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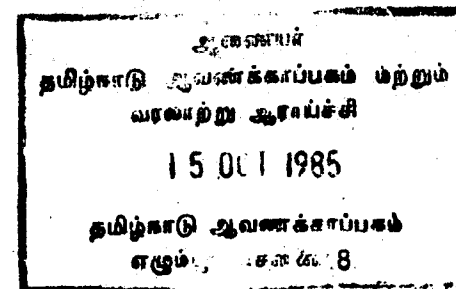
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RESTAURATOR

International Journal for the Preservation
of Library and Archival Material

359

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Publisher's Note

RESTAURATOR

I would like to inform the readers that in agreement with the present editor, Mr. Poul A. Christiansen, we have appointed a new Editor-in-Chief for RESTAURATOR. With great pleasure we announce that Dr. Helmut Bansa, Institute of Restoration of Books and Manuscripts of the Bavarian State Library, Munich, has accepted our invitation to take over the editorship for the journal beginning with Vol. 7, 1985. Dr. Bansa and Munksgaard have agreed to make every effort to re-establish a regular quarterly publication.

The new editorial office is:

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I would like to take this opportunity to express my respect and admiration for Mr. Poul A. Christiansen, the founder of RESTAURATOR, who after nine years of running the journal, in 1978 handed over the publication to Munksgaard.

Today the journal has nearly 1,000 subscribers in 53 countries, which proves Mr. Christiansen's foresight as well as the need for such a journal, and we feel convinced that with renewed efforts and a shorter publication time, the journal will fulfil this need more strongly.

MUNKSGAARD International Publishers Ltd.



Oluf V. Møller

Publisher

RESTAURATOR

International Journal for the Preservation
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Conservation: The Curator's Point of View

by KARL DACHS

This paper concerns the objectives which the librarian sets for the conservator in the treatment of manuscripts and precious printed works. In contrast to the book in daily use, they have a high material value and the quality of rarity or even irreplaceability. The most important difference from our point of view is that their purpose is not exhausted by giving the reader their textual content, because their outward appearance and material form is an integral part of their mission, equal to or even superseding the meaning of the text. In book conservation we are precisely concerned with the physical body of the book. The highest standards of conservation must therefore be observed in the case of manuscripts and precious printed works.

Books are objects composed of organic materials. From the moment of their production they suffer an unrelenting process of destruction, which can be considerably accelerated by inappropriate storage and excessive use. Naturally the book will not be completely spared even by the most careful treatment and ideal storage conditions, but methodical care can lengthen its life span by centuries and ensure its service to subsequent generations, whilst books that have not received attention will have long turned to ashes.

Conservation Entails Two Aspects:

One is preventative care, i.e. the production of ideal climatic conditions in Stores and Reading Rooms, the education of library staff and the public to treat books in a responsible manner, and the restriction of the use of books to the absolutely necessary. We have a rich collection of literature devoted to discussion of this first aspect, and it would be superfluous to further expand it here.

The second aspect is the active, healing treatment of the physical substance of the book, i.e. conservation. The conservator is the most important link to the librarian in his function as a conserver. The conservator has the knowledge of materials and their durability, of the various conservation methods and their limits and dangers, and he has a mastery, often to the point of virtuosity, of the techniques used in each method. The curator must have the ability to decide the importance of a book in terms of cultural and scholarly history, i.e. the ability to gauge its historical and aesthetic value and to put a figure on its material value. Moreover, only he can calculate the extent of the wear and tear the book will be exposed to in the future as a result of the amount of use predicted for it.

When the librarian considers the book to be a cultural treasure exposed to public use, he sets for the conservator objectives associated with active conservation. Librarian and conservator decide together whether and to what degree these objectives are attainable given the present day level of technology; this solves the problem of whether the cost and result of a restoration are on balanced proportions. As a rule of thumb, the cost of conservation should not exceed the value of the book.

Each item, whether a manuscript or a high-quality printed work, is unique, or at least has unmistakably individual features. Each restoration is therefore an individual operation, whose objectives must be determined according to circumstances and feasibility in each case. Nevertheless, certain general basic rules must be adhered to; the objectives must be governed by them and modified where necessary. They must form a logical system, which might be described as the style of conservation. Practical conservation will also invariably bear the stamp of the chief librarian's temperament and taste, the signature of the conservator responsible, and the tradition of the house in which the work is carried out.

For want of a better definition, the goal of book conservation is to protect the book and to restore it to a usable condition by means of technical intervention that safeguards the form it has acquired over the years, either by the most careful protection or by recreating its external appearance. In conservation, technical, historical and aesthetic considerations must therefore be taken into account, and it must be realised that these three factors do not just have a bearing one on the other, they often represent different facets of one and the same principle.

1. MATERIAL AND TECHNIQUE

All replacement materials needed for conservation must match as closely as possible those to be found in the book concerned. This applies equally to the binding, the body of the book, the stitching and the head-caps. It is also essential that these materials will age in a similar way to the original materials.

All treatment methods that could trigger chemical reactions in the book must be researched before their use to ensure their harmlessness.

Furthermore, the principle must be observed that new techniques and methods should not be tried out or even developed on important items. The danger of this happening is very pronounced: the librarian is keen to have his major items restored, and the ambition of the conservator leads him to put his abilities to the test on valuable objects.

If the durability and chemical innocuousness of a technique has not been

established beyond all doubt, then the implementation of any drastic conservation work using this technique should be avoided at the time. Conservation techniques are constantly progressing, undergoing improvement and refinement. What can not yet be done satisfactorily today will perhaps be common practice in 10, 20 or 30 years time. To bridge the gap, a straightforward repair can be made which will improve a ruined appearance and keep further decay in check. An alternative recommendation is to leave the damaged item untreated, put it in a box to protect it, store it under the best possible conditions and restrict its use to the bare minimum, or replace it by a photographic copy, until the time is ripe for the delayed conservation to take place.

A similar procedure is advised for techniques which may well be durable but which gravely alter the optical and tactile characteristics of the original, like the sealing of faded inks and colours. These techniques may be reluctantly employed as a last resort if the item has reached a state of intensive decay and it is not possible to wait for a more satisfactory technique to be developed. In most cases however it is better to wait and to take the book out of circulation.

As has just been indicated, book conservation techniques are constantly progressing, developing and improving. A necessary consequence of this is that restorations dating back several decades no longer seem satisfactory, even where the work is skilled and free of mistakes. Outdated technical methods may be responsible, but certainly a change in aesthetic requirements as well. The call for renewed conservation work to replace the earlier "flawed conservation" may be loudly made. Conservation methods must therefore be reversible and revisable. In practice however, conservation is usually shown to be reversible only to a limited degree. Reason enough to warn against over-confident, enthusiastic use of unperfected methods.

All methods, chemical methods included, must be done or guided by hand, i.e. extremely individual and non-standardized. This demands that all processes and treatments be carried out under the constantly watchful eye of the conservator, whose sensibility has matured with experience.

It is the task of conservation to prepare a book in such a way that it once again bears examination. Restoring the book to a usable condition should not however be the primary objective. The degree of robustness that can be attained depends on the demands of historical and aesthetic conservation. Less ruggedness should be balanced out by more preventative conservation in the future.

The documentation of conservation procedures is necessary, and it should include a record of the damage discovered and all the steps taken to combat it.

In the case of important items, photographs must be made to document the condition before, during and after treatment.

2. PRESERVATION OF THE SUBSTANCE OF THE BOOK

The concept of the material substance of the book is to be understood here in the widest sense. The core is the body of the book, consisting of the pages together with the text written or printed on them, as well as any decorative work painted or printed into the original.

The body of the book also includes its composition, its construction of quires and inserted single sheets. This construction must not be altered in any way, especially in the case of manuscripts, even if the pages have separated themselves into single sheets, since the composition may be historically informative. Only the most patently obvious connections may be restored.

The stitching and the head cap also belong to the substance of the book, but the sacrifice of these elements cannot be avoided when re-binding. This increases the importance of closely matching techniques and materials to the present condition of the book. In this connection I can refer to parchment joints, which were used in the late Middle Ages to strengthen the resistance to wear of the stitching of paper manuscripts. Parchment joints with pre-13th century inscriptions may be removed in the hope of piecing together important texts from the fragments. However, it is difficult to understand why textually meaningless joints of later times should not be returned to the book to fulfil their original functional purpose.

The curator includes in his appraisal of the historically valuable substance of the book, to be preserved at all costs, all additions and entries that have been made either at the time of the book's production or in later centuries. The old book is not merely a vehicle for transmitting a text. Even an old printed work, of which there are a number of textually identical copies, is an individual, fulfilling a historical destiny that may be documented in its outward appearance. Research has recently paid much attention to precisely this sort of feature.

Here we stumble on the binding. Until the 19th century, books mostly had individual bindings. These bindings must be considered an integral part of the book even where they do not date from the time of the body of the book. It is not only the binding itself, or what is left of it, that must be preserved, but also everything that is attached to its inside or outside, whether it be an *Exlibris*, a *Supralibros*, notes regarding purchase or possession, library classification numbers, title plates or whatever else is to be found.

I would like to draw attention to two particular points. In manuscripts of the

Middle Ages, and also in incunabula, handwritten fragments were very often stuck onto the inside of the book cover. Librarians in the last century or later frequently removed them in the hunt for texts for a collection of fragments. This tampered with a first-rate historical source, for the fragment and the book often helped to throw light on each other. It must therefore be insisted upon that fragments are treated in the same way as loose leaves, and must only be detached from the cover to the point where they are readable on both sides. Panelling on binding covers, the wooden covers on manuscripts and early printed works, and manufactured cardboards are also often overlooked. The enthusiastic replacement of old wooden covers with new covers will invariably mean a loss of historical substance and a delicate disturbance of the historical atmosphere. In most cases it is possible to rescue broken and even highly worm-ridden wooden covers. The same is true of old cardboards, although if they are composed of fragments glued together they may be replaced, as it is reasonable to look for important discoveries amongst the fragments.

The same demand for complete preservation must be extended to the body of the book. Here we find varying paginations, remarks in the margin made by scholarly readers of centuries long past, and additional texts bound in. It was usual, for instance, to bring liturgical up to date by stitching in the order of service for new feast days. Particular attention should be paid to the pictures which were stuck into the book by former owners to provide further decoration. It used to be the practice to remove such single woodcuts or copper engravings with the justification "It doesn't belong in the book," and to pass on the item removed to graphics collections. This showed no sense of history, for the use of individual graphics to decorate a book was customary in the 15th and 16th centuries.

The preservation of the substance must be taken still further. Spots of wax in sumptuous liturgical manuscripts of the Middle Ages are evidence of their use in worship. They must on no account be removed. To cite another example, the same principle applies to the heavy fingerprints found in well-thumbed vernacular epics of the Middle Ages, printed popular works and similar texts. Such marks do, of course, detract from the overall impression, but they point to the popularity of the literary genre.

Old printed works and even manuscripts from the Middle Ages have radically changed in appearance over the centuries as a result of conscious intervention. They have been enriched by additions of all descriptions, they have undergone one or more re-bindings, and culturally and historically interesting conservation and restoration techniques have been tried out on them. They are similar to architectural monuments of the past, which later generations have altered to preserve them or to suit their concept of good taste.

As in the case of architectural care of monuments today, book conservation must avoid stylistic purity, the usually impracticable attempt to recreate the original condition. Alterations of later years must be respected as a fact of history. Here I do not include more modern distortions of the book's character or technically dubious repairs and restorations, nor the disfiguring scribbles of children or the barbaric defacing of pictures and marks made in the text by modern readers. It can only be decided by looking at each case what is an original feature that should be preserved and what is an intolerable detraction from the overall effect. Here we are approaching the difficult area of the specification of aesthetic aims in book conservation.

3. PRESERVING OR RECREATING OF THE OUTWARD APPEARANCE OF THE BOOK

It should be re-emphasised that each old book is a carrier of information both in its text and in its material form. The importance of the material form is not exhausted by its historical documentation, as described above. It also lies in the historical atmosphere surrounding it, difficult to gauge or describe, and in the character of the book as an antique. The expert sees in it an irreplaceable value, the sensitive researcher a source of knowledge. The character of the antique can take on the quality of a work of art, sometimes even a most exquisite work of art. As in the case of other artistic genres, the objective in book conservation must be not only to preserve its antique character and artistic quality but where possible to let them shine through more clearly than before.

This task is extremely difficult to carry out, for books needing conservation have long since left behind their original appearance as a result of the ravages of age, which manifest themselves in the form of mechanical, biological and chemical damage. Book conservation, seen purely technically, is a process of intervention, designed to stabilise preserved but weakened elements (including any desired alterations that have been made) and to replace functionally important parts that have not been preserved.

The aesthetic aspect of conservation is a difficult and extremely complex business. It is supposed to concern itself with the removal or alleviation of disfigurement resulting from decay without affecting the overall impression given by an old book, even when new pieces are used to replace old.

The aim of conservation must not be an attempt to give back to the book the appearance that it had at the time of its creation. That would mean distorting its historical dimension. The historical patina which every old book takes on should therefore not be completely removed along with the defects. To express it more colourfully, the wounds should be healed, the scars rendered invisible

where possible, and a general rejuvenation achieved. With sensitivity the right degree of rejuvenation can be reached, located somewhere between a freshness that has been preserved and a mellowness that its venerable age has imparted to it, depending on the object concerned. The ideal restoration from the aesthetic viewpoint is achieved if the book takes on the appearance that its history would have given it had it always been stored in favourable conditions and treated with the greatest of care.

To move on to some detail: the treatment of paper is a particularly delicate matter. The often necessary wet treatment should combine a general cleaning process with the removal of spots of mildew and other defects, and may lighten the tone without producing a snow-white paleness. Old papers were never snow-white, and a slight yellowing suits them well as a sign of age. Particular value must also be laid on the tactile characteristics of the paper. Under no circumstances must the more or less rough surface of the paper be levelled by over-rigorous compression after the wet treatment, nor tangible relief of the print or the hollowed edge of intaglio be lost.

There is less opportunity for improving the appearance of parchment. It cannot hide the age it has attained. As well as dry cleaning it, parchment should be sized if it has been badly warped as a result of damp or heat.

Conversely, the appearance of leather bindings can be freshened by oiling the dried out, brittle binding covers, by the removal of marks, the colouring of unsightly cracks and scratches and the closing of severed joints. Great care must be taken in this work, however, to ensure that in the oiling process any embossing of the leather does not become ill-defined or spongy, and that when repositioning covers, the relief is not ironed out by over-rigorous pressing.

The concept of the 'cleaning' of materials and surfaces has appeared a number of times in our deliberations. In considering the question of cleaning, it is necessary to define the difference between the historical patina that should be preserved and dirt that should be removed. It is only possible to draw the line between the two under practical, not theoretical conditions.

As far as the aesthetic effect in book conservation is concerned, the replacement of the irreparably damaged is just as crucial as the treatment of that which can be preserved, in the case of both the binding and the body of the book. If the importance of using materials that are similar to the original has already been stressed on technical grounds, then that principle must be reinforced here by the demand for the closest possible colour matching and for similarity to the touch. Materials contemporary with the book are naturally more suitable than new materials, and conservators are thus well advised to build up as rich a fund as possible of old papers and uninscribed pieces of parchment. I find unacceptable the idea of imparting an artificial historical patina to colour-

matched replacement papers. The same principles apply to binding restorations, which are rarely completed without some degree of replacement of the leather cover. Colour-matching requires in this instance a masterly command of the techniques of colouring leather.

A particularly controversial problem in restoration concerns retouching and reconstruction. We take both terms to mean restoration of writing, decorative artwork and pictures; retouching means the correction of smaller blemishes in an otherwise well-preserved area, whilst reconstruction means the replacement of large areas, be they whole pages complete with script and pictures or complete ornamental bindings. Retouching and reconstruction are forbidden in principle for book conservation in libraries, for the danger of forgery is too great. Nevertheless, retouching should not be seen as absolutely taboo in well-substantiated individual cases. Here I am thinking of blemishes on leaves of decorative graphics (but not graphic art), or on maps, etc. In binding restoration, the continuation of individual lines to round off the overall visual effect might be discussed. Some libraries even go so far as to retouch a seal to complete its decorative effect. In the case of illuminated manuscripts there is an absolute taboo even on retouching. The replacement of missing pieces of text or of whole pages of text in printed works should be avoided; likewise, the unification of sections of defective copies of a printed work to make one complete whole is quite out of the question. If copies of lost pages can be obtained, they should be kept separate from the book.

A reconstruction, in the strict sense of the word, using imitation decorative materials can be no replacement for a missing or lost binding. A plain binding which suits the book and its time in terms of appearance, material and bindery technique seems to me the best solution. The so-called 'historically neutral' binding poses more of a problem, as even a few decades later it will be exposed as a typical product of its time.

To sum up aesthetic demands in book conservation: "visible restoration," where every trace of the treatment is to be seen and all replacements can be clearly differentiated from the original parts, influences the book's character as an antique, and should therefore be avoided. "Invisible restoration" is a dubious proposition because it completely obscures the book's history. The type of restoration that is to be recommended is one that comes close to invisible restoration: skilled, and as inconspicuous as possible.

Note: This article was originally presented as a paper at the IFLA General Conference, Munich 1983 to the Conservation Section.

SUMMARIES

Conservation: The Curator's Point of View

The curator sets for the conservator goals of conservation for which the conservation of manuscripts and rare printed works make the highest possible demands. There are technical, historical and aesthetic considerations.

1. Durability together with chemical harmlessness and reversibility are the pre-requisites as far as the materials and technology used are concerned.
2. The need to preserve the item extends to all the historically important characteristics that the book has taken on in the course of its history.
3. The aesthetic considerations aim at as inconspicuous a restoration as possible, in which all damage and disfigurement is removed and replaced in harmony with the original, retaining the historical patina.

Les exigences du conservateur dans le domaine de la restauration

Ce sont les manuscrits et les ouvrages imprimés rares qui posent au conservateur de bibliothèque les problèmes les plus complexes dans le domaine de la restauration. En effet, ici interviennent des considérations d'ordre technique, historique et esthétique.

1. Il faut établir la présélection des matériaux et des méthodes à partir de critères tels que stabilité et innocuité chimiques et réversibilité du processus.
2. Il est nécessaire de conserver l'ensemble des caractéristiques historiques importantes que l'ouvrage a acquis au cours de son histoire.
3. Il faut avoir pour but, pour des raisons esthétiques, une restauration aussi discrète que possible qui supprime tout ce qui pourrait détériorer ou défigurer l'objet et qui le replace en harmonie avec l'original tout en respectant la patine du temps.

Forderungen des Bibliothekars an den Restaurator

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A Search for Procedures for Restoration and Stabilization of 16th and 17th Century Netherlands Atlases Damaged by Green Paint

by M. G. BLANK, S. A. DOBRUSINA AND N. B. LEBEDEVA

INTRODUCTION

The Saltykov-Shchedrin State Public Library possesses a rich collection of rare illuminated atlases and maps. Among them there are the well-known first world atlases designed by A. Ortelius in Antwerp in 1657; atlases of H. Mercator, the head of the Netherlands cartographer school, published in Duisburg in 1595; and atlases of the Amsterdam masters: Hondius, Janssonius, and Blau. Besides their rich contents these atlases are famous for the traditional way of decorating maps with emblems and conversation pieces. Bright colours of rich tones were used for painting. This tradition spread to the neighbouring countries, and similar atlases were published in Germany and France.

MATERIAL AND METHODS

The State Public Library collection of atlases is one of the largest in the world. It numbers over 300 volumes. Severe brownness was discovered on the reverse side of the paper in places where green paint had been applied to the foreshore. Parts of badly browned green paint were also discovered in some instances. The brittleness of the paper increased in these places, resulting in the loss of fragments of a sheet. In parts, where the colour remained bright, dark brown contours appeared on the back side. A careful study of the collection carried on at the Department of Cartography showed about 45% of the collection to be affected by the above-described damage to a higher or lower degree, with about 30 volumes demanding urgent restoration and stabilization. One can also find the phenomenon of this green paint destruction in German and French atlases. The problem was to find a procedure for the conservation of both paper and paint and then develop proper conditions for this work.

STUDY OF ATLASES' PAPER PROPERTIES AND COMPOSITION OF THE PAINT

Two types of atlases with badly damaged green painted areas of sheets were chosen for the investigation. The fibre composition was determined by micro-

Table 1: Paper of atlases and model samples characteristics.

Table 1: Papiers d'atlas et caractéristiques des échantillons.

Tabelle 1: Kennwerte für Papier aus Atlassen und Modellmuster.

No. Type of tests	Paper of atlases		Paper of samples	
	1	2	hand made	machine product
1 Fiber composition	Cotton	Cotton	Cotton	Cotton
2 Ash content	–	2.78*	0.4	–
3 Mineral filler	No	No	No	No
4 Adhesives	Gelatine	Gelatine	Gelatine	Gelatine
5 pH cold extract	5.1	5.0	6.7	6.6
6 Weight of paper in grams per square meter	80	120	100	80
7 Thickness, mm	0.14	0.24	0.21	0.1
8 Beating degree, °SR	–	–	45	50
9 Folding endurance, number of double folds	–	–	2770	84**
10 Tensile strength, N	–	–	126.4	40.3**
11 Elongation, %	–	–	6.7	4.4**

* The value 2.78 is due to surface contamination of paper.

** The results of test are taken in machine direction.

structure tests and colouration tests in appropriate solutions. The absence of fillers was ascertained by means of determining the ash content and infra-red spectroscopy method. Adhesives were identified by qualitative reactions with tannin or ammonium molybdate. The results of the experiments with paper of two 17th century atlases (Table 1) shows the paper under study to be similar in composition, devoid of mineral fillers and having surface adhesives. pH values are similar while the weight of 1 sq.m and thickness are different.

Literature sources¹ point out the basic or neutral salt of copper acetate, i.e. verdigris, to be mostly used as a green pigment in Europe, mainly in

Table 2: Results of the analysis of the paint composition.

Table 2: Résultats de l'analyse de la composition des peintures.

Tabelle 2: Ergebnisse aus der Analyse der Farbenkomposition.

No.	Type of object	The composition of green paint
1	Water extract pH	4.8
2	Pigment	Cations: Cu ²⁺ , Ca ²⁺ , Mg ²⁺ , Al ³⁺ , Pb ²⁺ , Fe ²⁺ , Na ⁺
3	Binder	Gelatine
4	Plasticizer	Honey

the Netherlands, Germany and Italy, from the 12th to the 17th centuries. This pigment was also well known in Russia. Its approximate formula is $\text{Cu}(\text{CH}_3\text{COO})_2 \cdot n \text{Cu}(\text{OH})_2 \cdot m \text{H}_2\text{O}$. Its major advantage is a pure green tone. Copper acetate was frequently used with additives of stannum and plumbum. It gave the paint another tint. Some works^{2,3} describe a modification of verdigris. This is a transparent green substance, obtained by dissolving the pigment in a balsam, a kind of Venice turpentine. Copper and its salts are known to react with such resins by forming green coloured solutions (copper resins).

Illuminated manuscripts' paint is proved by recent investigations⁴ to contain basic copper nitrate – Gerhardtite $\text{Cu}(\text{NO}_3)(\text{OH})\text{Cu}(\text{OH})_2$, malachite $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$, atacamite $\text{Cu}(\text{OH})\text{Cl} \cdot \text{Cu}(\text{OH})_2$. However, copper acetate is recognized to be the most reactive and unstable of all earth pigments⁵. The results of the analysis of the paint composition are presented in Table 2.

Samples of paint were taken both from damaged parts which fell through and those where a paint coat remained undamaged. The data presented indicate pH of the paint coat to be low. Emission spectrum analysis discovered a number of cations prevailing in paper. Microscopic study showed the paint to be transparent in an absolute majority of the samples, which is typical of copper acetate. Also, X-ray structure analysis discovered atacamite in some samples.

The thin-film chromatography analysis of the binding discovered glucose and amino acids. Thus one comes to the conclusion of a honey and gelatine presence. They are known to be used in the period concerned.

