The drying phase was complete when no ice was deposited on the condenser.

Surface treatment: Within an hour after the drying process was complete, the shoe was removed from its nylon encasement. At this point, the leather was stiff, but with an application of British Museum Leather Dressing, the desired flexibility was obtained. Within a few minutes, the dressing was absorbed into the leather (in cases of very thick leather, a second application of dressing.
would sometimes be necessary). The dressed leather was allowed to stand for several days without further activity before any subsequent steps were instituted. With this process complete, the shoe could be consolidated or a secondary support added prior to assembly.

### 3.2 Consolidation or Addition of Auxiliary Support

EVEN AFTER LEATHER has been impregnated and freeze-dried, it is important to correct problems within its structure prior to reconstruction of the artifact.

*Consolidation:* “Red rot” can be identified as a powdering of the leather, possibly caused by sulfur dioxide.\textsuperscript{13} Suspected areas of “red rot” in a piece of freeze-dried leather were consolidated with a 20% (w/v) solution of Acryloid B-72 in ethyl alcohol applied directly to the affected area.

Although no difficulties were encountered with the Leather Dressing, B-72/Ethanol interface, B-72 in Acetone or Xylene might be substituted to overcome any incompatibility. Initially this darkens leather slightly, but after the solvent evaporates, the resulting color is not significantly different from its appearance before consolidation. This application is repeated until the area does not readily accept the resin mixture.

*Auxiliary support:* Disruptions in the leather's surface were supported with wet strength tissue and a PVA emulsion adhesive (Fig. 2). This auxiliary support was attached after the leather's surface was pre-treated with a single coat of 20% (w/v) B-72 in Ethanol. For aesthetic reasons, all tissue supports were applied to the inner shoe surface.

![Fig. 2. Support of disruptions in the surface of leather with wet strength tissue and an adhesive.](image)

The pre-treatment serves two purposes: first, on top of the surface dressed with the British Museum Leather Dressing the B-72 enhances adhesion, and second, the resin coating is easily reversible.
3.3 Assembling the Parts for Display and Study

WHEN STABILIZATION was complete, the shoe was reassembled (Fig. 3). Using the holes from the original stitches, each part was sewn with dark colored cotton thread which had been coated with a microcrystalline wax. When sewing was not possible because the stitch holes had been mutilated, parts were adhered using a process similar to the one described for supporting a disruption.

Fig. 3. Shoe—completed.

4 A CONSERVATION TREATMENT FOR TEXTILES FROM THE DEFENCE

LINEN, HEMP, AND SILK have been the fibre-contents of the textiles recovered from the site of the DEFENCE. The treatment presented below was used in the conservation of these textiles to impart flexibility and stability.

5 A CASE STUDY: A LINEN SHOT BAG

PRIOR TO THE INVOLVEMENT of professional archaeologists and conservators, several artifacts were recovered from the wreck of the DEFENCE. One of these artifacts was a partial stand of grape shot (Fig. 4). It was intended to be fired from a cannon, with an action similar to that of a modern-day shotgun pellet. Originally, this object would have been made from wood, metal, and fabric (in this case, the wooden spindle was not recovered). The canvas bag with iron and lead balls inside had been allowed to dry without attention. When the artifact was finally submitted to the conservation laboratory some three years later, the metal balls were corroded and powdering; the textile was concreted in metallic salts. On mechanical removal of the surface concretions, the fabric remained stiff and brittle from the metallic salts still adhering to the fibres.
The textile was woven in a tabby weave from rough spun yarns determined to be linen by microscopic examination. The count was $32 \times 26$ per inch.

6 TREATMENT OF THE SHOT BAG

INVESTIGATIONS WERE INITIATED on samples of textiles similar in fibre content and structure to the artifact. After testing was completed, the following steps were instituted: removal of metal salts, immersion, and drying.

Removal of metal salts: The removal of metal salts has been previously discussed (see removal of metal salts in the Leather Section of this paper). It was found that by using a 5% (w/v) aqueous solution of oxalic acid metallic encrustations could be significantly reduced in most textiles over a short time period (e.g. 1–2 days). The shot bag required a longer time, 15 days. Following this salt removal, the fabric was thoroughly washed with tap water for a week.

Several years ago, a new preservative compound (Modocol) was introduced for archaeological materials. Its purpose was to provide support and flexibility for an archaeological textile. More recently, a similar mixture of Ethulose, PEG 400, and a fungicide has been employed for the stabilization of other archaeological materials. The use of these two methods of stabilization on DEFENCE textile samples caused them to become unacceptably brittle.

Immersion and drying: To overcome the rigidity, tests were once again initiated. It was found that as a precursor to freeze drying, immersion in an aqueous solution of 1% (w/v) Ethulose and 5% PEG 400 would leave the fabric flexible. At the same time, it was consolidated. To prevent gross fibre collapse, the textiles were frozen ($-18^\circ$C) and then freeze-dried following the same procedure as for leather (Fig. 5).
Ropes and wadding were found to need an additional treatment step. The freezing of the artifacts was interrupted at the point of “jelling.” This term refers to the state when the cords or lines and their fibres are still manipulatable in the highly viscous impregnating medium. These artifacts were removed from the net casings and while held in place by the jelled solution, the individual cords of the rope or wadding were separated to reduce the matted effect of loose fibres (see Figs. 6 and 7).
Fig. 7. Specially treated wadding (jelling) and arranging of fibres.

Protective mounting: In some cases, the textiles needed physical support after their consolidation. Using conventional methods, washed unbleached muslin was stretched over a sealed wooden strainer for a textile mount. In some cases, the textile to be mounted was first sewn to nylon net and then the net was mounted on the muslin (see Fig. 8). \textsuperscript{16,17}

Fig. 8. Ribbon on muslin.

7 CONCLUSION

THESE CASE STUDIES and accompanying data represent the results of testing and successful treatments for leather and textile artifacts from the DEFENCE. The use of modified immersion solutions, oxalic acid to reduce metallic encrustations and freeze-drying for textiles are not necessarily solutions for the problems of other underwater sites, as each site varies due to biological and other environmental conditions. Other treatments and procedures related to leather and textiles are still under investigation.
ACKNOWLEDGEMENTS

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REFERENCES


Lawson, Eric, Personal Communication, May 1977. 25 Cardena Road, Snugcove, Bowen Island, Von 1G0 B.C., Canada.


**MATERIALS**

Teflon Tape
AIN Plastics, Inc., 65 Fourth Ave., New York, NY 10001.

“TYVEK”

“Nylon Net”
Polyethylene Glycol 1500
(Average molecular weight 500–600, mixture of 300/1540 in equal weights), Union Carbide Corp., 270 Park Ave., New York, NY 10017
.Polyethylene Glycol 400
British Museum Leather Dressing
(Chemical #B-381), Fisher Scientific Company, Pittsburg, PA 15219.
Acryloid B-72
An ethyl methacrylate copolymer. (Rohm and Haas Independence Mall West, Philadelphia, PA 19105)
.Wet Strength Tissue
“Skintex,” Technical Paper, 29 Franklin St., Needham Heights, MA.
.Emulsion Adhesive
Talas, Jade No. 403, PVA, Technical Library Service 104 Fifth Ave., New York, NY 10011.
.Ethulose, ethyl-hydroxyethyl cellulose
Signo Trading International Ltd., 208 S. 14th Ave., Mt. Vernon, NY 10550.
CONSERVATION OF LEATHER WALL HANGINGS IN THE JAMES J. HILL MANSION

David Dudley

ABSTRACT—Leather wall hangings in a St. Paul, Minnesota, Victorian mansion are described and their condition, conservation, and remounting are discussed.

1 CONSERVATION OF LEATHER WALL HANGINGS IN THE JAMES J. HILL MANSION

JAMES J. HILL began his career in transportation in 1856 at the age of seventeen as a clerk on the St. Paul levee. After a twenty-year apprenticeship in the freight business during which he had amassed a small fortune and a wealth of information, he and a few others acquired an almost bankrupt St. Paul & Pacific Railroad which in 1890 was renamed The Great Northern. He built his Great Northern as an end in itself. His railroad had the flattest grades, the straightest track and the lowest rates. The locomotives were the most powerful, the trains the longest. In his mind The Great Northern was an immortal work. “When we are all dead and gone,” he said, “the sun will still shine, the rain will still fall and this railroad will run as usual.”

James J. Hill died in his St. Paul mansion on May 29, 1916.

The mansion, located on St. Paul's prestigious Summit Avenue, was completed in 1891 at the cost of more than $900,000. The Boston firm of Peabody, Stearns, and Farber was engaged and subsequently was dismissed when it ignored Hill's orders to the stone cutters. Hill was a dominant force in the building of the house, overseeing its planning and construction and furnishing it as if it were a new extension to his railroad.

The mansion's dimensions are: 63,000 sq. ft. of living space that include 32 rooms, 13 bathrooms, 22 fireplaces and a 100-foot entrance hall. After his death in 1916, his wife Mary maintained the mansion until her death five years later. In 1925, it was presented to the St. Paul Catholic Archdioces which occupied the property until 1978 when it was acquired by the Minnesota Historical Society.

The dining room is half paneled in mahogany with a built-in buffet and corner cabinets. The upper half is decorated with embossed leather (possibly by a mechanical process) which had been colored with gold, red and blue. It was manufactured by a New York firm of leather embossers and workers in gold, Charles R. Yandall & Co., Fifth Avenue, New York, at the cost of $21 per yard.

The original method for mounting the leathers to the walls was: first, slats had been nailed to the wall corresponding to the size of each piece of leather.
Second, burlap was stretched and tacked to the slats leaving no area of wall exposed. Third, the leather was tacked over this and finally finished with moulding around the edges.

Naturally, due to the constant changes in climate within the house over the years, the leathers had become dry and brittle. They had ripped in places. There were a number of losses due to the pull of the weight of the material, and a certain amount of distortion had taken place.

Several attempts had been made to repair them by gluing burlap to areas on the reverse. Adhesive tape also had been used to support the weight of the leather where it had broken away from the top. Upholstery tacks had been used at random all over the leather to help as a support. Moulding had been added later where the vertical joins had broken and parted. Each panel was heavily coated with years of dust and grime.

The removal of each of the panels was relatively simple. First, all the tacks and upholstery pins were removed along the bottom and the sides and those that had been added at random. Foam core was held against the surface of the leather while removing the tacks from the top edge. The leather was held to the foam core, the panels were gradually lowered to a flat surface. The panels were transported to the laboratory for treatment.

The surface of the leathers was gently brushed in order to remove loose dirt and grime. The front surfaces were washed with a 2% solution of vulpex liquid soap in warm water. The residue was swabbed off. The material which was decided to be used as a support was “Tetco,” a polyester monofilament silk-screen fabric. This was sprayed with several applications of PVA AYAA/AYAC. Each leather was to be mounted onto an aluminum honeycomb core panel with the polyester between the leather and the panel.

To prepare the panel, Hexcel aluminum honeycomb was sandwiched between 1 mm gauge aluminum sheets. The adhesive was a Scotch-weld Epoxy 2158 A & B with a work life of 1-1/2 hours. This was applied by hand and evened out with scrapers or trowels on the top and bottom sheets and the honey-comb was then placed between them. They were weighted and left to set for a couple of days. The fabric backing was applied to the leather and the aluminum sheet by using the vacuum hot table. The backing attached itself to the reverse of the leather and to the aluminum sheet.

The losses were filled using new leather, fixed into place by its attachment to the mounting panels, and the design was matched by tooling and coloring to match the original pattern.

The panels were re-attached to the walls in the dining room with 2-1/2″ screws into the original plugs which had been refitted. The original moulding was replaced along the top and new moulding was used for the bottom. The upright
moulding, which had been found between each section of leather but which was not original to the room's decoration, was not replaced.

The weight of the largest panel of approximately 8 feet by 54 inches was about 50 pounds.

SUPPLIES

Polyester monofilament silk screen fabric
Tetco Inc. 5050 Newport Dr. Suite 1, Rolling Meadows, Ill 60008,(312) 253-1340

Aluminum Honeycomb
Hexel, 2710 Avenue E East,Arlington, Texas 76011, (817) 274-2578

Vulpex Liquid SoapAlkaline Methyl, Cyclohexyl Oleate, Soluble in Water or White Spirit
Picreator Enterprises Ltd. 44 Park View Gardens, London NW4 2PN, England, Tel. 01-202-8972

Scotch-weld Epoxy 2158
Barry Sewall, Box 50, Minneapolis, MN, (612) 331-6710

Aluminum Sheets
Vincent Brass & Aluminum Co. PO Box 360, Minneapolis, MN 55440, (612) 378-1131
Recent Developments in the Conservation of Parchment Manuscripts

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Over the past ten years many new developments have been made in the field of parchment conservation both in the U.S. and abroad. Three of the most exciting developments have occurred in the areas of media consolidation, humidification, and repair. While some of these new techniques have been developed by conservators and scientists specifically for the treatment of parchment, many methods have been adapted from the closely related field of paper conservation.

Media Consolidation

Flaking and friable media on parchment can be a challenging problem, especially if the manuscript is still in bound form. The paint and/or writing ink can be unstable for many reasons including: improper preparation of the parchment surface or the media itself; desiccation of the binder upon ageing; abrasion to the paint surface; stress caused by excessive flexing of the parchment support; or inherent instability of the media. The aim of any consolidation treatment is to arrest the flaking process and to ensure that no further loss occurs. The consolidant should be compatible with both the media and the support, should not create any visual change in the area being treated, and should have good ageing characteristics. In addition, the technique for applying the consolidant should be highly controllable such that the surrounding media is not disturbed and only the minimum amount of consolidant is deposited on the flaking paint or ink.

In the early 1960's conservators at the Walters Art Gallery became increasingly aware of the poor condition of the illuminations in many of the museum's 800 manuscripts and they felt that urgent stabilization treatment was needed. After consulting the British conservation scientist Anthony Werner on the most appropriate material to be used for paint consolidation soluble nylon was selected by the Walters conservators and was used for this purpose for the next 15 years.\(^1\) In 1977 visiting book conservator Christopher Clarkson recommended that the use of soluble nylon be discontinued due to recent concerns that had arisen among conservation professionals regarding the material's long term stability and its suitability for media consolidation.\(^2\) During his brief tenure at the Walters Mr. Clarkson introduced the practice of using a dilute solution of parchment size for the consolidation of flaking paint in parchment.
manuscripts.\textsuperscript{3} This new technique was adopted wholeheartedly by the other conservators at the Walters, who used it with success for the next 17 years. More recently leaf gelatin, instead of parchment size, has been used for media consolidation at the Walters. This change in approach is due to heightened concerns about certain organic pigments, frequently found in medieval manuscript illuminations, that could be adversely affected by a solution of parchment size used for paint consolidation. For example, it is possible that an adhesive made from clippings of new parchment - which can be processed in several ways depending on the country of origin - might contain impurities that would have a negative affect on these organic colorants. In addition, the greater alkalinity of parchment size could cause a pH-sensitive organic pigment to shift slightly in color when it came in contact with such a solution.\textsuperscript{4}

Fig. 1. Consolidation of flaking paint is performed using a dilute solution of leaf gelatin, kept warm on a small hot plate.

