Lamination and Other Methods of Restoration

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IN RECENT YEARS there has been an increasing interest in the problem of the preservation of the various types of library and archival material. The text of great quantities of such material is now being preserved by such methods as microfilm, microcard, and photostat. In many cases the originals are being destroyed after they have been photographed. These methods of preservation, while satisfactory for certain types of material, are not suitable for all. In fact, photography is not actually a method of restoration. It is a method of conserving the text of a record but not the record itself. In addition, it is often not acceptable to either librarians or library patrons. Thus there remain many items which for one reason or another it seems desirable to preserve in their original form. Among these are valuable historical documents, literary papers, rare books, much used reference works and bibliographies, and many others.

While this paper is not primarily concerned with the causes of the increasing awareness of the problem of preservation and restoration, there seem to be three major reasons for it. First is the great increase in the use of the material. Second is the fact that much of it has been stored under adverse storage conditions, with little attention having been paid to such things as temperature and humidity control. As a result, deterioration has set in. Most important, however, has been the gradual lowering in the past 300 years of the quality of paper and other materials used for printing and writing. In quantity the largest group of this material is that written and printed since 1870 on wood pulp paper. But there are many earlier manuscripts and printed books in an equally poor state of repair. Both groups will be discussed in this paper, although it should be noted here that the processes described below are

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not applicable, because of their cost, to long runs of modern newspapers or magazines or to the run-of-the-mill book which can be readily replaced for a few dollars. Excluded will be documents on parchment, vellum, and papyrus. What the authors are primarily concerned with are the processes applicable to deteriorated manuscripts and printed books of some value. Finally, the authors do not recommend the use of any preservation or reinforcement procedures on material which is in good physical condition. The fact that a book or document is old does not mean that it is in need of restoration. If in good physical condition, it should normally be left alone.

Requirements in a Restoration Process. There are three basic requirements which any good restoration process should meet. They are legibility, permanency, and durability. Each will be described briefly.

1. Legibility—The readability of the restored item should not be reduced appreciably.

2. Permanency—In order to insure permanency, the impurities which caused deterioration of the item should be removed or made inert. The materials used to strengthen the sheet should be chemically pure and stable and should be resistant to the harmful action of certain agents present under normal storage condition and usage. In addition, the process used should not reduce the permanency of the item treated.

3. Durability—After restoration, items which will get much use should have both good resistance to tearing and folding endurance. Seldom used items, such as exhibit pieces, may have a lower requirement.

All of these qualities are needed and one of them should not be overemphasized to the extent that the others will suffer materially. Many restoration processes have proved to be unsatisfactory because their product did not meet all three of the requirements.

One further condition must often be met. This concerns the cost of the processes. Some are so expensive that they are impractical. An attempt will be made to give some idea of the relative costs of the various processes described.

The Silk Process. Developed during the latter part of the nineteenth century, the silk process was until quite recently the principal method of restoration. Basically, silking consists of pasting to each side of a sheet of paper a piece of semi-transparent silk cloth. With proper application the product will have relatively good visibility, be quite strong

and have a high resistance to tearing. Unfortunately, the silk used in the process has not proved to be stable. Eventually it becomes brittle, discolored, and loses its resistance to tearing. In addition to the instability of the silk, the starch paste used to apply it is often attacked by insects and molds. The impurities in the paper which caused the deterioration are also left in to continue their destructive work. Thus the silking process cannot be considered as a permanent one. Since the process is a slow one and requires highly skilled labor, it also is quite costly. While still used in some places, it is no longer considered to be a satisfactory method of permanent restoration.

The Tissue Process. This method is quite similar to the silking process, varying primarily in that tissue is used instead of silk. Usually thin sheets of tissue made of high grade fibers are pasted to each side of the deteriorated sheet. This produces a sheet of limited strength with a decided loss in legibility. If a thicker tissue is used to give additional strength, there is a very great loss in legibility. To overcome this defect, thicker paste is sometimes used with the thinner tissue. This produces a relatively stiff sheet, as the starch paste has a tendency to harden with time. It also is susceptible to attack by insects and microorganisms. While loss of visibility and relatively low physical strength are the primary reasons for the limited use of this process, it is also somewhat slow. It also makes no provision for eliminating the active compounds in the sheet that caused deterioration.

