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Problems of the treatment of modern paper produced over the last one hundred years

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Introduction

Twenty years ago all too many libraries were unaware of, or ignored, the alarming deterioration of the books in their collections and many conservators felt they could deal with the situation if they could be left to handle it themselves.[1] It took some considerable time for both librarians and conservators to realize the huge scale of the problem and the need to treat conservation as one of the major functional units of the institution requiring proper management control.

In 1971 Frazer Poole at the Library of Congress reported that 6,000,000 of the 17,000,000 books in the library were too brittle to use and that even to keep a tenth of these brittle books would cost 18,000,000 dollars (at that time) and would take some 30 years to restore them. The same concerns were being expressed in many other libraries and archives in other parts of the world and the situation has begun to change in regard to increased awareness and acceptance of the need that something has to be done.

Many consider the Florence flood of 4 November 1966 as the turning point and in many ways it was in that it brought the problem of disasters in libraries to the attention of the world. Certainly since the Florence flood the awareness of the preservation problem has grown enormously in the USA and the UK and much activity has been put into conservation surveys, preservation programmes, research and microfilming activities.

Paper and its deterioration

Older books were mainly produced with hand made paper utilizing stable materials that have a long life. As the demand for paper increased, paper making machines were developed to increase output and indirectly led to the deterioration of paper as they made the scarcity of rags more acute and stimulated the search for alternative sources of cellulose. Introduction of wood pulp, and in particular ground-wood pulp containing high levels of lignins has contributed very considerably to the discolouration and embrittlement of modern paper. This is very much related to the desire to get the maximum quantity of paper from a

double fold[4]. The British Library has also been undertaking a large scale conservation survey of its humanities and social science collections belonging to the Department of Printed Books and containing some 10,000,000 volumes. It is based on random sampling methods and is recording the date of publication, country/language, the number of pages, the condition of the binding and the condition of the paper. This latter factor is assessed in post-1850 volumes by folding over a corner of a page up to five double folds. So far the survey has looked at part of the monograph collections and academic periodicals published mainly in the 19th and 20th centuries. The collection sampled contains just over 1,000,000 volumes from which over 1,740 items published since 1850 had been selected. Overall 5 % of the paper broke on one double fold, 9 % on 2 or fewer double folds, and 12 % on 3 or fewer double folds. Clearly the more temperate environmental conditions combined with lower storage temperatures have served to considerably increase the life of paper stored in the UK compared with the folding endurance figures at Yale and the Library of Congress which are some 4 times higher. An analysis was also carried out to assess the proportion of items failing the fold test by their decade of publication. Thus although on average only 12 % of the collections sample broke on 3 or fewer double folds, of those books published between 1870 and 1899 over 30 % broke on 3 or fewer double folds.

Preservation programmes - problems and implications

The basis of a preservation programme will involve a need to preserve the intellectual content of the materials in the collections and a need to preserve the physical form. Such objectives must of course be related to the aims of each library but one thing is absolutely clear; that it will be impossible to preserve everything in the collections that need to be preserved in their original form and even attempting to keep the intellectual content of the collections is likely to prove an impossible task. Every library is faced with the situation where the needs far outweigh the resources available and has to find ways of introducing greater selectivity in what is to be preserved and to assign priorities to decide what is to be dealt with first. One approach is to aim to preserve all the rare books but age alone is no indicator of value. Another approach could be based on the concept of material that should be regarded as of archival value and this extends to modern material but again who is to assess worth.

Individuals' views vary and certainly time has a habit of changing the assessment of the writers' contemporaries. However difficult the choice may be it is one that will have to be imposed more and more and will require the involvement of academic colleagues.

given amount of wood and lignin can account for between 20 % and 40 % by weight of the wood depending on the source. Processes which get rid of the lignin such as the chemical pulp process are essential if paper is to last and the development of semi-chemical pulps combining both chemical and mechanical stages will frequently leave enough lignin in the paper to limit its life expectancy. This of course is not the only factor aiding fibre deterioration and the introduction of alum rosin sizing has also been recognized as a major contributing cause. Apart from wood pulp paper and problems associated with the pulping techniques, bleaching processes, sizing and the loading of paper with minerals such as china clay, libraries see as many problems arising from modern book production processes with the growth of paperbacks and the use of single sheets with adhesive bindings instead of folded and sewn sections.

Of the chemical processes of deterioration, hydrolysis is a major cause and is catalysed by acids present within the substrate which come in not only during the production processes but by atmospheric pollution. Light will also degrade lignin while high temperature and humidity levels will accelerate all these chemical processes. Wear and tear resulting from use is the other major factor in paper deterioration whether in handling by readers, during retrieval and re-shelving or while undergoing reprographic operations of which photocopying is the most notorious.