The consolidation technique used at the Walters employs a very dilute (approximately 1\%) solution of leaf gelatin that is kept warm in a bain marie, adjacent to the work area (Fig. 1). The adhesive wicks in to the cracks and losses more successfully if a small amount of ethanol is applied first to the area being treated. If desired, ethanol can also be added directly to the adhesive in the bottle in order to further reduce the surface tension of the consolidant. Since the water gradually evaporates out of the warmed solution over a few hours one must regularly check the viscosity of the adhesive and add more water if necessary, in order to keep it at the desired concentration.
Although liquid gelatin works very well in most cases there are some instances where another type of adhesive or a different application method would be more suitable for media consolidation. Certain pigments found in illuminated manuscripts often present unique deterioration problems and must be dealt with on an individual basis when consolidation is required. White lead was the principal white pigment used in manuscript illumination throughout the middle ages and, during the 14th and 15th centuries, it was used extensively on its own and in mixtures with other pigments. Partly due to its method of manufacture white lead forms a brittle paint film when bound with gum or glair and it is therefore very prone to flaking, especially in a bound manuscript where the leaves are subject to a considerable amount of flexing (Fig. 2). To compound the problem the consolidation of flaking white lead can be especially tricky since the thin paint film is easily swollen or otherwise disturbed by most aqueous consolidants.
One approach to the problem of flaking white lead in manuscripts is to use one of the cellulose ethers instead of gelatin for consolidation. Methyl cellulose is considered to be very stable, in comparison to the other types of cellulose ethers, yet it is only soluble in water. However, it is possible to prepare an alcohol-based solution by adding ethanol to a viscous mixture of methyl cellulose in distilled water, until the solution becomes thin enough for use in consolidation. Depending on the degree of instability of an area of flaking white lead, however, the small amount of water that is present in this particular methyl cellulose solution may still cause too much swelling of the delicate paint film. In these cases the alternative is to use hydroxypropylcellulose or Klucel - the only cellulose ether that is completely soluble in organic solvents. A dilute solution (approximately 1-2%) of Klucel-G in ethanol is prepared and then carefully applied with a fine sable brush along the edges of the losses and under loose flakes of paint, as seen in Fig. 3.

For illuminated manuscripts that are still in bound form the long-term strength of the adhesive used for paint consolidation is important to consider, since the parchment leaves and the attached media are subject to a considerable amount of flexing. Parchment also has a greater tendency than paper to expand and contract on its own, even with very small fluctuations in the surrounding environment. This natural reactivity of parchment puts more stress on the applied paint layer which can cause it to fracture over time. For bound illuminated manuscripts, that exhibit unstable whites and other light-colored paints, the author prefers not to rely solely on the methyl cellulose/water/ethanol solution or Klucel-G in ethanol as the only means of consolidation. In these cases the cellulose ether is used instead as a pre-treatment, to initially stabilize a fragile area of white or pastel-colored paint and prevent it from swelling. Once the stabilizing consolidant has dried a very small amount of dilute gelatin is applied to the same area of flaking paint. The gelatin, which is stronger and
perhaps also longer lasting than either methyl cellulose or Klucel, further consolidates the flaking paint and prevents additional losses from occurring.

Fig. 4. Fragmentary illumination from a 15th c. Italian manuscript which exhibits friable blue and green paint. (Walters Art Gallery MS. W.414)

Depending on their relative state of deterioration several other pigments frequently found in medieval manuscripts can often be difficult to consolidate using a liquid adhesive. Orpiment, a naturally occurring arsenic sulfide admired for its bright yellow color, was primarily used during the 8th - 10th centuries for manuscript illumination. The thin plate-like pigment particles, which resemble mica in many ways, do not adhere well to parchment and readily flake off the surface of the page. Orpiment cannot usually be treated with gelatin or other liquid consolidants containing water and/or alcohol because the bright yellow pigment becomes noticeably darker and more saturated in color when these adhesives are applied. Other coarsely ground pigments, such as ultramarine blue, form a solid layer of paint when first applied to parchment. However, if the outer skin of paint becomes scratched or abraded, the pigment starts to crumble away. Often this kind of friability is barely detectable, even when the media is examined under the microscope. However, when a dry brush is drawn across a damaged area under very high magnification, tiny particles of pigment can be seen coming away from the surface. As more and more particles are lost over time, small cavities or craters start to appear in the paint layer and the resulting damage becomes more visible to the naked eye (Fig. 4). Verdigris, an artificially
made copper green paint, can also become very crumbly as it deteriorates and, as a result, the paint film can often be difficult to stabilize in the normal way. Like ultramarine blue, the friable pigment particles of verdigris are sometimes disturbed by a liquid solution of gelatin and the particles can accidently be picked up on the tip of the brush being used to deliver the consolidant.

Fig. 5. An Ultrasonic Mister is assembled using an ultrasonic humidifier, a Nalgene bottle for the consolidant, and a plastic reducing connector to dispense the mist. The aquarium pump (not seen) is connected to the narrow tube on the side of the bottle.

In 1991 an exciting new device called the "Ultrasonic Mister" was developed by the conservation scientist Stefan Michalski and was used initially for the consolidation of matte, powdery paint on wooden artifacts. After a series of modifications to the original design the Ultrasonic Mister was quickly adapted for use in paper conservation. Most recently, a slightly more modified version of the Ultrasonic Mister has been used at the Walters Art Gallery for the consolidation of friable paint in illuminated parchment manuscripts. This device has proved to be particularly useful for the treatment of the types of crumbly or brittle paint described above, that are often disturbed by liquid consolidants. The equipment that has been used to assemble the Ultrasonic Mister at the Walters is similar in many ways to that described by Sherry Guild in 1994. The liquid consolidant is held in a low density polyethylene (eg. Nalgene) bottle, which is placed over the oscillator of the ultrasonic humidifier and surrounded with distilled water. A small size aquarium pump, attached
to a narrow hose, provides the air pressure which forces the mist out of the bottle. A larger hose, inserted in the top of the Nalgene bottle, has a plastic reducing connector at the opposite end which serves as the tip from which the mist is dispensed (Fig. 5). Although, in theory, one should be able to change the volume of mist coming out of the bottle by moving the dials on the ultrasonic humidifier this idea does not really work in practice. Instead, is more effective to connect a plastic T-piece and a small length of hose with an attached clamp to the hose coming from the aquarium pump, as a means of reducing the mist volume. Alternatively, one can plug the aquarium pump into a rheostat and then move the dial on the rheostat until the mist coming out of the dispensing tip is at the desired velocity.

Fig. 6. A fine mist of 1% gelatin is delivered to an area of friable paint on the Italian manuscript fragment. (MS W. 414).

Since the original design of the Ultrasonic Mister was altered to better suit the needs of paper conservators the device has almost always been used in conjunction with a paper suction table. The suction table helps to draw the mist down into the flaking media and also prevents distortion in the support when it comes in contact with the misted consolidant. The objects that have been treated in this way have all been one-sided works of art, executed on a single sheet of paper. Illuminated manuscript leaves, however, are almost always written and painted on both sides and are often bound together in a codex format. These two factors combined make it difficult to perform any type of paint consolidation treatment on an illuminated manuscript using a suction device and a binocular microscope. Without the suction to rapidly dry the area being treated it is essential to keep the mist at the lowest possible level, using the hose
clamp set-up or the rheostat, so as to avoid over-saturating the media or the parchment support. One must also be particularly careful, when applying the mist to a given area, not to hold the tip in one place for too long; otherwise the paint will swell and the parchment will start to cockle from the excess moisture (Fig. 6).

So far, a wide variety of adhesives and other materials have been tested for use in the Ultrasonic Mister yet the most favored material for paint consolidation is gelatin. Gelatin readily forms a mist in this device and the results achieved in the consolidation of flaking paint have so far been very successful. A dilute solution of 1% leaf gelatin is made up with the addition of a small amount of ethanol to reduce the surface tension of the consolidant. The Nalgene bottle is filled with approximately 1" of the gelatin solution and placed over the oscillator of the ultrasonic humidifier. Since the ultrasonic vibrations can only be transmitted through water the well of the humidifier is filled with distilled water, to approximately the same level of the consolidant in the bottle. The vibrations that pass through the Nalgene bottle generate a certain amount of heat. This works to the conservator's advantage, by keeping the gelatin solution warm and therefore more liquid. However, the vibrations also cause blisters to form on the bottom of the bottle with repeated use and eventually the bottle has to be replaced.

Fig. 7. Photomicrograph showing consolidation of friable green paint using the Ultrasonic Mister. (MS. W.414)

Like almost any piece of equipment the Ultrasonic Mister is not completely foolproof and droplets of condensed mist, which collect at the end of the hose or in the dispensing tip, can occasionally fall on the surface of the object being treated. To prevent this from happening it is important to position the ultrasonic humidifier on the floor or at a low level, so that the mist drains back down the hose instead of collecting at the opposite end. While the Ultrasonic Mister is in use the dispensing tip should occasionally be tapped on a blotter, so as to dislodge any drops that have collected in the reducing connector. A piece of thin blotter or chromatography paper can also be
wrapped around the hose end of the reducing connector, to absorb the excess liquid that tends to collect there. Since there is no easy way to turn the mist on and off at its source one must always use a blotter to protect the surrounding area, as the nozzle is lowered into place and the mist is applied to the flaking media (Fig. 7).

Fig. 8. Product literature describing the Dosiergerät KD made by Köhler GmbH, Germany.

Another new device for the consolidation of flaking paint in illuminated manuscripts was introduced in 1994 by Dr. Robert Fuchs, a German scientist who teaches at the conservation training program in Cologne. Dr. Fuchs realized that a commercially available machine called the Dosiergerät, which is made for precise gluing operations in the assembly of computers and other electronic equipment (Fig. 8), could be adopted for a wide variety of conservation applications including paint consolidation. The Dosiergerät or "Dosing Device" works on pneumatic pressure and, once the machine is charged up with compressed air, tiny drops of adhesive can be dispensed from a syringe using a foot pedal. By moving the dials on the pressure regulator the amount of adhesive dispensed at one time from the syringe can be infinitely adjusted. The clear polypropylene syringes come in three different sizes, from 5 to 30 cc, and the stainless steel tips that attach to the end of the syringe range in size from 18 to 30 gauge.
Fig. 9. An illumination from the Ebulo Codex shows considerable loss of paint, due in part to the poor quality of the parchment. (Petrus de Ebulo. Liber ad honorem Augusti sive de rebus siculis. Palermo, 1195 - 97. Burgerbibliothek, Bern, Cod. 120, II., f.139)

Fig. 10. Photomicrograph of an area of actively flaking green paint from the Ebulo Codex before consolidation treatment. (Burgerbibliothek, Bern, Cod. 120, II., f.139)

Ulrike Bürger, the head of book conservation at the State and University Library in Bern, Switzerland, was the first to use the Dosiergerät for paint consolidation at the recommendation of Dr. Fuchs. A late 12th century Italian manuscript called the Ebulo Codex, which came to Bern’s university library for conservation, was written and painted on a poor quality parchment made from a somewhat greasy sheepskin (Fig.)
The manuscript had suffered from careless handling over the centuries and from a crude rebinding job in the early 1920's and was in very poor condition. A copper green paint, used extensively throughout the Ebulo Codex, exhibited many losses and was found to be extremely friable (Fig. 10). The illuminations were in urgent need of consolidation and the Dosiergerät seemed to be particularly suited for the job. In addition to suggesting this new device for the treatment of the Ebulo Codex Dr. Fuchs also recommended that a solution of isinglass and gum tragacanth be used for consolidation. Isinglass has a very long history of use in western and eastern Europe, both as a painting medium and as an adhesive for conservation applications. It has a very low surface tension, a neutral pH, and good flexibility and was therefore considered to be very suitable for the treatment of flaking paint in the Ebulo Codex. Pieces of best quality Russian isinglass or sturgeon swim bladder were soaked in water overnight to soften and swell the dried material. It was then cooked slowly in a bain marie at 450°C, during which time the adhesive was agitated with a stirring apparatus. Since the conservator experienced some difficulty in using pure isinglass in the dosing device a small amount of gum tragacanth, dissolved in water, was added to the strained solution of isinglass to act as an emulsifier. The syringe of the Dosiergerät was filled with about 6 ml of the isinglass/gum solution which was then applied while working under the binocular microscope. After pre-wetting the area with ethanol a tiny drop of the consolidant was deposited directly at the site of flaking paint. The conservator usually found it necessary to guide the drop under the edges of the paint with a brush held in the opposite hand. Although somewhat awkward, this technique seems to be more efficient than other methods that employ liquid adhesives, since the reservoir of consolidant is right over the area being treated and can be dispensed in very precise amounts.

Humidification

Fig. 11. Hard vertical creases in a thin parchment manuscript leaf are humidified locally using ultrasonic mist and eased out by tensioning the fore edge. (Walters Art Gallery MS. W.196, f.1)

In recent years ultrasonic water mist has proved to be an ideal means of humidifying parchment, especially when only local treatment is desired. In large folio size
manuscript codices, and in others that have especially thin parchment leaves, a characteristic creasing and pleating of the pages can develop as the books are repeatedly opened and closed during use. To relax and then flatten out these sharp creases and pleats the parchment must be humidified in a controlled manner, preferably without affecting the surrounding undamaged areas. A narrow jet of cool ultrasonic water mist can be delivered either with the Ultrasonic Mister or with the Preservation Pencil, a commercially available device sold by University Products.\footnote{19} The plastic nozzle that is provided with the Preservation Pencil is not as narrow as the reducing connector that is used for the tip of the Ultrasonic Mister, but both devices work equally well for this purpose. During humidification tension is gradually placed on the edges of the manuscript leaf in order to draw out the pleats in the skin (\textit{Fig. 11}). Final drying of the leaf is then done under pressure, with the leaf sandwiched between polyester web and thick wool felts.

Ultrasonic water mist has also proved to be useful for the treatment of a 13th c. Greek Psalter (Walters Art Gallery MS. W.733) that had been damaged by heat around its outer edges. The parchment was severely discolored and gelatinized from the heat and the corners were curled inwards and were very inflexible. Initially the disbound leaves were humidified overall in a chamber yet this was not enough to completely relax the distorted corners. The next step was to humidify these heat-damaged areas locally, using a combination of ultrasonic mist and weighted sandwiches of polyester web and damp blotters. After pressure drying the treated corners under small squares of thick wool felt the manuscript leaves were much flatter than before and the parchment was no longer stiff and horny.