Mending. Strictly speaking, mending is not really a method of restoration. While it is desirable sometimes to mend tears in paper or to reinforce leaves at weak points with Japanese tissue and paste or with transparent tapes (not with ordinary Scotch tape), such reinforcement does not add to the strength of the page as a whole. This process is good for sheets of good quality paper which have been torn or otherwise damaged; it is of no value for paper which is already deteriorated. In some cases it seems desirable to fill out incomplete leaves by joining new paper to the original leaf and perhaps including the reproducing in facsimile of missing letters or words. Although this may be done with no intent to deceive, it is sometimes called the "gentle art of faking"; in higher bibliographical circles it is known as "sophistication."

Washing and Bleaching. Paste, glue and some stains may be removed from paper by washing it in clean water, after precautions have been taken to make sure that the ink will not run. This process, however, does not necessarily remove most of the harmful acids often found in paper and does not strengthen the sheet.

Bleaching has been used for many years to remove stains. While it is still practiced in some shops in America and in many abroad, it can be very injurious to paper if the chlorine or other bleaching agents are not removed thoroughly. It is also ruinous to many writing inks. It does not add to the strength of the page treated but may improve its appearance. The process is relatively slow, since each sheet must be handled separately.

Resizing. One of the more common processes used by persons attempting to strengthen deteriorated paper is that of resizing the sheet. All papers are sized with animal glue, gelatin, or starch, etc., during the process of manufacture, and it has been thought by many that the strength of deteriorated paper could be renewed by resizing. Usually this is done by dipping the sheet into a bath of 2 to 4 per cent animal glue or gelatin. It is thought that this will restore or improve the strength and coherence of the fibers of the paper. If the paper lacked sizing, or if it has been destroyed by microorganisms, a small amount of sizing would increase its physical strength. Some recent research has shown, however, that many deteriorated papers have not lost their sizing and that this has not been the cause of the weakening of most paper. Since too much size will stiffen a sheet and make it less flexible, there is no reason to think that resizing will add much strength to a deteriorated sheet. It is also true that modern wood pulp paper contains non-cellulose materials which have no fiber structure. Sizing will have little or no value in trying to bind together the components of such paper.

Sprays. In the past few years many have hoped that there would be invented or developed some sort of cheap method of spraying a transparent coating, perhaps a plastic film, over the surface of a sheet. This would form a protective coating and also give the sheet more physical strength. Such sprays exist and have been tried. The earlier ones were composed of cellulose nitrate, which is now considered to be unstable and injurious to paper. Other sprays have also been found wanting. They have given a protective coating to the surface of the paper but have added little to its physical strength. It has been shown that they sometimes increase the brittleness of the paper. Nor do they remove or neutralize whatever chemical impurities were in the sheet originally and these are left there to continue the process of deterioration. So far, then, we have no worth-while spray method of restoration.

Inlaying or Framing. Inlaying is a term used to describe a method of extending the margins of a single sheet of paper by framing it with a larger sheet. While these extended margins make it safer and easier

to handle the sheet, the process adds little strength to the leaf itself. It has often been used for the repair of documents for display purposes and for extra illustrating books when it is desirable to make the added pictures the same size as that of the book they are being inserted in. In fact, since the rate of expansion and contraction due to the change in temperature and humidity is seldom the same in two different papers, inlaying may result in the formation of undesirable cockles and a premature breakdown of the original sheet. The process is slow and rather tedious and since it gives so little added strength is not a satisfactory method of restoration.

Lamination with only Cellulose Acetate Film. Lamination may be described briefly as the process by which a sheet of thermoplastic cellulose acetate film is applied to each side of a sheet of paper by means of heat and pressure. It must be applied by the use of special precision built equipment with controlled heat and pressure. This process was first used as a means of rehabilitating deteriorated material in the middle 1930's. The film has a high rating in permanency. When this process was first introduced into the restoration field, it was thought by some to be the final answer to their problem. Time has shown, however, that the film has limited tear resistance and many documents which were treated have become damaged because of this weakness. In addition the process does not eliminate those harmful compounds frequently found in paper which cause deterioration within the fibers of the paper.

Lamination with Films Containing an Adhesive. Cellulose acetate films containing thermoplastic and pressure sensitive adhesives were developed in the late 1930's. They can be applied to paper with comparatively inexpensive equipment. These films are satisfactory for use on material of temporary value, but after a few years the film usually peels off, leaving the adhesive embedded in the pores of the paper. In some cases the adhesive has discolored the paper. This film also has little tear resistance. While this process serves a useful purpose when used on menu cards, inexpensive book covers, etc., it should never be used on books or manuscripts of permanent value.