The browning of the paint and paper is supposed to have different origins: – acid or alkaline oxydegradation of cellulose⁶,
– hydrolysis of the pigment in wet atmosphere with brown copper oxides and acetic acid formation⁷,

- copper sulphide formation as a result of sulphur dioxide adsorption from atmosphere by the pigment⁵,
- copper resinate's destruction with the formation of brown organic products^{2,3},
- hydrolytic destruction of cellulose,
- presence of Fe cations in the paper⁸.

MODEL SAMPLES' PREPARATION

To solve the problems raised in the work it was decided to prepare model samples of some paper with the paint on the basis of the evidence obtained. After subsequent artificial aging resulting in obtaining a material similar in properties to the original, it was necessary to develop a procedure for restoration and stabilization of the paper and the paint.

According to the obtained evidence concerning the paper, composition paper samples were prepared in the laboratory. Some special industrial paper was also studied. The characteristics of the papers are presented in Table 1.

The paper of the atlases under study having similar composition but different 1 sq. m. weight, the same proportions were kept for the model samples. The paint of a watercolour type was prepared for the study according to the most well-known old recipe⁹.

It was composed of the following components: ground pigment of copper acetate; the binder - 1.5% gelatine solution; the plasticizer - a water solution of honey (1:4). The prepared paint pH was 4.8. The paint was applied to the prepared paper casts.

Dried and conditioned paper samples were subjected to the artificial moisture aging under $t = 102 \pm 2^\circ\text{C}$ for 72 h in hermetic glass tubes with moisture at 5% of the paper weight. The latter accelerated both oxidation and hydrolytic processes.

The value of tensile strength (I), folding endurance (II) and water extract pH (III) were measured while aging both for paper with the paint and the control paper without paint. The results are presented in Fig. 1. The curves' slope indicates an intensive decrease of all registered values for paper with the paint and satisfactory stability of the control paper. Those paper samples with the paint which, having been subjected to artificial aging, reserved 2.5% of initial strength were used for further investigations.

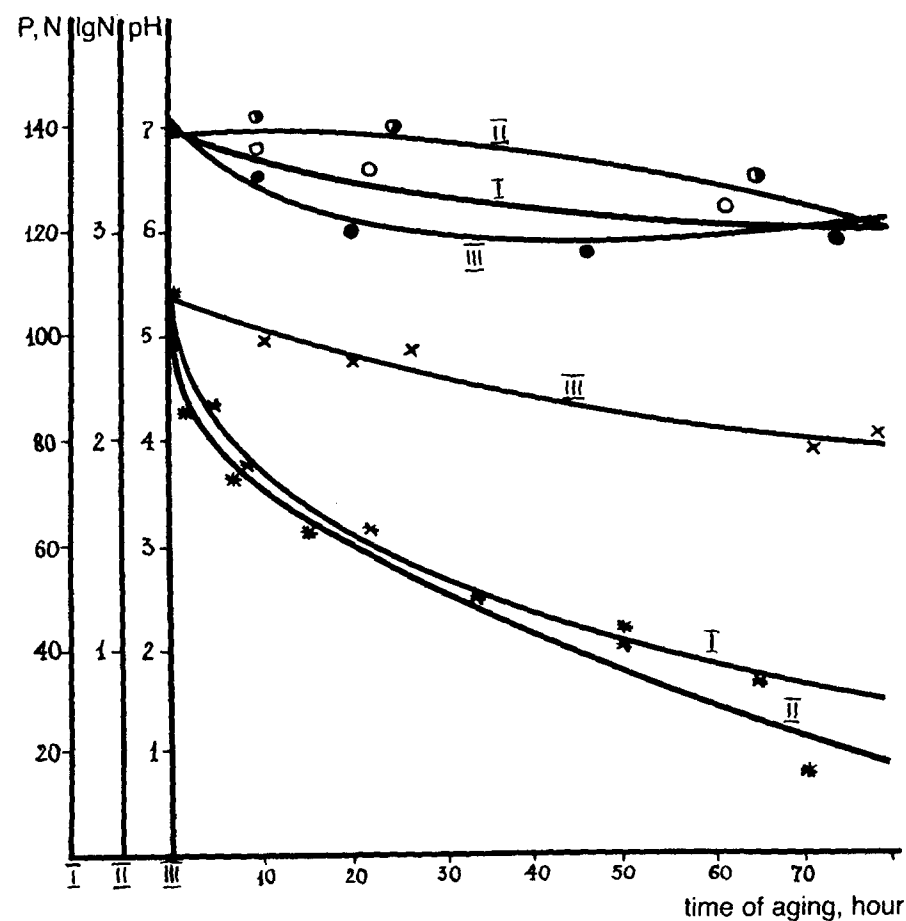


Fig. 1. Change of the values of tensile strength (P, curve I), folding endurance (N, curve II), and pH (curve III) of the paper in the process of artificial aging.

Fig. 1. Evolution des valeurs de la résistance à la traction (P, courbe I), résistance à la rupture après pliage (N, courbe II) et pH (courbe III) du papier lors du processus de vieillissement artificiel.

Abb. 1: Änderung der Zerreißfestigkeitswerte (P, Kurve I), der Bruchwiderstandsfähigkeit bei Faltung (N, Kurve II) und des pH (Kurve III) des Papiers im künstlichen Alterungsprozess.

○ ● - sample without paint
× × × - sample with paint

A SEARCH FOR PROCEDURE FOR STABILIZATION AND RESTORATION OF THE ATLASES

On investigation of the atlases' paper state, a considerable number of sheets which changed colour affected by the green paint, revealed a sufficient strength

Table 3: Characteristics of the polymers used.

Table 3: Caractéristiques des polymères utilisés.

Tabelle 3: Kennwerte der angewandten Polymere.

No.	Type of polymer	Designation used in the text	Solvent	Concentration, %	Polymers' characteristics
1	Polyvinylalcohol	PVA	Water	3.5; 8.0	DP -1400 η 3.5% -0.5 Pa · c pH -6.9
2	Polyamide	PA	Ethanol	13.0%	-
3	Fluoroplastic	F	Amilacetat, acetone, ethylacetate (1:2:2)	2.0	-
4	Polyvinylbutiral	Butvar	Ethanol	8.0	-
5	Ethylcellulose	EC	Bensol, ethanol (1:1)	3.0	mark K

while the rest were badly damaged and broke into pieces at a touch. Paper of the first kind should be stabilized to prevent its further degradation and, furthermore, should be given an increased strength reserve. Paper of the second kind needs taking measures to provide restoration of the lost properties and to give strength. A search for a procedure for removing intensive tracks of browning by means of oxidation reaction proved to be advisable.

To solve the first problem – stabilization – water solutions of Ca and Mg bicarbonates were prepared according to W. J. Barrow¹⁰. The solutions were applied to the painted parts by spray. Strengthening the model samples was achieved by impregnation with PVA, polyamide, fluoroplastic, polyvinylbutyral, ethylcellulose solutions. The polymer characteristics are presented in Table 3. The highest values of mechanical strength were obtained with PVA and fluoroplastic samples.

Special attention was paid to the degree of the change of the paint colour in the presence of polymeric cover. The samples' colour before and after polymeric treatment was determined by means of RFC-3 spectrometer. Values X, Y, Z were interpreted as co-ordinates of a point in a space of 3 dimensions¹¹.

Table 4: Change of the strength of the paper subjected to different treatments in the process of restoration.

Table 4: Evolution de la résistance du papier soumis à différents traitements durant le processus de restauration.

Tabelle 4: Änderung der Stärke des Papiers, nachdem es im Restaurierungsprozess verschiedenen Behandlungen unterzogen wurde.

No.	Name of the sample and its treatment	Double folds number in % to the double folds number of the control sample
1	Control sample	100
2	Green painted sample a. after painting b. after artificial aging under conditions: b-1. severe b-2. moderate	52 0.5 2.0
3	Sample 2 b-1 after bleaching	0.5
4	Sample 3 after impregnation with PVA solution	0.5
5	Sample 2 b-2 after bleaching and impregnation with PVA solution	18.5
6	Sample 3 after lamination with tissue paper	150

The distance was calculated for every pair of points, one complying with the colour of the paper without polymer, the other with polymer. The shortest distance between two points indicated the least difference between the colours. The experimental evidence pointed out that fluoroplastic has the best properties, while the second place is occupied by PVA. The permanence and durability values calculation was performed both for samples with fluoroplastic and PVA cover, according to the technique based on the kinetic concept of strength¹². The value of the activation energy of the process of the covered samples was for fluoroplastic $U_F = 121$ kJ/mol, for PVA $U_{PVA} = 119,6$ kJ/mol; $U_K = 99,3$ kJ/mol was the control value.

The second stage of the work included the investigation of the model samples, also subjected to artificial aging. Before bleaching, the paint on the samples was fixed by 4 different types of solutions. For characteristics see Table 3 (numbers 2–5). The process of fixing was repeated three times with 24 h intervals. Then the samples were subjected to chloramine B treatment with active

chlorine concentration 3%, by means of tamponing the reverse side of the sheet for 20–30 min with subsequent washing in running water for 1.5–2.0 h and neutralization in Ca and Mg bicarbonates solution. The samples were dried at room temperature for 24 h. Appropriate solvent was used to remove the film of the polymer spread over the paint. The treatment resulted in removing the browning and the paint acquired a rich green shade.

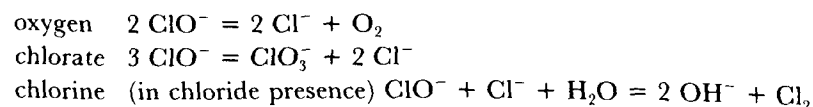
The paint fixing agent for bleaching was chosen according to the degree of colouration of a moistured filter-paper when put in contact with the surface of the fixed paint. Ethylcellulose provided the best fixing, its film being easily removed by ethyl alcohol.

The samples' strengthening was achieved either by impregnation of the paper with 8% PVA solution or by lamination with tissue paper by means of the same solution as an adhesive. The fold endurance value was determined for every sample by means of folder, 4.9 N load (P 0.5 kg). The results are presented in Table 4.

Table 4 shows the painted samples, subjected to artificial aging and bleaching, to be distinguished by badly reduced strength that is less than 1% of the initial strength (severe conditions). The strength doesn't return after impregnation of the samples with 8% PVA solution. It considerably increases, however, when the samples are laminated with tissue paper (Table 4, No 6). On the other hand, model samples with the paint, subjected to artificial aging up to the rate providing 2% of the initial strength kept (moderate conditions) appeared to increase its strength 9–10 times after subsequent impregnation with 8% PVA solution (Table 4, No 5).

CHEMICAL SIDE OF THE OXIDATION PROCESS IN BLEACHING

To remove the brownness by bleaching, Chloramine B (RNHCl) was used as an oxidizing agent. Also, hypochlorous acid (HClO) plays an important role in the oxidation process. The acid forming in the course of hydrolysis is characterized by 3 types of dissociation:



Oxygen dissociation is the most probable in this case. The acid, according to modern concepts, associates in double-bonds of coloured products of cellulose destruction with subsequent formation of colourless oxidized or chlorinated combinations.

As the object of the treatment was changed from the model samples to the original atlases, chloramine treatment appeared to result in partial discolouration of violet-pink pigment together with positive results for the green paint. This violet-pink pigment, like many others, was supposed to dissolve in hydrochloric acid, the latter being formed in the course of chloric acid dissociation. Therefore, the bleaching agent was changed to hydrogen peroxide. The oxidizing effect is due to perhydroxonium ions, formed in the course of peroxide dissociation:



Alkalis are the catalysts of the dissociations, therefore the solution pH was kept at 9.5–10. In maps, the bleaching effect caused by peroxide is similar to chloramine, although the former involves more time for treatment.

Bleaching with a 3% water-alcohol solution (1:1) of hydrogen peroxide was performed by means of a compress or a reverse side tamponing. The paints were fixed previously with ethylcellulose solution. Also, a test of the violet-pink pigment on a filter-paper gave a positive result and a visual study found the colour intensity unchanged. Thus, the bleaching due to an oxidizer, affecting the coloured admixtures and products of cellulose destruction, permits their conversion into colourless compositions. The paint gains an intensive green colour.

The subsequent treatment with Ca and Mg bicarbonate solutions results in neutralisation of all acid components in paper, and precipitation weak-soluble in water Ca and Mg carbonates on fibres. The salts serve as a buffer and prevent further accumulation of acid products in paper.

Thus, the investigation proved the procedure for restoration and stabilization of 16th–17th century Netherlands atlases to be composed of:

- three times-repeated fixing of the paints with 3% ethylcellulose solution in a benzol-alcohol mixture,
- bleaching with 3% water-alcohol (1:1) solution of hydrogen peroxide (pH 9.5–10) or chloramine solution with 3% active chlorine concentration by means of a compress or tamponing from the reverse side of a sheet,
- washing in running water,
- neutralization with Ca and Mg bicarbonate solutions according to Barrow,
- removal of ethylcellulose film with ethylalcohol,
- impregnation with PVA solution (8%) or fluoroplastic solution (2%); lamination, if necessary, with tissue-paper by means of 8% PVA or 3%

NaCMC solutions. It is important, that while operating with PVA, one must work fast and apply it thoroughly over a sheet surface to prevent irregular impregnation that causes stains.

SUMMARIES

A Search for Procedures for Restoration and Stabilization of 16th and 17th-century Netherlands Atlases Damaged by Green Paint

The Netherlands illuminated atlases of the 16th–17th centuries of the M. E. Saltykov-Shchedrin State Public Library collection have been badly damaged due to the effect of green paint. The browning of the green paint, as well as of the parts of the reverse side of the sheet where the green paint was applied on the foreshide, was observed. The brittleness of the paper under the paint increased which resulted in the fracture of the sheet or losing fragments. The problem was to find a procedure for the conservation of paper and paint and develop proper methods for work with these materials. The paper properties and the paint composition of the atlases were investigated. In most cases the green paint was found to contain the pigment verdigris, which is the salt of copper acetate. Model samples were produced using copper acetate as the pigment of the paint. The change of properties in the process of artificial aging was estimated. The procedure for conservation of the atlases' sheets included the spreading of a protection cover by means of ethylcellulose solution; bleaching with Chloramine B or hydrogen peroxide solution; removal of the ethylcellulose film; stabilization treatment with Ca and Mg bicarbonate solutions and impregnation with PVA or fluoroplastic solutions; or lamination with tissue-paper. The permanence and durability value of the paper after the treatment was approximated.

Recherche de procédés de restauration et de stabilisation d'atlas néerlandais des 16ème et 17ème siècles endommagés par la peinture verte

Les atlas néerlandais enluminés des 16ème et 17ème siècle de la collection de la Bibliothèque Publique D'état M. E. Saltykov-Stchedrin ont fait l'objet de dommages sévères dus à l'effet d'une peinture verte. On a pu observer le brunissement de la peinture verte ainsi que de parties du verso des feuillets sur lesquels la peinture verte avait été appliquée au recto. Un accroissement de fragilité du papier sous la couche de peinture a été noté conduisant à une rupture du feuillet ou au détachement de fragments de papier. Le problème consistait à trouver un processus de conservation du papier et de la peinture et à mettre au point des méthodes appropriées de travail avec ces matières. Les propriétés du papier et la composition de la peinture des atlas ont été étudiées. Dans la majorité des cas, la peinture verte s'est avérée contenir le pigment dénommé vert-de-gris ou acétate de cuivre. Des échantillons ont été réalisés en utilisant l'acétate de cuivre comme pigment de peinture. L'évolution des propriétés du papier lors du processus de vieillissement artificiel a été estimée. Le processus de conservation des feuillets d'atlas a comporté l'étendage d'une pellicule de protection à base d'une solution d'éthylcellulose; le blanchissement par une solution de chloramine B ou d'eau oxygénée; l'enlèvement du film d'éthylcellulose; un traitement de stabilisation par des solutions de bicarbonate de calcium et de magnésium et l'imprégnation au PVA ou par des solutions de plastiques fluorés; ou un traitement de laminage du papier de tissu. Les valeurs de la stabilité et de la durabilité du papier après traitement ont été évaluées.

Die Suche nach Verfahren zur Restaurierung und Stabilisierung von niederländischen Atlassen aus dem 16. und 17. Jahrhundert, die Schäden durch grüne Farbe aufweisen

An den niederländischen illuminierten Atlassen aus dem 16. und 17. Jahrhundert, die Die Staatliche öffentliche Saltykov-Shchedrin Bibliothek Sammlung gehören, haben sich durch die Beeinträchtigung von grüner Farbe ernsthafte Schäden herausgestellt. Es wurde Bräune der grünen Farbe an den Vorderseiten sowie an den entsprechenden Flächen der Kehrseiten der vorne grün bemalten Blätter festgestellt. Die Sprödigkeit des Papiers unter der Farbe var erhöht, was Seitenbrüche und abgefallene Teilchen zur Folge gehabt hat. Die zu lösenden Probleme waren die Ausfindigmachung eines für Papier und Farbe geeigneten Konservierungsverfahrens sowie zweckmässiger Arbeitsvorgänge zur Behandlung des schadhafte Materials. Die Eigenschaften des Papiers und der Farbmischung der Atlasse wurden untersucht. In der Mehrheit der Fälle wurde festgestellt, dass die grüne Farbe das Pigment Verdigris beinhaltete, welches das Salz von Kupferazetat ist. Modellmuster wurden angefertigt, und es wurde hierfür Kupferazetat als Farbpigment verwendet. Die Änderung der Eigenschaften im künstlichen Alterungsprozess wurden berechnet. Der Konservierungsvorgang für die Atlasse umfasste die Beschichtung mit einer Schutzschicht anhand einer Ethylzellulose Lösung; als Bleichmittel wurde Chloramin B oder eine Hydroxygen Peroxid Lösung verwendet; Beseitigung des Ethylzellulose Films; stabilisierende Behandlung mit Ca und Mg Bikarbonat Lösungen und Imprägnierung mit PVA oder Fluorplastik Lösungen; oder Laminierung mit Seidenpapier. Die Beständigkeit und Dauerhaftigkeit nach der Behandlung wurde annähernd berechnet.

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Conservation for Libraries and Archives: 1981–2001

Considerations of Future Developments and Personnel

by DONALD B. McKEON

HISTORICAL BACKGROUND

Most fields of study eventually establish some point from which developments in the field are dated, so that an event is described as being before or after Event X. In the case of library and archives conservation, the flooding of the River Arno in Italy on 4 November 1966 and the subsequent international efforts to remedy this damage will probably serve this benchmark purpose. In the words of Peter Waters, then crew chief of workers from a dozen lands trying to save the historic heritage of Florence and the world, and now head of the Restoration Office of the Library of Congress, the Florence Flood was “where the modern world of library conservation began. Drying techniques and ways of fighting mould were exhaustively tested and techniques developed. A lot of the people and ideas of today started in the mud of Florence.”¹

This event also had as a spin-off an increased movement of library and archives conservators from Europe towards North America. To the customary pool of European-trained conservators relocating independently to North America was added an influx of influential alumni of the Flood to head and staff the new library and archive conservation installations at the Library of Congress, other United States and Canadian governmental installations and various university and private collections.

These conservators joined previous European-trained conservators and graduates of the few North American conservation programs in existence. These programs – all affiliated with universities and museums and all located within a few hundred kilometres of New York City – were small, with about ten students admitted to each per annum.² Larger museums had the custom of training their own personnel in-house, as they still do.

It is unknown what portion of this pool of conservators specialises in book and paper conservation, but some idea may be drawn from the fact that when Mary Todd Glaser received a certificate in paper conservation from New York University in 1964, the occasion merited a special mention in the IIC-American Group journal.³ As late as 1978, of the 20 interns from the programs at the Winterthur Museum and Cooperstown, New York, *none* was to intern in a library.⁴

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There were several factors which operated to keep these training programs small. In North America, there was little of the tradition of apprenticeship of the type common in Europe, and the steady supply of European-trained personnel had rendered such a tradition unnecessary. Further, the highly decentralised nature of North American education inhibited any concerted effort towards training in conservation. Finally, until the 1970's, there was comparatively little interest in preservation in library and archive circles. These institutions had developed in the direction of emphasis on improving access to and use of materials rather than protecting them.

As a result, the North American situation in the early 1980's was that there was no real control of training for library and archives conservation, and only one specific program in the area (Columbia University) was beginning.

There were many library and archives personnel who had become interested in the preservation of their materials, but relatively few were trained and experienced personnel. The library and archives worlds were gradually moving away from those conservators who were museum-oriented but these latter were still heavily involved in the conservation services provided to libraries and archives.

PURPOSE AND METHOD OF THE RESEARCH

As part of a doctoral program, the author conducted a Delphi study in 1980–81 to establish the outlines of the future developments in library and archives conservation and training for it.

The Delphi technique involves surveys of probably future trends as predicted by knowledgeable individuals active in the field. The statistical data are then compiled and returned to the respondents repeatedly to allow them to match their own responses against the averages, and then alter their responses if desired. After several repetitions, a consensus generally emerges. The technique, developed by the Rand Corporation, has high predictive value. It not only a) provides predictions of future developments, but also b) establishes the general body of agreed opinion in the field. This study concentrated upon North America, but radically different developments in the rest of the world are unlikely. The main factor which might condition differences in other countries would be the different technology/personnel mix in any given area. This article concerns itself with some of the study's results having global implications.⁵

CONSERVATION IN THE FUTURE

The traditional source of conservation personnel for libraries and archives has

been the world of art and museums; the study indicates that this will cease to be true. The chief sources of personnel will be science graduates and library personnel; these will not be expected to have the traditional manual skills of the conservator, but rather will be chosen for their wide knowledge of the field. In a supplementary question, respondents indicated roughly 5:1 that this development is desirable.

The customary source of conservation administrators has been former bench conservators, and most of the more prominent individuals stem from this background.

This situation will not continue. The source predicted will be administration with science and technology as secondary sources. In a related question, librarians, archivists and curators are predicted to be exercising their expertise in conservation by choosing materials to be preserved; in other words, these employees will make library/archive decisions utilising the insight of conservation knowledge.

Perhaps the most salient change in the next two decades will be the development of a library/archive conservation community connected only historically with its museum forbears. For reasons too complex to be treated in a brief article – large technological reasons – library/archive developments throughout the world have tended for decades to move towards North American models. There is little reason to suppose that library/archive conservation will not follow a similar course. The pace may also accelerate due to fewer established bodies in other countries to slow down the development.

Conservation in the library/archive field will move away from concentration upon the beautiful artifact towards concern for the information carrier. Inherent in this development will be the fading away of the guild orientation and the "trade secret" approach.

IMPLICATIONS OF THE SURVEY RESULTS

With due allowance for national variations and priorities, the next two decades in library/archives conservation will be characterized by greater use of outside centres to treat materials. As there is no reasonably simple way to verify many conservation treatments once they have been performed, much reliance will have to be placed upon the integrity of the centre.

The most widely used technique for general preservation of information will be microfilming (or some as yet unknown successor technique) to transfer the information from the original carrier, with mass deacidification for the fraction of paper materials to be retained in the original form. In conservation, preference will be given to processes requiring fewer hands and advanced materials,

although this may well not be the case in countries having a greater labour force available than in North America. As regards conservation training, most professional and perhaps archives personnel will receive theirs in formal library schools; some form of certificate or diploma is seen as inevitable for entrance into the field.

POSSIBLE VARIATIONS OUTSIDE OF NORTH AMERICA

In extrapolating the results of the study to areas outside of North America, some limitations should be mentioned. In educational terms, the North American experience is unusual. The historically very limited role of the U.S. and Canadian national governments in education is not paralleled in other countries. In turn, the central government's role in other countries in establishing national priorities may well have a much more determinative role in conservation training than is the case in North America.

Similarly, the group in North America which is viewed by many as speaking for the conservation community – the American Institute for Conservation – is respected, but has no real power to licence or authorise any conservators, and no governmental agency on the continent seems inclined to exercise these functions. Other countries, with very different professional traditions and licencing procedures, may well exercise closer supervision over the entrance and functioning of conservation personnel.

As an offset to the North American technological orientation, other countries may be able to resolve more easily one of the most difficult situations in North American conservation: the paucity of training programs and opportunities for conservation benchworkers.