\section*{Repair}

Many new techniques for the repair of parchment manuscripts have also been developed within the past ten years. These new methods fall into two basic categories: adhesive-coated tissues and animal membranes for the repair of splits and tears and techniques for pulp-filling multiple losses in parchment manuscripts and documents. The new adhesive-coated tissues and transparent membranes have proved to be especially useful for the repair of extremely deteriorated mold-damaged parchment that is adversely affected by liquid adhesives and is too weak to support a mend made with new parchment or heavier types of paper.\footnote{20} Conservators have prepared these particular repair materials using Japanese tissue and goldbeater's skin and a variety of adhesives including methyl cellulose, hydroxypropylcellulose or Klucel, a mixture of acrylic resins and isinglass.
Fig. 12. A group of Dead Sea Scroll fragments before treatment, housed between sheets of plate glass. (Israel Antiquities Authority, Jerusalem)

Fig. 13. A group of treated fragments of the Dead Sea Scrolls, hinged with methyl cellulose-coated tissue into an acid-free mat. (Israel Antiquities Authority, Jerusalem)
Fig. 14. An extremely weak, mold-damaged leaf from a 10th c. French Gospels was repaired with green silk thread in the 18th c. (Walters Art Gallery MS. W.3, f.1)

In 1992 a small group of conservators working at the Rockefeller Museum in Jerusalem began the daunting task of restoring the thousands of Dead Sea Scroll fragments that had been stored between glass plates since the 1940's and were in extremely poor condition (Fig. 12). A large number had suffered from mold attack and the parchment was found to be extremely weak and in the process of delaminating. Since the fragments were in such unstable condition they could not be repaired in the normal manner, using a liquid adhesive and patches of paper or parchment. Instead the Israeli conservators prepared a delicate adhesive-coated tissue for use in the repair and hinging of the scroll fragments (Fig. 13). In this technique a slightly viscous solution of methyl cellulose in water is evenly brushed over a piece of lightweight Japanese tissue, which is supported on a piece of glass or Plexiglas. Once dry the tissue is peeled off the glass and small pieces are torn for repair work. The tissue is placed adhesive side down over the tear, moistened with a small ball of damp cotton and gently pressed in place with the fingers. When compared to standard parchment repair methods that use gelatin or other collagen-based adhesives the methyl cellulose-coated tissue is relatively weak. However, because of this particular quality, the material is well suited for the repair of extremely soft, degraded parchment such as is found in the Dead Sea Scrolls. In some cases, however, even the small amount of moisture that is needed to activate a methyl cellulose-coated tissue can cause noticeable darkening of a piece of mold-damaged parchment. It is preferable then to use an adhesive-coated tissue that is activated with organic
solvents. At least ten years ago Frank Mowery, the head of conservation at the Folger Shakespeare Library, developed a method of fabricating an extremely thin kozo tissue using a leaf caster and then coating with a dilute solution of Klucel-G in ethanol. This so-called Gossamer tissue is used in the same way as the tissue coated with methyl cellulose, except that the dried film of adhesive is activated with ethanol instead of with water. Not every conservator has access to a leaf caster, nor the time to make their own gossamer tissue. Fortunately, though, it is possible to take a ready-made lightweight Japanese tissue such as tengujo, or the even thinner RK-O tissue made by Paper Nao, and coat it with a solution of Klucel-G in the manner described above. In 1992, when faced with the need to stabilize a complex series of tears and losses in a 9th century French manuscript from the Walters collection, the author chose to use a Klucel-coated tissue for repair. The parchment had been degraded by mold and was extremely soft and weak, and an insensitive repair and rebinding job carried out in the 18th century had led to further deterioration of the textblock (Fig. 14). Since the manuscript could not be disbound all aspects of the treatment had to be carried out in situ, within the bound codex.

Fig. 15. The French Gospels is positioned for treatment on a book suction device with the old repairs removed from folio 1. (Walters Art Gallery MS. W.3)
Fig 16. After realigning distorted areas on the book suction device, splits and tears were secured with temporary repair patches of Klucel-coated tissue. (Walters Art Gallery MS. W.3, f.1)

Fig. 17. The losses on folio 1 were filled with laminates of toned Japanese tissue and tears and splits were repaired with Klucel-coated tissue. (Walters Art Gallery MS. W.3, f.1)
The manuscript was set up on a book suction device, with the severely damaged first leaf in contact with the suction platen, and the old thread repairs were carefully removed (Fig. 15). Consolidation of the degraded parchment was then carried out by lightly spraying a very dilute solution of parchment size in water and ethanol on to the surface, while the leaf was held flat under suction. After consolidation the parchment was noticeably stronger and there was no apparent change to the color of the skin from the adhesive that had been applied. For the repair work a piece of lightweight kozo tissue was coated with a solution of Klucel-J in 50/50 ethanol and acetone and allowed to dry. The first leaf of the manuscript was humidified overall using a damp blotter and Gore-tex and, with the suction turned on at a low pressure, distortions and creases were gently eased out of the skin. The splits and tears were gradually realigned, with the localized humidification of certain areas, and then temporarily held in place with patches of the Klucel-coated tissue (Fig. 16). Once all of the distortions had been worked out of the leaf, and the split areas were realigned as best as possible, the temporary repair patches were peeled away after dampening them with solvent. Profiled repair strips of the Klucel tissue were carefully torn and set in place with the ethanol/actone mixture. Larger losses in the leaf were then filled with laminates of toned Japanese tissue applied with a minimal amount of dry wheat starch paste (Fig. 17).

Another type of adhesive-coated tissue for use in paper repair was first described in 1989 by Tatyana Petukhova, a paper conservator at Cornell University Library. This tissue is coated with a solution of isinglass, made from best quality Russian sturgeon bladder. Although similar in many ways to parchment size and other forms of animal gelatin, isinglass is unique in that a dried film of the adhesive can easily be reactivated with moisture. The adhesive is prepared as described earlier, by soaking and then cooking the dried fish bladder in a bain marie at a low temperature. In Russia honey is traditionally added to a solution of isinglass as a plasticizer but a few drops of glycerin work just as well. The repair tissue is prepared and used in the same way as the other adhesive-coated tissues described above. Based upon preliminary tests by the author and her recent interns, it is possible to use a mixture of ethanol and water, as well as water alone, to activate the adhesive. This would be advantageous in a situation where one would prefer to have only a minimal amount of moisture come in contact with the parchment that is being repaired. Isinglass has a greater adhesive strength than either methyl cellulose or Klucel and may be chosen for this reason, whenever a stronger type of adhesive-coated tissue is desired.

Experiments of a similar nature have also been carried in recent years using goldbeater's skin or fish skin with a variety of adhesives. These highly transparent animal membranes are widely used for the repair of parchment and are most often applied with a liquid solution of gelatin or parchment size. Sometimes, however, there are occasions where one would prefer to apply goldbeater's or fish skin in another manner, using only a minimum of water or none at all. Mathew Hatton, a book conservator at Dublin's Trinity College Library, has experimented in coating pieces of degreased and pumiced fish skin with a mixture of the acrylic resin dispersions that are normally used in the manufacture of heat-set tissue. Much like the Klucel-coated tissues, the acrylic resin-coated fish skin is activated with ethanol or acetone and pressed in place over the area to be repaired. Based upon recent tests that were conducted at the Walters Art Gallery it is also possible to coat a piece of prepared goldbeater's or fish skin with a thin film of isinglass. Although the making of
this repair material has proved to be relatively easy it is more difficult to activate the adhesive-coated membrane and to get it to adhere to a piece of parchment, in the same manner that one adheres the adhesive-coated tissues. This is partly due to the fact that an unsupported piece of membrane can curl quite dramatically when moistened with water and thus can be difficult to set precisely in place over a tear. The membrane is also not as permeable as paper and the moisture that is applied to the uncoated side does not readily transfer through the skin to activate the adhesive on the opposite side. As such, these two types of adhesive-coated goldbeater's and fish skin are still in the developmental stages and have not, as yet, been adopted for regular use in parchment conservation.

Fig. 18. After brushing the casein adhesive over the cast area of dry hide powder the fill is pressed in place through Mylar.

Over the past ten years several laboratories in Europe have made great progress in developing new methods for pulp filling losses in severely damaged parchment manuscripts. The earliest method was described in 1985 by Per Laursen, a Dutch paper conservator who occasionally treats parchment. In this technique the parchment manuscript or document is laid on a paper suction table and a dry powder, made from unprocessed animal hide, is applied to the area of loss with a spray apparatus. The excess hide powder is brushed away from the surrounding area and the fill is lightly sprayed with ethanol and smoothed in place through a piece of polyethylene. A casein-based adhesive, called Eukanol Glanz-N, is applied with a brush to the dry powder fill, which is then left to dry for about 10 minutes (Fig. 18). The object is removed from the suction table, sandwiched between polyester web and blotter, and put under pressure for 12 hours. According to conservators who have experience with this particular pulp filling technique it is not easy to control the way in which the dry powder is deposited in an area of loss and the resulting fills are not always even in thickness. In addition, large pulp filled areas do not adhere well to the
edges of the loss and must be supported on both sides with a sandwich of goldbeater's skin.\textsuperscript{32}

Fig. 19. A severely mold-damaged bifolio from a 15th c. Corvinus manuscript before treatment. (National Szechenyi Library, Budapest)

A second method of pulp filling losses in parchment was developed in 1987 at the Hungarian National Library in Budapest. The library is known for its large collection of 15th c. illuminated manuscripts that were made for the Hungarian King, Mathias Corvinus, by the best scribes and illuminators that he could import from Italy. When the country was invaded by Turks in the 18th c. they took these priceless treasures back to their homeland and had many of them rebound in Islamic style bindings. Eventually the Corvinus manuscripts were returned to Hungary yet, by that time, they were in much worse condition due to damp and moldy storage conditions in Turkey (Fig. 19). After investigating various methods of parchment repair that were currently being practiced in major European laboratories the conservators in Budapest devised a unique method of pulp filling, which they then used to restore these particular manuscripts.\textsuperscript{33}

One of the principal ingredients in the Hungarian pulp recipe is a very fine hide powder that is prepared in a small laboratory grinding machine using dried pieces of untanned animal hide. Paper-based materials are also added to the pulp, to provide body and opacity to the completed repairs. A sulfite-processed paper pulp, purchased from the Yugoslav papermaking industry, and various types of Japanese paper are macerated together in a blender, along with the hide powder. Parchment size, made according to a common German recipe that incorporates wine vinegar,\textsuperscript{34} and hydroxyethylmethylcellulose are also added to the pulp, along with ethanol, isopropanol and a fungicide.\textsuperscript{35} Before any repair work is begun on a manuscript test pieces of pulp are first cast on the suction table in order to determine the ideal color.
for the completed fill. The color of the pulp is usually altered by changing the type of Japanese paper that added to the mixture, from a selection of lighter and darker colored papers.

Fig. 20. The Hungarian parchment pulp is cast with an eye dropper on to the areas of loss while the suction is turned on.

Fig. 21. Wet pulp was used to fill large losses in this Corvinus manuscript and to strengthen the weak margins, also badly stained by mold. (National Széchenyi Library, Budapest)

There are three different ways in which the pulp fills are cast in Budapest and this depends largely on the condition of the original object. The so-called "wet method" was used to repair the majority of the mold-damaged Corvinus manuscripts. In this technique a parchment leaf is placed on a paper suction table and humidified by spraying it with a solution of ethanol and water. With the suction turned on the liquid pulp mixture is applied with an eye dropper to the areas of loss (Fig. 20). A light box below the suction table allows the conservator to judge the
relative thickness of the fill and to add more pulp to the loss, should it be required. After the fills are cast on one side of the leaf the object is turned over and a thin layer of pulp is cast on the opposite side of the loss. The manuscript leaf is covered with thin silk fabric (the Hungarian equivalent to polyester web) and allowed to dry on the suction table for approximately 30 minutes. The leaf is then transferred to a sandwich of blotters and pressing boards and left to dry for several weeks under gradually increasing pressure. In manuscripts that had losses in addition to weak and perforated areas the conservators filled the losses and then cast a thin layer of pulp over the surface of the highly deteriorated areas, as seen in Fig. 21.

Fig. 22. Other types of dry fills are pre-cast on to silk fabric, leveled off with a straight edge and dried under pressure.

Fig. 23. Fills prepared from cast sheets of the Hungarian pulp are adhered with thick wheat starch paste to both sides of a loss in a parchment document.
In a semi-dry pulp-filling technique developed in Budapest the liquid pulp is cast on to a piece of silk and the excess water is absorbed with a blotter. The damp sheet of cast pulp is then carefully lifted off the silk, placed over the loss and pressed gently in place around the edges. The entire parchment artifact is then dried under pressure. With this method there is limited control in defining the shape of the fill and in placing it over the loss without excessive overlap. The third method of pulp filling is completely dry and is therefore reserved for manuscripts that are particularly sensitive to moisture. Here the pulp is cast on to a piece of silk fabric and then evened out with a straight edge (Fig. 22). Another piece of silk is placed on top and the excess moisture is wicked away with a blotter. The cast pulp is then dried completely under pressure. The repair patches are not cut to size in the usual manner but are left large and trimmed later. The edges of a loss in a parchment document are brushed with a stiff wheat starch paste and the large patches of cast pulp are adhered by pressing with a bone folder (Fig. 23). Almost immediately, the excess of the cast piece of pulp is removed by deftly trimming around the edges of the fill with a knife. A large Corvinus manuscript that was still in its original 15th c. velvet binding had mold damage that was limited to the head edge of the parchment textblock. After disbinding the codex the textblock was entirely repaired using the dry pulp filling method and then rebound back into its original covers (Fig. 24).

The third and most promising technique of pulp filling losses in parchment manuscripts was developed between 1990 and 1992 by Dr. Jan Wouters, a scientist at the Royal Institute for Cultural Heritage in Brussels, who worked in collaboration with two book conservators from Ghent, Lieve Watteeuw and An Peckstadt. They were faced with the repair of a very important 8th c. illuminated manuscript from the Netherlands, called the Codex Eyckensis, that had been badly damaged by mold and by a crude restoration job that had been carried out in the 1960's (Fig. 25). The pulp is made in the laboratory of the Institute from purified hide powder, imported from England, and a small amount of the water soluble cellulose ether, Tylose MH-3000. Once prepared the dry parchment pulp is reconstituted in water using a blender.
Fig. 25. A leaf from the 8th c. Codex Eyckensis showing severe deterioration of the parchment by mold. (Sint. Catharina Church of Maaseik, Limburg, Belgium)

Fig. 26. A leaf from the Codex Eyckensis partially repaired at its head edge with a cast fill of parchment pulp. (Sint. Catharina Church of Maaseik, Limburg, Belgium)
Tracings are done of all of the manuscript leaves to be repaired and calculations are made as to the amount of liquid pulp that is needed to fill each of the losses. In order to keep the amount of moisture to a minimum, and to therefore reduce the chances of any alteration in the original parchment, only the areas to be filled are locally humidified before casting, using an ultrasonic humidifier. A custom built suction table was made for this project and fitted with a totally porous polyethylene cover plate. Illumination is provided by a bank of fluorescent lights underneath the table. A mask is made in a piece of polyethylene, with a hole slightly larger than the area to be filled. The parchment leaf is placed on polyester web, over this mask, and the area of loss is locally humidified. With the suction table turned on the liquid pulp suspension is then cast on to the area of loss using a pipette. The area is then dried under pressure, between polyester web and blotters (Fig. 26). In the case of the Codex Eyckensis, which was the first manuscript to be repaired using the Belgian pulp filling technique, a conscious decision was made not to tone the pulp in any way, in order not to affect its ageing properties over time. Extensive testing that was carried out during the development of the pulp indicate that it has a high degree of purity, almost 100% collagen, and is therefore very compatible with parchment. The material is also very flexible and has excellent ageing characteristics. Since the spring of 1995 small quantities of the dry prepared pulp have been available for purchase from the Royal Institute in Brussels, for those who are interested in experimenting with this particular form of reconstituted parchment. However, the high cost of the prepared pulp, combined with the difficulties that some have encountered in trying to replicate this method by themselves, may discourage many conservators from putting the Belgian pulp filling method to use in their own work.