Scotch tape is a similar type of film whose use has caused much damage to a number of valuable items. It should never be used for repair or preservation. In recent years there has come on the market a new type of Scotch tape which seems to have better possibilities since it apparently does not turn yellow or become brittle with age. While it may be satisfactory for use in mending torn pages of tem-

porary value, it too should not be used for the repair of papers to be kept permanently.

Deacidification and Lamination with Cellulose Acetate Film and Tissue. Some persons interested in the restoration of deteriorated material reasoned that if lamination with cellulose acetate film was combined with other procedures which would overcome the deficiencies of the use of the film alone, the final product of restoration would have properties which were superior to those of any other single method then in use. The two qualities which needed to be added were greater strength in the restored sheet and some treatment of the paper so that deterioration would not continue after the sheet had been restored. The rest of this part of this paper will be devoted to a description of such a process. It is generally known as the Barrow Method of Restoration since the procedures followed were developed by W. J. Barrow. The equipment used (i.e. the machine used to laminate the sheet being restored) was also invented and developed by Barrow. These procedures and equipment are used in his shop and in some thirteen other shops (chiefly in libraries and archival agencies), which are now using this method of restoration.

As was noted above, the application of cellulose acetate film to a sheet of paper did not increase its resistance to tearing. In fact, it has a tendency to decrease the tear resistance of some papers. In order to overcome this fault, it was necessary to find some other material with good tear resistance which could be incorporated in the laminae to give it added strength. For this purpose a high quality tissue was chosen as it not only increased the tear resistance but also improved the folding endurance. The way the tissue and film are applied to the sheet may be likened to a sandwich:

Tissue
Film
Paper to be restored
Film
Tissue

The film softens under heat and is then pressed into the pores of the paper and tissue to form a homogeneous unit.

The second need mentioned above was for some treatment of the deteriorated paper so that deterioration would not continue after the paper had been restored. Tests on deteriorated papers showed that nearly all of them contained acidic compounds. They also showed that in most cases the degree of embrittlement was in direct proportion to

the amount of acid present in the paper. Thus it seemed likely that if this acid condition could be eliminated deterioration might be stopped. The causes of this condition were acid inks, absorption of sulphur dioxide from the air, alum in the sizing and the bleaching methods used in the manufacture of paper. Experimentation has indicated that calcium hydroxide and calcium bicarbonate are the best chemicals to use as neutralizing agents. Not only do they deacidify the paper but they also precipitate small amounts of calcium carbonate in the paper fibers. This will neutralize acids absorbed by the paper in the future and also have a stabilizing effect on the fibers. The process, in brief, consists of soaking the sheet first in a solution of calcium hydroxide and then in a solution of calcium bicarbonate. The sheet is then air dried and laminated with cellulose acetate film and tissue.

This process has several good features. It gives a product with good legibility, no discoloration and good resistance to tearing and folding. It can be delaminated if necessary. The materials used (tissue and film) have been shown by laboratory test to have a good degree of permanence and should last for many years. The film is relatively resistant to the passage of gases and to insects and microorganisms. The acidity which is neutralized is not apt to become active again. The restored sheets are not difficult to use or store and can, with the addition of a binding margin of tissue or good paper, be bound up in volumes. While the sheets are slightly thicker than they were originally, they are not as thick as photostats and will lie perfectly flat. Although the film has some elasticity, it will not stand much creasing or sharp bending when in a laminae. An examination of several hundred volumes restored by this process disclosed that books which had been used thousands of times were still in good condition. Some recent tests made on sheets which were laminated in 1939 showed that there had been no physical breakdown of the film when compared with film of recent manufacture. This was likewise true of some unlaminated film made in 1940. Unstable paper would have shown considerable deterioration in this 15-year period.

This process, while several times faster than the silk process, is still relatively slow. Yet its cost is less per sheet than photostating, and the product is easier to use, more legible, and longer lasting. While not cheap enough to be used for the restoration of the great mass of modern newspapers, magazines and books printed on low grade wood pulp paper, it is economical enough to use on valuable manuscript

and archival material, on rare books, much used reference works and bibliographies.

Print Transfer. Print transfer is the name which has been given to a process of restoration which is in an experimental stage and about which little has been written. It is now being studied by Barrow. It has been used by him on 100 volumes, primarily on material belonging to the Virginia State Library and to the Library of Congress. Since it is being used and has possibilities of greater use, it seems appropriate to describe it briefly.

About five years ago efforts were begun to determine whether it was possible to lift and transfer the print from a deteriorated sheet to a sheet of rag paper with a high degree of permanency. The process consists of heating cellulose acetate film and then pressing it hard enough against the deteriorated sheet to cause the particles of ink to adhere to the film. This film is then stripped from the sheet and laminated to a new sheet of rag paper.