Scale of the problem

It is perhaps the scale of the problem that characterizes the dilemma facing libraries and archives when considering the problems of treatment of modern paper. Book production has been constantly growing for so many years and the number of titles seems to continue to expand so that the size of the collections published in the last one hundred years is enormous. Many major libraries in the USA have reported up to half their stocks being so brittle that they will fall apart when handled. A survey of over 2,000 monographs randomly selected from the card catalogues of the University of California libraries[2] found that only 4 % failed an MIT fold endurance test of 0 to 1 fold while 11 % failed 0 to 3 fold. A large scale survey by Yale University Library[3] was reported this year. They selected over 36,500 volumes from their total holdings which exceed 7.7 million volumes but excluded their rare book collection.

Brittleness was tested by folding the corner of a page back and forth four times, that is 2 double folds. The overall result showed that 29 % of the paper broke on one double fold and 37 % broke 2 or fewer double folds (one double fold being roughly equivalent to one fold on the MIT tester which bends the paper through 270 degrees of arc - 135 degrees to the right and 135 degrees to the left). A survey of a large part of the Library of Congress collections was reported as showing 25 % of the paper being brittle - representing I believe one

leather. These activities help to extend the life of the volumes and can be done cheaply and utilize low-grade staff providing they are trained and supervised adequately. Such activity at the shelves can also serve as a check on those volumes in a poor condition and act as a selection tool in deciding which items need to go for more intensive treatment. Books in poor condition can also be protected by placing them in relatively cheap acid free boxes which help to reduce wear and tear while on the shelves and may in fact serve to defer conservation treatment. It is not a long term answer though it can be undertaken by those staff retrieving and reshelving books and helps to prevent loose pages getting lost.

Large scale treatment

The massive long term problem of wood pulp paper requires however the use of methods either to extend the life of the paper by deacidification or support systems or to provide substitutes. The first stage not to be forgotten when looking at the long term aspects is to try to tackle it at source by encouraging the production and use of long-life paper produced on alkaline systems. Such paper needs to be based on chemical wood pulp and be free of ground wood or lignin, to be alkaline sized and contain an alkaline reserve. There has been much activity in the USA to promote the use of such paper together with the production of a standard. A similar campaign has started in the UK but this is an issue of world wide consequence. Publishers often do not know what paper is being used for printing and are concerned with the costs though the indications are that such costs need not be significantly different when using such paper. The interpretation of what is meant by long-life paper varies however as much of what is claimed to be long-life paper would not archivally persist for 400 or 500 years. However even semi-chemical pulps with low levels of lignin that have been alkalined sized with a reasonable alkaline reserve can be expected to last two or three times the life of current papers and even this would provide significant improvements from a preservation point of view.

To deal with the quantities requiring preservation therefore requires processes for treating whole books without the need for disbinding and rebinding. Attempts to treat whole books with water-based processes led to swelling of the paper resulting in severe damage to the bindings[5] and non-aqueous methods have been delivered.

One liquid based non-aqueous process is the Wei T'O process proposed by Richard Smith which has been developed and tested in the Public Archives of Canada. This system works as follows:

Books chosen for mass deacidification are placed in wire baskets and dried for 36 hours in a vacuum drier to remove normal dampness of paper - reduced to less than 0.5 % water content. Two baskets containing 20-30 books are then

Treatment options

Faced with the problems of modern paper a range of choices are available. As a starting point there are the traditional hand based methods of conservation involving disbinding, washing, deacidification, sizing, paper repair and rebinding. These can undoubtedly represent the most careful ways of conserving an object but are slow to carry out, make intensive use of skilled crafts which are in short supply and are expensive. There are undoubtedly many individual items published during the last one hundred years that fully deserve such careful conservation treatment but it is impossible to apply such techniques to more than a very small proportion of the modern items and certainly too minute a proportion to make any difference to the overall scale of the problem.

If we start by accepting that such hand treatment can only be given to the lucky few what choices are there to try to tackle the vast and ever growing problems of modern collections? The first approach is to undertake preventive measures to minimize the rate of deterioration. Environmental factors are of major importance and the difference in paper deterioration shown in North America and in the United Kingdom emphasizes this. Undoubtedly storage temperatures are a significant part of the equation and temperatures in the book stacks should be kept below 18° C.

There are limits to what can be done to improve the existing accommodation but improvements can often be made by eliminating hot spots in heating systems, improving air circulation or ensuring that building maintenance is carried out preventing leaks and floods. The limitation of light levels and especially keeping books out of direct sunlight and fitting ultra-violet screening filters to windows and light tubes is invaluable. Regular book cleaning programmes should also be introduced and maintained to keep down dust levels.