As the field of parchment conservation continues to grow, and greater knowledge and understanding of the material itself is gained by conservators worldwide, new treatment techniques will be developed and older methods may or may not be discarded. Judging from the many exciting developments that have occurred in the field in the last ten years conservators can only benefit from sharing information with each other, from publishing the positive results of their experiments and also from openly discussing methods that, in practice, failed to work for whatever reason.

**Notes**


2. During the 1960's and early 1970's soluble nylon was used in many fields of conservation, for the stabilization of stone and a wide variety of organic materials. It was not until these later years, however, that questions concerning the reversibility and other characteristics of soluble nylon were raised among conservation professionals worldwide.


4. Some of these issues about the use of parchment size for paint consolidation in illuminated manuscripts have been raised in recent years by Dr. Robert Fuchs. For a
list of his articles see the bibliography in: Chapter 18, "Parchment," *Paper Conservation Catalog*, 1994.


6. The author initially learned this method from the paper conservators at the Philadelphia Museum of Art, who had developed it many years ago for the consolidation of flaking paint in Indian miniatures.


10. This method of controlling the mist volume is illustrated in the previously cited articles by Guild, et.al. (1994) and Maheux and McWilliams (1995).

11. The author finds that a rheostat allows the conservator to easily adjust the volume of mist at any time during the consolidation process.

12. Although book suction devices are now made for the treatment of single leaves in a bound book it is virtually impossible to position a microscope over such a device. Since it is critical to have a microscope for the consolidation of discreet areas of flaking paint in an illuminated manuscript, the author has developed other ways of controlling the velocity of mist being produced by the Ultrasonic Mister without the aid of a suction device.


15. References to the use of isinglass or sturgeon glue as a painting medium can be found in the treatises cited in: Mrs. Merrifield, *Original Treatises, Dating From the XIIth to XVIIIth Centuries on the Arts of Painting*, (London: John Murray, 1849) and Daniel Varney Thompson, *The Materials and Techniques of Medieval Painting*, (New York: Dover, 1956).


17. Personal communication from Ulrike Burger.

18. Personal communication from Ulrike Bürger.

19. The design of the Preservation Pencil also allows the conservator to heat the ultrasonic water mist and create a jet of steam in a hand-held device. This component of the Preservation Pencil should never be used for the treatment of parchment, however, since hot water or steam can cause irreparable damage to an untanned skin material.


23. Since Klucel-J produces a slightly more viscous solution than Klucel-G it was considered by the author to be a more effective adhesive to use for the fabrication of this type of repair tissue. Acetone was added to the solvent mixture to speed up the drying of the adhesive film and thus prevent any alteration of the mold-damaged parchment that was being repaired.


25 When preparing a solution of isinglass the fish bladder should always be cooked at a low temperature; otherwise the proteins in the skin will be denatured and the solution will lose all of its adhesive strength.

26. Personal communication from Tatyana Petukhova.

28. The development of the adhesive-coated membrane came out of a more established method, practiced by Tony Cains and his staff at Trinity College Library, of using regular heat-set tissue as a "solvent-set" tissue, for the repair and reinforcement of paper and leather. In these two applications the tissue and the membrane are coated with the same mixture of acrylic resin dispersions (Plextol M360 and Plextol B500) and are applied with solvent, not with heat. For further information see: Anthony Cains, "A Facing Method for Leather, Paper and Membrane," in Sheila Fairbrass, editor, Conference Papers Manchester 1992, (London: The Institute of Paper Conservation, 1992), pp. 153-157.

29. Priscilla Anderson, a recent intern at the Walters Art Gallery, found that it was more effective to activate the adhesive layer of isinglass on the goldbeater's skin using ultrasonic mist, rather than damp cotton swabs.

30. Although commonly referred to as "parchment pulp" these pulp recipes are based, not on a powder made from new parchment, but rather on a finely ground, dried unprocessed animal hide that is obtained from the leather industry.


32. Personal communication from Ulrike Bürger, a Swiss book conservator who has considerable experience with this particular pulp filling method.


38. Personal communication from Dr. Jan Wouters.

39. The scientists and conservators in Belgium who developed this pulp filling technique acknowledge that it is not easy to replicate and that "...even small modifications of products or slight alterations in the preparation may result in a poor-quality reconsituted parchment." See: Wouters, et. al., "Leafcasting with Dermal Tissue Preparations," (1995), p.20.

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BEVA 371 AND ITS USE AS AN ADHESIVE FOR SKIN AND LEATHER REPAIRS: BACKGROUND AND A REVIEW OF TREATMENTS

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3 REVIEW OF BEVA 371 APPLICATIONS ON SKIN AND LEATHER

3.1 ADHESIVE PROPERTIES SOUGHT

There are several requirements of an adhesive for use in skin and leather repair. Ideally, the adhesive should be compatible with the substrate in its physical and chemical properties. It should not stain or change the appearance of the skin or leather and should remain flexible to allow movement of the object. The bond should be strong enough to hold the repair and to withstand stresses to which the object will be subjected. Such stresses can be induced by the weight of the skin or leather or through the handling required during mounting, exhibition, or travel. In terms of chemical qualities, an adhesive used for backing repairs should not interact with the substrate. It should be chemically stable and have good aging properties, i.e., it should release no harmful vapors and should not weaken over time. Also, the adhesive should be easily removable without adverse effects on the skin or leather. Thus, a stable adhesive that can create a sufficiently strong, flexible nap-bond would be ideal, as this type of bond minimally penetrates the skin and is most easily removed.

BEVA 371 meets most of these requirements. It can create a nap-bond without saturating the substrate. If required, it can be adapted (e.g., used at higher temperatures) in order to flow and more readily impregnate the substrate. It adheres very well to most skins and leathers. As previously mentioned (Fenn 1984), this characteristic is especially true for skin artifacts treated with wax polishes or oily leather dressings to which most adhesives, particularly water-based ones, will not adhere. Concerning aging or stability, BEVA 371 solution has proved to be highly stable according to the testing accomplished at the CCI, and it is assumed that the same holds for BEVA film. Reversibility can be accomplished by exposure to hexane or heptanes for a short time, in either liquid or vapor form, or by mechanical means, with or without heat (Berger 1976).

Compared to BEVA 371 solution, BEVA 371 film is a more recent product, but it is used increasingly for skin and leather repairs. As was seen in section 2.2, the film has been shown to produce more consistent bonds than the solution and gives a higher degree of control (Forest 1997). In relation to these results are BEVA film's practical advantages over BEVA solution: it requires no preparation time, is easier to apply,
and is more even and uniform than any film cast in-house. BEVA solution, on the other hand, may need its thickness built up in layers, a process that requires diluting the solution, warming it up, and applying it on a backing either by rolling, squeegeeing, spraying, or flocking. Sufficient drying time is required between each application.

Although BEVA 371 has been used successfully on numerous occasions for skin and leather treatments (see sec. 3.2), in some cases it will fail to meet the objectives of a treatment or simply not succeed as well as an alternative. It can be helpful to examine the reasons invoked in the literature for not selecting BEVA 371 after its initial testing for a skin or leather repair treatment. Dignard (1989, 1992) mentions that BEVA 371 solution was considered for the treatment of tears in a kayak, but was avoided due to the lack of proper solvent extraction. Also, heat-setting or solvent reactivation in this case was difficult because of limited access to the back. Fenn (1984) reports that BEVA 371 solution used at room temperature did not adhere well to gut artifacts such as Inuit parkas and bags made from caribou stomachs. It also altered the translucency of the thin skin (if heat-set, the adhesive is stronger and becomes transparent, but presumably heat was to be avoided for these vulnerable materials). In these instances, more success was found using water-soluble (Klucel G or Modocoll EK1200) or water-dispersed (Elvace 1874 or CM Bond M2) adhesives. Fenn also describes issues concerning the treatment of buckskin shirts with friable pigments rubbed into their surface. Tests suggested that if these were to be treated with BEVA 371 solution, later attempts at reversal with specific solvents could drive the adhesive into the pigments, thus altering the color through saturation. For these reasons, it was believed that the polyvinyl acetate (PVAC) emulsions may give better results. Kite (1991) reports that in the treatment of an alurntawed fur-skin, the film was tested, and, although it held well, it was visually disturbing and seemed to penetrate the skin, making it look translucent. She ended up using a wheat starch paste–sodium alginate mixture with a paper backing material. For the treatment of a sheepskin lining of a saddle, Selm (1989) found that BEVA 371 solution used in solution or cast as a film (and presumably heat-set) gave a weak join, saturated the leather causing staining, and had an unpleasant, lingering smell. Instead, Paraloid B-72 film cast from a 15% solution in acetone was employed. The acrylic film was applied to Reemay and either heat-set or solvent-reactivated with acetone.

3.2 TEAR REPAIRS

Besides its initial use on paintings and textiles, BEVA 371 solution was also used at a fairly early date on leather, specifically upholstery. Sheetz and Cochran (1978) describe backing an upholstery leather piece with BEVA 371 solution and Stabiltex (now called Tetex). They describe the process:“After the [fill] repairs were made, the leather was turned unfinished side up and lined with a reinforcing material, Stabiltex, a sheer synthetic [polyester] material, both flexible and strong. The Stabiltex was placed over the leather and attached to it with BEVA 371, which was melted over the Stabiltex a small area at a time with a warm tacking iron.” Following this publication, literature on BEVA 371 repairs covers a range of objects, such as leather upholstery, saddles, gilt leather, and wall coverings. Most frequently, the treatments involve a
system of applying the adhesive to a backing, or carrier, and heat-setting this “band-age” as a repair or stabilization measure. However, there are many interesting variations. The following review attempts to give a different perspective to the published information on skin and leather tear repairs using BEVA 371 by presenting the treatment variables that researchers have quantified (see table 1) and that practitioners have used to achieve the bond they required. It should be recognized, however, that probably the most important variable in determining the strength of the adhesive bond is the object's surface and condition (Berger 1972).  

3.2.1 Variables in Manipulating the Adhesive  
The quantity of adhesive plays a major role in bond strength. Lining tests have shown that, when heat-setting at 65°C and 70°C, doubling the thickness of the 2.5 mil BEVA film can double or even triple the peel strength (Forest 1997). An increase in weight in the BEVA 371 solution used in a lining context also results in an increase in bond strength when used at temperatures above 60°C (Pullen 1991; Gayer 1992; Hardy 1992). Pullen (1991) also gives correlations between temperatures and thickness of adhesives; for example, a bond strength achieved at 70°C could be produced at 65°C by using 50% more adhesive. None of the treatment articles that were reviewed specified the coat weight when using BEVA 371 solution. For the film, though, not surprisingly, the thickness is usually specified (as given by the manufacturer).  
The most common method of applying BEVA 371 solution to the backing material in skin and leather treatments is to spread it on with a brush, allow it to dry, and, if necessary, reapply the BEVA in successive layers. The adhesive can also be spread by using a roller or a squeegee, or it can be sprayed on. As can be expected, the coat weights achieved using these methods can vary greatly (Hardy 1992). Another method of applying the BEVA 371 solution is to flock it onto the carrier fabric. This method differs from spraying in that it produces cobweb-type filaments of adhesive. Flocking is said to help reduce or better control the amount of adhesive applied. This method has been used for the treatment of deteriorated upholstery leather from two 17th-century chairs, using Reemay as the carrier (Howard and Berry 1995). The prepared backing was heat-set in the form of sutures for tears as well as in the form of a full lining to the back of the upholstery. Dignard and Gordon (1999) also use this flocking technique to apply BEVA 371 solution onto Stabiltex (Tetex). The prepared backings were heat-set to individual tears as well as to the full backside of a degraded and powdery fur trim and collar.  
Generally in a conservation repair involving a backing, the adhesive is applied to a carrier and not to the object's surface. However, just as the application of a slight sizing of BEVA 371 to the back of a painting has been found to improve adhesion (Berger 1975), some practitioners have applied BEVA 371 to both the skin/leather and the repair material in order to increase the bond strength. Calnan (1992) used BEVA 371 film on the carrier and BEVA 371 solution as a primer to repair tears in Spanish gilt leather. The prepared lining was heat-set in place. Similarly, Sturge (2000) used BEVA 371 solution on the leather as well as the carrier and heat-set the elements in place. Fenn (1984) describes repairs using BEVA 371 solution applied
sparingly on the inside of a weakened buckskin artifact. When the adhesive had almost dried, an equally sparing layer of BEVA solution was spread on the lining material and pressed onto the artifact without heat. It is likely that the success of this practice is due in part to an increase in wetting or contact with the object's surface. Experimental tests to compare these various application practices were accomplished by Calnan et al. (1991). They found good bond strengths (as measured by peel tests) resulted when BEVA 371 solution was heat-set after having been applied to the backing fabric alone, to the new upholstery leather alone, and to both the fabric and the leather. A slightly stronger bond was achieved when the adhesive was applied to the leather alone. However, when the tests were repeated using a thinner, deteriorated leather, the most appropriate bond for BEVA 371 was formed by applying the adhesive to the support fabric only, rather than on the leather only (application to both was not tested in this case). These somewhat contradictory results suggest that the condition of the skin object, and perhaps other treatment variables, plays a large role.

BEVA 371 solution has also been tested and used in leather conservation as a discontinuous film applied to a carrier fabric and heat-set onto the object. The optimum arrangement was found to be a series of 2 mm diameter dots, 1 mm thick, 5 mm apart, in a staggered formation. A 1 mm thick aluminum sheet was used to produce the pattern (Calnan et al. 1991). The theory behind this preparation was to provide the backed leather with more freedom of movement when exposed to a fluctuating climate. Tests performed on this repair technique did show an increased flexibility as compared to a continuous film of adhesive, but, as could be expected, a weaker bond resulted. Such a discontinuous film of BEVA 371 solution was used with Reemay to fully support the front-seat cover of a 19th-century Panhard-Levassor automobile (Calnan 1991). This method of application appears to be rare, as there are few reports of its use in the literature.