Because the oxidation and polymerization of the oils of different inks vary, no two books present the same problem. Some inks transfer easily, others are very hard to soften. In some cases it has been found that one section of a book will transfer more easily than another. This is the chief unsolved problem in the process. Some progress has been made by boiling the sheets in an alkaline solution to convert the oils to a soap. Of course, this adds to the cost of the process.

A variation in the process is to soften the print and press it on to another sheet of paper. This sheet is then treated and the print transferred to permanent rag paper. The materials used in this variation are cheaper than those used with the acetate film method. More research is needed on this process.

The cost of this process is about the same as that of lamination with cellulose acetate film and tissue; it is less than photostating. It has the advantage of giving a sheet which is stronger, less bulky and will wear better than will the product of any of the other methods of restoration. In fact, these sheets when bound will result in a volume which is easy to use and is considerably stronger than practically any new book produced today. It is possible that a machine could be constructed which would remove the ink from the deteriorated sheet and then put it on a sheet of new rag paper. Such a machine would probably be quite costly and it is possible that there is not enough demand to justify it. This process has been used on a number of volumes in the Virginia State Library. These have been primarily much-used reference works printed in the last 75 years, but the number also in-

cludes several volumes of a periodical printed in the period, 1900–1910. Some of the paper was in very poor physical condition; the rest was in better condition but was chosen because it seemed sensible to preserve it while all the text was still intact. An impartial examination of these volumes shows that they have stood up well under rather hard usage. Their legibility is generally good, but there is some inconsistency in the transfer of the ink. Some books appear to be sharper and blacker than they were originally while others are lighter and a little more fuzzy. The later was true particularly of some of the volumes of the periodical restored where the ink apparently varied considerably from issue to issue. Similar conclusions have been drawn by A. W. Kremer, who has examined the volumes done for the Library of Congress.

In summary, no one working in the field of restoration believes that our present processes are the best that can be devised. As more facts are discovered about the composition of deteriorated paper and as new developments are made in plastic films, there will be possibilities of improvement. Both subjects are being worked on now.

There are a number of new thermoplastic films on the market now which have some characteristics which seem to be superior to the cellulose acetate film now used. One is myla, which has several desirable properties but which softens at a temperature too high for use in the lamination of documents. Another is polyethylene. It can be easily laminated to paper but is difficult to delaminate. It may prove to be useful for certain types of material which it will never be necessary or desirable to delaminate. It should not be used, of course, on material of historical value.

Another possibility is that a process will be developed which will strengthen the deteriorated fibers in paper. At the present time it is possible to de-ink low grade papers and to reprocess the fibers into a stronger paper. Naturally, the de-inking feature must be eliminated before this can be considered for library materials. There is also a possibility of the relinkage of the cellulose molecules in deteriorated paper and the consequent rehabilitation of the original structure of the fibers. Such a process appears to be in the somewhat distant future.

This summary will not attempt to review all the processes described. It will point out the major points which should be kept in mind by every person responsible for the restoration or preservation of valuable material:

1. All materials used in restoration, such as papers, textiles, fibers, films, adhesives, etc., should be known to conform to standards which

have been determined by laboratory experiment to insure permanency.

2. The materials used should assure as great a degree of visibility, tear resistance, flexibility, etc., as is necessary in view of the probable use of the restored item.

3. The procedures followed, such as the application of heat and pressure, should not reduce permanency.

4. The process used should not lock into the treated sheet those elements, such as acid, which are the causes of its deterioration.

5. After restoration, the item should be kept in suitable storage conditions—away from contaminated papers and atmosphere, excessive heat, too high or too low humidity, etc.—so that it retains the durability given it by the restoration process.

Finally, while there has been good progress in the development of sound restoration methods in the past 20 years, much more remains to be done. Libraries and archival agencies have spent practically none of their own money on research in this field. In view of the importance of the problem and the magnitude of the material in need of restoration, it would appear that librarians and archivists might well devote more of their time and give greater support to the development of better procedures of restoration.

BIBLIOGRAPHICAL NOTE

The material in this paper has been taken primarily from two works by Barrow. One is "An Evaluation of Document Restoration Processes" in *American Documentation*, 4:50-54, Spring (April) 1953. The second is *Manuscripts and Documents; Their Deterioration and Restoration*, recently published in a preliminary edition by the University of Virginia Press.

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