Little in the brief history of regional conservation centres indicates to this researcher that these wish to or could be a good supply of bench conservators or technicians. A development which the author would consider much more promising and expedient would be basic training of bench personnel at community colleges/junior colleges/folk high schools and analogous institutions across the world. This idea, however, was not covered in the study.

Although there seems little doubt that the general outlines of these conservation developments will be similar world-wide, the personnel situation outside the North American area may vary somewhat. The greater tradition of manual skills and the educational "streaming" into vocational area – common in other areas – may provide a more balanced personnel pool elsewhere. A long-term consideration may be to create an impulse to once again encourage conservation personnel to relocate to North America – no longer trained conservators as before, but rather bench workers and technicians to support the

administrators which the North American schools will be geared to produce. Whether such an effort would succeed the author considers highly doubtful, and would consider it unwise, in any event.

The following are the detailed results of the study:

GENERAL FIELDS	(1) Manuscripts	38.6%
	(2) Books	25.0%
	(3) Newspapers	22.7%
	(4) Film	20.4%
In 1981-2001, the most important factor in the probable increase in conservation activity will be:		
	Visible deterioration of materials	52.2%
	Citizens' awareness of conservation	29.5%
	No opinion/Don't know	18.1%
The materials in greatest danger of loss through deterioration in 1981-2001 will be:		
	Post-1880	86.2%
	Pre-1880	06.8%
	No opinion/Don't know	06.8%
Although a decision will have to be made on any individual item the assertion that original library and archive materials should in general be preserved in 1981-2001:		
	Will have to be proven	68.1%
	Will be assumed	27.1%
	No opinion/Don't know	04.5%
In 1981-2001, the most used method by academic libraries and archives to provide for conservation of their materials will be:		
	Sending them to outside centers	56.7%
	Creating in-house facilities	31.7%
	No opinion/Don't know	00.0%
Where local bodies fail to act, the proper body to take responsibility for preserving the cultural heritage will be:		
	National government	59.0%
	Nobody	20.3%
	No opinion/Don't know	18.1%
In 1981-2001, the classes of materials perceived as being in greatest danger will be (list in order):		
	(1) Manuscripts	38.6%
	(2) Books	25.0%
	(3) Newspapers	22.7%
	(4) Film	20.4%
During 1981-2001, institutions will give priority to preserving (list in priority order):		
	(1) Printed books	47.7%
	(2) Film	31.8%
	(3) Newspapers	22.7%
In 1981-2001, the chief hindrance to preservation will be:		
	Lack of funds for work	89.0%
	Less control of environment	11.0%
	No opinion/Don't know	00.0%
TECHNOLOGY		
Future library and archives preservation programs will prefer processes employing:		
	No opinion/Don't know	45.4%
	Low labor/expensive materials	34.0%
	High labor/cheap materials	18.1%
The development of reproduction technology in 1981-2001 will result in a need for preservation of the original library/archive materials:		
	Yes	52.2%
	No	24.9%
	No opinion/Don't know	22.7%
In the period 1981-2001, the procedure which will receive greatest encouragement for preserving the mass of library materials will be:		
	Microfilming	72.6%
	Mass deacidification	18.1%
	No opinion/Don't know	09.0%

TRAINING

The role of the standard library school in 1981–2001 will be to provide future librarians with:

Conservation consciousness	61.2%
Applications of techniques	27.2%
No opinion/Don't know	13.6%

At the MLS level, future librarians interested in conservation will need to be instructed by a faculty member who is:

A trained conservator	70.4%
A library generalist	18.1%
No opinion/Don't know	11.3%

Of the many personal qualities needed by future conservation personnel, most emphasized will be:

Wide knowledge of the field	77.2%
Manual dexterity	15.9%
No opinion/Don't know	09.0%

In 1981–2001, standard MLS library schools will provide their students wishing to specialize in conservation with:

A complete minor	47.6%
No opinion/Don't know	17.2%
No conservation course	24.9%

In library schools, a course in conservation for librarians and archivists will concentrate on:

The effects of various techniques	61.3%
No opinion/Don't know	27.2%
The history of materials	11.3%

Except for hands-on experience in repairing materials, study of the conservation literature will provide future conservation personnel with:

A complete background in conservation	47.6%
No opinion/Don't know	29.5%
Nothing but theory	22.6%

Before the end of the twentieth century, conservation personnel will be accepted by:

Formal test/degree procedure . .	47.6%
Informal acceptance by cons. community	38.5%
No opinion/Don't know	13.6%

PERSONNEL

In 1981–2001, a major source of conservation personnel for the library and archive worlds will be established:

Operating through existing institutions	61.3%
Unconnected with existing institutions	29.5%
No opinion/Don't know	09.0%

In 1981–2001, conservation administrators will come largely from backgrounds in:

Administration	49.9%
Science and technology	29.4%
No opinion/Don't know	20.4%

Because of their background and training, librarians, archivists and curators in 1981–2001 will be called upon to choose:

Materials to be preserved	63.6%
No opinion/Don't know	25.0%
Appropriate conservation techniques	11.3%

In 1981–2001, the largest new source of conservation specialists will be:

Library personnel	45.4%
Science graduates	38.5%
No opinion/Don't know	18.1%

SUMMARIES

Conservation for Libraries and Archives: 1981–2001. Considerations of Future Developments and Personnel

The last two decades of the twentieth century will see extensive changes in the training and sources of conservation personnel for libraries and archives. In North America initially, most such personnel will be trained as administrators, and will come from library or scientific backgrounds. There will be emphasis on scientific knowledge rather than manual skills and a certificate/diploma will be expected. Lack of money will hamper conservation of materials.

Conservation du domaine des bibliothèques et des archives: 1981–2001. Passage en revue des développements futurs et des personnels

Les deux dernières décennies du vingtième siècle apporteront des changements importants dans le domaine de la formation et du recrutement du personnel de conservation des bibliothèques et des archives. En Amérique du Nord, dans la phase initiale, la quasi-majorité de ce personnel recevra une formation d'administrateur provenant de bibliothèques ou disposant d'une formation scientifique. L'accent sera plus mis sur les connaissances d'ordre scientifique que sur la dextérité et un certificat/diplôme sera exigé. Le manque de ressources entravera la conservation des matières.

Konservierung für Bibliotheken und Archive: 1981–2001. Betrachtungen zu künftigen Entwicklungen und künftigen Personal

Im Laufe der letzten zwei Jahrzehnte des zwanzigsten Jahrhunderts werden sich umfassende Änderungen in den Anforderungen auf Ausbildung sowie in Hinsicht der Bezugsquellen von Konservierungspersonal für Bibliotheken und Archive herausstellen. Mit Nord-Amerika als Ausgangspunkt wird die Mehrheit des diesartigen Personals als Leiter ausgebildet werden, und die gestellten Anforderungen auf Bildung werden bibliotheken- oder wissenschaftsbezogen sein. Es wird eher Wert auf wissenschaftliche Kenntnisse als auf handwerkliche Tüchtigkeit gelegt werden, und Bewerber müssen im Besitz von Zertifikaten/Diplomen sein. – Geldmangel wird die Konservierung von Gegenständen beeinträchtigen.

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The Yale Non-toxic Method of Eradicating Book-eating Insects by Deep-freezing

by KENNETH NESHEIM

In June 1977, Yale University's Beinecke Rare Book and Manuscript Library instituted a deep-freezing program to rid the library of an infestation of book-eating insects. As it was the first use of this non-toxic method by a library or archive to deal with this problem, the university, at the end of November 1977, issued a news release describing the program. Through December and into the following January, accounts of it based upon the news release appeared in the press in the United States and abroad.¹ The accounts generated a number of requests for additional information about the program, as well as comments from critics who urged alternative methods which, in their eyes, were more sensible means of eradicating the infestation. The library responded to these requests and helpful critics, but decided not to make further public comment until the initial program had run its course and it was possible to evaluate it. As Associate Director, I was the library's administrative officer responsible for managing the deep-freezing program. This paper presents the reasons behind the library administration's choice of deep-freezing over alternative, toxic methods, and describes how the program worked over the initial two-year period of its operation.

Book-eating insects are ubiquitous in non-arctic (temperate and tropical) areas. These insects are called domestic insects because they live with man. They are usually tropical in origin and include beetles, book lice, book mites, and, rarely, cockroaches, silver fish, and termites. They are particularly attracted to old leather-bound books in which they breed, feeding on digestible materials imbedded in the paper (they cannot digest cellulose itself), and the glue and leather of the bindings. Though found in heated buildings in colder climates, book-infesting insects mostly originate in semi-tropical and tropical areas where daily temperatures and humidity levels range well above 15°C (60°F) and 50% R.H.

When the Beinecke Rare Book and Manuscript Library was designed in the late 1950's its planners requested of the architect that its air-conditioning plant have the capacity to free the incoming air of pollutants, and to maintain within the building (especially within its bookstacks) a constant temperature of 21° ± 3°C (70° ± 5°F) and humidity levels of 50 ± 5% R.H. These limits provide the so-called "ideal" environment both for the preservation of materials perma-

nently housed in archives and rare book and manuscript libraries, and for the comfort of the humans who staff them and come to use the materials.

From the summer and fall of 1963 when the staff moved the collections into the building in preparation for its official opening the following October, the staff's experience with potential book-attacking insects was confined to cockroaches commonly seen in the Sterling Memorial Library, the university's main library, where the Beinecke collections were formerly housed and which is connected to the Beinecke Library by a large underground tunnel. The cockroaches subsequently seen in the Beinecke Library were thought to come from the main library via the tunnel passage and were dealt with by a New Haven, Connecticut pest exterminating firm on the rare occasion when a cockroach was seen. The staff naively believed that, as the pest exterminators had controlled the cockroaches, the library's collections were perfectly safe from insect attacks, and were protected further by the ideal environment. Thus it was a shock to discover an infestation of book-eating insects among our books.

The insects were discovered in early March 1976 by a former staff member, Christine Hansen, then Assistant Research Librarian. The infestation occurred in Area I of the underground bookstack, a large space (2,030 m³, [71,680 cubic feet] in volume) shaped like a reversed inverted "L" (Γ), and located on the west end of the building, two floors below ground level. Area I then housed 37,000 books, chiefly folios, quartos, and a few thousand octavos. Most were catalogued, and thus were subject to call by the library's readers. While looking for a book among the folios, Ms Hansen found next to the books on the shelves of several sections, piles of light-colored dust and considerable numbers of dead adult insects. Ms Hansen immediately reported her discovery to me, and from a preliminary examination of the books it was apparent that the infestation was severe, and the damage to the books extensive. Most of the books were vellum-bound, their bindings riddled with minute holes, and many of their text-blocks looked like stacks of lacy doilies, evidence that the insects were voracious eaters (Fig. 1). We would later learn that the infested books had only been in the Beinecke Library for about a year. They had come from the Sterling Memorial Library's cataloguing backlog (housed in a non-air-conditioned environment) where they had been for an indeterminate time. Because the acquisitions records were incomplete, we could not determine how long the books had been in the Sterling Library, nor could we identify their source. It was believed, however, that they had been supplied from a source in southern Europe's Mediterranean climate. In any event, the rare book cataloguers had assigned the books to the Beinecke Library because they met the Yale University Library's rules for housing rare books. When visually inspected during cataloguing, they apparently were found free of insects and of evidence of insect damage. The



Fig. 1. Damaged book. Charles Remington, left, and Kenneth Nesheim, right, survey some of the damage done to a rare 16th century theological work written by Mariano Socini (1482–1556). The large holes were made by larvae as they ate their way along the loops of galleries; adult beetles made the relatively straight tunnels. Female beetles probably laid eggs in the satellite chambers along the main tunnels.

Fig. 1. Livre endommagé. Mr. Charles Remington, à gauche, et Mr. Kenneth Nesheim, à droite, examinent quelques-uns des dégâts survenus à un ouvrage théologique rare du 16^{ème} siècle écrit par Mariano Socini (1482–1556). Les mangeurs importantes ont été faites par des larves qui ont progressé dans des galeries en forme de boucle, les coléoptères adultes ayant progressé dans des passages couverts quasi rectilignes. Les coléoptères femelles ont probablement déposé leurs oeufs dans des cavités satellites situées le long des passages principaux.

Abb. 1. Beschädigungen an einem Buch. Charles Remington, links, und Kenneth Nesheim, rechts, betrachten die Schäden, die an einem seltenen theologischen Werk aus dem 16. Jahrhundert von Mariano Socini (1482–1556) angerichtet worden sind. Die grossen Löcher stammen von den Larven, die so ihren Weg an den Gangwindungen entlang gefressen haben; die relativ geraden Tunnel sind von den erwachsenen Käfern angelegt worden. Die weiblichen Käfer haben wahrscheinlich ihre Eier in den an die Haupttunnel angrenzenden Kammern gelegt.

books, however, probably contained eggs, too small to be seen without magnification. The eggs might have remained dormant until the books had been some time in the Beinecke Library's "ideal" environment, where they incubated and hatched into larvae.

Having informed the staff, Beinecke Library's Director at the time, Louis L. Martz, and the university library's administration, I called Jane Greenfield, then Yale University Library Conservator. Since the establishment of the university library's Conservation Studio in 1968, Mrs. Greenfield had played an

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important role in all conservation problems affecting the library system. With respect to the infestation, she was liaison with experts within and without the university and was responsible for a) having the insects identified; b) determining the extent of the infestation; and c) obtaining recommended methods of eradicating the insects and preventing further infestations.

Mrs. Greenfield began her task by taking several of the adult specimens to the Connecticut Agricultural Experiment Station (CAES) in New Haven, and to the university's biologists for the purpose of having the insects identified. While the biologists at CAES (Charles C. Doane and Kenneth Welch) and Yale (Charles L. Remington and Joseph G. Gall) were examining the insects,² Mrs. Greenfield and the staff of the Conservation Studio inspected the library's 26 miles of bookstack shelving.

The inspection began in March. In mid-April, the inspectors found that the infestation appeared to be confined to 167 folios housed on shelves in the north-east periphery of Area I. Mrs. Greenfield, however, also found living larvae in some bound volumes of Near Eastern manuscripts shelved in a double-faced range on the top tier of the adjacent Wall Street bookstack. This underground bookstack has three levels. It parallels Areas I, II, III on the south, and has connecting doorways into these areas at its lowest level. The manuscript volumes involved, some 740 in number, and mostly small octavo and quarto in size, were from two sources: one in America, the other in the Near East, on the coast of the Mediterranean. While the bulk of the manuscripts had come from the Near Eastern source in the late 1960's, all were in the library by 1971. They were uncatalogued, but had been given a preliminary examination on receipt, during which many were found to have been previously infested, but appeared free of living eggs or larvae. In Mrs. Greenfield's inspection, larvae were to be seen in a few of the volumes, and there were piles of cream colored dust (which the larvae make by excreting the paper they eat) on the shelves. But no dead adults were found on the shelves and floor, as in Area I, and there was no evidence of insects elsewhere in this bookstack. Consequently, it was thought that this infestation was confined to the volumes in this stack range. Thus, before it could be determined whether the two infestations were related, all of the volumes in the range were packed up and sent in mid-April to the New England Document Center for Vacudyne fumigation with ethylene oxide and Freon®.

At the outset of Mrs. Greenfield's inspection, the biologists came to the library, viewed the Area I infestation, and examined some of the infested books. Kenneth Welch, entomologist and Curator of the Insect Collection at CAES, and his fellow entomologist Dr. Charles C. Doane, concurred with the Yale biologists, Joseph G. Gall; Ross Granville Harrison, Professor of Biology and Molecular Biophysics; and Charles L. Remington, then Associate Professor of



Fig. 2. *Gastrallus*, the Death-Watch Beetle that damaged Beinecke Library books. This species has never before been found in the United States and its species may be new to science.

Fig. 2. *Gastrallus*. Coléoptères Atropos qui ont endommagé les livres de la Bibliothèque Beinecke. Cette espèce n'a jamais été trouvée auparavant aux Etats-Unis représentant une espèce nouvelle pour les scientifiques.

Abb. 2. Der *Gastrallus* oder Klopfkäfer, der die Schäden an Büchern der Beinecke-Bibliothek verursacht hat. Diese Art ist nie zuvor in den Vereinigten Staaten beobachtet worden, sie ist eventuell neu für die Wissenschaft.

Biology and Forest Entomology and Curator of Entomology at the university's Peabody Museum of Natural History. They pronounced the pests to include several kinds of insects: book mites (arachnids) and booklice (Corrodentia) which feed on adhesives and sizing in seldom-used books, but were too few to do much harm; one specimen of a species of stored-products beetle known as Dermestidae; but the chief culprit, they thought at first, was a tiny species of the beetle family Bostrichidae, which includes various museum beetles and hide and glue beetles, and dry-wood infesters. The adults were less than 0.05 cm ($\frac{1}{40}$ inch) in length and dark brown in color. Charles Remington, on further examination, diagnosed them as a species of another, related beetle family, the Anobiidae, and sent specimens to the authority on anobiids, Dr. Richard White of the National Museum of Natural History (Smithsonian Institution, Washington, D.C.). He later identified them as a species of the genus *Gastrallus* never before found in the United States and possibly new to science (Fig. 2).³ *Gas-*

trallus, according to Remington, is a mostly Old World genus of the Anobiidae, a family of very small beetles that with habits like Bostrichidae, infest furniture, dried grain, fruit, and other dry materials such as leather and paper. Like the Bostrichidae and other domestic insects such as book lice, book mites, cockroaches, silver fish and termites, the Anobiidae find books a good breeding place. When feeding, the larvae stages of the Anobiidae and Bostrichidae make serpentine tunnel patterns, and because in the adult stage they bore holes while seeking mates or dispersing, both families are popularly called "shot-hole" borers or "powder-post" beetles. Some are called "Death-Watch Beetles" in Europe where they are frequently found in old houses. The "Death-Watch" name comes from a superstition held since the Middle Ages that the sound of their courtship clicking when heard by human occupants of a house is a portent of impending death.⁴

As the inspection team observed, our *Gastrallus* seemed to prefer vellum-bound books. The larvae usually started work near the spines or edges of the books, but eventually ate into the text. They ate glue along the spines, cutting through the threads so that many of the books were completely separated. The live larvae were sensitive to touch and rose in their holes when touched with a pencil. In addition to the lacy patterns they made by ingesting the paper, their excretions in heavily infested books caused the leaves to stick together. All of the books had small holes in their text-blocks and in the spines and covers of their bindings. These were made by the adult beetles which bored from the interior to reach the outside to mate and lay eggs. On the shelves outside heavily infested books, small piles of cream colored dust (excretions of the larvae) were seen, but inexplicably, no live or dead larvae. A few live adults were seen on the edges of the books but most of the adults were found dead on the shelves and floor.

Because the beetles can fly considerable distances, and could be transported on cleaning equipment, books, and people, our biologists recommended that the doors of the infested area be kept closed and house-cleaning and movement of books cut down as much as possible.

In addressing the two-fold problem of eradicating the infestation and preventing it from recurring, the CAES entomologists recommended installing Vapona (dichorovinyl dimethyl phosphate) pest strips and employing a professional exterminating firm to use standard fumigation techniques involving lethal gases or chemical fluids. These techniques, while suitable for some situations, did not appeal to the library's administration. They thought the techniques might by themselves damage the books, the gas technique certainly would disrupt reader service and the library's normal operation, as the building would have to be closed and sealed for a lengthy period at a significant time



Fig. 3. Beinecke Library folios in polyethylene "freezer" bags.

Fig. 3. Feuilletts de manuscrits de la Bibliothèque Beinecke dans des sacs de surgélation en polyéthylène.

Abb. 3. Bücher der Beinecke-Bibliothek in Gefrier-Beuteln aus Polyäthylen.

in the academic year. Because of the design of the building, the location of the infestation, and the complexity of ventilating this bookstack and the building, they feared that some of the gas might remain after the operation and possibly prove hazardous to personnel. Informed of these concerns, Charles Remington suggested that the library employ deep-freezing. This is a technique he developed and has used for many years to preserve specimens for his own research and for the Peabody Museum's collections. In his tests, he had found that all insects he examined, especially domestic insects, could be exterminated in all their life forms – egg, larva, pupa, adult – by exposure to deep-freezing. He developed the technique because it was superior to standard fumigation techniques employing lethal gases, crystalline fumigants, or chemical fluids, which are hazardous to humans and alter an insect's coloration.⁵ When recommending it, he wrote, "... Deep-freezing is certainly as effective as any chemical fumigation you might use and is not toxic to humans, has no residual effects, avoids chemicals that might harm books and should be less expensive."

All of this appealed to the library's administration, and as the other biologists agreed with Remington, we decided to test his technique. Within a week following the discovery of the infestation, we purchased a standard 19 cubic

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foot upright home freezer and began our tests. Remington, who normally used a temperature of -23°C (-10°F) and a period of 48 h, recommended that we freeze our infested books for a period of seven days. To prevent condensation from forming on the cold books when removed from the freezer, he suggested that we put them in freezer bags (Fig. 3) before freezing and hold them in the bags after removal from the freezer until the books returned to room temperature. It was also thought that the bags might prevent insects from re-infesting treated books. Thus the books would remain in their bags after they were returned to the shelves.

Meanwhile, to monitor the pest control, Jane Greenfield set out bait-traps as Professor Remington recommended. The bait-traps are crystallizing dishes, 70 mm in diameter $\times$ 50 mm in height, (available from chemical supply houses) which are coated on the outside with white flour paste, which on drying gives the insects a non-repellant rough surface making it easy for them to crawl up the outside and drop into the baited dish. The inner walls are kept paste-free and clean, which retains most or all trapped insects, because they cannot climb smooth glass. The traps are baited with small amounts of wheat flour and put on the floor or lowest shelf in a stack section throughout the bookstacks. They are inspected every ten days. If no insects are found in the traps it is presumed the area is not infested.

As our deep-freezing tests progressed from April through October 1976, Mrs. Greenfield and her staff treated some 700 folios from the infested area, each load for a week's duration. 10% of the frozen books were examined by Dr. Remington after freezing and no live insects were found. Moreover, we found no evidence that exposing the books to deep-freezing damaged them in any way, and were confirmed in this when the Scott Polar Research Institute, Cambridge, England, assured us that the books found with the bodies of the Scott Polar Party in 1913 were in excellent condition.⁶ Certainly the tests proved that Remington's technique was effective. They also showed that it was time-consuming. Nevertheless, the procedure seemed preferable to the library's administration. Vacudyne fumigation was the obvious alternative, and it would also be effective. The Near-Eastern manuscripts sent to the New England Document Conservation Center for treatment in their Vacudyne fumigator were returned to the Wall Street bookstack. When inspected, after a considerable period, they were found free of insects. Moreover the bait-traps showed no evidence of recurrence of the infestation in the areas. But sending 37,000 volumes to the Center was not only expensive, but also extremely disruptive to reader service, and would, moreover, present enormous logistical and security problems for the library. These problems would not be mitigated by renting freezer space locally, or by bringing freezer trailers to the library, or by using the Cen-

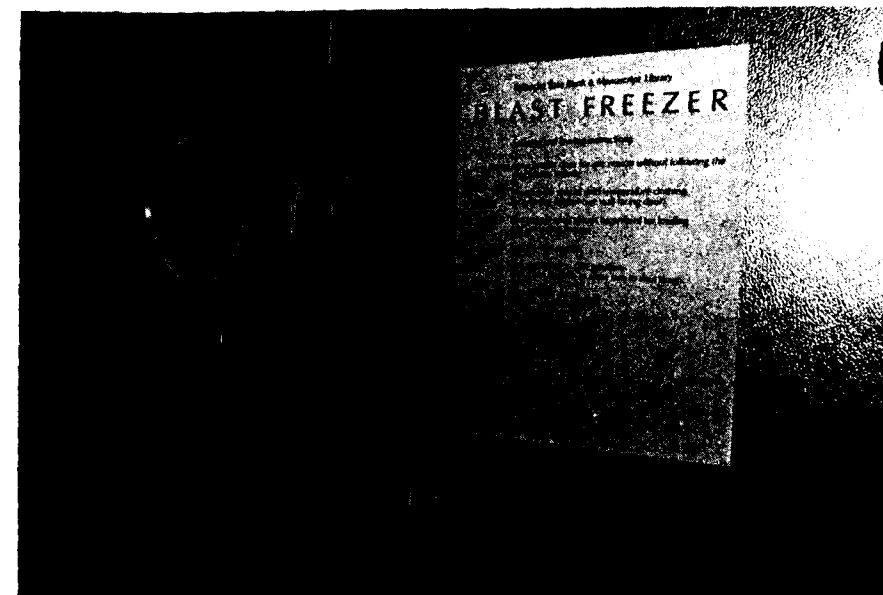


Fig. 4. View of the blast freezer showing the 24 hour 7 day graph temperature recorder, item 1 in the equipment list; the ground switch (item 3) above the recorder; and the sign containing operating instructions for the freezer, item 5.