The activation temperature used will affect the degree of penetration or impregnation of the adhesive into the substrate and the color change or staining of the substrate. BEVA 371 solution becomes tacky at 55°C, liquid with an aggressive tack at 65°C, and at 70°C produces an even stronger bond (Berger and Russell 2000). In the case of the BEVA 371 film, peel strengths on lined canvases were found to vary considerably within this 15°C range of temperature: at 55°C they were too weak to even be measurable using a tensometer; at 60°C they were too low to ensure acceptable lining for a canvas painting (average of 0.05 N/mm); at 65°C they were on average approximately 10 times higher than at 60°C, falling within what was established as an acceptable strength for linings; and at 70°C they were found to be quite strong, being approximately twice as high as at 65°C (Forest 1997). This direct relationship between bond strength and temperature was also measured for BEVA 371 solution (Pullen 1991; Gayer 1992; Hardy 1992). In view of these results, the performance of hot spatulas or other heating devices becomes very important, in terms of the accuracy of the temperature and of its precision (or variability of the heat delivered). Although such data are not outwardly presented in the treatment literature, it is reasonable to assume that treatment temperatures for skins and leathers have fallen within, or close to, this range, depending on the required results. For example, in the treatment of a very fragile, fragmented ermine fur lining of a cape, Kite (1990)
mentions heat-setting BEVA 371 film at 70–75°C using nylon gossamer as the backing material. Similarly, Calnan (1991), in the treatment of elements of the previously mentioned 19th-century automobile upholstery, mentions heat-setting a discontinuous film (dots) of BEVA 371 solution at 70°C. Other reported heat-set treatments using the film include the treatment of torn stitchings within a saddle (Sturge 2000), a variety of skin materials including deerskin drums and lizard natural history specimens (Nieuwenhuizen 1998), a pair of fine suede gloves (Kite 1996), and a leather sedan chair (Selm and Bilson 1992). Heat-set examples employing the solution include the repair of Spanish gilt leather (Calnan 1992), repairs to parts of the above-mentioned 19th-century automobile upholstery (Calnan 1991), and the treatments by Howard and Berry (1995), Dignard and Gordon (1999), and Sheetz and Cochran (1978) mentioned earlier. One case study describes the use of very high temperatures to repair fragmented and weakened vegetable-tanned leather car upholstery. During this treatment, BEVA 371 solution was impregnated into the Reemay backing material and heat-set to the leather at 100°C using a short contact time (Sturge 2000). This is said to have allowed some reshaping of the leather while the BEVA was warm and soft, while producing a strong, secure bond once the adhesive was cool. In the vast majority of cases, such high temperatures are avoided for degraded skins and leathers.

BEVA 371 bonds quasi-instantaneously once the activation temperature is reached (over 60°C), but if the activation temperature is applied for a length of time, the bond strength is significantly affected. In a series of lining tests, Forest (1997) found that, with the hot table used, it took approximately 12, 14, and 18 minutes to reach the activation temperatures of 60, 65, and 70°C respectively, and about 20 minutes to cool back down to room temperature. If a holding time of 10 minutes was added when each activation temperature was reached, a bond of twice the peel strength resulted, as compared to the bond created with no holding time. In particular, it was found that at 65°C with no holding time, the bond was too weak for half of the samples. But, with the 10-minute holding time under the same conditions, the peel strengths ranged between moderate and too strong. Also, it is likely that the rate at which the BEVA 371 is heated and cooled may affect strength (Forest 1997). Holding time was not found to be reported in the treatments surveyed, but it would be expected to be in the range of seconds or tens of seconds rather than minutes. Rate is never mentioned either and most likely varies with the type, quality, and age of the equipment used.

Another treatment variable that affects bond strength but is not often quantified in skin and leather treatments includes the amount of pressure applied (Gayer 1992). In the case of the BEVA 371 solution, the amount of solvent retained or the length of time for solvent evaporation to occur prior to use will also have an impact on bond strength (Hardy 1992).

Conservators have often chosen to use BEVA 371 solution without any heat beyond room temperature to avoid potential heat damage. This technique results in a weaker bond than that achieved through heat-setting (Calnan et al. 1991). In some cases a weak bond is all that is required. Boulton (1986) describes repairs to a pair of Aleutian Islands boots using BEVA 371 solution diluted in toluene, brushed onto
goldbeater's skin, and applied at room temperature. Fenn (1984) also mentions the use of BEVA 371 solution without heat with various nonsynthetic backing materials to repair Inuit clothing water-proofed with sea mammal oils and also native-tanned clothing. Kronthal (2001) experimented with BEVA 371 solution at room temperature for some repairs to rawhide shadow figures.

In painting conservation, if temperatures lower than the activation temperature are required, they can be obtained by spraying films of the BEVA 371 with solvents. According to the BEVA 371 film technical data sheet, spraying the film lightly with naphtha makes it tacky at about 38–43°C (methylene chloride is also mentioned, but it is highly toxic). For BEVA 371 solution, the activation temperature can be lowered to 40–45°C or less by lightly spraying with aromatic mineral spirits. It can also be lowered by using the adhesive about two hours after applying it to the backing material, while it still retains some of the solvents (Berger 1975). No references to using BEVA 371 in this way on skins and leathers were found in the literature.

Another method of using BEVA 371 that avoids the use of heat is solvent reactivation of the dry film. The solvent can be sprayed onto the film or, for small repairs, applied with a syringe or a fine brush. If the solvent is applied with a syringe, it becomes possible to position the adhesive-covered carrier behind the object while the adhesive is in a dry state, an advantage shared with the heat-setting technique. The amount of time that good contact must be held through the application of pressure before the bond is achieved can be short, but it depends on the type and quantity of solvent used. In comparison, heat-setting involves quasi-instantaneous bonding time. Solvent reactivation was one of several methods used by Kronthal (2001) in the treatment of shadow puppets. In this context, goldbeater's skin was brushed with the BEVA 371 solution. This solution was left to dry as a film, and the backing and adhesive were applied by reactivation with naphtha or petroleum benzine. Though this technique was sufficient in many cases, a stronger bond was achieved with other adhesives in combination with the gold-beater's skin.

### 3.2.2 Choice of Lining Material

Many carrier materials have been used for skin and leather repairs, depending on the nature of the substrate and the required results. Their composition, method of construction (woven or nonwoven), and nap can affect the bond strength (Calnan et al. 1991; Gayer 1992; Daly Hartin et al. 1993; Forest 1997; Berger and Russell 2000) as well as flexibility of the repair.

Both spun and woven synthetics have been used successfully, including Stablitex (Tetex) woven polyester (Sheetz and Cochran 1978; Dignard and Gordon 1999), Hollytex spun polyester (Nieuwenhuizen 1998), Reemay spun polyester (Kaminitz and Levinson 1988; Calnan 1991; Howard and Berry 1995; Nieuwenhuizen 1998; Sturge 2000), Dacron woven polyester taffeta (Tsu et al. 1999), Arvex woven polyester or polyester sailcloth (Calnan 1991; Calnan 1992; Selm and Bilson 1992), and Cerex or nylon gossamer (Kaminitz and Levinson 1988; Kite 1990; Calnan 1991;

Natural materials have also been used. Tsu et al. (1999) describe repairs to tears within an 18th-century gilt wall hanging using Japanese paper with BEVA 371 solution in combination with the BEVA gel. Fenn (1984) used both new oil-tanned skin and cotton fabric with the BEVA solution in treating native tanned skins (Fenn 1984; Tsu et al. 1999). Skin lining materials, such as goldbeater's skin and natural skin condoms, have also found useful applications. For example, Kronthal (2001) found that the translucent properties of goldbeater's skin matched those of a collection of Chinese shadow puppets while also producing a strong, flexible mend. Boulton (1986) has also used goldbeater's skin with BEVA solution at room temperature to treat Aleutian boots.

### 3.3 FILLS

One can utilize BEVA 371's thermoplastic properties and flexibility to create a fill material and to replicate textured surfaces. Calnan et al. (1991) investigated a series of possible polymeric fills, including the use of BEVA 371 film. They found that the heated film could be worked to create a flexible and extensible fill and had the following advantages: it requires virtually no drying time, it is easy to reverse with heat or solvents, and it is easily overpainted with acrylic emulsion paints. They also noted that the fill material needed reworking to ensure a smooth finish and uniform adhesion and had a tendency to spill over onto the immediate surrounding leather surface. In this case, the preferred application involved heat activation of small rolls of the film placed in the crevice and building up the fill material in layers to ensure that the adhesive was fully activated and bonded well to the leather. Kaminitz and Levinson (1988) used the solvent form of BEVA 371 mixed with dry pigments and glass microballoons to fill losses in untanned skin stretched over wooden drums and harps. The mixture was applied in a thin layer over an insert of Japanese tissue paper or synthetic web fabric. In this case, considerable strength was required to join the fill material to the very thin edges of the loss, and great flexibility was necessary to allow the skin to respond to environmental changes without separating from the fill. Nieuwenhuizen (1998) mixed warmed BEVA 371 film with dry pigments and glass microballoons and applied it as a fill material to replicate textured surfaces. In this case, the solution was avoided in an attempt to minimize shrinking. Sturge (2000) describes the use of colored BEVA “sticks,” made by mixing small amounts of dry pigment into BEVA 371 solution and allowing the solvents to evaporate after spreading the mixture onto silicone paper. Once dry, the solid BEVA 371 can be cut into strips and melted into cracks and splits using a heated spatula.
NOTES ON A METHOD FOR CONSOLIDATING LEATHER

Morgan W. Phillips

ABSTRACT—An experimental method of consolidating leather by the precipitation within the leather of polymethyl acrylate is described.

ALTHOUGH LEATHER IN FAIR or good condition may benefit from lubrication or the adjustment of moisture content, crumbly (often “red rotted”) leather may instead require consolidation—the introduction of a resinous binder. The subject of consolidating old leather has received relatively little attention. In 1972 Waterer reported successful consolidations of leather using dilute solutions of a polyacrylate resin; in some cases repeated applications of the solution were used. In 1978 Nikitina described the impregnation of fur clothes with an aqueous dispersion of a copolymer of vinyl acetate and 2-ethyl hexyl acrylate. In the same year Thompson noted that BEVA 371 had a consolidating effect on leather. Also in 1978 Hallebeek and van Soest suggested methods for using a flexible aliphatic epoxy consolidant, which had been formulated as a wood consolidant by Munnikendam. Hallebeek reported in 1980 that tests of this system were in progress. In 1984, van Soest, Stambolov, and Hallebeek stated that improved properties in the cured product had been obtained by using a revised formulation based on a higher-molecular-weight homolog of the aliphatic epoxy.

Cains has used hydroxypropylcellulose for some years as a consolidant for bookbinding leathers at Trinity College Library, Dublin. A polyurethane has recently been recommended to the British Library for this purpose.

1 AN ACRYLIC PRECIPITATION METHOD

IN VERY PRELIMINARY TRIALS, I have observed that an acrylic precipitation consolidant can work well for strengthening some leathers. The acrylic precipitation method was described in some detail in 1982, in respect to test applications on wood, stone, and brick. Essentially, an acrylic monomer is mixed with a solvent and initiating materials and soaked into a porous substrate. Polymer is formed after impregnation; at present a thermally activated initiator is used which requires the impregnated object to be heated to about 40°C or higher. Evaporation of the consolidant during polymerization is prevented by wrapping the treated object in foil. The object is unwrapped after polymerization to allow the solvent to evaporate. A solvent is chosen in which the polymer to be formed will be insoluble: thus, the newly formed polymer is not drawn out toward the surface with the evaporating solvent.

The precipitation method may sometimes circumvent limitations inherent in other methods of using acrylics as consolidants: the higher viscosities of
polymer solutions and their tendency to consolidate the surface of an object more than the core; and stresses that may occur when undiluted monomer is polymerized within an object. In addition, the precipitation method often seems to darken an object less than other polymeric treatments that impart similar strength, perhaps because the resin is deposited as a light-scattering gel or as particulates. The amount of monomer used, in relation to the solvent, can be varied over a wide range.

In earlier work on wood and masonry materials I used methyl methacrylate as monomer: the current trials on leather have been done with methyl acrylate, which forms a flexible polymer. The brand of monomer used contained 15 p.p.m. of p-methoxy phenol inhibitor. A “starting” formulation that seems promising is, by weight,

Methyl acrylate 100
Exxon IsoparRG solvent 50
Noury PercadoxR 16N initiator 2

PercadoxR16N is bis [4-t-butyl cyclohexyl] peroxydicarbonate. Exxon IsoparRG is an industrial grade of mixed isomers of mostly C-10 and C-11 aliphatic hydrocarbons. Laboratory grades of decane or perhaps dodecane should work similarly. In previous work on masonry materials and wood, heptane was used, but there may be some advantage in using solvents more viscous than heptane, as the polymerization rate and the molecular weight of the polymer formed might be enhanced by higher viscosity.

2 TEST APPLICATIONS

SMALL SAMPLES OF DETERIORATED LEATHER were soaked in the consolidant solution, wrapped in aluminum foil, and embedded in sand that had been preheated to about 45°C–50°C. The sand, with the samples, was placed in an oven and maintained at roughly this temperature for four hours. The purpose of the sand was to buffer the temperature changes of the poorly controlled oven, and to draw off any heat of exothermic reaction from the samples. The samples were then withdrawn, unwrapped, and dried to remove solvent and residual monomer. The samples were dried by overnight warming followed by a week's airing at room temperature. Most of the samples continued to stiffen slightly over the following weeks. The following describes the uneven but encouraging results.

An early-nineteenth-century American calfskin, brittle and rather crumbly, was greatly strengthened, though also darkened. The strength increase was easily sensed by abrading the leather or by breaking narrow strips in tension. The treatment, however, made the leather more subject to cracking on being folded sharply. Another, similar, piece seemed completely unaffected by the treatment—neither strengthened nor darkened.
A red-dyed and gold-striped late-nineteenth-century calfskin, thoroughly red-rotted and intolerant of bending, became remarkably strong in tension, and was darkened only on the reverse side. Though stiffened, the treated leather became tolerant of repeated gentle flexing; it still cracked on being folded sharply. The gilding was unaffected.

A late-nineteenth-century suede, partially rotted, was made much stronger in tension and much more resistant to abrasion. It was darkened more than would be desirable, but mostly on one side.

Two late-nineteenth-century embossed leathers from wall coverings, both completely rotted, were considerably strengthened. The consolidant attacked the leafed-and-painted finishes on one of the leathers, but did not disrupt the metal leaf or paint on the other. Neither example was darkened at all—either on the finished surfaces, on the reverse, or in spots where the finishes had broken away.

The strengthening of these wall covering leathers was somewhat uneven. Pretreatment of one small sample with a dilute solution of the polymer (polymethyl acrylate in toluene) followed by the precipitation consolidation produced a more uniform, though darkened, product. Perhaps, besides contributing some strength on its own, polymer deposited on the fibers from solution enhanced subsequent deposition of precipitated polymer.

3 FURTHER CONSIDERATIONS

WHILE POLYMETHYL ACRYLATE alone is flexible, and rather soft, leather impregnated with the resin is a composite material of which the hardness and other properties may not be easy to predict. The surface hardness of the composite would determine whether there is a tendency to pick up dust, in which case a surface coating might be needed. The composite's comparative strengths in tension versus compression would affect its resistance to cracking when folded sharply: if the inside surface of a fold does not compress easily, the outside may break in tension. Though only one formulation was tried—rather “rich” in monomer—the properties of composites made by treating different leathers varied widely.

Outline tracings of the samples indicated little or no shrinkage during treatment. Shrinkage might be observed in some cases, caused either by contraction within the polymer as it formed or dried, or as a direct effect on the leather of the heating needed to activate the polymerization initiator. Room-temperature initiation systems, such as those activated by ultraviolet light, might be useful.

An important consideration is reversibility of treatment. Polymethyl acrylate is a linear acrylic resistant to cross-linking and thus, theoretically, removable. The actual practicality of removal is another question, however, involving the molecular weight of the polymer, the effect of solvents on the leather, and stresses exerted by the polymer when swollen by solvent during removal.
4 CONCLUSION

VERY GOOD RESULTS ACHIEVED in treating some of the samples indicate that the method deserves further study. A water-white thermoplastic polymer can be uniformly deposited throughout the thickness of leather, in substantial quantity but with relatively little darkening effect. The strengthening of the leather can be dramatic. Various linear and cross-linked acrylic copolymers could be tried, including very soft ones made with n-butyl acrylate.