Reducing the effects of wear and tear may seem mundane but is of equal importance. Much of this necessitates education of staff and readers in how to handle books, promoting awareness by use of leaflets or posters, providing suitable equipment for handling and ensuring storage equipment is safe without sharp edges. Handling extends to microfilming activities where careful handling with the use of foam rubber to support books and counter-balanced glass sheets to hold them flat can help to minimize damage during the filming. Photocopying has for many years been a major cause of damage to books and the development of overhead photo-copiers such as the one developed on behalf of the British Library shows promise in helping to reduce such damage. It is even possible to take a photograph with the book closed by use of an electro-luminescent screen and sensitized paper and our Reprographic Services now have this as an additional option.

Slowing down the rate of deterioration can also be aided by undertaking furbishing of many books involving such simple operations as dusting, pasting in loose pages, repairing small tears and where appropriate cleaning and feeding

Another approach to the problem of mass treatment of paper has involved the concept of paper strengthening with deacidification as an additional measure. This work is being carried out on behalf of the Preservation Service of the British Library by the University of Surrey. This involves the introduction of mixtures of ethyl acrylate and methyl methacrylate in the proportion of 5:1 followed by an exposure to a gamma-ray source which results in polymerisation. The choice of the monomer proved critical. For the polymer to confer strength improvements it must be polar in nature and flexible at room temperature, the latter being deduced from its glass transition point.

The polymer is deposited throughout the core of the fibres of the paper as well as on and between the fibre surfaces with interfibre bonding increased through polymer filaments as is interfibre fibrillation. Using fold endurance as the criterion of strength enhancement we are aiming at strength improvements at least 10 fold (but can be higher) with a weight increase averaging about 15 %. The bulk is not altered and papers do not stick together. The question now is what will be involved in converting a laboratory process into a practical operation, what problems remain to be solved and what if any problems are likely to be encountered with inks or adhesives. This is the next stage of work and will involve questions concerning the process chemistry, problems relating to introduction into and transport of the monomers within the papers, the likely effects on papers, inks, binding materials, and the behaviour of paper after treatment in response to standard conservation techniques.

Substitution

Extending the life of paper by for example deacidification has obvious benefits that catalogues remain unchanged and storage requirements unaltered but the methods so far developed are not generally available. The other principle line of approach is to record the intellectual content of the items through a substitute with or without retention of the original and such a substitute can often be acquired by other libraries to avoid duplication of effort or to enhance their collections.

Substitution media used need to satisfy a number of criteria. The first criterion is that of an acceptable archival life. A report by Hendley[9] reviewed the archival life of microfilm, magnetic media and optical data disks and demonstrated that only microfilm currently approaches an acceptable life span - in order of 100 years with care - and can be copied again if required. Data stability is another factor with microfilm coming out the best though optical disk technology shows promise but as yet unproven. Standardization provides a pitfall for all non-print media while variable page sizes and problems of older discoloured paper are other factors which such media have to handle. The principal medium available generally for substitution is microfilm and it has been in use for many

loaded into the process tank and the deacidification solution pumped in (magnesium methoxide in methanol and freon) and pressure is then increased to ensure complete penetration. After 50 minutes the solvents are removed by vacuum drying and can be recovered for re-use. Warm air is introduced at the end of the cycle, pressure returned to normal and the books removed. The books are placed in cardboards boxes overnight to return to room temperature and regain normal moisture levels.[6]

The system currently treats up to 40,000 books a year at a direct cost of about $ 3.5 to $ 4 Canadian dollars (probably covering labour and materials only). The plant costs about $ 500,000. Two technicians are needed to process this quantity and the system is currently limited by the inadequate capacity of the vacuum drier which prevents any more than five one hour cycles per day. Existing accommodation also created problems of lack of space for extra equipment.[7] The process tank currently used limits books to 8.25" x 10" and problems have been encountered with coloured illustrations and with inks used by some library stamps migrating and offsetting on to neighbouring pages. Some plastics used on modern books may be dulled or crack or can be affected in other ways as well as glues attaching Mylar film to books. This also affects the glue on some book labels and labels may become detached.

The other main approaches have involved gaseous or vapour phases, but the only method really showing progress is the use of diethyl zinc by the Library of Congress.[8] The process consists of drying the books in a vacuum chamber for a period of 3 days during which the pressure is reduced to 35 microns absolute and the temperature raised to 45° C to remove all water to avoid the violent reaction of diethyl zinc with water. After isolating the chamber diethyl zinc is added in an amount equal to 3 % of the weight of the books avoiding contact of the liquid with the paper. The diethyl zinc volatizes and the chamber is left for 3 days for complete reaction to achieve a reasonable alkaline reserve in the books. After treatment the chamber is purged with dry nitrogen and any excess treating agent destroyed with a small amount of alcohol. When tests show that all diethyl zinc is gone water is added equivalent to about 3 % of the weight of the books and the chamber raised to nearly atmospheric pressure with carbon dioxid. The moist carbon dioxide ensures the alkaline reserve is in the form of zinc carbonate rather than zinc oxide (the latter photosensitizes paper but zinc carbonate does not). The chamber is then evacuated, refilled with air and the books removed. The complete cycle takes about 8 days including loading and un-loading and has a capacity of about 5,000 books each time. There is no evidence of damage or colour changes and again direct costs about 3.5 to 4 U.S. dollars per book (probably covering labour and materials).