Fig. 4. Vue du congélateur à circulation d'air montrant l'enregistreur de courbes de température quotidiennes et hebdomadaires, article n° 1 de la liste des équipements, l'interrupteur principal (article n° 3) situé au-dessus de l'enregistreur et le panneau d'instructions d'emploi du congélateur, article n° 5.

Abb. 4. Ansicht der Gebläse-Gefrieranlage, aus der folgende Teile zu erkennen sind: Diagramm-Temperatur-Registriergerät (24 Stunden, 7 Tage) – Artikel Nr. 1 der Ausrüstungsliste, Schalter (Artikel Nr. 3) über dem Registriergerät sowie das Schild mit der Bedienungsanleitung für die Gefrieranlage (Artikel Nr. 5).

ter's mobile Vacudyne fumigator. City ordinances required that the fumigator be specially vented and the same ordinances, plus the design of the building, prevented purchasing a fumigator to install in the library, and at the time, elsewhere at the university. Mrs. Greenfield also found that the cost of a fumigator of sufficient capacity was considerably above the estimated cost of a walk-in freezer. Thus, of the three eradication procedures, the library's administrators chose, early in 1977, the non-toxic deep-freezing method. The tests had shown it to be effective and it seemed to us not only to promise to be the least expensive, but also the least disruptive to the library's normal operation, the latter consideration probably the most important factor in our decision.

While investigating the possibility of renting freezer space locally, Mrs. Greenfield met George A. Dion, Manager of Purchasing in the university's dining hall system. He had had experience in purchasing and supervising the in-

The Yale Non-toxic Method of Eradicating Book-eating Insects

stallation of walk-in freezers for the dining halls. We invited him to join our team. He came to the library, agreed to undertake our project, recommended that we purchase a walk-in blast freezer and install it in basement bookstack Area I. A blast freezer is a standard quick-freeze food storage freezer which has electric fans behind its freezing coils. The fans move the cold air generated by the coils around the interior of the freezer at a very rapid rate. Thus, a product loaded in at normal room temperature of 21°C (70°F) is brought to temperatures below freezing much more quickly than is possible with a conventional freezer. Because installation of the blast freezer would require the services of the university's Physical Plant department as well as an outside supplier, Mr. Dion called in Ralph Chandler, Senior Mechanical Engineer of Physical Plant, and together we determined that the available space in Area I would accommodate a walk-in blast freezer with interior dimensions of 3.05 × 3.35 × 2.44 m (10 × 11 × 8 feet). It would be supplied and installed by a local refrigeration company, and connected to the library's electrical system by university electricians. The freezer, composed of a series of insulated aluminum panels, each approximately 4' × 8' × 4' thick would be easily erected. The freezer would use Refrigerant R-502, an inert chlorofluorocarbon gas, and a synthetic refrigerant oil called Sunesco. The supplier would regularly service the equipment on a contract basis.

The blast freezer (Fig. 4) was installed during the spring of 1977. It was additionally equipped with the following:

- 1) a temperature recorder attached to an exterior wall to record the temperature within the freezer on a graph 24 h per day over a period of a week;
- 2) a recording device containing three thermocouple leads running from its meter through a hole in the freezer's wall and placed in the center of each of three thick volumes to monitor their interior temperatures during the freezing operation;
- 3) a ground switch in the electrical circuit for the freezer's fan motors. The ground switch detects moisture which results from condensation forming in the motors when the system is turned off and the door to the freezer is not kept open to allow the moisture to evaporate. If the system is restarted when the motors contain moisture the motors burn out. The ground switch prevents this condition from occurring;
- 4) a smoke detector for the fan motors;
- 5) a sign giving operating instructions mounted on the entrance door of the freezer;
- 6) a padlock for the door to prevent entrance while the freezer is operating;
- 7) six standard stainless steel multi-shelf food service trucks fitted with wire

Fig. 5. Stephen Jones in a parka and cold climate gloves, item 9 in the equipment list, pulling one of the stainless-steel multi-shelf food service trucks (item 7) loaded with quartos in freezer bags up the freezer's ramp (item 8). One of the freezer's fans can be seen inside the freezer, to the right of Stephen's head.

Fig. 5. Mr. Stephen Jones, revêtu d'un anorak et de gants pour climats froids, article n° 9 de la liste d'équipements, en train de tirer le long de la rampe du congélateur (article n° 8) l'un des chariots de cantine en inox à plusieurs étagères (article n° 7) chargé d'in-quartos dans des sacs de congélation. Observer l'un des ventilateurs situé à l'intérieur du congélateur à la droite de la tête de Stephen.

Abb. 5. Stephen Jones mit Parka und Winterhandschuhen bekleidet (Artikel Nr. 9 der Ausrüstungsliste) zieht einen der Regalwagen aus rostfreiem Stahl (Artikel Nr. 7), der mit Büchern in Einfrostfolie beladen ist, die Rampe zur Gefrieranlage (Artikel Nr. 8) hinauf. Eines der Gebläse der Gefrieranlage ist im Inneren, rechts von Stephens Kopf zu sehen.



- shelves (Fig. 5) designed for freezer use and available from restaurant and food service equipment suppliers;
- 8) a ramp from the stack floor to the freezer, mounted with non-skid strips, to move the trucks in and out of the freezer;
- 9) two standard parkas and two pairs of cold climate gloves for use of the loading crew while working in the freezer.

While the freezer was being installed, Jane Greenfield and her Conservation Studio staff began sealing the 37,000 books in Area I into polyethylene bags. The bags had a dual purpose: a) to prevent the spread of the infestation by con-

fining the insects to the bags; and b) to prevent condensation from forming on the books when returned from the blast freezer to the bookstack. The following sizes were obtained:

23 × 38 cm (9 × 15"), 33 × 46 cm (13 × 18"), 38 × 53 cm (15 × 21"), 46 × 61 cm (18 × 24"), 56 × 91 cm (22 × 36").

Thirty-two thousand bags were initially ordered plus 610 m (2,000 ft.) of 91 cm (36") tubing to make bags for the outsize folios. The bags were sealed with an electric sealing machine designed by Jane Greenfield and built by the university's Polytechnic Instrumentation Shop. Because the sealing machine, mounted on a wheeled table, employed a voltage transformer and an extra long extension power cord, it was possible to roll the machine through the bookstack aisles and bag most of the books at the shelves. Two people working at the machine could bag about one hundred books per hour. Folios, however, were removed shelf by shelf to a central area for bagging because the aisles between the folio shelf stack ranges were too narrow to permit the bagging crew to work easily.

The freezing operation began when the installation of the blast freezer was completed in July 1977. The operation was based on a plan that permitted us to freeze systematically all 37,000 books in Area I, as well as other non-book materials containing cellulose stored there, e.g. extra wooden book shelves, office supplies made of paper, and pamphlet binders. With the blast freezer's ability to reach and hold -29 to -32°C (-20 to -25°F) within four to five hours after being fully loaded and started at normal room temperature 21°C (70°F), Charles Remington recommended for extra security that we freeze each load at -29°C (-20°F) for a period of 72 h. We began with the octavos and quartos and proceeded shelf by shelf throughout the bookstack. The loading crews, under my supervision, were composed of two to three people. For each load they executed the following procedure:

- 1) they loaded books onto the trucks;
- 2) unlocked the entrance door and put the trucks into the freezer;
- 3) inserted the three thermocouples between the leaves of three of the thickest books in the load;
- 4) closed the entrance door and locked its padlock;
- 5) turned on the freezer, following the operating instructions, and recorded on a sheet:
 - a) the load number;
 - b) date and time placed in and removed from the freezer;

- c) bookstack range and shelf numbers for the load;
- d) temperature readings of the interior of the freezer and the interior of the three books read from the graph of the interior temperature recorder and from the thermocouples' meter (taken during the library's working hours) including date and time taken.

At the end of 72 hours, the crew:

- 1) removed the trucks from the freezer;
- 2) wheeled the trucks to an out-of-way location to stand for several days until the condensation on the polyethylene bags evaporated;
- 3) put a new load into the freezer;
- 4) returned the books from the previous load to the shelves marking each of their bags to show they had been frozen;
- 5) and at the end of seven days, filed the load-record sheets with the week's graph from the temperature recorder.

Throughout the deep-freezing operation, books shelved in Area I requested by the library's readers were removed from their bags and brought to the Reading Room. They were subsequently rebagged before being reshelved in order to comply with Charles Remington's recommendation that the Area I books be retained in their bags after being frozen, until all other volumes had been treated and for six to eight months following the end of the freezing operation. On the 24th of August 1978, the 115th load was removed from the freezer; and with it the last of the area's 37,000 books, all of its non-book materials, and several loads of new acquisitions had been frozen.

In the course of the project, Jane Greenfield regularly inspected the bait-traps placed throughout the library's bookstacks. In late May 1979, the six to eight month extension period ended, and Mrs. Greenfield having made yet another inspection of the bait-traps without finding a trace of our anobiid beetle, nor for that matter, signs of other insects, Charles Remington pronounced the project a success and recommended that we

- 1) cease rebagging previously frozen books shelved in Area I after removal for reader use,
- 2) continue in perpetuity to bag and freeze all material new to the library's collections, removing the bags after freezing;
- 3) continue in perpetuity to maintain the bait-traps throughout the library, and to continue to monitor them on a frequent and regular basis;
- 4) offer the use of the blast freezer to other Yale library units charged with pre-

serving rare books, manuscripts, archival records, ancient instrument cases, and the like.

CONCLUSION

In general, our deep-freezing program worked well. It was time-consuming (other important programs were postponed because of it), yet we were able to complete the project in slightly less than the two years we had projected for it. In the process we found that twice the number of trucks initially ordered were required to permit the freezer to work at full capacity. While half of the trucks were in the freezer, the remainder were holding books removed from the freezer awaiting evaporation of the condensation which formed on their bags, requiring no more than twenty-four to thirty-six hours. The books were then off-loaded and replaced with the next load. When freezing new acquisitions, we found that ice crystals formed on materials which had not been previously in the library and had been stored in a damp environment. Subsequently, we decided to hold all new acquisitions for a two week period after receipt before putting them in the freezer. The two week period allowed new acquisitions to become acclimated to the library's normal temperature and humidity.

As we learned from the experience the truth of the old adage "an ounce of prevention is worth a pound of cure", we became advocates of the idea that every institution charged with preserving for posterity library materials gathered from all over the world should assume that their new acquisitions may be infested with the eggs or other stages of book-infesting insects. They should, therefore, have available some means of protection against infestation in their normal processing procedure. Our program of deep-freezing at -29°C (-20°F) for a period of 72 h proved effective against our beetle infestation; and our decision was supported further because the infestation did not spread beyond the area initially infested. The freezer continues to be employed for deep-freezing acquisitions new to the library's collections and for those housed in similar units in the Yale Library system.

SUMMARIES

The Yale Non-toxic Method of Eradicating Book-eating Insects by Deep-freezing

The method chosen to eradicate the insects and prevent a recurrence of the infestation had to be non-toxic to humans, not harmful to the materials, not disruptive of service to the library's readers, and economically feasible. This was the first use of the deep-freezing technique by a library or archive to deal with this problem, and it continues to be used at Yale as a preventive measure in the processing of new acquisitions.

The Beinecke Library has twenty-six miles of bookshelves (mostly underground) with filtered air-conditioning constantly controlling temperature and humidity at $21^{\circ} \pm 3^{\circ}\text{C}$ ($70^{\circ} \pm 5^{\circ}\text{F}$) and $50 \pm 5\%$ R.H.

The infestation occurred in two adjacent underground bookstacks and involved two kinds of material: printed books (chiefly vellum-bound) in one area and leather-bound, Near Eastern manuscripts in the other.

Biologists, at our request, inspected the infested materials and pronounced the pests to include: book mites (arachnids) and book lice (Corrodentia); one specimen of a species of stored-products beetle known as Dermestidae; but the chief culprit, they thought at first, was a tiny species of the beetle family Bostrichidae. The adults were later diagnosed as a species of another related beetle family, the Anobiidae, and subsequently identified as a species of the genus *Gastrallus* never before found in the United States and possibly new to science.

However, the proposed standard fumigation techniques employing lethal gases, crystalline fumigants, or chemical fluid were rejected in favor of deep-freezing, a technique developed at Yale over several years to collect entomological specimens. As the technique exterminates all insects, it is as effective as any chemical fumigation. Additionally, deep-freezing appealed because it could be effective within the confines of the library and would be least disruptive to normal library operations.

The paper concludes with a detailed description of the Library's deep-freezing program. The principal steps are: seal all books (and non-book materials containing cellulose) in polyethylene bags or tubing; freeze for 72 h; remove and let stand until condensation formed on the bags evaporates; mark bags as having been frozen and reshelve books; remove bags 6-8 months following the freezing of last load; monitor bait-traps regularly at frequent intervals and continue in perpetuity.

The equipment includes: a standard walk-in blast freezer which has electric fans behind its freezing coils; a 24 h, 7 day graph temperature recorder; a monitor meter with thermocouple leads to check interior temperature of the books.

La méthode non-toxique de Yale d'extinction d'insectes bibliophages par surgélation

La méthode sélectionnée pour l'élimination des insectes et pour la lutte prévenant une réapparition de l'infestation devrait être exempte de toxicité à l'égard des personnes et non dommageable vis à vis des matières, ne pas entraver le service des lecteurs de la bibliothèque et d'une économie fiable. C'est la première fois qu'une technique de surgélation a été utilisée par une bibliothèque ou par des services d'archives en vue de résoudre ce problème. Cette technique continue d'être utilisée à Yale à titre de mesure préventive lors du traitement d'acquisitions nouvelles.

La bibliothèque Beinecke dispose d'environ 42 km de rayons de livres (dans la majorité en sous-sol) avec un conditionnement d'air filtré contrôlant constamment la température et l'humidité aux niveaux de $21^{\circ} \pm 3^{\circ}\text{C}$ ($70 \pm 5^{\circ}\text{F}$) et à une H.R. de $50 \pm 5\%$.

L'infestation des documents a eu lieu dans deux piles de livres contiguës dans un sous-sol et a affecté deux types de matériels: livres imprimés (principalement à reliure vélin) dans un secteur et manuscrits provenant du Moyen-Orient à reliure de cuir dans un autre secteur.

Sur notre demande, des biologistes ont inspecté matériels infestés et ont identifié les insectes nuisibles suivants: mites de parchemins (arachnides) et puces de livres (corrodentia). L'un des spécimens de l'espèce des coléoptères s'attaquant aux stocks est connu sous le nom de Dermestidae, mais le coupable principal, du moins à l'origine, était une espèce de petite traile de la famille des coléoptères Bostrichidae. Les adultes ont ensuite été identifiés comme étant une espèce de coléop-

rière voisine, les Anobiidae, puis finalement identifiés comme faisant partie de l'espèce du genre *Gastrellus* qui n'a pas été rencontré aux Etats-Unis auparavant et probablement totalement nouvelle pour les scientifiques.

Toutefois, les techniques de fumigation standard proposées à base de gaz à effet mortel, de produits de fumigation cristallins ou de produits chimiques liquides furent rejetés au profit de la surgélation, technique mise au point à Yale durant plusieurs années pour recueillir des spécimens d'insectes. Vu que la technique anéantit tous les insectes, elle s'avère aussi efficace que l'ensemble des fumigations chimiques. De plus, la surgélation est attrayante, car elle peut être appliquée dans le cadre des bibliothèques et n'entraîne qu'un minimum de dérangement des activités normales de ces bibliothèques.

Le document conclut sur une description détaillée du programme de surgélation de la Bibliothèque. Les principales étapes étant: scellement de tous les livres (et de tous les matériels à base de cellulose à l'exception des livres) dans des sacs ou des tubes de polyéthylène; congélation durant 72 heures, sortie et étalage des sacs jusqu'à évaporation de la condensation formée sur les sacs; repérage des sacs congelés et réarrangement des livres sur les rayons, retrait des sacs dans les 6 à 8 mois suivant la congélation des derniers lots; contrôler les pièges à appât à intervalles réguliers et poursuivre le programme de façon ininterrompue.

L'équipement comporte: un congélateur à circulation d'air avec accès pour le personnel, équipé de ventilateurs électriques derrière les évaporateurs, un enregistreur de températures quotidiennes et hebdomadaires, un enregistreur/contrôleur de température intérieure des livres par thermocouples.

Die nicht-toxische Yale-Methode zur Bekämpfung buchfressender Insekten durch Tiefkühlung

Die Methode, die gewählt wurde, um die Insekten auszurotten, und die ein erneutes Auftreten der Plage verhindern sollte, musste für Menschen ungiftig sein, durfte die Bücher nicht beschädigen, den Service den Besuchern der Bibliothek gegenüber nicht stören und sie musste ausserdem ökonomisch innerhalb gewisser Grenzen liegen. So kam es zum ersten Mal zur Anwendung der Tiefkühlmethode in einer Bibliothek bzw. einem Archiv, wo dieses Schädlingsproblem zu lösen war. Heute findet diese Methode immer noch in Yale Anwendung, und zwar als vorbeugende Massnahme bei der Behandlung von Neuerwerbungen.

Die Beinecke-Bibliothek verfügt über ganze 26 Meilen Bücherregale (die sich zum grössten Teil in Räumen unter der Erde befinden). Mit Hilfe einer Filter-Air-Conditionanlage werden Temperatur und Feuchtigkeit konstant bei $21^\circ \pm 3^\circ\text{C}$ ($70 \pm 5^\circ\text{F}$) und $50 \pm 5\%$ R.H. gehalten.

Der Befall zeigte sich in zwei angrenzenden Bücherstapeln in den unterirdischen Räumen, und zwar in zwei Materialien: in gedruckten Büchern (vor allem in Pergament gebunden) in dem einem Bereich und in Leder gebundenen Manuskripten aus dem Nahen Osten in dem anderen.

Wir liessen Biologen die angegriffenen Bücher untersuchen und dabei wurde festgestellt, dass es sich um folgende Schädlinge handelte: Büchermilben (arachnids) und Bücherläuse (Corrodentia), ein Exemplar der Art von Käfern, die in gelagerten Gegenständen leben, bekannt als Dermestidae; die schlimmsten Angriffe waren jedoch verursacht worden, wie man annahm, von einer kleinen Art der Käferfamilie Bostrichidae. Die ausgewachsenen Insekten wurden später identifiziert als eine Art einer anderen verwandten Käferfamilie, nämlich der Art der Anobiidae, bis sich schliesslich erwies, dass es sich um die Gattung des *Gastrellus* handelte, der nie zuvor in den Vereinigten Staaten aufgetreten und der eventuell für die Wissenschaft neu war.

Es wurde abgelehnt, eine der vorgeschlagenen üblichen Desinfiziermethoden anzuwenden, wie z.B. letale Gase, kristallinische Desinfektionsmittel oder chemische Flüssigkeiten. Stattdessen gab man der Tiefkühlmethode den Vorzug, die im Verlaufe von etlichen Jahren in Yale entwickelt worden war, um entomologische Exemplare zu sammeln. Da diese Methode alle Insekten ausrottet, ist sie genauso effektiv wie ein chemisches Schädlingsbekämpfungsmittel. Daneben hat sie den Vorteil, dass dieses Verfahren die tägliche Arbeit in einer Bibliothek am wenigsten stört.

Die Abhandlung schliesst mit einer eingehenden Beschreibung des Tiefkühlprogrammes für Bibliotheken, welches sich prinzipiell in folgende Schritte untergliedern lässt: alle Bücher (und andere Materialien, die Zellulose enthalten) in Polyäthylenbeuteln oder -schläuchen versiegeln; 72 Stunden lang tiefkühlen; aus der Tiefkühlanlage entfernen und stehen lassen, bis das Kondenswasser, das sich an den Beuteln gebildet hat, verdunstet ist; die Beutel, die tiefgekühlt waren, kennzeichnen und die Bücher wieder auf die Regale stellen; die Beutel 6-8 Monate nach dem Einfrieren der letzten Portion entfernen; regelmässige Überwachung der Sammelstellen und Wiederholung des Desinfiziervorganges.

Die Ausrüstung für diese Methode umfasst: eine Standard-Gefrieranlage in der entsprechenden Grösse, ausgestattet mit elektrischen Gebläsen hinter den Gefrieraggregaten; ein Diagramm-Temperatur-Registriergerät (für 7 Tage, 24 Stunden); ein Monitor-Messgerät mit Thermoelement-Leitern zur Überwachung der Innentemperatur der Bücher.

ACKNOWLEDGEMENTS

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2. Mr. Welch later recalled that a representative of the library's professional pest exterminating firm had brought him a specimen of the same type of insect from the Beinecke Library on March 24, 1976, saying that dead adults had been seen on the floor in Area I for about five months (at least November 1975), but had not been previously reported to him or to the library administration.
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The Use of Redesigned and Mechanically Modified Commercial Freezers to Dry Water-wetted Books and Exterminate Insects

by RICHARD D. SMITH

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This paper is a revised version of "The Use of Electrically Modified Commercial Freezers to Exterminate Insects and Dry Water-wetted Books" presented at the 1983 Conference of the Internationalen Arbeitsgemeinschaft der Archiv-, Bibliotheks- und Graphikerrestauratoren, The Hague, Netherlands, September 15, 1983.

1. INTRODUCTION

This paper will report on the background, modification and use of a supermarket ice cream freezer in 1) drying water-wetted books and 2) exterminating insects. The freezer is designed capable (1) of drying 2–300 books in 2–4 weeks, and (2) of exterminating the insects in 4–60° books in a 3-day cycle.

Freezer drying and extermination are related through the use of temperatures below freezing. The nature, background, and operating times and temperature of the drying and extermination cycles differ and will be discussed separately.

These new freeze-drying and extermination techniques are more easily understood if one views his refrigerator and freezer from a different prospective. One must change from perceiving freezers as food preserving mechanisms and see them instead as low temperature drying ovens as well as cold fumigators.

2. MODIFICATION OF A FREEZER

The purpose of modifying the commercial freezer is to make the treatments (1) safe for books, (2) increase their effectiveness, i.e. speed of drying and (3) provide information for use by conservators in controlling the drying and exterminating cycles.

A commercial freezer was used for each of the four Wei T'o Book Dryer-Insect Exterminators manufactured to date because the cost of designing and constructing a freezer specifically for treating books is prohibitive. The Hussman Refrigeration, Inc., Model UML-51BF, self-contained, vertical glass door freezer for ice cream was chosen because it is well constructed, an international network of maintenance centers exists, and its potential treatment capacity is adequate to cope with minor disasters in libraries. A vertical unit with a top mounted evaporator (freezing unit) and glass doors was selected because it provides superior air flow as well as visual control. Moreover, the compressor and condensor compartment is mounted on a slide-out base to facilitate cleaning and servicing. No water drains are required and this freezer can be permanently installed against walls. The refrigeration unit uses low temperature refrigerant R-502 and has a cold output sufficient for blast freezing.

Even with these advantages, many changes are required to change this ice cream freezer into a dryer/exterminator that meets conservation requirements. The rate at which drying naturally occurs in a freezer must be accelerated. The minimum temperature the freezer can reach must be lowered. More sensitive temperature controls are needed. Safety devices and procedures to protect books from damage during treatment are required.