Though offered as a subject for further study, the method is by no means recommended as a treatment. Systematic testing and modification would be needed to make the process safer and more predictable.

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REFERENCES


CONSERVATION OF CHINESE SHADOW FIGURES:
INVESTIGATIONS INTO THEIR MANUFACTURE,
STORAGE, AND TREATMENT

LISA KRONTHAL

ABSTRACT—Chinese shadow figures of the Beijing, East City, type were cut from translucent skin, painted with dyes, and coated with tung oil. The history of the American Museum of Natural History's collection of Chinese shadow figures and details concerning the materials and techniques used in their manufacture are described in this article. Also covered is the shadow theater's relationship to Chinese opera in symbolism, color, and form. The tung oil coating in this collection, as in most, has remained tacky, resulting in extensive damage due to adhesion of elements to themselves and to storage materials. Other common damage includes tears and distortions of the skin and detached elements. A survey of the collection is given, and research into appropriate materials and techniques for new storage and treatment is described, as well as investigations into silicone-coated Mylar as a long-term storage material. For tear repairs, a range of intestinal lining materials including goldbeater's skin, reconstituted collagen, and natural skin condoms, in combination with adhesives including gelatin, Beva 371, Paraloid F-10, and polyvinyl acetate resins, is presented.

Fig. 1.

Shadow figure, Beijing, East City type, 30 x 16 cm, from the Anthropology Division Collections, American Museum of Natural History, no. 70/10181
1 INTRODUCTION

Asian shadow theater is a dramatic art form that has survived centuries to tell historic tales and myths that remain relevant in contemporary cultures and societies. A comprehensive collection of 19th-century Beijing, East City, type shadow figures was acquired for the American Museum of Natural History (AMNH) by the renowned sinologist and ethnographer Berthold Laufer (187?–1934). The small skin figures were carved and painted to project vividly colored and detailed images upon the screen. Articulated limbs, detachable heads, and magnificent scenery enhance the fantastic stories and tales (fig. 1). There are similar collections of East City type shadow figures in the United States and Europe. The puppets within these collections have comparable condition issues due to a traditionally applied coating that remains sticky over time and to the inherent fragility of the finely carved skin, which is prone to tears and losses. The AMNH archives contain extensive correspondence between the keepers of these collections, primarily concerning the problematic coating. These documents show a clear attempt to resolve condition issues using a variety of materials and techniques, including applying Scotch tape for tear repair, sandwiching puppets between sheets of waxed paper, and completely removing the coating. Once considered acceptable, these methods of treatment are no longer used, as they often left individual puppets as well as whole collections irreversibly damaged.

Although the coating is problematic, its historic importance makes its removal unacceptable. Its preservation was considered paramount in this project, and treatment procedures that were compatible with it needed development. Additionally, a storage system that would resolve the problems encountered in the past would also need to be designed.

2 THE ORIGIN OF THE AMNH SHADOW PUPPET COLLECTION

In 1901, Franz Boas, then a curator in the Department of Anthropology at the AMNH, commissioned the German ethnologist Berthold Laufer to travel to China for field investigation and the collection of artifacts documenting the daily life of the Chinese people. These investigations continued the work of the Jessup North Pacific Expedition, launched in 1897 to research the cultures living along the rim of the North Pacific Ocean, from British Columbia to China and Japan (Stalberg 1983).

Laufer was particularly thorough in gathering objects connected with popular performing arts, such as the puppet theater, shadow theater, and local music. He purchased the complete holdings of a 19th-century puppet master of the late Qing (1644-1911) dynasty, including musical instruments, stage curtains, playscripts, and more than 1,000 shadow figures. Additionally, he made wax cylinder recordings of dialogue and music, creating a collection that is extraordinarily complete and well documented.
Laufer saw value in studying Chinese shadow theater since he felt it could be the origin of shadow theater around the world. He explained to Boas that many studies published in Germany covered the shadow theater of Turkey, Syria, India, and Indonesia, yet none focused on Chinese shadow theater. Since many of the plots show Buddhist influence, he also considered the material important in understanding the migration of Indian tales throughout East Asia. Unfortunately, Laufer was unable to completely catalog the material he collected before he left for Chicago's Field Museum, which holds another large collection of East City figures.

2.1 DEVELOPMENT OF CHINESE SHADOW THEATER

The first recorded proof of shadow puppetry in China dates to the Song dynasty (960-1279), though references to related activities and events exist prior to that time (Hirsch 1998). A famous story from the Han dynasty (206 B.C.-220 A.D.) became widely accepted as telling the origin of shadow theater. It describes a time in the life of the Han emperor Wu in which he became despondent over the death of his favorite concubine. To comfort the emperor, a court magician, through the use of shadows and candles, made the image of the concubine appear to the emperor from behind a curtain (Sima 1959). Scholars stress that this unlikely origin for shadow theater became accepted and popularized in the 11th century (Hirsch 1998).

The more likely predecessor for shadow theater occurred during the Tang dynasty (618-907), when the art of storytelling was combined with visual components to aid in illustrating the narrative (Hirsch 1998). Buddhist narratives were illustrated with pictures on paper screens or scrolls. Additionally, during the Tang, paper-cuts were pasted on lanterns, screens, and windows with light illuminating them from behind. The images, similar to those created by shadow figures, lead many people to see them as inspiration for shadow puppets. In fact, the earliest Chinese shadow puppets known from the Song dynasty were made of paper.

More concrete evidence of the existence of shadow theater occurs in the Song dynasty. The Mengliang Lu (A Record of the Millet Dream) was written about the southern Song capital and gives a descriptive account of shadow theater:

There are also performers of shadow plays. In the beginning in Ban capital, they made them from plain paper and carved bamboo. Later, men became more clever and their craft more skilled and they carved the likeness (of men) from sheepskins and adorned them with colors so they would not deteriorate. (Hirsch 1998).

Beginning in the 11th century, the shadow theater tales of battles and myths were performed by itinerant entertainers throughout the countryside and were no longer performed within walled cities or towns. This development was due to numerous decrees by a series of rulers prohibiting ritual and drama. By the early Ming dynasty (1368-1644), a general revival of shadow puppetry took place, and the performances again became part of the culture within the cities and in the countryside (Hirsch 1998). The artistry of the figures had assumed an important and respected role in theater, and several distinct schools of shadow theater emerged.
The Luanzhou School in Beijing gained fame and royal sponsorship during the late Ming. Under the Qing dynasty, two branches within this school developed and were known as East City (Beijing) and West City types.

2.2 EAST CITY SHADOW THEATER

The Eastern school, which is the focus of the AMNH collection, is considered by many to be the most refined of the Chinese shadow puppet schools (Erda 1979; Stalberg 1983). It employs very skilled, detailed carving techniques and the thinnest and most translucent skins. The puppets are carved into shapes of human figures, animals, or scenery and are designed to be manipulated by rods in front of a lamp projecting colorful shadow images onto a translucent screen. The audience gathers on the opposite side of the screen to view the shadow (fig. 2). Unlike their more common Indonesian counterparts, the East City shadow puppets are cut from paper-thin skin. Because of the increased translucency of the tung oil–saturated paint and skin, they appear brilliantly colored when lit. When the puppets are held very close to the screen, the colors and details in carving are all sharply in focus (fig. 3). When the puppet moves back, its shadow becomes larger and less distinct.

Fig. 2.
Shadow performer (Stalberg 1984, 94). As the puppets are held close to the screen, their images come into sharp focus.
Fig. 3.

Shadow performer (Stalberg 1984, 94). As the puppets are held close to the screen, their images come into sharp focus.

The theater incorporates elaborate props, furniture, and scenery, creating spectacular and complex compositions on the screen. Dragons, monsters, and flying immortals as well as fires, battles, and bloody deaths are vividly depicted. The advantage of shadow theater is that myths and legends involving fantastic transformations can be performed with great ease and depicted more fully than in other performing arts such as opera, marionette theater, or hand puppetry. The illusion of light and colored shadow allows for flight, decapitation, spurtting blood, sudden growth, shrinkage or appearance of hidden features, and other supernatural phenomena that often take place in Chinese legends.

2.3 INFLUENCE BY CHINESE OPERA

As in regional opera, the puppet masters used painted faces, masks, distinctive movements, and elaborate costume design to identify and distinguish the characters. The masks, face painting, and costumes allowed the viewer, familiar with the meanings of each color and form, to recognize the personalities of the characters in a drama (fig. 4, 5). As in the opera, the characters in shadow theater are divided into four major groups: the Chou (male or female comic actors), the Jing (male military characters), the Sheng (scholars or officials), and the Dan (women characters who can be military, educated, or servants, old or young). Immortals, supernaturals, or demons can take any of these roles (Broman 1981). Painted faces and headdresses
symbolize the personality traits or rank of the different characters. For example, a fierce and powerful general may wear a red and black mask, the red designating strength and the black loyalty. A female gossip might have an ornate hat and a pockmarked face.

Fig. 4.
Shadow figure heads, Beijing, East City type, each head measures approximately 12 x 8 cm. The faces of noble gentlemen and women are usually completely cut away, leaving graceful outlines of eyes, nose, lips, and forehead. Anthropology Division Collections, American Museum of Natural History, acc. no. 1903-13.
Fig. 5.
Shadow figure heads, Beijing, East City type, each head measures approximately 12 x 8 cm.
The faces of the comic actors, warriors, mythological, and hell figures will most often be left solid or painted. Anthropology Division collections, American Museum of Natural History, acc. no. 1903-13.

The style and methods used for cutting and carving the skin also help to distinguish personalities or identities. The faces of noble gentlemen and women are usually completely cut away, leaving graceful outlines of eyes, nose, lips, and forehead (see fig. 5), while those of the comic actors, warriors, mythological, and hell figures are most often left solid or painted (see fig. 4). Different styles of facial hair provide clues for male characters. A finely combed beard is appropriate for a highly respected gentleman, while a fiercer character would wear a fuller beard. Costumes are also used to indicate social standing. Generally, the more detailed the carving, the more important the character. Lower-class characters are depicted wearing very plain, unembroidered, and therefore uncarved garments. The costumes of officials and generals are elaborately carved and painted to represent their lavish embroidery and complex armor. These distinctions would have allowed the audience to remain completely aware of the hierarchy of the characters on stage.
3 TECHNOLOGY: MATERIALS AND MANUFACTURE

The construction of a shadow figure of the East City type begins with soaking a hide in water and then stretching it on a frame. The wet skin, traditionally donkey, is rubbed and scraped, first with a stone, then with bamboo, until it is thinned to translucency. Often, the hide of a young animal or a hide that has been split or skived is used for parts of the figures that require greater translucency. When thicker skins were needed, sheep or cow was used (Erda 1979; Jilin 1988).

The outline of the figure is traced or drawn freehand onto the skin, usually by incising, and is cut out using specialized chisels and knives (fig. 6). Most of the puppets depict human figures and are composed of 11 parts. For less important figures, the legs, torso, and even head may be cut from one solid piece of hide. These characters are not required to express multiple personalities and therefore do not need to make the range of movements obtained with the more complex articulated puppets.

As mentioned, different parts of the puppet body are made from different sections of the hide. Traditionally, the skin from the belly of the donkey is employed for faces and upper body parts, while thicker sections are more appropriate for the feet, legs, and torso. The thinner skins of the faces transmit more light, creating a sense
of illumination, while the weight and rigidity of the thicker skins in the lower body keep the puppet balanced and stable. Often tiny lead plates are attached to the bottom of the pant legs to obtain greater balance and to allow the legs to swing back and forth, simulating a walking stride.

The puppet maker cuts joints between the legs, arms, and torso into shapes resembling wheels with spokes. These radial cuts prevent a large dark spot from appearing on the screen where parts inevitably overlap, creating two layers for the light to penetrate. This technique can be seen in the puppet shown in [figure 1] at the elbow junctures, at the tops of the legs, and through the center of the figure. Silk, cotton string, or flaps of rawhide hold the parts together, and occasionally metal wire is used to reinforce separate elements. The heads are not attached permanently. Instead, they fit into a collar of parchment, allowing the character to change costume or persona in the course of a performance. Often many heads are needed to show the changing status and emotions of a single character in the course of a play. This construction also allows decapitation, a frequent mode of execution, to be convincingly portrayed. The puppeteer attached iron alloy wires with bamboo handles to the figures for manipulation.

Traditionally, the skin was painted on both sides with vegetable dyes. Later, synthetic dyes and paints were used. An application of oil, usually tung oil, was applied in order to saturate the colors, resulting in a more vivid projection as well as greater transparency. Periodically, as part of the regular maintenance of his collection, the puppeteer reapplied the coating.

3.1 CONDITION: INHERENT INSTABILITIES

Structural instabilities throughout the collection are mostly related to the manufacture of the puppets, specifically their thinness and intricately cut designs. Common damage resulting from this inherent disadvantage include tearing of the skin, distortion, and detached elements. It was common for the puppet master to manufacture his own figures and to regularly restore damaged figures. Therefore, before any treatment is accomplished, a clear distinction must be made between ethnographic and modern interventions. Ethnographic repairs in the Laufer collection include sewing, pinning, and patching with skin. These repairs have historic importance and should be preserved if possible. Modern attempts at restoration include applying transparent, pressure-sensitive tape to tears and using paper clips to connect detached elements. In most cases, it is appropriate to remove and redo these repairs using more appropriate materials or techniques.

3.2 THE TUNG OIL COATING

The tung oil coating is the main culprit in creating condition and preservation issues in many shadow puppet collections. In the AMNH collection, old storage facilities in non-climate-controlled environments aggravated these issues. Puppets piled into shallow trays were found stuck to adjacent puppets, to storage materials like brown Kraft paper, or to plastic bag enclosures. Correspondence with other institutions and
private collectors indicates that this sticking problem was widespread. A 1974 letter to AMNH restorers from a restorer working in a large American museum reads:

We own a large collection of shadow puppets made of traditional “parchment,” dyed with bright colors, and then coated with a shellac-like substance. The problem lies with the latter material which in time has become tacky and sticky and adheres to whatever guard sheet we lay between the images. We've not been able to find a solvent which can remove the sticky material without removing the color.” (AMNH 1974)

The AMNH response to this inquiry suggested either complete removal of the coating using methyl ethyl ketone solvent (MEK) or “if one wanted to preserve the coating then application of Butcher's wax would act to prevent sticking.” The collection from the corresponding museum was treated by soaking the artifacts in baths of MEK, removing the coating entirely along with much of the originally applied color.

Another letter in the AMNH archives describes a different approach. In this case, removal of the coating would cause irreparable changes. Instead, paraffin was applied directly to the surfaces in an attempt to reduce the sticking. When conservators were unsatisfied with the results, the surfaces were rubbed with Vaseline (AMNH 1974).

These approaches to the problematic coating either attempted to cover it with another material or to remove it altogether. At the AMNH, we consider both of these options unacceptable. Instead, a less intrusive treatment involving upgrading storage conditions and developing treatment procedures compatible with these inherently fragile and sticky artifacts needed to be developed.

