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THE PRESERVATION AND RESTORATION OF PAPER RECORDS AND BOOKS: A RAMP STUDY WITH GUIDELINES

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PREFACE

The Division of the General Information Programme of Unesco, in order to better meet the needs of Member States, particularly developing countries, in the specialized areas of records management and archives administration, has developed a long-term Records and Archives Management Programme - RAMP.

The basic elements of the RAMP programme reflect the current overall themes of the General Information Programme itself. RAMP thus includes projects, studies and other activities intended to:

1. promote the formulation of information policies and plans (national, regional and international);

2. promote and disseminate methods, norms and standards for information handling;

3. contribute to the development of information infrastructures;

4. contribute to the development of specialized information systems in the fields of education, culture and communication, and the natural and social sciences;

5. promote the training and education of specialists in and users of information.

The present study, carried out under a contract with the International Council on Archives, is for archivists and librarians, especially in developing countries. It makes a detailed review of the systems and principles relevant to the planning and implementation of a programme for the preservation and restoration of paper documents and books. Comments on the preliminary version of this study were requested from experts of the International Council of Archives, specialists in this field. This study contains the most recent results and experience in the field of archival research.

Comments and suggestions regarding this study are welcomed and should be addressed to the Division of the General Information Programme, UNESCO, 7 place de Fontenoy, 75700 Paris. Other studies prepared under the RAMP programme may also be obtained at the same address.

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INTRODUCTION

This study examines current methods of conserving paper records and books in archives and libraries. Reference is made to the fairly ample, if scattered, literature and the work of various laboratories, particularly that of the Centro Nacional de Conservación y Microfilmación Documental y Bibliográfica de España which has devoted its energy over the past 12 years to the conservation of this part of the national heritage.

In conservation as such, we distinguish two distinct but complementary areas: the first includes all methods designed to avoid the deterioration of records (preventive or preservative methods); the second involves the direct treatment of items that have suffered damage or deterioration (curative measures and restoration).

Ideally, conservation policy should include preventive measures that obviate the need for the second set of measures. 'Prevention is better than cure' applies to this part of our cultural heritage no less than to health.

Without doubt, the correct application of either method calls for accurate knowledge of the material and structural qualities of the support (paper), of the graphic elements sustained by it (inks) and of their behaviour over various periods of time.

Thus the study of the environmental (external) as well as the inherent (internal) causes and effects of the deterioration of paper is of great importance to the archivist.

Some of these topics are not treated as fully as others in this study. The characteristics of the supporting and the sustained media (paper and ink) and the causes of their deterioration will receive relatively brief attention and will largely serve as an introduction to the preventive and curative measures that make up the meat, the crux of this study.

Now, there is quantitative difference between preventive and curative methods and this paper focuses special attention on just one: the curative side. Its complexity and diversity are such, that there is still a great deal of uncertainty about it, not only among laymen but also among experts. The whole subject of restoration is in a state of constant flux, as technical and scientific innovations follow one another in quick succession. The preventive side, by contrast, is not only less controversial but also much less variable.

We hope that this study will be of use to all concerned with the preservation of records and books and especially to archivists and restorers.

CHAPTER 1

PAPER AS A SUPPORT

1.1 General

Paper is without doubt the most commonly used, if not the only, material of documents in archives and libraries.

Like other writing materials before it, it originated in China, where its birth is celebrated in legend, and it was brought to Spain and hence to the rest of Europe by the Arabs(1).

Paper is different from such earlier writing materials as papyrus (from which it probably derives its name) and parchment in that it is the result of a manufacturing process and bears little resemblance to the materials from which it is made.

There are no written accounts of the original manufacturing processes in the East or later in Europe, but the survival of craft techniques enables us to infer something about them.

In the East, paper was largely manufactured from rags of animal (silk) or vegetable origin (rice paper). Nowadays many papers made in Japan derive their names from the plants used to produce them (e.g. mitsumata - paper mulberry, gampi, kozo, etc.).

1.2 Paper in Europe

The first paper manufactured in Europe was made of vegetable fibre (linen, hemp and cotton). This method of preparation continued until the mid-nineteenth century, when a new base material, wood, caused a radical change.

Paper-making in Europe can therefore be divided into two main periods: the first when paper was made from rags and the second when paper was made from wood.

1.2.1 Paper from rags

This heading covers rags of various origin: linen and hemp in earlier times, cotton at a later period. In technological respects, we distinguish between handmade and machine-made rag paper.

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(1) The pages of the Mozarabic Missal from the Monastery of Santo Domingo de Silos are considered to be the first examples of European paper. The palaeographic characteristics of the text and the fact that the Mozarabic liturgy was abolished in Spain in 1080 during the papacy of Gregory VII show that the Missal must have been written before that date.

1.2.1.1 Handmade paper

This type of paper was used during the earlier phase. White rags were treated in paper mills (possibly in flour mills, as well) on the banks of rivers and converted into the new writing material. The process began with the sorting of rags, followed by the removal of dust, soaking, fermentation, bleaching, maceration and beating to separate the fibres into a pulp. This paste, diluted to a suitable consistency in large vats made of wood, stones or metal, was poured on to a linen fabric stretched on a wooden frame, later replaced by bamboo strips held together by silk threads and by metal mesh or wire cloth. When most of the water had filtered through, a thin layer of matter fibre was left on the fabric. It was dried, stripped from the fabric, cut to size and flattened, giving the first 'laid papers'.