The rate of drying is increased by operating (a) the book compartment between 0°–5°C (23°–32°F) and (b) the evaporator compartment between –45°C and –50°C (–49°F to –58°F). In addition, variable speed fans are installed to circulate air and create maximum air turbulence in the book compartment. The rate of condensation is maximized by maintaining the air in the evaporator compartment as quiet as possible. The defrost cycle frequency is established to produce a balance between the heat introduced by defrosting and reduction in minimum temperature caused by the insulating effect of hoar frost on the evaporator.

The minimum temperature the book compartment can reach is lowered by turning down or off unnecessary heat sources (lights and door and frame heaters) and insulating areas of cold loss (glass doors and metal door frames).

More accurate temperature controls are installed. The main temperature control is provided by an industrial minimum/maximum temperature controller which turns the compressor on and off. An indicating thermocouple is installed to monitor the temperature at twelve critical points. Temperature cut-out and alarm controls are installed to signal high temperatures and protect against accidental defrosting or “melt downs” of frozen books. Automatic signal devices are installed to alert the security office if the unit reaches a preset temperature.

In addition, the breather and weep holes in the unit are sealed to prevent entry of moisture from outside. Time delay timers are installed to prevent fans from turning on before any residual water drops freeze after defrosting.

3. DEEP FREEZE EXTERMINATION OF INSECTS

3.1 Introduction

One cannot help but be concerned about the passion with which conservators and conservation scientists are debating the hazards and future of chemical fumigation. The question, however, should not be whether conservators are endangered by chemicals, but simply: “Is fumigation necessary?”

3.2 Alternatives to Chemical Fumigation

An archive, library, or museum can be described as a continually operating extermination center. Those institutions always have different life forms, i.e. fungi, insects, and rodents present. The relative humidity is too low for these destroyers to multiply and be troublesome under normal storage conditions. Therefore, moving infested portions of any collection to locations with lower

relative humidity (when immediate extermination is not necessary) will bring the infestation under control. In other words, air at 50% RH and 22°C (72°F) aided perhaps by a fan to improve circulation will reduce the numbers of fungi, insects, and rodents to an ordinary, i.e. virtually non-existent, level in a short time.

As carbohydrates, books and documents can be considered food, Pasteur showed that a few minutes at 57.2°C (135°F) is adequate to kill many of the fungi, bacteria, and viruses found in food. Pasteurization will kill insects too. Unfortunately, many deteriorated components, e.g. leather book bindings, are damaged at these temperatures. Consequently, pasteurization temperatures are not suitable for books with deteriorated leather bindings.

Pressure variation also has a killing effect. Cell structures rupture when the pressure is reduced to vacuum levels, and the life forms, whether mammal, insect, or microscopic fungi, ooze to death. Higher pressures, sufficient to collapse cell walls, would be lethal and probably would not affect books. Somewhat lower pressures need a longer exposure time for gas absorption in blood before a quick and final reduction to atmospheric pressure. The killing potential of pressure variation is self-evident to persons familiar with the hazards of the aqua-lung.

Modifying the composition of the storage atmosphere is another interesting alternative. For example, infected books could be placed in a vacuum chamber, a partial vacuum drawn, and carbon dioxide introduced to bring the pressure back to atmospheric pressure. One affect of increasing the carbon dioxide content is to cause the organism to live more rapidly, i.e. increase its metabolic rate. Raising the level of carbon dioxide to 5% causes human beings to breathe 300% faster. In a sense, this speed-up causes the organism to breath itself to death. At 7%, carbon dioxide will asphyxiate humans.

3.3 Background of Deep Freeze Extermination

All living organisms are affected by cold. Although the temperature varies, each organism has a body temperature at which it will die. The difference between species is simply that some die more quickly than others. Insects can withstand sub-zero temperatures, especially when time exists for their bodies to adapt to the cold.

In 1936, Salt¹ reported the results of his Ph.D. research at the University of Minnesota on *Studies on the Freezing Process in Insects*. He found that all insects died rather quickly when exposed to temperatures below -17°C (2°F) if they had not had an opportunity of weeks or months to condition themselves and change their metabolism to resist these temperatures. More recently, Clive and

Mullen,^{2,3} (Stored Products Laboratory, U.S. Department of Agriculture, Savannah, Georgia), investigated the temperate climate insects commonly associated with grain and other foodstuffs. Exposure to temperatures a little below -18°C (0°F) for a few days was found to be 100% lethal.

In 1976 the Beinecke Library, Yale University, was infected with "Death Watch" beetles. It chose to eliminate the infestation by deep freezing each of the 30,000 books in its Rare Book Room at -29°C (-20°F).⁴⁻⁷ Remington⁸ investigated the lethal temperature of these insects and other insects found in libraries and found exposure for 48 h at -23°C (-10°F) would be effective. The lower temperature of -20°C (-20°F) was selected to allow for error in fluctuation in treatment temperature.

The insects found in libraries are domesticated animals in the sense that they live in symbiosis with man. They are transported by man and live in association with him. Tropical insects, like man, cannot survive exposure to winter's cold. Temperate climate insects, though more resistant, cannot tolerate a sudden change to sub-zero temperatures between -29°C to -40°C (-20°F to -40°F).

Many arctic and temperate climate insects can survive exposure to extreme cold during certain periods of their life cycles. Some insects are resistant in the egg form, others are resistant in the pupa stage, but none are resistant as an adult. Even these insects must have time to prepare themselves. This natural phenomenon occurs in late autumn before the onset of winter cold. They cannot, prior to their autumn substitution of glycols (similar to automobile anti-freeze chemicals) for water in their cell structure, resist deep-freeze temperatures. Moreover, these insects normally bury themselves in the ground, down under the snow, where the temperature is 15° to 40°C (27° to 40°F) warmer than the frigid wind-chill temperature above. Even those insects which can tolerate frigid surface temperatures seek protective locations where the rate of temperature change is not great.

3.4 Deep Freeze Extermination Cycle

The use of the modified commercial freezer to exterminate insects and freeze dry books is explained in this and the following section. The exterminating insects cycle differs from the freeze-drying cycle in that the book compartment operates at much lower temperatures during the cycle. A temperature of approximately -40°C (-40°F) is believed to produce the maximum killing rate. Freeze-drying of books, however, occurs best when the difference in temperature between the book and evaporator compartments is maximized. The pur-

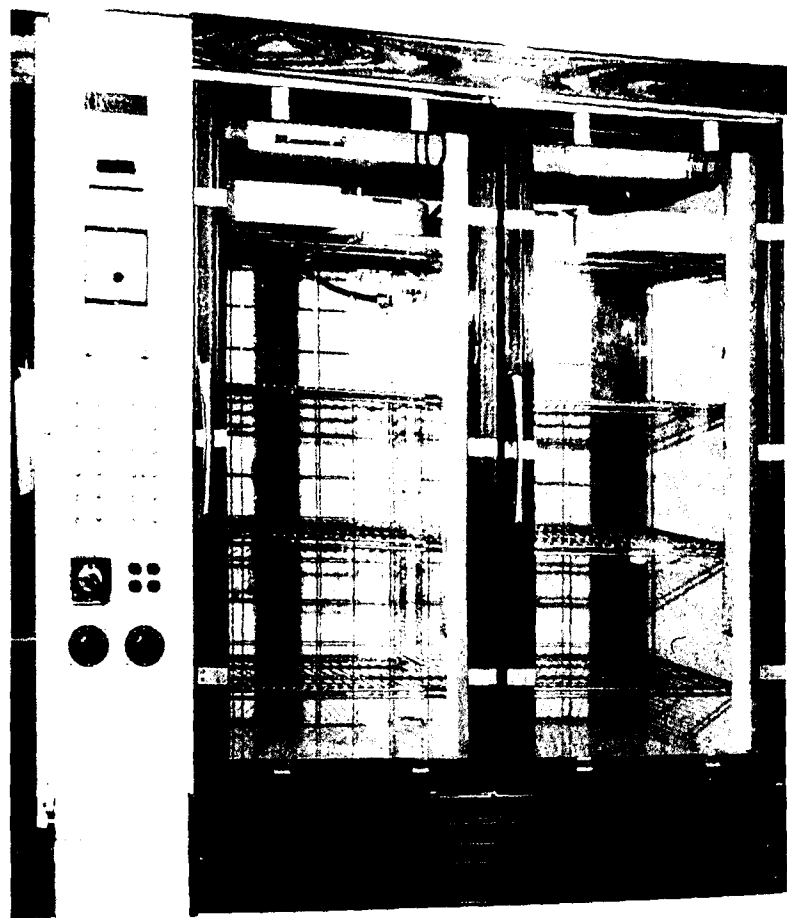


Figure 1. General view of Book Dryer-Insect Exterminator showing control panel and shelving of book compartment.

Fig. 1. Vue générale du secheur des livres et de l'exterminateur d'insectes montrant panneau de contrôle et rayonnage à livres.

Abb. 1. Allgemeine Ansicht des Buch-Trockners und Insekten-Vertilgers mit Bedienungs-pult und Regalen in der Buchabteilung.

pose of these two sections is to explain how the controls of the modified freezer are adjusted to achieve these objectives.

3.41 Starting the Extermination Cycle

Freezers exterminate most effectively at the lowest possible temperature that can be achieved. The primary difficulty in maintaining temperatures below

-40°C (-40°F) in the freezers tested is the insulating effect of excessive quantities of hoar frost accumulating on the evaporator fins. Most of the moisture causing this hoar frost does not come from the books themselves, but rather as moisture entering through holes or cracks in the freezer unit.

The physical arrangement of books during the extermination cycle is not critical provided they become cold. They can be densely packed either lying flat or standing up. Books should be arranged in groups so air may circulate around them. The rate of cooling and warming can be speeded up by inserting aluminum foil to transfer heat every hundred pages.

At start-up (at room temperature), the compressor and evaporator fans operate continuously to produce the maximum rate of cooling and minimum temperature. Lights and other heat sources are turned off to accelerate the rate of freezing.

3.42 Control Adjustments During Extermination Cycle

The control panel requires very little adjustment during an exterminating cycle because the control settings that produce the maximum cooling rate also reach and maintain the minimum temperature during the 24 h holding period. The only likely adjustment required during the extermination phase is an increase of heat input to the door and door frame to prevent an excessive buildup of frost on these less thickly insulated parts of the freezer.

3.43 Deep Freeze Extermination Phase of Cycle

The books being disinfested are brought below -29°C (-20°F) within 12 h and below -40°C (-40°F) within 24 h from the start-up time. This fast cooling is the advantage of blast freezers, i.e. the evaporator fans greatly improve the rate of cold transfer over freezers having no fans.

Although no studies of insects in library books are available for this temperature, it is believed that exposure at -40°C (-40°F) for a minimum of 24 h will kill the eggs, larvae, pupa and adult stages of insect life.

Thermocouple data are used to follow and control the rate of temperature drop, monitor the book and evaporator compartment temperatures, determine whether a defrost cycle is necessary, and prevent over-heating (as discussed below) during return to room temperature.

The rate of temperature fall and penetration of freezing temperatures throughout books follows a pattern from cycle to cycle. Some variation, lag, or acceleration occurs when the temperature rises or falls in the room where the freezer is located. A defrost cycle is definitely not required during the fast cool-

down period, and, to date, has never been found necessary during the 24 h holding period.

3.44 Recovery to Room Temperature

Recovery to room temperature begins with a defrost cycle to insure that moisture which has been frozen onto the evaporator section is removed from the system. After defrost, the compressor and defrost components are turned off. Thereafter, all heat sources are turned on to accelerate return to room temperatures. These heat sources include the evaporator fan, compartment fans, fluorescent lights, and door and door frame heater. The books will warm rapidly both from the heat produced by these components as well as from the heat penetrating through the walls of the freezer.

A freezer is a potential oven where the insulation seals the heat in and the heat sources function as miniature electric heaters. It is possible for these components to raise the temperature of the compartment containing four hundred books to above 66°C (150°F) overnight. It could even reach 85°C (185°F), a temperature that potentially would harm the books.

Consequently, the heat sources should function only during the working day when the unit is checked once per hour. The compartment fans, however, may be set at low speed and operated overnight because these small fans produce little heat at low speed.

The "fumigated" books may be removed as soon as the centers of large books have reached temperatures above the dew point, e.g. approximately 10°C (50°F).

The serious hazards which require prevention during return to room temperature are the potentials for overheating which would occur as a consequence of negligent supervision or condensation which would occur without vigorous air movement, e.g. the fans ceased functioning, and cold spots developed.

3.5 Comments on Exterminating Insects

The original research plan specified exposure of thriving colonies of representative insects to -29°C (-20°F) for 24 h. Subsequently, these colonies were to be observed under favorable living conditions to determine whether insects in the adult, pupa, larva, or egg stage survived the treatment. These tests were not conducted because the scientific literature suggested and entomologists believed insect colonies found in libraries would not survive this treatment.^{8,10,11}

The evaluation of this insect extermination procedure consisted of inspections to verify that books were not harmed by (1) blast freezing to -28°C

(-20°F), (2) exposure to temperatures below -29°C (-20°F), and (3) return to room temperature within 24 h. The actual testing temperatures were 6°C (10°F) colder than the target temperature of -28°C (-20°F). The minimum temperatures at which books were exposed was below -40°C (-40°F).

Condensation will not occur as books are warmed and return to room temperature because the evaporator and compartment fans (latter at low speed setting) maintain vigorous air flow throughout the freezer. The warming energy comes from fan operation and heat entering through the walls and doors of the freezer. Air circulation prevents condensation by maintaining a uniform temperature and relative humidity as warming proceeds.

The drain holes in the bottom of the door gaskets should be checked before each cycle, and, if not sealing, retaped with electrical tape from both the bottom and top surfaces. All holes and door gaskets and seals should be checked periodically to insure that proper contact is maintained.

During this cycle, the freezer doors should not be opened unless absolutely necessary. Large quantities of moisture will condense on the books at -40°C (-40°F) and create a potential for either reducing the efficiency of the evaporator or causing a moisture problem.

4. FREEZE-DRYING OF WATER-WETTED BOOKS

4.1 Introduction

In the early 1950's, Willman Spawn,¹² American Philosophical Society, used a semi-trailer freezer truck to salvage the books water-wetted during a disaster. Spawn periodically removed the books to warm and dry air before returning them to the freezer truck. His concept is elegant; drying books with readily available equipment operated by people without any special technical experience. It puzzles me why Mr. Spawn's idea on the use of freezer trucks has not become a standard conservation salvage technique.

4.2 Alternative to Air Drying

The air drying of books is the most used technique of salvaging books wetted by water. It consists of drying books in air at ambient temperatures. Fans or other techniques may be used to speed drying by circulating air. Neither heat nor relative humidity control are normally used.

Many efforts have been made to speed the process, reduce costs, and avoid the mold attack which typically begins about three days after wetting. Library

cooperation has brought people, regional resources, and knowledge together to improve techniques.

The time during which books can be salvaged may be extended indefinitely by freezing books for subsequent thawing and drying. This drying is usually done by conservators, and more recently, has been speeded up using vacuum freeze-dryers. The manual procedure has the disadvantages of cost and skill requirements, but the advantages of giving books the individual care they may require. The vacuum freeze-drying procedure is less expensive on a per book cost but is frequently unavailable because large vacuum dryers are not accessible.

Fires and floods will remain one of the nightmares that librarians face. There is no obvious solution, but the use of freeze-drying proposed here may alleviate the problem in future.

4.3 Background of Freeze-drying

The first known use of vacuum freeze-drying to salvage water-wetted books occurred in the early 1950s following the Library of Parliament fire in Ottawa, Canada.¹³

The publicity following the 1960's use of freeze-drying in Denmark made conservators aware of the potential in vacuum freeze-drying. In the 1970's, the large vacuum chambers constructed to test rocket components by major U.S. aerospace contractors were found ideally suited to salvaging water-wetted books.¹⁴⁻²²

The major problem vacuum freeze-drying encountered is cost of the equipment and available vacuum drying facilities. Both the space testing facilities and the large vacuum freeze-dryers used in the food industry are geographically widely dispersed but frequently unavailable for emergency purposes like drying books. On the other hand, the thousands of books and records that were successfully vacuum freeze-dried dramatically demonstrate the merit of this process.

Efforts have been made to reduce costs. Kelly²³ developed a low cost, high capacity vacuum freeze-drying system for laboratory use. Cook and Grattan²⁴ took advantage of cold Canadian winters to freeze-dry wooden objects on building roofs in Ottawa.

Theoretically speaking, the technique of freeze-drying is identical to the technique used in vacuum freeze-drying. Vacuum freeze-drying techniques have been investigated and found to produce the best results in salvaging books. The following analyses explains the close relationship between the two techniques.

Vacuums are defined as empty spaces. Gases are "vacuums" in that only a

very small portion of the volume of the space is filled by the molecules of the gas. For example, as a liquid, 18 g of water fills 18 cubic centimeters. But, as a gas, 18 g of water would fill 22,400 cubic centimeters of vapor at sea level. In other words, 99.92% or 22.382 cubic centimeters of the water vapor is vacuum, i.e. the empty space between the molecules of a gas.

The air we breathe is similar to water vapor in the sense that only a small portion of the space that air occupies would be filled with molecules if the air were compressed into a liquid. Virtually, the same ratio of vacuum to matter as with water applies: 99.9% of air is vacuum. The remaining 0.1%, composed primarily of nitrogen, oxygen, and argon, would cause virtually no effect on the free movement of water vapor molecules.

In fact, the only molecules which have an effect are the other water molecules originating from the wet books. This fact is clear from Dalton's gas law of partial pressures. Dalton taught that the total pressure of a mixture of gases like air is the sum of the partial pressures of its component gases. In other words, the properties of each of the gases in air are independent of the properties of the other gases in air. Thus, the properties of water vapor in air are determined not by the pressure of the other gases in air, but rather by the number of water molecules which exist at particular locations in the air. Freeze-drying works because a variation in humidity exists; high close to the object being dried (giving off water vapor) and low where water vapor is being removed (condensed into ice). The gaseous water molecules flow in the direction of lower pressure; that is, away from the object being dried.

In a freezer, the lowest water vapor pressure (smallest number of water molecules) occurs at the point of coldest temperature. The pressure is lower because water vapor is continually being removed, i.e. condensed into ice, and a steady stream of water molecules flows from the point of high pressure towards the low pressure point where ice condenses. Thus, drying occurs because water vapor at the higher temperature in the frozen water-wetted books is forced towards the ice on the freezers cooling coils where the pressure of the water vapor is much lower. For example, the vapor pressure of ice at -4°C (25°F) is 3.0 mm Hg; at -50°C (-58°F), the vapor pressure of ice is only 0.03 mm Hg, thus producing a drying ratio force of one hundred times.

Industrial vacuum freeze-dryers operate at 0.1 to 0.2 mm Hg even though their vacuum pumps can reach blank-off pressures of 0.01 mm Hg. Moreover, vacuum freeze-dryers use freezing coils to remove water vapor and prevent it from reaching and fouling the oil of their vacuum pumps. Such freezers operate in the range of -45°C to -50°C (-49°F to -58°F) and have built-in defrost units. Theoretically, therefore, the major difference between a vacuum freeze-

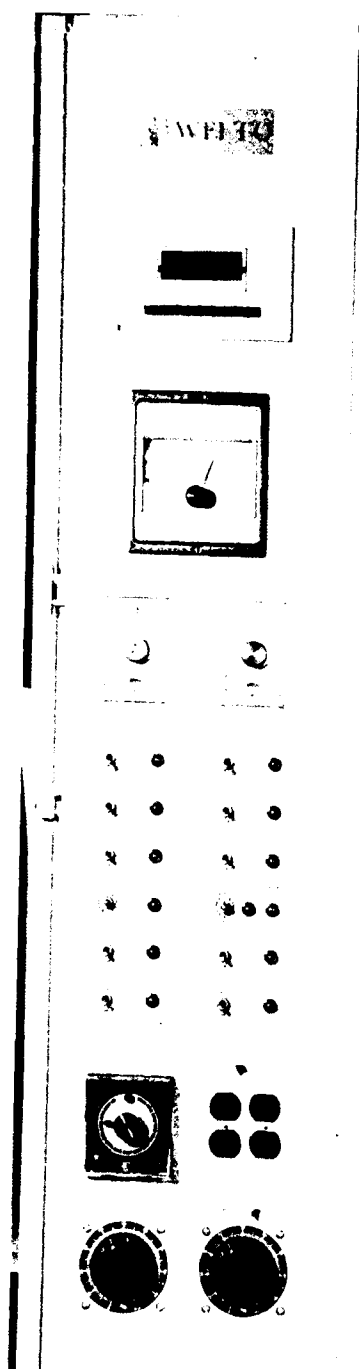


Figure 2. Close-up control panel showing (from top) (1) ten-point push bottom digital temperature indicator, (2) indicating temperature controller, (3,4) back and front compartment fan speed controls, (5-14) on/off switches for 115/240 volt power, compressor, defrost heater, evaporator and compartment fans, door/frame heaters, fluorescent lights, high temperature alarm silence, and electrical outlets, (15) fan delay timer, (16) electrical outlets, and (17) door and frame temperature controls.

Fig. 2. Vue rapprochée du panneau de contrôle qui montre (d'en haut) (1) Indicateur de température digital avec dix boutons-pression, (2) Contrôle de température indiquée, (3,4) Vitesse de ventilateur des compartiments d'arrière et d'avant, (5-14) Commutateurs de courant de volt 115/240, compresseur, Dégivrage, Ventilateurs d'évaporation et de compartiment, Réchauffeur de porte et de cadre, lumière fluorescente, alarme de haute température et prises électriques, (15) Régulation du temps du ventilateur, (16) Prises électriques et (17) Contrôle de la température de porte et de cadre.

Abb. 2. Detailansicht des Bedienungspultes, das (von oben angefangen) enthält: (1) 10-Ziffern-Digital-Temperaturanzeiger-Gerät mit Druckknopf, (2) Temperatur-Kontrollgerät mit Anzeige, (3,4) Steuergeräte für Gebläse der hinteren und vorderen Abteilung, (5-14) Ein-/Ausschalter für 115/240 Volt Strom, Kompressor, Entfroster, Verdampfer und Gebläse der Abteilung, Tür-/Rahmen-Erhitzer, Fluoreszenzlichter, Alarmdämpfer für hohe Temperaturen und elektrische Anschlüsse, (15) Verzögerungsschalter für Gebläse, (16) Elektrische Anschlüsse, (17) Temperatur-Kontrollgeräte für Tür und Rahmen.

dryer and our modified freezer-dryer is the presence of other gases, and the effect of these gases, as shown above, is insignificant.

The introduction of frozen foods has been one of the recent "convenience" improvement of food processors. The lower temperatures needed to sell these foods in grocery stores required the development of new refrigeration gases such as Refrigerant R502. R502 produces temperatures in the evaporators of freezers ranging from -45°C to -50°C (-49°F to -58°F). The newer freezers have automatic defrost units. Thus, the cryogenic cold temperatures that make vacuum freeze-drying practical are available in commercial freezers. The question for library conservators is whether this capability can be used to save water-wetted books.

4.4 Freezing Wetted Books Cycle

4.41 Introduction

Wetted books and documents should be stabilized by blast freezing as quickly as possible. Fast action is essential to prevent mold, i.e. fungus, attack from commencing within 72 h of wetting. Outside freezing facilities should be used when the book dryer-insect exterminator is in the middle of a cycle that cannot be interrupted. Water-wetted books should be frozen rapidly to minimize ice crystal size and further damage.

Good conservation and library practices must be followed. The materials being frozen should be identified in a manner which will facilitate their location and retrieval for patron use.

4.42 Preparing Wetted Books for Freezing

The library administration should prepare its plan, the necessary materials, and train its staff on how to prepare wetted books for freezing. The preparation of books for freezing should not simply focus on stabilizing the books but should also take into consideration how the books should be frozen to improve the subsequent drying and recovery treatment.

The wetted books should be flushed with clean water or otherwise washed insofar as practical to avoid the subsequent difficulties in removing dried, encrusted materials. All bound books should have Remay non-woven paper inserted between the spines and fly leaves and periodically through the text block to act as wicks to remove (by capillary attraction) water from books and accelerate drying. This technique is particularly effective for thick books and for

books whose binding cloth is impermeable. The Remy insert should stick out of the books at least one inch from the top, fore, and tail edges.