3.3 TUNG OIL: CHEMICAL AND PHYSICAL CHARACTERISTICS

An investigation into tung oil and its drying properties offered some help in understanding the troublesome surface treatment. Most references concerning Beijing shadow figures describe tung oil as the primary coating material. Several oil samples were removed from puppets in the collection. These represented the range of oil types found on the puppets as distinguished by their surface characteristics. All samples were positively identified as tung oil by using Fourier transform infrared spectroscopy (FTIR) and gas chromatography–mass spectrometry (GC-MS). George Wheeler accomplished the analysis at the Metropolitan Museum of Art Conservation Laboratory.

Tung oil, also known as Chinese wood oil, is obtained from the seeds of the fruit of Aleurites fordii, a tree that has grown in China for centuries (Gettens and Stout 1942). The native method for separating the oil involves roasting the seeds over a flame and grinding them with stones or wooden presses. A coldpressed version of
the oil called “white tung oil” is light in color and is mostly exported. The hot pressed oil has a very dark color and is called “black tung oil.”

Tung oil contains a large proportion (75-85%) of eleostearic acid, a stereoisomeride of linoleic acid, which is found in linseed oil. These acids contain two unsaturated double bonds, a property that gives an oil its drying property. However, under normal temperature and humidity conditions, tung oil takes approximately 30 days for a full gain in weight or for drying to be complete, distinguishing it as a slow-drying oil. In fact, tung oil is not recommended as an artist's material since it requires extensive processing to dry to a satisfactory level (Gettens and Stout 1942).

Under humid conditions the oil will dry more rapidly, with a resulting film that is wrinkled, cracked, or reticulated. This drying-rate increase in moist air is not “drying” in the usual sense through oxidation and polymerization. Instead it is thought that the oil is coagulating from the high moisture exposure and is therefore thicker and more viscous but not necessarily drier (Gettens and Stout 1942). The reticulated surface texture of the coatings on the puppets is common and could have resulted from application and “drying” in a humid environment.

4 REHOUSING AND SILICONE MYLAR

Since the oil has ethnographic significance and cannot be altered or removed, choosing appropriate and compatible storage materials for rehousing is a priority. Several attempts at creating safe housing for the collection were undertaken in the past. In spite of good intentions, these campaigns have complicated storage and condition issues. A variety of materials were used as interleaves, including silicone release paper, acid-free tissue, brown Kraft paper, Mylar, and plastic. The figures stuck to all of these surfaces. Requirements for the new storage environment included controlled temperature and humidity conditions as well as storage on a surface that is nonstick, nonreactive, and nontextured.

We considered vertical storage, Teflon surfaces, and silicone-coated Mylar surfaces. Vertical storage was impractical due to space considerations. The thought was that the puppets would hang from a horizontal support so that none of their surfaces touched any storage material. An additional concern with this concept was distortion of the skin over time.

During this investigation, which began in 1994, the Teflon we were considering was in a thick sheet or tile form, and the cost of this product was too high. At the time, we were not aware of the possibilities of using Teflon films. Teflon tape (plumber's tape) was considered but later eliminated as an option due to the narrow strip form in which it was supplied. Since then, we have been made aware of the use of such film supplied in a wider form (Odegaard et al. 1997). The film can be purchased in widths up to 12 in. and is a viable option for long-term storage of artifacts with tacky surfaces. Initial investigation into the material indicates that its release level is not as high as necessary for the high tack of the puppets.
At the time of the shadow puppet rehousing project, our focus went to silicone-coated Mylar as a practical choice. During our investigation into this material, we realized that the silicone coating on the Mylar on hand in the conservation laboratory was not permanently “adhered” to its substrate and was readily removed by a range of solvents. For long-term storage, such qualities were unacceptable since the eventual loss of the nonstick properties of this material when in contact with the soft oil seemed too risky.

Further research into the range of technologies involved in the manufacture of the product led to the discovery of several interesting facts. Many companies purchase the raw Mylar, using Dupont Mylar A or D, and apply the silicone coatings using several polymerization techniques, the major ones involving UV or heat-curing technologies. Conflicting opinions from the suppliers about the effect of these processes on the final physical qualities of the coating were common. Most claimed there are varying levels of transfer of the coating to whatever material is laid upon it, the UVcured coatings transferring the least and the heatcured coatings having a higher possibility of transfer. Requirements for the storage surface for the shadow puppets included a film with a low transfer potential and medium or high release levels. A coating company named Douglas Hanson uses a UV activation polymerization technique that results in a product that meets these requirements, and both Conservators’ Products and Talas distribute this product.

Rehousing the collection involved preparation of each shelf by lining it first with acid-free corrugated board and then with the Douglas Hanson siliconecoated Mylar. Puppets were laid onto the Mylar surfaces and pinned in position through preexisting holes in the carvings with map pins that had been coated with an isolating layer of Paraloid B-72. The pins were used to keep the puppets from sliding out of place when trays were pulled out of their cabinets. This event was common on the slick Mylar surface.

5 TREATMENT

During the rehousing, a survey of the entire collection was conducted in order to prioritize treatment. The survey results were entered into a database created specifically for the collection. It was found that more than 300 of the approximately 1,500 puppets were considered first priority, and most were in need of treatment. These puppets often required the removal of old storage materials stuck in the coating, mending of tears within the skin, or reattaching separated elements.

Solubility tests on the coating revealed that it was soluble, in varying degrees, in a wide range of solvents. Acetone and ethanol solubilized the coating readily, toluene, petroleum benzine, and xylene moderately, and Stoddard solvent minimally. In most cases, the coating had saturated the storage material, and separation would inevitably involve some loss of coating. The goal in removal of the storage materials from the puppet surfaces was to retain as much of the original coating as possible along with its original, reticulated texture. By wetting the papers with Stoddard solvent, a scalpel could be inserted at the interface of the coating and
the paper, and, in most cases, the paper could be removed with minimal loss of oil. The Stoddard solvent appeared to function mostly as a lubricant enabling separation of the layers while retaining the original surface texture of the coating.

5.1 MENDING TEARS IN TRANSLUCENT SKIN: LINING OPTIONS

The goals in mending were to find a combination of materials that was compatible with the skin and oiled substrate and that would maintain the transparency of the skin when viewed through transmitted light. Various materials were considered for repair of tears, including Japanese gampi papers, oiled papers, goldbeater's skin, natural skin condoms, and sausage casings (reconstituted collagen). The papers were eliminated as an option for many reasons, including differential aging of the paper when in contact with the acidic skin and oil, dimensional incompatibility, and visual inconsistencies.

The collagens were given primary consideration due to their visual and chemical compatibility with the skin substrate. Several concerns developed when considering the use of the sausage casings in this treatment. The preparation of the collagen in manufacturing a casing involves reducing bits of animal skin (generally cowhide) in hydrochloric acid, spiningtruding the gelled product, bathing it in aluminum sulfate, buffering it, and adding plasticizers, consolidants, and tanning agents (Morrison 1986). These steps, especially the acid preparation, reduce the length of the collagen fibers, resulting in a product that has a very short shelf life and quickly becomes brittle upon removal from the package (Woods 1997). Requirements for a stable, flexible mend led to the elimination of this product as an option.

The natural skin condoms were more promising. The intestinal material used in their manufacture comes from the cecum of the large intestine of sheep or lamb. The processes involved in its preparation include trimming and defatting of the skin, soaking it in salt solutions, addition of surfactants, light tanning, and coating with a lubricant that can be removed with acetone or ethanol. There is no acid...
preparation involved, as maintenance of strength and endurance are crucial requirements for such products. Unfortunately, for use on the puppets, the final product is too thick and does not lead to visually acceptable results, but it may be useful for other types of mending that require more thickness or strength.

Fig. 8.
Photomicrograph of shadow figure's head, after treatment of tears using goldbeater's skin and gelatin, 6.5x. Anthropology Division Collections, American Museum of Natural History, no. 70.0/2995

It was concluded that goldbeater's skin resulted in successful mends that were strong, unobtrusive, and transparent. Talas supplies sheep appendix goldbeater's skin, but other suppliers will carry skin made from the cecum of intestinal material. Before use, it must be degreased using acetone and its surfaces lightly abraded with pumice to reduce unevenness. The final product is much thinner and more transparent than any of the other products considered. It can be toned with dyes in order to achieve desired colors while maintaining translucency. Orasol dyes in ethanol were used for this purpose.

5.2 ADHESIVE OPTIONS

Several adhesives in both film and solvent form were tested in conjunction with the goldbeater's skin lining. Requirements of the adhesive include compatibility with the skin, the coating, and the lining material, as well as long-term stability, transparency, and flexibility. Included in these categories were gelatin, Beva 371, polyvinyl acetate resins, and Paraloid F-10. After a number of trials, it was found that the F-10 and PVA resins had difficulty attaching to either the oily skin or the goldbeater's lining material. Additionally, they seemed to lack the strength required by some of the mends. A dilute gelatin solution adheres most strongly to the coated skin and the lining material while also maintaining the strength and integrity required of the mend. In some cases, the Beva in solvent form or as a reactivated film also fulfills the mending requirements.

The long-term stability of adhesives in a low pH environment, like that created by skin or oil, is an area that needs investigation and research. Most of the research to date tends to focus on how adhesives age in neutral pH environments. Experiments currently are being developed in the conservation laboratories at the AMNH that
will attempt to determine the aging properties of commonly used adhesives for skin repair.

5.3 THE MENDING PROCESS

Prior to applying mending materials, the oil in the mend locations was reduced. Since the oil penetrates into the porous skin, it is impossible to remove completely. If necessary, the area to be mended can be relaxed into position using controlled humidification techniques, then dried under pressure. (Humidification techniques involve layering Goretx, slightly dampened blotter, and plastic over the distorted area. Generally, the skin reacts to humidification readily, and this step needs to be closely monitored to avoid wetting the skin.) Often, both sides of a tear will need the reinforcement offered by the mending materials. The final mended tear is strong, clear, and flexible (fig. 7, 8).

6 CONCLUSION

In the 20th century, especially between 1920 and 1970, shadow puppetry in China went through dramatic transformations. Plastic sheets replaced the fine skin puppets, and synthetic colors supplanted the natural dyes. Combined with cruder cutting techniques, the effect was cheap and represented a sad departure from the tradition of the elegant, older shadow puppets. Communist ideology became a dominant theme for shadow troupes so that content within the dramas changed as well. After the Cultural Revolution (1966-76) ended, village troupes began to perform traditional dramas again, using puppets that were 100 to 200 years old (Berliner 1986). Even with this rebirth, the popularity of this theater has suffered in the shadow of modern film and performance.

An interview with an old shadow puppeteer in Beijing in the 1930s concerning the state of the theater reveals his beliefs concerning the future of shadow theater in China:

We produce no plays in terms of present day life. Those who love the shadows, it seems, love also the glorious past. Young people and women are now going to theaters and motion pictures. Only four companies are now operating in Peking, all in the hands of white-headed old fellows like myself. I have no son to succeed me and I have no pupils to continue the old traditions, to make my shadows dance when I am gone. (Wimsatt 1936, 33)

The current state of shadow theater has been presented to reinforce the importance of preserving these items and was a determining factor in prioritizing the AMNH collection for rehousing and treatment. The rehousing, survey, and treatment of the AMNH Chinese shadow puppet collection demanded resolution of conservation issues that, while focusing on ethnographic artifacts, can be applied to a wider variety of collections. Preservation of the original function and composition of the puppets was considered paramount, and treatments were developed to accommodate the challenging materials that compose them. These treatments were
customized for a large-scale collection that is often the focus of research and exhibition.

In pursuing an acceptable approach to the needs of this collection, the author was granted the opportunity to research the history and technology of shadow puppetry in China. Simply understanding the importance of color and form within the figures was a determining factor in their subsequent treatment. Investigations into past treatments created focused awareness on the detrimental results that these efforts can have. This accumulated knowledge concerning a wide range of issues allowed for the development of a sensitive and appropriate approach to storage and treatment.

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NOTES

1. Other large collections of the East City type puppets are in the Museum of Folk Art, Hamburg; the Asian Art Museum, San Francisco; the Volkekunde Museum, Leiden, Netherlands; the Ethnographic Museum of Sweden, Stockholm; and the Lederschaft Museum, Offenbach, Germany.

2. In her master's thesis, Mary Hirsch gives a detailed, academic survey of the history of Chinese shadow theater, referring to historic texts and play scripts. Additionally, Hirsch presents detailed distinctions between the different schools of shadow puppetry.

3. Caretakers of similar collections who have noted sticking problems include those at the Asian Art Museum in San Francisco and the Museum of Folk Art in Hamburg, as well as various private collectors.

REFERENCES


FURTHER READING


SOURCES OF MATERIALS

Paraloid B-72
100% solids, ethyl methacrylate copolymer, manufactured by Rohm and Haas, Philadelphia, Pa. 19105 Conservation Support Systems P.O. Box 91746 Santa Barbara, Calif. 93190-1746

Paraloid F-10

Beva 371 Solution
40% solids in a solution of toluene and naphtha. Solids are composed of ethylene vinyl acetate copolymer (Elvax 150), cyclohexanone resin (Laropol K80), ethylene vinyl acetate copolymer (A-C copolymer), phthalate ester of hydroabietyl alcohol (Cellolyn 21), and petrolatum (paraffin). Conservation Support Systems P.O. Box 91746 Santa Barbara, Calif. 93190-1746

Gelatin
Supplied in sheet form Kremer Pigments Inc. 228 Elizabeth St. New York, N.Y. 10012

Goldbeater's skin
Talas 568 Broadway, #107 New York, N.Y. 10012

Natural skin condoms
Most drugstores

Orasol dyes
Manufactured by Ciba-Geigy. Soluble in both alcohol and ketone solvents. Conservation Support Systems P.O. Box 91746 Santa Barbara, Calif. 93190-1946

Polyvinyl acetate resins
100% solids Conservation Support Systems P.O. Box 91746 Santa Barbara, Calif. 93190-1946

Sausage casings
Your neighborhood butcher

Silicone Mylar
Douglas Hanson P.O. Box 528 Hammond, Wisc. 54015 Conservators' Products Co. P.O. Box 411 Chatham, N.J. 07928

Teflon Film
Plastomer Products Coltec Industries 23 Friends Lane Newtown, Pa. 18940
Contact: Leonard Plewes.
AUTHOR INFORMATION

LISA KRONTHAL received a B.A. in art history from the University of Rochester in 1988 and an M.A. and certificate of advanced study in art conservation from the State University College at Buffalo in 1993. She pursued her graduate internship at the Brooklyn Museum of Art focusing on archaeological conservation, specifically working with ancient Egyptian collections. She began working at the American Museum of Natural History as an assistant objects conservator in 1994 and remains there as an associate conservator in the Anthropology Division, specializing in archaeological and ethnographic objects. She is a Professional Associate of AIC and currently co-chairs the conservation committee within the Society for the Preservation of Natural History Collections (SPNHC). Address: Anthropology Division, American Museum of Natural History, 79th St. at Central Park West, New York, N.Y. 10024.
All book conservators know that leather turn-ins discolor or "burn" books' endpapers, and that the amount of "leather-burn" varies with the leather, the paper, and the age of the book. We all have our favorite examples; mine is a magnificent Oxford Lectern Bible bound by Roger Powell in full green Chieftain goat with doublures formed by the bare, waxed oak of the boards, and with white free endpapers. The leather has burned the endpapers brown, the oak has burned them slightly less with the wood grain reflected in the burn, and I cannot decide whether I deplore the echoed pattern as damage more than I admire its beauty.