The Library of Congress has recently obtained a sum of $ 11.5 million to build a process plant to treat 500,000 books a year and are likely to concentrate on current acquisitions to prevent the problem growing so rapidly.

with an average access time of 4 seconds. These micrographic images are converted to digital-electronic signals by a scanning unit with a 200 points per inch resolution for fully integrated retrieval and operation with conventional computing applications, interfacing into host computers and other networks.

Co-operation

Co-operative action is also required in dealing with a large scale of preservation problems. It is most evident in the avoidance of duplication of effort in microfilming programmes with the development of registers of microfilm masters as in the USA. The British Library is currently looking at the development of a register of microform masters for its own activities with the aim of trying to extend this to the activities of selected other libraries in the UK. This of course involves problems of catalogue standards and how to choose between high bibliographic standards as in full cataloguing systems or similar standards as in many union catalogue finding lists. The British Library has also established a NEWSPLAN programme to assist other libraries on a regional basis in the co-ordination of newspaper microfilming programmes and this principle could be extended to other areas and activities. The establishment of a National Preservation Office in the UK is another step to encourage co-operative initiatives and will help in tackling such large scale problems. It may well be that in the long term co-operative approaches will be necessary in tackling bulk deacidification, or paper strengthening projects or optical disk systems as all are likely to require high capital investments.

Conclusions

This paper has tried to outline some of the problems involved in tackling the preservation of modern paper produced over the last one hundred years and some of the approaches that are being or are likely to be followed. It is clear that with a large quantity of material needing to be treated no one library will be able to retain everything in its collections even with the bulk treatment or substitution facilities and selectivity in what is to be preserved and co-operation with other institutions are the two themes that will be essential. It is therefore for those of us active in this field and for those institutions with responsibility for collections of importance to do all they can to raise the awareness of the preservation problems that are being faced, to ensure preservation is given the importance it must have in the institution and to ensure that a significant proportion of the resources available are directed into preservation activities.

years. The maturity of the medium is well illustrated by the range of standards,[10] equipment is in the price range that can be afforded by all major libraries and unit costs are reasonably low. In the British Library we have standardized on 35 mm microfilm for our archival masters and during 1984/85 produced some 4 million frames of archival negatives of newspapers and 2 million frames of archival negatives of books, periodicals, and records. Microfilms are extending into the area of maps with the 105 mm format becoming a recognized international standard format. This is already being used by bodies such as the Library of Congress, the Public Archives of Canada and the Hydrographic Department of French Navy and the Reference Division has now acquired a 105 mm camera for such work. This system allows a single sheet map to be recorded on a black and white microfiche format on an accurately scaled basis helping to conserve the original map, enabling microfiche copies to be provided and further allowing accurately scaled good quality black and white prints to be produced.

The latest development of course is the use of optical disk systems with the potential for high storage density, for local and remote access, good data stability and eventually long life though this is not yet proven. The technology holds a promise for long term preservation of the intellectual contents of the collection and although costs are very unclear it seems likely they will provide a cost similar to that of microfilm.

One of the largest pilot projects is being run by the Library of Congress and the results of this will be awaited with interest. Input to the system is based on scanning single pages, up to 11" x 14" in size, at a resolution of 300 lines per inch. Since the system has only the images recorded and the data are not encoded, indexing information has to be added and this is proving to be one of the major costs of such a system. Some idea of the degree of compaction can be gained by the fact that one 8" x 10.5" page occupies 54,000 square millimetres, the same page on 35 mm microfilm occupies 150 square millimetres, a 98 frame fiche format occupies 70 square millimetres, while on optical disks the image of that same page occupies between 3 and 6 square millimetres. It seems as if the service aspects of this project are beginning to go ahead rapidly though the preservation implications are still unclear, mainly I feel because the life span of the disk is still very limited. In the long term optical disk technology is likely to prove to be a major preservation option that would help to bring together the preservation, storage, retrieval, and local and remote access aspects in a way previously inconceivable.

It is interesting however to see the older technology of micrographics fighting back with Rank Cintel having announced new video micrographics systems to cater for high volume document handling and storage called "Retriever". Storage is based on the use of "ultra strips", 8" lengths of 35 mm microfilm on each of which are 2,000 images at 200 times reduction. A drum based unit containing 500 ultra strips is very compact and allows access to individually addressed images

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