The books should be straightened and flattened insofar as possible. Loose case bindings must be correctly positioned for re-adherence during the drying process.

Pressing water from books aids drying books with leaves made of porous paper. Experience with coated papers is insufficient to recommend a pressing treatment. One concern is that pressing might cause the coatings to bond together during drying. Fortunately, coated paper is much more difficult to wet and frequently only the margins of books composed of coated paper are wetted.

Acrylic plastic book plates are used to support wetted books which are unable to stand straight by themselves. Experience indicates the dynamic technique of using large rubber bands around groups of eight to ten books functions satisfactorily. $\frac{1}{4}$ or $\frac{3}{8}$ inch diameter wooden dowel rods are useful for hanging wetted journals, magazines, and pamphlets.

The Remy paper should be fully inserted into the spine of books. It provides a "parting layer" so the covers can be opened and the books can be stood and splayed open during the drying phase once the covers are partially dry and strong enough to stand without support.

During the freezing process, air circulation should be obtained from the evaporator fans only. The compartment fans are not used because they introduce additional heat and slow the freezing rate.

4.43 Preparation of the Freezer

4.431 Placement of Wetted Books

The objectives in book arrangement are: (1) minimize further damage, (2) facilitate drying and access, and (3) provide good air circulation. The grill in many freezer compartments insures sufficient space for air flow at the back. Care should be taken in placing books to insure that space also exists for air to flow along the sides and front of the compartments. A passageway between two, e.g. front and back, rows of books should be maintained from the top to bottom of the compartment. Similar passageways from front to back should also be left.

The physical arrangement of books during freeze-drying is more critical than during the extermination cycle. More space must be allowed for air to circulate around the books. In effect, the treating capacity is reduced by 50–70%.

Books which can stand alone should be opened so that air may circulate, in so far as possible, throughout the book. Books should be faced alternately front

and back for more efficient use of the freezer. Books which cannot stand alone must be supported during the freezing process, e.g. through use of plastic book plates and rubber bands as previously mentioned. After freezing, the plates can be removed and the books separated to improve air circulation. Frequently, if Remy separating sheets were used, the covers can be opened and the books splayed open immediately.

Journals and pamphlets may be dried lying flat, but it is far more efficient to hang them using wooden dowel rods. One of the advantages of freeze-drying is the potential for interaction by the conservator. The freezer may be opened quickly, a book removed and examined, straightened, or otherwise manipulated, and returned for further drying. Moreover, books which could not be opened to speed drying, may be opened after drying is partially completed.

4.432 Control Panel Settings for Fast Freezing

From start-up temperature, the compressor and evaporator fans are set to operate continuously and quickly stabilize the water-wetted books by blast freezing. Other sources of heat (lights, door and frame heaters, etc.) should be turned off to speed freezing and stabilization. The centers of thoroughly wetted books should be brought to at least -7°C (20°F) before the evaporator fans are turned off and the compartment fans are turned on, as discussed in Section 4.523 control panel settings for freeze drying.

4.433 Estimated Times to Freezing

The temperature in the book compartment will drop rapidly and fall below freezing in a few hours. Thin books, pamphlets, and magazines will freeze rapidly. Rows of thick books, like encyclopedias, may take twelve or more hours to freeze all the way to the center. The rate of freezing can be measured using thermocouples.

4.5 Drying Frozen Books Cycle

4.51 Introduction

Frozen books dry slowly compared to drying at normal temperatures, because the amount of heat available to sublime, i.e. vaporize, ice is low. Consequently, efforts to increase efficiency are restricted by facts that cannot be avoided. For example, if adequate heat for faster drying is provided, the ice will melt and the benefits of freeze-drying are lost.

The methods available to increase the rate of drying are: (1) increase the drying surface area, (2) minimize the thickness of the high relative humidity air film next to the books, (3) maximize the temperature differential between the book compartment and the evaporator compartment, (4) accelerate the rate of moisture transfer from the inside of the book to its surface. The techniques by which these methods are used are discussed throughout this section.

The rate at which different kinds of paper and books dry varies greatly. Books with porous paper (particularly groundwood), untrimmed leaves, and rough edges dry much more rapidly than books made from coated, dense papers with razor smooth edges and coated margins. Books with bindings manufactured from impermeable cloth or covered with plastic films dry much more slowly than books with bindings of cloth or uncoated paper bindings. These bindings and books will dry more rapidly if placed in rapidly circulating turbulent air.

4.52 Starting the Drying Cycle

4.521 Introduction

This section discusses the arrangement of books in the book compartment, setting the control panel, modifying start-up control settings based on data from indicating thermometers and thermocouples, and interpreting the rate of water collection.

4.522 Arrangement of Books

Books being freeze-dried may be arranged very much as they were during the fast stabilising freezing cycles. The objectives are related in that we want to modify the temperature and wetness of the book by passing air around it. This necessity for air circulation means passages for air flow must be provided along the back, sides and front of the book compartment as well as in passageways between the rows of books. The turbulent, rapid air flow throughout the book compartment produced by the compartment fans minimizes the thickness of the moist, high RH air film close to the books and maximizes water vapor flow towards the evaporator where it condenses as ice. The drying rate increases directly with increase of rate of air flow and air turbulence. The correct air flow rate is that produced by the fastest fan speed that can be tolerated without causing any damage or adding so much heat as to bring the book compartment temperature above freezing.

4.523 Control Panel Settings for Freeze-drying

In the test freezers, the Temperature Control is set at -43°C (-46°F) as the minimum temperature and at -39°C (-38°F) for the maximum temperature. The compartment fans speed controls are set midway between the medium and low dial settings. These settings produce temperatures inside the book compartment which ranged between -7°C to -2°C (20°F to 28°F).

The daily defrost cycle is set to last 15 min.

A 4 l (1 gal) bottle is attached to the drain hose at the back of the freezer to collect the amount of water removed each day. This water is weighed and recorded each day following defrosting as a measure of the drying progress.

4.524 Location of Thermocouples

Five thermocouples in the test model are installed when the unit is constructed. Thermocouple No. 1 is clamped onto the refrigerant gas outlet, i.e. return line from the evaporator to the compressor. This location is the coldest spot after 1 or 2 days of drying because it tends to become the point at which the last liquid refrigerant evaporates. Thermocouples No. 2 and 4 are located behind the evaporator in the cold air flowing from the evaporator compartment to the book compartment. Thermocouples No. 3 and 5 are in front, and measure the temperature of the warm return (relatively speaking) air as it flows from the book compartment into the evaporator compartment for re-cooling.

The remaining 7 thermocouples are placed by the conservator as necessary for the books being dried. Typically, 3 of the thermocouples are used to measure the air temperature in the book compartment: Thermocouple No. 6 half-way between the floor and bottom shelf, No. 7 in the middle of the book compartment touching a book binding, No. 8 just above and touching the top row of the books. Thermocouple No. 9 is placed inside a thin book and No. 10 inside a thick book. Thin glass wire (32 ga) thermocouples are used for No. 9 and No. 10, and the cracks alongside the wires sealed to obtain true readings. Thermocouples No. 11 and No. 12 are placed as desired.

4.53 Control Adjustments During Cycle

Control adjustments during the cycle are directed towards: (1) protecting the books being dried from further damage and (2) maintaining optimum drying conditions. The conditions just below freezing, under which drying occurs, are optimum in terms of protecting the book and its components during the drying process. The primary hazards during drying are water damage if a "melt

down" occurs, i.e. the book compartment becomes too warm and the ice in frozen books melts.

The primary requirement for efficient freeze-drying is to maintain the maximum temperature difference between the evaporator compartment and the book compartment. Drying is further accelerated by keeping the air as quiet as possible in the evaporator compartment and as turbulent as possible in the book compartment. As the leaves of the books and documents gradually dry and become flexible, the rate of air flow, i.e. fan speed, must be reduced to prevent the leaves from fluttering and tearing.

In general, four components provide temperature control: fluorescent lights, compartment fans, door and frame heaters, and defrost frequency. The heat input provided from the fluorescent lights is straightforward; either the lights are on providing heat or they are off and not providing heat. Normally, the fluorescent lights are off. Their primary functions are to provide light for inspection and heat when warming the books at the end of the cycle.

The temperature control rheostat of the door and frame heaters is adjusted to control the amount of heat input. However, this source of heat is normally not used during the drying cycle. The compartment fans introduce the heat which is necessary. Actually, it is necessary to run the fans at a low speed (if a cold air snorkel is not used to draw air from the evaporator area). In practice, the compressor runs continually to produce the minimum temperature on the evaporator. The evaporator fans are turned off to minimize the amount of cold air which flows to the book compartment.

The book compartment is kept at a temperature as close to freezing as possible provided the daily temperature fluctuations do not bring the temperature or the book compartment above 0°C (32°F). In the test units, the four compartment fans introduced the heat necessary to maintain the temperature just under freezing.

The defrost timer is set for one defrost cycle each day. This defrost cycle should be observed and take place at the same time each day. A record kept to ensure the average temperature of the freezer is not gradually changing. The rate of drying slows if the temperature drops, and a potential "melt-down" may occur if the temperature rises above 0°C (32°F) for more than a brief period.

4.54 Use of Thermocouple Temperatures

The thermocouples are the primary source of the temperature data used in operating the freezer at maximum efficiency. As explained in Section 4.524 the twelve thermocouples are located at key points throughout the book and evaporator compartments. Their locations are selected both to verify that the freeze-

drying cycle is functioning correctly and to guide the operator in "fine tuning" the freezer.

The accuracy and reliability of the temperature controller to produce optimum can be verified during the drying phase. The temperature controller is set to produce (1) the maximum operating temperature range in the book compartment and (2) the minimum average temperature in the evaporator. The book compartment temperature should fluctuate between approximately -7°C to -2°C (20°F to 28°F), preferably -2°C to -3°C (26°F to 28°F). The evaporator temperature given by the thermocouple No. 1 should be well below -40°C (-40°F), preferably fluctuating between -45°C and -50°C (-49°F to -58°F). The dial thermometer (mounted in test unit at top right side of middle door frame) inside the freezer and thermocouples No. 3 and No. 5 can be just above freezing, e.g. 0°C to 2°C (32°F to 35°F), because they monitor the warmest location in the Freezer.

The thermocouples also indicate the need for defrosting. The temperature indicated by thermocouple No. 1 will increase noticeably, perhaps 3°C to 5°C (5°F to 8°F), as an insulating coating of hoar frost develops on the evaporator. (Do not confuse this temperature rise with the smaller and normal fluctuation caused by opening and closing of the non-accessible expansion valve that adjusts the flow of refrigerant liquid.) This temperature rise is caused by delayed vaporization of the refrigerant and loss of its full cooling potential to the evaporator.

In summary, the rate of drying is determined by the factors mentioned above. The thermocouple data indicate the maximum temperature differential that is possible to achieve is actually being attained.

As an aside, the collection and weighing of the water removed during defrost cycles is a positive and direct method of monitoring the drying progress. The technique is to tape the hose draining the evaporator pan inside a two-quart (4 l) or one-gallon bottle. Weighing and recording the weight of the water collected on a daily basis (weighing after each defrost cycle is not necessary) provides data to evaluate progress. Graphs of the quantity of water collected each day measured efficiency of drying. Graphs of the cumulative water estimate the progress of a drying cycle.

4.55 Recovery to Room Temperature

Recovery begins with a defrost cycle to melt the hoar frost on the evaporator and remove it from the unit. Thereafter, the compressor and defrost heaters are turned off. Both the evaporator and compartment fan switches are turned on. The fluorescent lights may be turned on and the door and frame heater control

set to full open. The book compartment will warm to room temperature in 6–8 h from the heat produced by these components plus the heat flowing in through the walls of the Freezer. The heat produced by these components could raise the temperature of a book compartment containing 200 books to well above 60°C (140°F) overnight. In other words, freezers are potential ovens with the insulation holding the heat in, and the various components functioning as miniature heating elements. Consequently, the above components should be operated only when the book compartment is being monitored during the working day. Overnight, only the compartment fans, set at low speed, should be operated.

The “dried” books can be removed from the unit as soon as the insides of thick books have reached a temperature above the dew point, approximately 10°C (50°F). The serious hazards during return to room temperature are that overheating (a consequence of insufficient monitoring) or condensation (if vigorous air movement is not maintained) might occur.

4.6 Straightening Books During Drying Cycle

4.61 Introduction

Books can be straightened at three points during the freeze-drying process: (1) during preparing wetted books for freezing (Section 4.42) (2) during freeze-drying process and (3) after completion of freezer drying. Each point has advantages and each is used whenever suitable.

4.62 Straightening During Freeze-drying

Active or passive techniques can be used to straighten distorted books. The passive technique views the drying book as an object which expanded from water take-up, and which will shrink as this water is removed. The necessity for continuously adjusting press is avoided through use of the acrylic plastic book plates and rubber bands 1.6 cm wide by 17.8 cm long ($\frac{5}{8}$ inch wide by 7 inches long). A number of Remy interleaving papers are helpful to wick water to edges for drying because the plastic plates prevent water from escaping through covers and the books cannot be splayed open.

In the active technique, the temperature of the freezer is raised to perhaps 5°C to 8°C (34°F to 45°F), and the books straightened manually before placing them between the plastic book plates again for refreezing and continuation of drying. The boards of case bound books must be properly aligned to insure that they dry and re-adhere in correct position.

Straightening during freeze-drying is sharply limited for books containing coated papers. Wetted coatings of adjacent pages may stick more strongly to each other than they do to their respective paper fiber substrates. This coating to coating bonding can be avoided by freezing and drying without thawing and straightening.

4.63 Straightening After Completion of Freeze-drying

The standard techniques that libraries apply when using vacuum freeze-drying are equally applicable in freeze-drying. In vacuum freeze-drying, books which are frozen straight, dry straight. Books which are distorted when frozen, dry crooked with warped boards and cockled pages. Straightening requires dismantling the book and flattening the leaves one by one in the traditional manner. This expensive restoration step can be avoided in freeze-drying because almost dry books can be removed and pressed flat. The workability of slightly damp paper makes it possible to press an entire book as a part of the final drying stage. This straightening technique is comparable to the pressing of books after “casing-in” to insure the boards and leaves do not warp or cockle as a consequence of the moisture introduced with the paste.

4.7 Comments on Drying Water-wetted Books

Although definite data is not yet available, experience to date indicate that this freeze-drying technique either does or will come to equal or exceed the efficiency of vacuum freeze-drying. In one 1982 instance, a nineteenth-century Probate Court Record Book was received which had been frozen following wetting during a fire in the winter of 1976. If this large book, approximately 30 × 45 × 6 cm (12" × 18" × 2½") thick, which was received frozen solid, was sufficiently dried after 72 h of freeze-drying, restoration could have commenced.

The quality of freeze-drying appears equivalent to the quality of drying obtained in vacuum freeze-drying. For example, modern coated book papers can be dried without blocking, i.e. sticking together. An advantage of freeze-drying over vacuum freeze-drying is that books which are deformed during wetting can be frozen, partially dried, thawed, quickly straightened, refrozen, and drying continued. This procedure allows many deformed case bindings and book blocks to be salvaged that otherwise would be lost. In addition, case bindings that loosen while wet will gradually re-adhere as the wetting water is removed during drying.

Our impression is that freeze-drying produces less stress in books and results in a more uniform drying than vacuum freeze-drying does. This tendency to-

wards uniformity of wetness is useful because books can be removed when almost dry for final straightening and drying in a book press.

An unexpected result, noted by Professor Gary Frost, School of Library Science, Columbia University, is the effect that watching wet books freeze-dry may have on library administrators. Professor Frost asserts library administrators will be converted into conservation zealots when they see droopy, dripping, slimy, sopping wet books become straight, dry, and available for patron use.

SUMMARIES

The Use of Redesigned and Mechanically Modified Commercial Freezers to Dry Water-wetted Books and Exterminate Insects

This paper reports on the background, modification and use of a supermarket ice cream freezer in 1) drying water-wetted books and 2) exterminating insects. The dryer-extinator constructed is capable (1) of drying 2–300 books in 2–4 weeks or (2) of exterminating the insects in 4–600 books per 3-day cycle.

A Hussman Refrigeration, Inc., Model UML-51BF, self-contained, vertical, glass two-door freezer for ice cream was chosen because it is well constructed, an international network of maintenance centers exists, and its treatment capacity is adequate for minor disasters in libraries.

Industrial vacuum freeze-dryers operate at 0.1 to 0.2 mm Hg even though their vacuum pumps can reach blank-off pressures of 0.01 mm Hg. These vacuum freeze-dryers use freezing coils to remove water vapor and prevent it from reaching and fouling the oil of their vacuum pumps. Such freezers operate in the range of -45°C to -50°C (-49°F to -58°F) and have built-in defrost units.

The primary requirement for efficient freeze-drying is to maintain the maximum temperature difference between the evaporator compartment and the book compartment. Drying is further accelerated by keeping the air as quiet as possible in the evaporator compartment and as turbulent as possible in the book compartment.

An advantage of freeze-drying over vacuum freeze-drying is that books which are deformed during wetting can be frozen, partially dried, thawed, quickly straightened, refrozen, and drying continued. This procedure allows many deforming case bindings and book blocks to be salvaged that otherwise would be lost. In addition, case bindings that loosen while wet will gradually re-adhere as the wetting water is removed during drying.

The physical arrangement of books during freeze-drying is more critical than during the extermination cycle. The treating capacity is reduced by 50–70% because more space must be allowed for air to circulate around the books. As the leaves of the books and documents gradually dry and become flexible, the rate of air flow, i.e. fan speed, must be reduced to prevent the leaves from fluttering and tearing.

Frozen books dry slowly compared to drying at normal temperatures, because the amount of heat available to sublime, i.e. vaporize, ice is low. Consequently, efforts to increase efficiency are restricted by facts that cannot be avoided.

The books being disinfested are brought below -29°C (-20°F) within 12 h and below -40°C (-40°F) within 24 h from the start-up time. The books are held at about -40°C (-40°F) for a minimum period of 24 h.

L'emploi de congélateurs commerciaux reconstruits et mécaniquement modifiés pour le séchage de livres mouillés d'eau et pour l'extermination d'insectes

Cet article traite du fondement, de la modification et de l'emploi d'un congélateur d'un supermarché pour 1) le séchage de livres mouillés d'eau et pour 2) l'extermination d'insectes. Le sécheur et l'exterminateur d'insectes produit est capable 1) de sécher 200 à 300 livres en 2 à 4 semaines ou 2) d'exterminer les insectes de 400 à 600 livres au cours de 3 jours.

A Hussman Refrigeration, Inc., Modèle UML-51BF, indépendant, vertical avec deux portes en verre a été choisi parce qu'il est bien construit, parce qu'il existe un réseau international de centres de maintien et parce que sa capacité de traitement convient aux dommages aux petites bibliothèques.

Des sécheurs de congélation à vide fonctionnent à 0.1–0.2 mm Hg, bien que leur pompe à vide puisse atteindre une pression «blank-off» de 0.01 mm Hg. Ces sécheurs de congélation à vide emploient des spirales de congélation pour enlever de la vapeur d'eau et pour l'empêcher d'atteindre et de polluer l'huile des pompes à vide. De tels congélateurs fonctionnent à des températures entre -45°C et -50°C (-49°F et -58°F) et sont munis d'unités de dégivrage.

L'exigence fondamentale d'un séchage de congélation efficace, c'est la conservation de la différence maximale de températures entre le compartiment d'évaporation et le compartiment des livres. Le séchage est accéléré davantage en maintenant l'air dans un état aussi immobile que possible dans le compartiment d'évaporation et dans un état aussi turbulent que possible dans le compartiment des livres.

Un avantage du séchage de congélation par rapport au séchage de congélation à vide, c'est que des livres qui ont été déformés par l'humidité peuvent être congelés, séchés partiellement, dégelés, étirés, recongelés et reséchés. Cette procédure a pour effet que beaucoup de reliures peuvent être sauvées qui autrement auraient été perdus. En outre, des reliures qui deviennent peu consistantes sous l'effet de l'humidité, deviennent consistantes à la mesure que l'eau est enlevée pendant le séchage.

Le placement physique des livres pendant le séchage est plus critique que pendant le cycle de l'extermination. La capacité de traitement est réduite de 50 à 70% parce qu'il faut plus de place pour faire l'air circuler autour des livres. A mesure que les feuilles des livres et des documents sont séchés et deviennent flexibles, le passage d'air, c'est-à-dire la vitesse du ventilateur doit être réduite pour empêcher les feuilles de flotter et d'être déchirées.

Des livres congelés séchent plus lentement en comparaison de séchage aux températures normales, parce que la quantité de chaleur à la disposition pour «sublimier», c.-à-d. évaporer la glace, est modeste. Les efforts pour augmenter l'efficacité sont limités par des faits auxquels on ne peut remédier.

Les livres dont il faut enlever des animaux destructeurs sont portés au-dessous de -29°C (-20°F) avant 12 heures et au-dessous de -40°C (-40°F) avant 24 heures à compter du début. Les livres sont maintenus à une température de -40°C (-40°F) pendant 24 heures au minimum.

Die Anwendung eines umkonstruierten und mechanisch modifizierten handelsüblichen Gefrierschranks beim trocknen von durchnässten Büchern und bei der Bekämpfung von Insekten

Die vorliegende Arbeit befaßt sich mit der Grundlage, der Abwandlung und Anwendung eines Gefrierschranks, der zur Aufbewahrung von Eis in Geschäften verwendet wird, einmal zum Zweck der Trocknung von durchnässten Büchern, zum anderen zur Bekämpfung von Insekten. Der hier

vorgestellte, kombinierte Trockner/Schädlingsbekämpfer kann (1) im Laufe von 2–4 Wochen 200–300 Bücher trocknen oder (2) in einem Zyklus von 3 Tagen die Schädlinge in 400–600 Büchern vernichten.

Ein Hussman Refrigeration, Inc., Modell UML-51BF – ein selbständiger, vertikaler Gefrierschrank mit zwei Glastüren – bestimmt zur Lagerung von Speiseeis, wurde aus einer Reihe von Gründen für diesen Zweck gewählt: seine Konstruktion ist gut geeignet, es existiert ein internationales Netz von Servicezentren und seine Behandlungskapazität ist ausreichend für begrenzte Schäden, die in Bibliotheken auftreten können.

Industrielle Vakuum-Gefriertrockner arbeiten mit 0,1 bis 0,2 mm Hg, obwohl die Vakuumpumpen dieser Gefriertrockner extreme Druckwerte von 0,01 mm Hg erzeugen können. Die Vakuum-Gefriertrockner sind mit Gefriersäulen, die den Wasserdampf entfernen und diesen davon fernhalten, das Öl der Vakuumpumpen zu verunreinigen. Gefrierschränke dieses Typs arbeiten mit Kältegraden von -45°C bis -50°C (-49°F bis -58°F) und sie verfügen über eingebaute Abtauvorrichtungen.

Eine effektive Gefriertrocknung beruht in erster Linie darauf, daß der maximale Temperaturunterschied zwischen der Verdampferabteilung und der Bücherabteilung gewährleistet wird. Der Trocknungsvorgang wird noch beschleunigt, wenn die Luft in der Verdampferabteilung möglichst ruhig steht, in der Bücherabteilung dagegen so turbulent wie möglich ist.

Ein Vorteil der Gefriertrocknung gegenüber der Vakuum-Gefriertrocknung besteht darin, daß Bücher, die durch die Nässe deformiert sind, gefroren, dann teilweise getrocknet, getaut, schnell geglättet und wiederum gefroren werden können. Mittels dieser Vorgehensweise können biege deformierte Bucheinbände und Bücherblöcke, die sonst verloren gingen, gerettet werden. Außerdem können Bucheinbände, die sich im nassen Zustand gelöst haben, schrittweise, so wie das Wasser während des Trocknungsprozesses entfernt wird, ihre Klebeeigenschaften zurückgewinnen.