Although leather-burn is a phenomenon well-known to benchworkers, it has rarely been mentioned in print, and there seems to have been no systematic study of it. The following comments are meant to promote observation, thought, and research. They are not systematic or rigorous, and should in no way be considered completed research.

The problem of leather's tendency to attack paper is distinct from that of its own permanence. Severe leather-burn is often seen in perfectly sound bindings. Doves full leather bindings on Doves Press books are convenient examples because they are comparatively common and comparatively uniform. Their leather remains in superb condition after eighty or ninety years, with no sign of red rot and little mechanical damage despite the fact that the leather is (by modern standards) pared rather thin. There is, however, always severe leather-burn from the turn-ins; this damage is blatant because the Doves Bindery's chaste white endpapers do not disguise the burn, as do the marbled endpapers used by most hand binders of the period. Another convenient example of the distinction between a leather's inherent soundness and its aggressiveness is found in native-tanned Nigerian goat, which is esteemed the most permanent of currently available vegetable-tanned leathers. It is also, to my observation, by far the most aggressive; and the turn-ins of a binding in native Niger less than twenty years old will often have caused stains the color of strong tea. It is my impression that native Niger is even more aggressive than Oasis, which is re-tanned from it; this is relevant because Oasis is considered the less permanent of the
two. There also seem to be examples of the reverse situation, where the leather is impermanent but not highly aggressive.

For a book conservator, damage caused by aggressive leather should be a greater worry than leather's own impermanence. Discolored endpapers are a cosmetic problem, but they are also a symptom: when ends stained over the turn-ins are lifted with water one finds that the stained area is extremely weak, as one might expect. Visible damage to the endpapers suggests similar damage, including mechanical weakening, to the folds of the sections where they touch the leather of tight-back, leather-lined, or unlined loose-hollow bindings. Such damage is often found when tightback bindings are pulled, although the damage caused by poor hide glue complicates the analysis of these bindings. Leather is essential for a moving tight back but is superfluous for a hollow back. Thus the aggressiveness of leather becomes a major factor in the choice of correct rebacking and rebinding structures, in the choice of flyleaves and linings for barrier as well as mechanical properties, and in adhesive choice since some binders say that PVA blocks leather-burn.

An obvious cause of leather-burn is the inherent acidity of all leather and tawed skin, and it is tempting to accept acid migration as the sole cause. I suspect, though, that fat-liquors and other tanners' lubricants also play a role, maybe the primary role with some leathers. The following notes will focus on tanners' lubricants because the dangers of oil migration from dressings and other restorers' lubricants are well-known and avoidable. However, observed damage from careless dressing should be kept in mind while considering leather-burn.

Modern alum-tawed skins may offer an example of the dangers of oil migration. Tawed skin is highly favored by conservators, largely for its inherent permanence and durability but also because tawed turn-ins four centuries old and more rarely burn paper as do tanned turn-ins of the same age. Unfortunately, tawed skin used in the last twenty years is said on the grapevine to have already burned endpapers; and at the U C Annual Meeting in 1987 a slide was shown of burn from the laced-in thongs of a recent limp vellum binding. Of various changes known to have been made in the manufacture of tawed skin, the most pertinent is "the substituting of a non-ionic oil for egg yolk for a variety of reasons such as greasiness, varied colors, inconsistency of oiling and smell." It is conceivable that the new oil has introduced a source of degradation not present in egg yolk or other traditional lubricants.

Full-leather Doves bindings may again give evidence. When the book was printed on vellum, as was normal for part of each Doves edition, vellum ends were used; and even these have been slightly stained by the leather of the turn-ins (although the stain is less than that seen on paper ends). It is hard to imagine leather acid enough to attack vellum, yet sound in itself; but it is easy to imagine sound leather oily enough for the oil to migrate into vellum and there discolor. This example also suggests that leather-burn may involve benign discoloration of the oil itself in addition to discoloration due to the degradation of the paper.

A highly subjective impression of mine may be used to broaden the implications. It seems to me that the color of leather-burned paper is different from that of paper damaged by inherent vice; it quickly grows far darker in tone than paper left to itself, darker even than century-old newsprint, and is perhaps a richer, less grey and less
yellow brown. Though paper left alone rarely takes on the rich, dark brown of leather-burn, a similar color does occur at the gutter margins of books where excess leather dressing has been wicked up by cracks in the spine and spread along the gutter by the sewing thread. Yet although discolored oil in the gutter does weaken paper, the paper often retains enough working strength and flexibility to remain quite usable; paper darkened to such a degree by inherent vice would be as weak and brittle as a mummy's bones. Again we may suspect that the oil itself has discolored, in addition to discoloration due to degradation of the paper.

As was mentioned, native-dressed Niger is particularly apt to cause leather-burn; and binders who work with it comment often on its tendency to oiliness\textsuperscript{2}. This can be so serious that paper touching native Niger sometimes will pick up wet-oil stains in just weeks or months\textsuperscript{8}. Wet-oil stains demand treatment urgently, since at first they can be lifted with solvents but later they will become brittle and may resist removal save by bleaching. It may be objected to my hypothesis of oil migration as one cause of leather-burn that no wet-oil stain is seen in most cases, which might imply that no oil has moved. However, oil migration from printing ink does occur, and without causing wet-oil stains\textsuperscript{9}. Perhaps the concentration of oil is low enough that no wet stain forms; acid migration too presupposes that moisture can move without a high enough concentration to form a wet-water mark.

A final point: leather-burn seems to develop faster and farther on absorbent paper than on hard-sized paper. I have a sample card obtained from one tanner around 1983; the card itself is slick coated stock, and the leather samples had stained through to its reverse within five years However, in books bound in the year I got the card, with leather from the same tanner, common colored endpapers are not yet stained over the turn-ins. Coated stock thus seems more apt to develop leather-burn, and I think this is because the clay coating is quite absorbent\textsuperscript{10}. Samples tipped to the boards in two books on leather deterioration from 1905 may offer the same lesson: in Hulme and Wyndom's \textit{Leather for Libraries}\textsuperscript{11}, the samples have burned many pages into the thick, fluffy esparto paper of the text block; in the Society of Arts' \textit{Report of the Committee on Leather for Bookbinding}\textsuperscript{12}, on harder-sized, more calendered paper, the damage to the text block is much less. The greater susceptibility of absorbent paper could be explained as well by acid migration as by oil migration; but there is a practical consequence. On a thesis of acid alone one might choose heavily buffered paper for endpapers, linings, or loose barrier sheets, hoping to neutralize the migrating acids. However, on a thesis of oil migration, heavily buffered barriers are not to be advised since they are (like other heavily filled and coated papers) quite absorbent, and therefore they would speed up migration without preventing the deterioration. This may offer a partial explanation of why heavily-buffered loose barrier sheets often seem ineffective. In consequence I would suggest that "permanent/durable" paper be avoided in endpapers, spine linings, and perhaps in flyleaves; instead, a less absorbent unfilled paper, possibly hard-sized with gelatine by the binder, should be used\textsuperscript{13}.

The substance of these remarks has been to suggest that there is a real danger of attack on paper by leather which is sound in itself; that tanners' lubricants as well as the acidity of leather are implicated in the attack; that some lubricants are worse than others; that absorbent papers are more at risk than hard-sized papers; but that the loss of working strength in the paper is less than one would expect considering the depth of color reached. I don't mean these observations to discourage unduly the use of
leather in binding: all covering materials have their dangers, and the speculative nature of many of my remarks makes them an unwise basis for immediate modifications of working practice. My intent is to bring the problems of leather-burn vividly before conservators and scientists; and, I hope, to induce them to give some extra observation, thought, and research to the matter.

Acknowledgments

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Notes

1. Bound in 1960; now in the Bancroft Library, University of California at Berkeley. Polrell tooled small gold stars on the free endpapers; this decorative touch, together with his closeness to woodworkers and his own knowledge of wood, suggests to me that he may have anticipated and sought to highlight the reflected pattern.

2. John Dean, for instance, uses PVA to put down endpapers for this reason; and he says that leather bindings done this way several decades ago have not yet developed trouble (personal communication 1987). Louise Genest-Cote uses PVA to laminate onlay-thickness leather to Japanese tissue for concertinas in exposed spine design bindings, with the same rationale (personal communication 1989).

3. In this paper I have avoided the causal term "acid migration", which many would use for the discoloration, since it prejudices the question of cause; I have used the symptomatic "leather-burn" since it is non-causal, or at least is causal in so crudely metaphoric a way that no one will take it that literal flames are involved.

In recent years "acid migration" as the single cause of staining has been challenged as inadequate, even where the gross source of damage is aggressive paper or board. Vincent Daniels has suggested that migration stains on paper are caused by induced oxidation by gaseous materials, including "hydrogen sulphide, organic acids, aldehydes, peroxides and various free radicals." See: "The Discoloration of paper on Ageing." The paper Conservator 12 (1988), p. 97.

I have also heard the term "tannin migration", especially for stains caused by leather touching paper during floods. Tannin migration, however, would not explain the aggressiveness of modern alum-tawed skins. Dr. Daniels tells me he has seen dye migration from dyed leathers, another complication (letter 25/1/1991).


5. The slide was shown by Bruce Levy, although it does not appear in the printed version of his talk: "The restoration rebinding of Speculum Naturale by Vincent of Beauvais..." Book and paper Group Annual 6 (1987), p. 79-84. Mr. Levy informs me: "I don't really know much about the stain or burn at this stage. I did a wet-surface pH reading on the burn area, the adjacent area of the same page, and the unaffected inner
text pages. I received a reading that was for me indicative that the stain, at least so far, hasn't altered the pH reading (surface). All readings were less than .5 difference... The book in the slide was bound during the last 8 years I think." (letter dated 1/1/88).


I am indebted to Christopher Clarkson for first suggesting to me that the lubricant in tawed skin was a potential source of trouble; he repeated a comment made by Ronald Reed. When I first circulated a rough draft of this article in 1987 I knew no published statement that modern lubricants had been substituted for egg yolk; substitution was hypothesized on the basis of the cost of eggs, and it was, in a grim way, gratifying to have the guess confirmed.

Other changes in tawing, not persuasive as causes of leather-burn, include the modern time-lag in salt between flaying and unhairing; the use of chemical bates instead of dung; the use of aluminum sulfate instead of potassium or ammonium aluminum sulfate (the latter two were rarely distinguished before the nineteenth century); and the drumming of skins to speed up manufacture. It is perhaps worth considering the possibility that egg yolks, which have been used on their own for oil tannage, acted as more than lubricant and gave traditional tawed skin a mixed oil-and-mineral tannage rather than an all-mineral tannage.

7. Malcolm Lamb gives a "Typical analysis of [native Niger] leather" containing "Grease 11.4%". The lubricant is groundnut (peanut) oil. See: "The Hausa Tanners of Northern Nigeria." *The New Bookbinder* 1 (1981), p. 61-2. For comparison, at the 1984 FAIC Leather Refresher Course, Pieter Hallebeek said that "New leather commonly has a fat content of 2-10%" and recommended an optimum 5% fat content for old leather; Sonja Fogle quoted D.H. Tuck as giving "typical extractable fat values from 3-20%." These figures are too few to confirm the greasiness of native Niger, but they are consistent with it. Hallebeek also said: "There may be a connection between age and fat content, with the oldest leathers having the least amount of bound fat. The values obtained for old leather are usually 1-2% of the weight of the sample... The values given by Tuck refer only to new leather. Chemically, old leather can no longer bind fats as it once could." See: *Recent Advances in Leather Conservation* (Washington: FAIC, 1985), p. 22-3. The loss of fat to old leathers is at least consistent with the thesis of this paper, and I believe supports it since forced-out fats must presumably go somewhere.

8. Linda Ogden has told me of one exceptional shipment of native-dressed skins received by the Library of Congress in the early 1970s. Books bound with them developed stained turn-ins in a very short time--- weeks or months. Several skins which she bought from the same shipment transferred distinct wet-oil stains to wrapping paper in contact with them (personal contact 1991). Bruce Levy has told me of a similar case at HRHRC in the middle 1980s (personal contact 1991).

9. Cheap non-drying oils adulterating boiled linseed or walnut oil in printing ink can cause both offset and halo browning. Vincent Daniels describes an offset image from printing ink "analysed by Mr. R. White of the National Gallery, who found that the brown stained areas had 'moderate amounts of non-drying fats', whilst the less badly stained areas contained smaller quantities." (Daniels op. cit. p. 95). The parallel to my thesis of oil migration from leather is obvious.
10. Vincent Daniels informs me: "I don't agree that heavily buffered paper ought to cockle more than other types of paper. One method of reducing hygro expansivity of paper is to use fillers." (letter dated 25/1/1991). It is, however, common at the bench to have problems with cockling, warping, and distortion of coated and buffered papers, particularly after tipping or other local application of paste. Furthermore, finely-divided powders have long been used for absorbing liquids. An old method of removing fat stains from books, for instance, was to cover the stain with French chalk and then iron it with a hot polishing iron; see Zaehnsdorf's *Art of Bookbinding* (London: George Bell, 1890) p. 164, and many other manuals. This method would work only if chalk were more absorbent than paper. The conflict between Dr. Daniels' comment and bench experience leaves me somewhat at a loss.

Shannon Zachary suggests that the apparent conflict may be the result of the different nature and mechanisms of full-sheet expansion/contraction, contrasted with distortions caused by localized wetting. Also involved may be the differing effects of absorption by the fibers, which is anisotropic and causes greater expansion across the grain, contrasted with absorption by finely divided powder, which clearly must be equal in all three directions. Or perhaps an *ad hoc* explanation is enough: coated and buffered papers may just tend to be slack-sized.


12. Ed. by Viscount Cobham and Sir Henry Trueman Wood. London: George Bell and Sons for The Society of Arts. At least 5 copies seen (University of California at Berkeley; San Francisco Public Library Special and Circulating Collections; Capricornus; Edith Diehl's copy in the Guild of Book Workers Library). Some of the samples are usually missing.

13. Modern marbled papers, especially American ones, often have powdery, weakly stuck colors; when used for endpapers it is best to gelatine-size them anyway, to consolidate the colors. Modern papers sized with (hydrophobic) alkyl ketene dimers may offer less of a barrier to oils than do traditional papers sized with (hydrophilic, oil-resistant) gelatine; see John R. Hubbard "Animal Glues" in: *Handbook of Adhesives*, ed. Irving Skeist (New York: Reinhold, 1962), p. 117.

14. Vellum, for instance, is considered an exceptionally desirable covering by many conservators; but I have used vellum that was (imperceptibly) greasy on its flesh side only, and caused wet-oil stains where the turn-ins lay over the endpapers of a limp vellum binding; the oil even wicked into paper lying beyond the turn-ins, which is how I became aware of it.

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