Die physikalische Anordnung der Bücher ist während der Gefriertrocknung kritischer als bei der Insektenbekämpfung. Die Behandlungskapazität wird um 50–70% reduziert, weil die Luft ausreichend um die Bücher zirkulieren können muß. Sobald die Seiten der Bücher und Dokumente trockner werden und somit ihre Flexibilität wiedererlangen, muß der Luftstrom, d.h. die Gebläsegeschwindigkeit, reduziert werden, um zu verhindern, daß die Seiten flattern und reißen.

Gefrorene Bücher trocknen im Vergleich zu einer Trocknung bei normalen Temperaturen langsamer, weil die Wärmemenge, die zur Verfügung steht, um das Eis zu sublimieren, d.h. zu verdampfen, gering ist. Dies bedeutet, daß Anstrengungen zur Erhöhung der Effektivität durch Faktoren begrenzt werden, die unumgänglich sind.

Die Bücher, die desinfiziert werden, werden innerhalb der ersten zwölf Stunden auf -29°C (-20°F), während der nächsten zwölf Stunden auf -40°C (-40°F) gekühlt. Die Bücher werden dann mindestens 24 Stunden lang bei -40°C (-40°F) gelagert.

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EDITOR'S POST SCRIPTUM

After this article had gone to press, Dr. Richard D. Smith learned that European and American research positively confirmed the suitability of deep-freeze extermination for archive and library use. The following excerpt is reproduced from *Pest Control in Museums: A Status Report (1980)* by S. R. Edwards *et al.*, Association of Systematic Collections, University of Kansas, 1981:

"Freezing, a technique elegant for its simplicity, has been tested at several European institutions. The following quote is taken from S. Crisafulli: *Herbarium Insect Control with a Freezer*. *Brittonia* 32 (1980): 224:

"Reports from the University of Aarhus in Risskov [Denmark] and the Royal Botanic Gardens at Kew [England] as well as Stockholm [Sweden] show freezing to be more consistently effective than chemicals like methyl bromide. Exposure times varied (2 days to 1 week), as did operating temperatures (–18°C to –40°C), but all institutions claimed they were killing all stages of insect life. Our own experiments with pupae, larvae and adult herbarium beetles (*Lasioderma serricornis*) have confirmed Kew's report that –18°C for 48 hours produces 100% kill.

30–40 cubic foot commercial chest freezers have been most commonly used. Treatment as cited produces no noticeable damage to dry specimens, paper, glues, etc.; exposure beyond two days was found to leave material somewhat damp (pers. comm. to [Patricia] Holmgren [New York Botanical Garden] from Bertil Nordenstam, Swedish Museum of Natural History, Stockholm".

The dampness problem at the Swedish Museum after two days of deep-freezing is comprehensible; a dampening effect has not been experienced in the Wei T'o® Book Dryer-Insect Exterminator because fans are used to maintain a vigorous air circulation and constant temperatures in the unit.

The History of Microfilm Blemishes

by ELLEN McCRADY

Microfilm, invented over 130 years ago, was first used in businesses during the 1920s and in libraries during the late 1930s for making copies of valuable records and research materials. As time went on, libraries and archives came to depend on microfilm as a permanent replacement for their deteriorating records. Then in the early 1960s, mysterious tiny spots were discovered on negative microfilms in "widely scattered locations around the United States" according to one source¹, and "in a few rolls of stored negative microfilm" according to another.²

The implications of the discovery were profound. Nobody wanted to transfer the records of civilization from one impermanent medium to another. The film industry was particularly nervous about its customers' possible reactions.³

The blemishes were concentrated on leaders and fogged edges, but sometimes went into the text frames. They were small, no larger than 0.006" or 150 microns in diameter, which is about the size of a single reduced character on the film. The most common type had sharp edges and concentric rings colored red, orange or yellow. They might occur on any percentage of the rolls in a given collection, and their density or frequency might be as high as a hundred or more blemishes per square centimeter. Research later showed that they might appear within a few months after processing⁴ and increase in diameter by 50% in a space of five years, but that there was a natural upper limit to the size of individual spots.⁵

The blemishes were seldom observed on any type of silver halide film but negative microfilm. This is not surprising. The image on negative microfilm is fairly dark, usually with white text on a black background, and contains a great deal of silver. Furthermore, microfilm uses fine grain emulsions to give high resolution to the tiny images it carries. Silver, normally a stable material, becomes more reactive when finely divided. As a result, silver halide microfilm is more strongly affected by processing, humidity and various oxidizing gases and contaminants than many other types of film.

Chronology of Events

The year of their discovery is uncertain. Two sources place the discovery of the first tiny spots in the mid-1950s,^{4,6} and two place it in 1961 or 1962.^{2,7} At any rate, blemishes were apparently discovered in both private and public col-

lections by Recordak, a subsidiary of Kodak, and reported to Kodak either immediately or after a delay. Kodak then began trying to discover the cause.

The National Bureau of Standards (NBS) was notified in 1963 and, together with the National Archives and Records Service (NARS), sponsored a meeting in July 1963 to discuss the problem with invited industry and government representatives. The involvement of NBS and this meeting were made known for the first time to the rest of the industry in the August 1963 issue of *National Micro-News*,¹ official journal of the National Microfilm Association, and in R.W. Henn and D. G. Wiest's 1963 article in *Photographic Science and Engineering*.⁸ NBS initiated an extensive research program with financial support from the industry,⁹ in which the first major step was a survey of major microfilm collections. Without delay it published its *Handbook 96*, which told librarians and archivists how to inspect a collection for blemishes and how to report observations to NBS.

The National Microfilm Association set up a committee to coordinate and assist research efforts, develop interim recommendations, and disseminate information on proper storage and handling procedures. It included a dozen or so representatives from trade and government organizations that were helping to finance the NBS research. These organizations included the Library of Congress, NARS, the Social Security Administration and Bell and Howell. The committee's deliberations, sometimes reported in *National Micro-News*, focused mainly on ways to handle public reactions and on the Bureau's plans for its research.

The public reaction was potentially something to reckon with, both because of the extent to which institutions had come to rely upon microfilm, and because the problem was found to be more extensive than originally thought. NBS's survey uncovered by July 1964, in its first year of work, a "widespread incidence of defects" in government collections. This led the General Services Administration (GSA) to issue a prompt directive to all government agencies instructing them to make positive masters, to retain original documents after filming until further notice, and to inspect all collections immediately.¹¹

Some of the defects uncovered in 1963 were at the National Archives.¹² However, in 1964 the executive secretary of the National Microfilm Association repeated an earlier assurance that no blemishes had been found at NARS or the Library of Congress.⁶

By June 1964, both the *New York Times* and the *Kiplinger Washington Letter* (a newsletter for businessmen) had published stories about the blemish investigation, and the wave of publicity that followed was distressing to the committee. Bills were introduced in Congress requiring all government records to be put on rag stock paper, but all bills died before being voted on.⁴

The research continued for about six years, during which time frequent interim reports appeared in the microfilm literature from Kodak, Recordak and later from NBS. Publications resulting from Kodak's research project continued to appear only till about 1965, when Kodak summarized its recommendations in its Data Book No. P-108.⁷ The NBS research was summarized in C. S. McCamy and Chester. I. Pope's report presented May 7, 1969, at a meeting of the National Micrographics Association (formerly called the National Microfilm Association). It was published a year later in the *Journal of Micrographics*. This report placed principal blame on peroxides issuing from deteriorating cardboard boxes. (By this time, most of the concern about the blemishes had diminished materially.)⁴ (Nelson)

During this same decade of concern over the permanence of microfilm, William J. Barrow's research on the permanence of paper was bearing fruit. The first modern permanent/durable paper for printing was produced in 1959; the Library of Congress printed two of its large bibliographical sets on permanent/durable paper in 1962 and 1967; and by 1969 the Barrow specifications had found their way into one of the ANSI standards.¹⁴

The Investigation

The NBS research started with a survey of microfilm collections to determine the extent of the damage. Over 7,000 rolls of film were examined by strong reflected light under magnification, with the help of 100 trained experts. About 50 questions were answered for each roll, using questionnaire forms. The mountains of data thus gathered were analyzed with the aid of the NBS Computer Lab and Statistical Engineering Section, and the U.S. Bureau of the Census. Factors found to be correlated with the incidence of blemishes were investigated in the laboratory of NBS's Photographic Research Section.

Some facts were already established before the research began. Poor quality paper and board (among other products) had been known for a long time to cause image deterioration in film, although they had never been linked to microfilm blemishes. The formation of tiny concentric rings by chemical reactions in a gelatin medium ("Liesegang rings") had been described in 1896.⁹ Henn and Wiest at Kodak knew that the spots were produced by oxidation of the silver grains to a soluble form which then migrated outward through the gelatin, and was reduced and deposited as colloidal silver. The size of the colloidal particle was thought to determine the color. However, at that time, they did not know the identity of the oxidizing or reducing agents.

In the early stages of investigation, the blemishes were called by various names, including "measles," "Saturn rings," and "J-type defects" (after Jupiter names, including "measles," "Saturn rings," and "J-type defects" (after Jupiter names,

ter, the name of the research projects at the National Bureau of Standards). Kodak authors showed an early and continuing preference for the term "microscopic blemishes," while authors from NBS came to prefer the term "redox blemishes."

Six types were distinguished, but only Type 1 blemishes had the colorful rings. Type 2 spots were light, colorless and filled up part of a letter image. Type 3 spots were very small and distinct, only 10–15 microns in diameter, pale yellow to orange with a silvery sheen; they occurred in great numbers when they did occur. Type 4 spots had an irregular shape, and a nucleus but no rings; they occurred in high-density background areas, and were often distorted to fill the space between characters or lines of a character. Type 5 was a reddening of the background next to characters. Type 6 spots had the same color and circular shape as Type 1, but no rings or sharp edges; a particle of silver or film backing was often found at the center of the spot, and the size of spots in the same region varied.^{8,10}

Type 1, which was frequently found on scratches, dents and dried droplets, was also found to occur more frequently than one would expect at the edge of characters. The NBS investigators suggested that this had to do with the hardness of the gelatin in areas of greater density and greater concentrations of residual chemicals there, together with the possibly greater gas permeability of the gelatin in the clear image area. They demonstrated, by exposing a photographic step tablet to peroxide-treated paper and observing that blemishes formed only at densities over 0.44, that blemishes occurred more readily in areas of greater optical density.

They were able to produce blemishes with concentric rings by touching a minute droplet of Metol-hydroquinone, a developer, onto a gel containing silver sulfide; they could even control the number of rings by exposing the films periodically to hydrogen peroxide.

The possibility of biological causation was investigated by NBS, Kodak and the Armed Forces Institute of Pathology, and no evidence to support this possibility was found.¹⁴

The Kodak researchers noticed that a small amount (0.2g/l) of potassium iodide (KI) in the fixer bath tended to stabilize the film.^{9,15} They tested its effect by sprinkling the processed film with zinc dust, which oxidizes and produces spots on unprotected film. Potassium iodide treatment markedly improved resistance to spotting. The NBS team tested KI-stabilized film and found that even film treated with KI sometimes formed blemishes when exposed to high humidity and peroxides. The KI did protect the films against peroxides, but not against formaldehyde or formic acid, which are also emitted by deteriorating paper.

Chester I. Pope found in 1963 that small amounts of residual hypo, or longer fixing times, inhibited development of blemishes by coating the silver filaments with more sulfur atoms than usual; but published reports were not very extensive, and Kodak publications continued until recently to advise elimination of all hypo by means of thorough washing and a clearing agent.

The NBS team picked up on some research from the paper industry showing that in natural aging of commercial papers, especially in high humidity, peroxides were formed. The older the paper, the greater was the production of peroxides. This seemed to explain some of the findings of the NBS survey, namely that incidence of blemishes was correlated with humidity of the storage area, age of the film, and use of cardboard or fiber boxes rather than cans for storage. They hypothesized that blemishes were the result of exposure to hydrogen peroxide issuing from deteriorating boxes. In order to test this hypothesis, the investigators found a way to produce experimental blemishes in the laboratory under repeatable, controlled conditions. They found that film stored in cardboard boxes at 50°C and 81% RH developed blemishes in two to three weeks. They were also able to induce blemishes by enclosing film in a high humidity (86%) jar with two pieces of paper that had been dipped in peroxide and dried. These results confirmed the suspected connection.

By June 1965, McCamy was able to voice some fairly definite conclusions: in high humidities, the peroxides from deteriorating cardboard boxes oxidized the silver; therefore, boxes should not be used for storing microfilm at all.¹⁴ The 1970 final report was even more specific: it pinpointed deteriorated boxes as the principal cause of the blemishes. Chemically stable cardboard was not seen as a remedy at that time. Until recent years it was generally thought to be impossible to make a boxboard that was chemically stable.

The NBS team ordered an ultramicrotome in 1964 to help them examine the structure of Type 1 blemishes. It enabled them to cut a thin transverse section of film with a thickness of less than a wavelength of light. Electron micrographs of these sections at a magnification of 75,000 showed the breakdown of silver filaments into smaller particles within the blemish, compared to full-size filaments at the edge. Electron probe analysis showed that silver and chlorine distributions tended to correlate with the morphology of the blemishes, whereas that of sulfur correlated only sometimes. Sometimes there was a speck of silver in the center, but silver was usually depleted in the center area and concentrated at the edges.⁹

They explained the colors of the rings by relating them to the presence of a small amount of chlorine in the wash water: silver reduced in the presence of chloride ions takes on a colloidal form that is reddish or yellow in color. Typical blemishes were formed when film washed in water containing small amounts of

chlorine was exposed to peroxides. No blemishes appeared when the film had been washed in distilled water or in water with less than one part per million of chlorine.

To summarize the NBS research in the authors' own words, "The blemishes result from the displacement of image silver by an oxidation-reduction reaction caused by peroxides and other gaseous products of degradation of the paper cartons in which the films are stored."⁹ Anything that made the film more vulnerable to these gaseous degradation products increased the incidence of blemishes. A large number of factors could have this effect: scratches (by removing the protective gelatin), residual chemicals (such as chlorine from wash water, which enhances the effect of peroxide), lack of air conditioning in the storage area (by allowing pockets of still air, through which the short-lived peroxides were able to travel further), dead storage (similarly), humidity (by enhancing the activity of the peroxide – an important factor), and high temperatures (by accelerating all chemical reactions). All these factors had been found, in the NBS survey, to be correlated with blemishes.

Because of the evidence that the blemishes were created by an oxidation-reduction process, the NBS investigators proposed that they be known henceforth as "redox blemishes." They did not make up this term, although it does not appear in all dictionaries. *Webster's Third New International Dictionary*, 1961 edition, defines it as "oxidation-reduction" and says it is pronounced "ree däk's."

Research was continued in laboratories overseas. Edith Weyde (1972) went further into the chemical processes and recommended an improved monitoring device as well as a restoration technique.¹⁸ The Swedish National Archives followed the published American research and added their own to it.¹⁹ Their response to the problem was to store archival microfilm in bags impervious to gases.

Recommendations and Their Effects

A total of about 25 recommendations were made to those in charge of microfilm collection by the investigators between 1963 and 1970. The first few publications emphasized conventional care: gold-toning for valuable films; proper manufacture, processing and storage; avoidance of high temperatures, humidities and polluted air; and inspection.^{1,6} Regular inspection and control of temperature and humidity continued to be recommended by most authors throughout the entire period. Maximum temperature recommended was either 65° or 70°F, but maximum RH ranged from 20%¹⁴ to 60%!²⁰

In 1964 both the General Services Administration and Henn and Wiest recommended making positive master or security copies, a fairly novel and radi-

cal proposal; GSA, as mentioned earlier, advised also retaining filmed originals, a measure which nobody since then has advised. In the sources consulted, there is no indication of how many collections' policies were affected by either the conventional or the novel advice of the early years. After their discovery of the stabilizing influence of potassium iodide, the researchers regularly recommended its use, a practice which was adopted without difficulty for many collections. They also advocated the storage of films in cans, a practice not widely adopted, perhaps because it involved an investment in time and money. Kodak reportedly made cans for this purpose but was unable to sell them. Most publications on this subject after 1964 recommended the use of both KI and cans.

Regular inspection was a standard recommendation from 1964 on, but was not widely practiced. Few authors followed GSA's lead in advising positive masters, but GSA continued to recommend them as late as 1971.

In 1965 NBS started reporting its ongoing research in the professional literature, and made a few novel recommendations. Low relative humidities were recommended for the first time 15–20% for archival storage, at least for new film. Each reel before use would have to be conditioned to room humidity for about a week.

Kodak's Data Book advised against the use of hypo eliminator for microfilm, though not against hypo clearing agent. I also advised careful squeegeeing and gentle drying, because the blemishes sometimes started on dried droplets of water. NBS seconded this, and mentioned cleanliness and other features of good processing. It also recommended for the first time that a security or backup copy be stored in a separate place and that excessive densities be avoided.²¹ Another practice, separate storage of masters is often recommended – and followed – today.²² The suggestion that excessive densities (very dark values) be avoided in processing has probably been put into effect in most labs.

By 1970 some recommendations had been dropped from NBS's list and others added. Some interesting unexplained omissions are the KI treatment, the avoidance of small amounts of chlorine in wash water, storage of copies in a separate place, and careful drying methods. Several relaxations of their earlier recommendations concern environmental control – perhaps because they had been told about how awkward that week-long wait would be for eager researchers and readers. Here is the final list of NBS recommendations, in full:

1. Use safety base permanent record film as specified in the United States of America Standards Institute Specifications for Photographic Films for Permanent Records.
2. Use no higher densities than are required for the intended purpose.
3. The residual thiosulfate concentration should not exceed 1 microgram per

square centimeter, but one should not attempt to reduce it to zero. The optimum concentration appears to be about 0.5 microgram per square centimeter in a clear area.

4. Keep processing machinery and film clean.
5. Avoid scratching film.
6. Store films in containers made of inert materials, such as metals or plastics of proven quality. With good ventilation and clean air, the containers need not be sealed.
7. Do not permit storage temperature to exceed 70°F nor the relative humidity to exceed 40%.
8. Avoid wide-range cycling of temperature and humidity, since these accelerate the inhibition of gaseous contaminants.
9. Inspect films on a regular schedule, using proper sampling and microscopic inspection techniques.
10. Maintain records of processing and storage conditions so that the next generation of archivists will be able to understand our successes or failures and act on the basis of facts.

The 13 most common recommendations from all sources are given below in order of decreasing frequency:

1. Avoid high humidities
2. Avoid high temperatures
3. Inspect regularly
4. Store in cans
5. Avoid polluted air
6. Process properly
7. Tone with gold
8. Make positive copies or masters
9. Use KI in processing
10. Avoid variable temperature
11. Follow relevant ANSI standards
12. Keep clean film and work
13. Avoid variable RH

This may seem like a lot of advice to follow, but good protection could be achieved without following all of it. Except in the worst cases, it was probably necessary to follow scrupulously only one or two of the recommendations listed. However, the matter of how many precautions were enough was never investigated, and no one ventured an informed opinion for the benefit of readers.

In retrospect, as far as it is possible to determine, the only recommendation in the list that was followed was No. 9. In addition, two recommendations on the NBS list but not on this list (separate storage of masters and avoiding excessive density in the image) have become fairly general practice, or at least more widespread than they were before.

Finally, a practice not originally recommended but based on the research of that period, is still growing: the use of acid-free, buffered boxes for storage. Perhaps before the more expensive measures, such as air conditioning and control of pollution, could be adopted, administrators would want assurance that the expensive measures were still necessary – i.e. that the simpler measures adopted had not taken care of the problem. Or perhaps, since control of temperature and humidity were recommended so often, and humidity had been so heavily implicated in the occurrence of blemishes, administrators *did* start laying long-range plans for new ventilating and air-conditioning systems.

Even if the experts' recommendations were not fully taken up, there were indications in the literature and elsewhere that some people, at least, had been listening. In 1971, the Library Technology Project published Veaner's *The Evaluation of Micropublications: A Handbook for Librarians*, which summarized both the Kodak and the NBS research, with recommendations.²³ In the late 1970s the Library of Congress, without much publicity, began writing procurement specifications for permanent/durable boxes that did not give off peroxides. These boxes were then offered by manufacturers to other purchasers, and have been available on the market ever since as an alternative to cans for safe storage of microfilms.

In 1978 the American National Standards Institute revised its standards for microfilm storage,²⁴ storage containers²⁵ and residual hypo testing,²⁶ taking into account some of the research that had been done. NARS published a set of proposed standards for archival storage of silver halide microfilm in the same year.

From all this it seemed that the nature and control of the spots was better understood, and it seemed that a lesson had been learned. However, there is reason to believe that many librarians and archivists never did learn the nature and implications of the new phenomenon. Between 1963 and 1967, the library literature ran only a few small news notices about the spots. Most of these new notices omitted or distorted some of the central facts.^{27,28} NBS's final report to the National Micrographics Association in 1969 was given only about five column-inches and a routine write-up in the *Library Journal*.²⁹

History Repeats Itself

Some librarians and archivists undoubtedly kept up with the microfilm liter-

ature, attended workshops and seminars, or were kept personally informed and were very aware of the major developments; however, there were not enough of them, and some that learned either forgot, or neglected to tell their successors in office. As a result, there has been at least one more microfilm blemish scare since 1970. The most recent one was in 1981.

In March of that year, the National Archives and Records Service startled the library and archival world by announcing in a news release that NARS was having second thoughts about using silver halide microfilm for storage of records of permanent value. (They had recently discovered or rediscovered the spots on their own microfilm). NARS more or less retracted that news release in September of the same year in an article in *Publishers Weekly* that was later reprinted in the *Library Journal*.³⁰ In that article, Archives officials were quoted as admitting that the survey on which they based their decision may not have been well designed or carried out. Something more to the point, but not mentioned, was the fact that NARS did not centrally administer its microfilm records and therefore had no organizational memory on the topic. Also relevant was the fact that none of the officials involved remembered the events of the sixties regarding redox blemishes. None of the earlier personnel listed as attending the July 1963 meeting at NARS were still on the staff in 1981.

In September 1981, NARS contracted for a microfilm inspection survey with Micrographic Systems Technology Corporation of Falls Church, Virginia. The survey, now completed, reportedly found the redox problem to be insignificant. There was no information loss due to redox blemishes on any film, and film produced since 1965 had fewer blemishes than film from the 1955-65 period. NARS has nevertheless begun storing their film in cans, and all master negatives are stored underground in Boyers, Pennsylvania.³¹

DISCUSSION

In an applied field like preservation of microfilms, even the best scientific research and the wisest advice cannot guarantee success. Ultimately, what matters is whether the microfilm is successfully preserved, and this depends on the extent to which available knowledge is applied in practice in the field. The application of existing knowledge to practice can be amazingly difficult, even when money is not a problem.

The flow of information across disciplinary boundaries is similarly difficult. First, the information has to be disseminated to the people who are in a position to use it. Then they usually like to evaluate it for possible usefulness or necessity under local conditions, for consistency within itself and with their own knowledge and beliefs, for cost and cost-effectiveness, and so on. Skepticism is a

common reaction of people who are hearing about new solutions to problems based on new discoveries. It may take time before new and unfamiliar chemical or microscopic concepts become real to them. Acceptance can be speeded by the prestige of the source of advice and by the number of people who, having adopted recommended practices, report that the new measures have not done any harm, but have in fact helped.

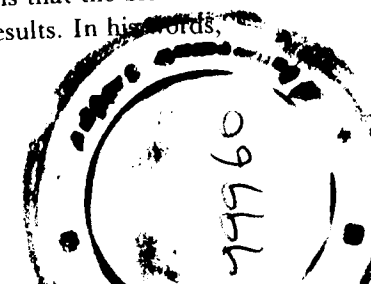
In the blemish episode of the 1960s, much advice was given that might be called "counsels of perfection." Few curators can have been expected at the time to follow these counsels, but it would not have been honest or useful for the advisers to suppress their publication for that reason. In some cases – environment control for instance – recent developments have made the recommendations more possible and affordable, especially for local areas within a building. The recommendations may even have stimulated a demand that encouraged improvement of technology available on the market.

The recommendation of cans for storage has not been widely accepted, but another path to the same goal was found by the Library of Congress, a few years after all the research was done and advice was published. The Research and Testing Office, which was familiar with Barrow's work on the stabilizing effect of carbonates, knew how to write specifications for permanent/durable paper. When blemishes were found on LC microfilm, the chemists there, having read the Kodak and NBS research, not only recommended the use of potassium iodide in processing, but specified buffered, acid-free boxes for storage and went out on bid in 1979. When the author was at the Library of Congress in 1980, chemist George Kelly verbally assured her that these two measures brought the problem under control.

It is interesting to see how readily the finding about peroxides from deteriorating paper was utilized in photographic research at NBS, one of whose recommendations was in turn made feasible by more paper research, carried out about ten years later and applied at the Library of Congress.

It has been 15 years since the "final report" of 1970. What is needed now is a reassessment of the recommendations of the 1960s. Both their feasibility and their efficacy need to be examined, and the results communicated to all who care for valuable microfilm collections. The products of this reassessment should include both technical and popular publications.

George Eaton, who has remained professionally active since retirement in 1975 from his post as head of the Photographic Chemistry department at Kodak Research Laboratories, maintains that the blemish scare of the 1960s has had two beneficial and continuing results. In his words,



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The "redox blemish" scare awakened not only the users of microfilm but the owners and custodians of all kinds of photographic records, including industry, business, government agencies, museums, libraries, archives, historical societies, etc. Not only were these organizations now aware of a problem related to photographs but (they) began to send representatives to seminars on photographic preservation held, first, at the Smithsonian Institute (1969–71) and later at the Rochester Institute of Technology (1977–83). The concerns generated more scientific research and the presentation of relevant research data at scientific meetings such as the International Symposium on the Preservation of Photographic Images held in Ottawa, Canada, in the fall of 1982.²²

The ultimate effects of this episode are hard to assess precisely, but perhaps this does not matter. It is always hard to reach agreement on the significance of historical events. The significance of this episode for conservation lies partly in the way it epitomizes and illustrates the problem of applying the results of basic research. The widespread concern, the brief period of intense and successful research by a respected organization, the scientists' frequent communications to concerned laymen as their research proceeded, and their limited success, even under these favorable conditions, in translating valid and useful research results into widely accepted curatorial practices – all this has a certain drama and suspense to it. We have a great deal to learn about the transfer of knowledge from one field to another, and especially from a scientific to an applied field. One day we may understand it better, and episodes like this may then be more predictable and less suspenseful.

SUMMARIES

The History of Microfilm Blemishes

Discovery in the early 1960s of small spots or blemishes on negative microfilm in American collections caused a great deal of concern and led to several years of research by Kodak and the U.S. National Bureau of Standards. The principal cause was found to be peroxides generated by deteriorating boxes, which attacked the silver emulsion under conditions of high humidity. Recommendations made by the investigators, and the extent to which they were adopted, are discussed. The episode is offered as an illustration of the problem of applying research results for practical effect.

Histoire de ternissures sur les microfilms

Au début des années 60, la découverte de petites tâches ou de ternissures sur les négatifs de microfilms de collections américaines fut à la base de préoccupations nombreuses et conduisit à plusieurs années de recherche effectuées par Kodak et par l'U.S. National Bureau of Standards. La cause principale s'est avérée être la formation de peroxydes lors de la détérioration des boîtes de stockage qui ont dégradé l'émulsion à base d'argent dans des conditions d'humidité élevée. Les recommandations formulées par les chercheurs et leur degré d'application sont abordées. Cet épisode sert d'illustration au problème d'application des résultats de recherche à des fins pratiques.

Geschichte auf Fehlern auf Microfilmen

Die Entdeckung von kleinen Flecken oder Fehlern auf negativen Microfilmen in den USA Anfang der 60er Jahre verunsicherte die Hersteller ernstlich. Für Kodak und das U.S. National Bureau of Standards war das der Beginn von jahrelangen Forschungsarbeiten. Dabei erwies sich, dass die prinzipielle Ursache für diese Flecken Superoxide waren, die von beschädigten Dosen erzeugt wurden und die die Silberemulsion bei hoher Feuchtigkeit angriffen. Die Empfehlungen, die die Entdecker gegeben haben und der Umfang, in dem diese eingehalten werden, stehen zur Diskussion. Diese Episode wird als Beispiel dafür angeführt, wie schwierig es ist, Forschungsergebnisse in die Praxis umzusetzen.

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Disinfection of Archive Documents by Ionizing Radiation

by HANA HORÁKOVÁ & FRANTIŠEK MARTINEK

INTRODUCTION

This paper presents the results of a study in which gamma radiation was used in eradicating mildews on archive documents. The effects of this radiation on the physico-chemical properties of paper were also investigated.

The irradiation was carried out in the Institute of Nuclear Research in Řež by a team headed by Dr. Juraj Urban, M.Sc.(Eng.), CSc. The mildews were tested in cooperation with the team of RNDr. Jan Nečásek, C.Sc., of the Department of Genetics, Microbiology and Biophysics of the Faculty of Sciences of the Charles University in Prague,¹⁶ and later in cooperation with Richard Wasserbauer, M.Sc.(Eng.), C.Sc., of the Electrotechnical Testing Institute in Prague.

All the work was carried out in the laboratories of the State Central Archive and in the laboratories of the Institute of Development and Rationalization of the Paper and Cellulose Industry in Prague.

THEORETICAL PART

Effects of Ionizing Radiation

Under ionizing radiation, energy quanta which exceed the chemical bond strength several times, are transferred to the electron envelopes of atoms.^{1,6,7,8,9,13,19} From an energetic point of view, therefore, any chemical bond may be destroyed. However, the mechanism and kinetics of energy delocalization and the subsequent chemical reactions determine how the transferred energy of ionizing radiation will be transformed. If only the translation energy were to change, i.e. into heat, the irradiated material would display high resistance to ionizing radiation, provided the dosage input and heat removal were balanced to avoid damaging the material as a result of higher temperature (heat degradation). Substances with metallic bonds between atoms, in which the ionizing radiation energy is very rapidly and effectively delocalized and transformed into heat, come close to the latter case. Aromatic systems of π -bonds delocalize the energy of ionizing radiation effectively and, therefore, sub-

stances which contain them belong to the very radiation-resistant ones. In general, there is no relation between heat and chemical resistance of substances, on the one hand, and their radiation resistance, on the other. Some highly chemical- and heat-resistant substances (e.g. teflon, silicones) are little resistant to the effects of ionizing radiation.

The effects of ionizing radiation themselves may be reflected in the change of several properties. The properties may change not only one way, but sometimes the dependence of a particular property on the radiation dose may display a maximum or minimum, which is evidence of the simultaneous occurrence of antagonistic processes, e.g. of cross linking and simultaneous degradation of macromolecules due to ionizing radiation.

Chemical reactions which are responsible for permanent changes of properties of irradiated organic polymeres, are cross linking and chain scission. Both reactions usually take place at the same time. Chain scission usually results in decreasing the elasticity coefficient, tensile strength, hardness, extensibility and solubility of the material involved.

Typical representatives of degrading polymeres are poly-isobuthylene, polymethylmetacrylate or teflon. Cross linking increases the elasticity coefficient, tensile strength, hardness, softening temperature and decreases the extensibility and solubility, as well as elasticity. After large radiation doses the polymere is brittle.

Gamma radiators were used for irradiation. These radiators are widely used in radiation technology. The penetrating capability of the radiation enables irradiation of thick layers, which makes it possible to work with large volumes of material. Sealed cobalt ^{60}Co radiators (decay half-life 5.3 years, radiation energy 1.173 MeV) and cesium ^{137}Cs radiators (decay half-life 29.9 years, radiation energy 0.662 MeV) are usually employed as gamma-radiation sources.

Subsidiary Reaction to Radiation

Radical positions, generated by irradiation, may further react with the compounds present such as water and oxygen.² Besides this, hydroxyl radicals,^{4,5} for example, are generated by water radiolysis; the radicals recombine to form hydrogen peroxide which may trigger an oxidation reaction.³ These subsidiary reactions take place particularly in the accessible regions of cellulose fibres where places affected by oxidation may be created without scission of the chain³ (this is true of irradiation with weak ^{60}Co radiation, assuming the source produces only 0.2 Mrad/hr).

Use of Gamma Radiation for Disinfecting Archive Documents

A number of authors have dealt with this problem. The possibility of using gamma rays for disinfecting archive documents and library funds would have a number of advantages, e.g. low cost of disinfection, processing large volumes of material, easy application, time saving, etc.

Lethal Dose of Gamma Radiation for Mildews

Individual authors differ in the determination of the lethal dose. Paun, Oprea and Goldhaar¹⁴ have determined a minimum dose of 720 krad; Belyakova¹⁷ claims that irradiation with a dose of 650 krad guarantees complete disinfection of books. Bokarev *et al.*¹⁸ claims a sterilization dose for medicines of 560–670 krad, whereas Bachman and Bysznska¹⁹ sterilized spices with a dose of 670–750 krad. Pavon maintains that the sterilization dose is 1800 krad.

All these authors agree that it should prove expedient and useful to make use of the synergic effect of temperature and radiation, which would decrease the required radiation dose considerably.

Effect of the Overall Radiation Dose on Physico-chemical Properties of Paper

According to the literature, no conspicuous changes in the physico-chemical properties of paper¹⁴ were observed at overall gamma-radiation doses of 720 krad. Only a decrease in the strength of the paper when folded was observed (double folding test) which is indicative of enhanced brittleness of the paper.

If the total dose is 1800 krad, the situation becomes more complicated, even if the irradiation is carried out in a protective nitrogen atmosphere.¹⁵ The radiation resistance of the paper depends strongly on the composition of the paper. Change in properties is manifested particularly in chemical parameters (copper number, viscosity) especially in papers which contain a larger amount of groundwood pulp. Pavon¹⁵ does not recommend the systematic use of gamma radiation as a fungicide because of these phenomena. He only recommends exceptions in special cases, in which the quality of the paper is guaranteed.

EXPERIMENTAL PART

Drawing on the research mentioned above, we decided to test the possibility of disinfecting archive documents by using gamma radiation under our own particular conditions.

1. MINIMUM RADIATION DOSE REQUIRED TO LIQUIDATE MILDEW CONTAMINATION

Tested species of mildew: *Aspergillus flavus* W
Aspergillus niger
Trichoderma viride
Ulocladium botrytis

Cultivation:

Czapek-Dox's agar of the usual composition was used as the cultivating medium.* In order to prepare spore suspensions, the medium was filled in 100 ml amounts into Erlenmeyer flasks, volume 500 ml. The inoculation was effected into the middle of the cultivating medium. The incubation period was 3 weeks at laboratory temperature. The spore suspension was obtained by adding 50 ml of sterile physiological solution with a trace of Tween 80. After thorough agitation, the liquid was filtered aseptically to obtain a homogeneous suspension. The density of the suspension was determined with the aid of a Bürker chamber.

Agar slants in test tubes, 16 × 160 mm, were used to test the effectiveness of the radiation. The incubation period was set at 7 days at laboratory temperature.

Method of Testing

The spore suspension in amounts of 0.1 ml was applied to strips of sterile Whatman 2 filtration paper, size 10 × 50 mm. After applying the suspension, the strips were dried for 2 days at laboratory temperature and, together with the check strip, were irradiated with doses of 200, 400, 600 and 800 krad. The strips were transferred individually to the agar slants and the culture growth or strip sterility were determined after the incubation period mentioned.

Results

The described method applied to cultures of *Aspergillus flavus*, *Aspergillus niger* and *Trichoderma viride* disclosed that a radiation dose of 600 krad was sufficient to achieve sterility of the contaminated filtration paper.

* Composition of Czapek-Dox agar:

NaNO ₃	3 g	FeSO ₄ · 7 H ₂ O	0,01 g
KH ₂ PO ₄	1 g	Sacharose	30 g
KCL	0,5 g	Agar	15 g
MgSO ₄ · 7 H ₂ O	0,5 g	Dest. H ₂ O	1000 ml

Table 1. Synergic effect of temperature and radiation.

Table 1. Effet synergétique de la température et des radiations.

Tabelle 1. Synergetischer Effekt von Temperatur und Strahlung.

°C	krad	1	2	3	4	5
20	200	0	0	0	+	+
20	600	0	0	0	0	0
45	200	0	0	0	0	+
45	600	0	0	0	0	0
60	200	0	0	0	0	+
60	600	0	0	0	0	0
80	200	0	0	0	0	0
80	800	0	0	0	0	0

Key:

0 - no growth

1 - test strain grows

2 - *Aspergillus flavus*

3 - *Chaetomium globosum*

4 - *Trichoderma viride*

5 - *Aspergillus niger*

The 600 krad dose did not prove lethal to spores of the *Ulocladium botrytis* species. It is possible that their resistance is due to their being multicellular.

A minimum dose of 800 krad was determined as the lethal dose for mildews. The combination of heat and radiation was applied tentatively to the species studied. The results are given in Table 1. At a temperature of 80°C a dose of 200 krad destroyed all the spores of the cultures involved.

2. EFFECT OF GAMMA RADIATION ON PAPER DEGRADATION

Three kinds of paper were chosen, the changes of whose physico-chemical properties due to radiation were investigated. The papers involved were:

a) Whatman no. 1 - chromatographic, pure cellulose

b) Rag paper - from the 1st half of the 19th century

c) Wood-free calendered paper - from the 2nd half of the 19th century.

The paper was irradiated with doses of 300, 500, 800, 1200, 1800 and 2600 krad. The following tests were adopted to test the degree of degradation of the paper:

a) Double-folding strength with a prestress of 1 kp pursuant to Czechoslovak

Table 2. Physico-chemical characteristics of irradiated paper.
 Table 2. Caractéristiques physico-chimiques des papiers irradiés.
 Tabelle 2. Physikalisch-chemische Eigenschaften von bestrahltem Papier.

Paper	Radiation dose (krad)	Double-folding strength (CsSt 500345)			
		longitudinal		transverse	
		0 days dh	3 days dh	0 days dh	3 days dh
Whatman	0	10.5	10.0	6.0	6.4
	300	13.9	12.1	8.3	7.6
	500	12.9	11.1	7.5	6.0
	800	12.8	10.8	7.3	6.3
	1200	11.5	7.6	6.8	4.8
	1800	12.0	6.8	6.4	4.2
	2600	12.9	7.0	6.0	6.4
Rag paper	0	22.2	17.0	11.7	8.5
	300	32.3	22.5	11.0	7.5
	500	15.9	19.2	9.3	7.8
	800	21.0	9.1	8.4	5.6
	1200	17.7	17.3	9.3	6.1
	1800	14.9	7.7	8.0	4.7
	2600	14.6	8.7	9.4	6.5
Wood-free calendered paper	0	20.9	23.1	11.5	11.0
	300	33.0	18.1	14.8	7.8
	500	35.7	11.2	14.0	10.1
	800	27.1	15.2	12.1	10.0
	1200	32.5	13.4	15.0	8.3
	1800	35.2	8.0	14.9	6.6
	2600	24.7	6.4	12.8	6.3

dh stands for dry heat at 103 °C – see headings of columns 3–6.

Standard 500345, instrument DOPPEL-FALZGERÄT, Messgeräte Leipzig, GDR – averages of 10 samples;

b) Tensile strength pursuant to Czechoslovak Standard 500340, Swedish instrument INSTRON, average of 20 samples;

c) Copper number – pursuant to Czechoslovak Standard 500275.

The properties of the paper were also investigated after accelerated aging (3 days of dry heat at 103°C). The results are presented in Tables 2–5.

Table 3. Physico-chemical characteristics of irradiated paper.
 Table 2. Caractéristiques physico-chimiques des papiers irradiés.
 Tabelle 3. Physikalisch-chemische Eigenschaften von bestrahltem Papier.

Paper	Radiation dose (krad)	Tensile strength (kNm ⁻¹) (CsSt 500340)			
		longitudinal		transverse	
		0 days dh	3 days dh	0 days dh	3 days dh
Whatman	0	2.440	1.997	1.440	1.350
	300	2.164	2.157	1.309	1.333
	500	2.074	2.100	0.964	1.273
	800	2.066	2.133	1.415	1.362
	1200	1.932	1.979	1.277	1.370
	1800	1.919	2.043	1.331	1.370
	2600	2.098	2.082	1.435	1.339
Rag paper	0	1.484	1.356	0.990	1.044
	300	1.419	1.390	0.907	0.998
	500	1.162	1.403	1.121	0.848
	800	1.374	1.392	0.829	0.771
	1200	1.122	1.176	0.829	0.859
	1800	1.422	1.189	1.166	0.770
	2600	0.892	1.206	0.543	0.791
Wood-free calendered paper	0	1.695	1.693	1.192	1.174
	300	1.862	1.532	1.200	1.189
	500	1.597	1.465	1.058	1.048
	800	1.194	1.796	1.690	1.283
	1200	1.728	1.250	1.011	1.103
	1800	1.600	1.130	1.098	0.908
	2600	1.600	1.100	0.981	0.896

dh stands for dry heat at 103°C – see headings of columns 3–6.

Results

a) The double-folding strength decreased with increasing radiation dose. At 800 krad the decrease is still not conspicuous. However, the decrease in double-folding strength becomes quite distinct after accelerated aging in all samples.

b) The tensile strength did not change conspicuously with any of the papers even after 3 days of accelerated aging.

Table 4. Physico-chemical characteristics of irradiated paper.
 Table 4. Caractéristiques physico-chimiques des papiers irradiés.
 Tabelle 4. Physikalisch-chemische Eigenschaften von bestrahltem Papier.

Paper	Radiation dose (krad)	Extensibility (%) (CsSt 500340)			
		longitudinal		transverse	
		0 days dh	3 days dh	0 days dh	3 days dh
Whatman	0	2.283	2.150	3.525	4.018
	300	2.180	2.175	3.260	3.670
	500	1.979	2.239	2.300	2.666
	800	2.062	1.879	2.943	3.453
	1200	2.283	2.082	3.019	2.954
	1800	1.934	1.818	3.735	2.505
	2600	1.685	1.563	3.602	2.777
Rag paper	0	3.508	3.336	4.401	4.029
	300	3.625	3.298	4.445	4.173
	500	3.481	2.821	4.189	4.179
	800	3.320	2.694	4.317	2.466
	1200	2.561	2.788	4.240	3.747
	1800	3.370	2.932	2.788	2.533
	2600	2.195	3.037	2.361	3.591
Wood-free calendered paper	0	2.106	1.796	3.353	2.644
	300	1.962	1.707	3.766	2.670
	500	1.635	1.402	2.610	2.766
	800	1.801	1.596	3.747	3.364
	1200	1.596	1.325	2.011	3.103
	1800	1.613	1.671	2.573	3.492
	2600	1.629	1.086	2.627	1.735

dh stands for dry heat at 103°C – see headings of columns 3–6.

c) The copper number increased with the radiation dose and after 3 days of dry heat this increase was even more conspicuous.

None of the quantities changed appreciably after the dose of 800 krad.

3. IRRADIATION OF AUTHENTIC MATERIAL

Two books (groundwood paper) were chosen; they were infected and sealed in

Table 5. Physico-chemical characteristics of irradiated paper.
 Table 5. Caractéristiques physico-chimiques des papiers irradiés.
 Tabelle 5. Physikalisch-chemische Eigenschaften von bestrahltem Papier.

Paper	Radiation dose (krad)	Copper number (CsSt 500275)	
		0 days dh	3 days dh
Whatman	0	0.49	0.97
	300	0.84	1.04
	500	0.81	1.33
	800	1.06	1.30
	1200	0.72	1.70
	1800	1.13	1.89
	2600	1.56	1.93
Rag paper	0	1.51	1.61
	300	2.07	1.97
	500	1.68	2.13
	800	2.52	2.36
	1200	2.20	2.30
	1800	2.13	2.74
	2600	2.42	3.13
Wood-free calendered paper	0	0.97	1.13
	300	1.10	1.49
	500	1.16	1.61
	800	1.03	1.55
	1200	1.52	2.13
	1800	1.71	2.45
	2600	1.94	2.45

dh stands for dry heat at 103°C – see headings of columns 3 and 4.

polyethylene bags. One book was irradiated with a dose of 800 krad, the second with a dose of 2000 krad. The books were placed in an air-conditioned cabinet for 3 months at a relative humidity of 100% and temperature of 30°C. No mildew was observed on either of the books after the test period.

CONCLUSION

1) A dose of 800 krad is lethal to mildew spores which usually occur in archive depositories.

2) This dose results in certain changes in the physico-chemical properties of the paper which are not, however, particularly conspicuous.

3) One must take into account that, after irradiation, certain reactions, whose effect will only be seen after a longer time following treatment, may take place.

One must realize that gamma radiation is lethal to mildews instantaneously, but has no long-term protective effect as compared to chemical disinfection. The treated document is easily infected on coming into contact with a contaminated medium.

Repeated radiation treatment for purposes of disinfection is not recommended. Since the effects of the individual doses add up, severe damage to the material after each further dose could follow.

SUMMARIES

Disinfection of Archive Documents by Ionizing Radiation

The effectiveness of disinfecting archive documents by using ionizing radiation was investigated. Test samples were used to test the changes of the physico-chemical properties of paper under different radiation doses.

It was found that a dose of 800 krad is sufficient to eradicate mildew spores occurring in archive depositories. This dose is responsible for a certain deterioration of the physico-chemical properties of the paper which, however, is not particularly conspicuous. One must bear in mind that, after irradiation, certain reactions may be triggered in the paper, the effects of which may be manifest only after a longer interval following treatment. Evidence of this is the deterioration of the properties of treated paper which occurred in the course of accelerated aging.

Désinfection des documents d'archives par radiations ionisantes

L'efficacité des opérations de désinfection des documents d'archives par radiations ionisantes a été étudiée. Des échantillons d'essai ont été utilisés pour noter les modifications des propriétés physico-chimiques du papier sous l'effet de doses différentes de radiations.

Une dose de 800 krad s'est avérée être suffisante pour éliminer les spores de mildiou présentes dans les magasins d'archives. Cette dose entraîne une certaine altération, quoique relativement faible, des propriétés physico-chimiques du papier.

Il convient de se rappeler qu'après irradiation certaines réactions peuvent être déclenchées dans le papier dont l'effet ne se manifestera seulement qu'à l'issue d'une longue période consécutive au traitement. L'évidence de ce phénomène est illustrée par l'altération des propriétés de papiers traités survenant durant le processus de vieillissement accéléré.

Desinfektion von Archiv-Dokumenten durch ionisierende Strahlung

Es ist untersucht worden, wie effektiv die Desinfektion von Archiv-Dokumenten mit Hilfe von ionisierender Strahlung durchgeführt werden kann. Durch den Vergleich von Testmustern, die

unterschiedlichen Strahlendosen ausgesetzt wurden, konnten die Veränderungen der physikalisch-chemischen Eigenschaften von Papier festgestellt werden.

Dabei ergab sich, dass eine Dosis von 800 Krad ausreichend ist, um Schimmelsporen, die in Aufbewahrungsräumen von Archiven Vorkommen, zu töten.

Diese Dosis führt auch zu einer gewissen Verschlechterung der physikalisch-chemischen Eigenschaften von Papier, die jedoch nicht besonders markant ist. Zu beachten ist dagegen, dass durch die Bestrahlung im Papier besondere Reaktionen ausgelöst werden können, deren Wirkungsbreite sich erst nach einem längeren Zeitraum nach der Behandlung zeigt. Ein Beweis dafür ist die Verschlechterung der Eigenschaften von behandeltem Papier, die sich bei der beschleunigten Alterung abzeichnete.

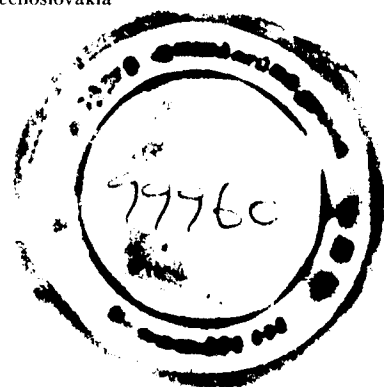
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