Next, the sheets were sized and glazed to provide a smooth writing surface, impermeable enough for ink not to run. In earlier times, the size consisted of vegetable paste, but that was later replaced with animal glues. The size also lent the fibres greater coherence and gave the paper, when shaken, its crisp sound.

The quality of paper produced in this way depends on the skill with which the craftsman moves the form to obtain a uniform distribution of pulp.

Wire-mesh or wire-cloth moulds leave translucent lines on the paper, where it has received a smaller amount of pulp than the rest.

In response to growing demand, the number of paper mills gradually increased and manufacturers took increasing pride in the quality of their product by impressing it with a special sign. This imprint became known as the filigree or watermark. The oldest known watermarked paper is of Italian origin and dates from the thirteenth century.

It was also in Italy that animal glue was first substituted for vegetable glue and that hand-operated beaters were replaced by water-driven beaters, the latter leading to a much more satisfactory separation of the fibres in the rag pulp.

From the second half of the seventeenth century, water-beating mills began to be replaced with 'hollanders', tubs made of cast iron, in which a roll fitted with bars was made to revolve. The rags were driven round the tub by water and were macerated as the roll revolved over the bed-plate in the bottom of the tub. With this invention, paper production was greatly increased and paper refining considerably improved.

Composition

Paper obtained by this method is essentially composed of cellulose (almost the only material for book paper). The only additives are sizing glues of vegetable or animal origin and a small trace of alkali from the lime used in the pulp making process.

Cellulose is an organic substance consisting of one large molecule made up of smaller molecules of sugar (cellobiose or cellose), each of which is divided into two molecules of glucose. The cellulose molecule forms a long chain and the union of several such chains produces a fibre. The glucose molecule in turn is made up of six carbon atoms in a chain. Each carbon atom combines with atoms of oxygen and hydrogen (hydroxyls) into rings made up of five carbon atoms and one oxygen atom each. The water molecules incorporated in the pulp during the paper-making process form semi-chemical bonds with the hydroxyls, serving as bridges between the molecules of adjacent cellulose molecules (hydrogen bridges) and hence strengthening their long chains.

If the cellulose fibre becomes dehydrated, some of the hydrogen bridges disappear and the fibre contracts in width. Alternatively, if it is well hydrated, the fibre expands. An excess of water softens the fibre to the point of disintegration.

Paper is highly hygroscopic, absorbing or releasing water in step with the relative humidity of the atmosphere. Its surface dimensions vary according to the residual humidity of its fibres. Handmade paper expands and contracts almost exactly in proportion to its length and width.

Vegetable glue used in paper manufacture consists essentially of flour mixed with water. The main ingredient is starch, a carbohydrate present in most plants and in special form in cereals (rice contains the largest proportion in granular form). It is almost insoluble in cold water but the granules inflate in warm water to form a viscous substance that hardens on cooling and surrenders its moisture.

Animal glue is obtained by boiling the scraped bones or cartilage of animals. As with vegetable glue, the viscous substance (collagen) thus obtained hardens upon cooling and dries.

1.2.1.2 Machine-made paper

In the late eighteenth and early nineteenth centuries, mechanical systems began to replace the traditional moulds and opened the way for the manufacture of strips of paper of endless length. An endless wire cloth passes horizontally over a series of rolls across the vat containing the pulp, which is deposited on it in highly diluted form. The water then drains away through the wire cloth, helped by the back pressure of the rolls. Paper produced in this way is of very uniform thickness(1).

Endless paper differs from handmade paper in that its fibres are mainly aligned along the direction of travel in the machine, expanding and contracting sideways, which is an advantage.

Composition

Machine-made paper has the same components as handmade paper: cellulose and water. However, from the late seventeenth century onwards, the vegetable and animal sizes in it were complemented, if not replaced, by a chemical compound, namely alum. Then, in the eighteenth century, the growing demand for paper and a shortage of white rags, led to the increasing use of coloured rags in papermaking, their colour having first been removed by chlorination.

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(1) Towards the middle of the eighteenth century, the wire cloth was replaced with woven cloth, in response to the demand of printers who preferred paper with a smoother, more uniform surface. Such paper was first produced in England and was known as vellum paper because its texture resembled that of vellum or parchment.

Alum is a hydrated double salt of aluminium sulphate and potassium sulphate. It was first used for sizing at the end of the handmade paper period, when it served as a hardener of gelatine. At the beginning of the nineteenth century it came into more general use because, thanks to the mechanical sizing method invented by the German watchmaker Illig, the alum could be added to the pulp before it was moulded into sheets. This obviated the need for applying the final coat of gelatine by hand and made the production of paper much easier.

A solution of alum in water has a strong acid reaction, which destroys the alkaline reserve of the pulp and attacks the cellulose fibre before and during the production of the paper.

Chlorine compounds

Chlorine was isolated by the Swedish chemist Karl Wilhelm Scheele at the end of the eighteenth century. From then on, chlorine compounds have been used to bleach stained and coloured rags. Their use became even more widespread after the invention of machine-made paper.

As it is difficult to get rid of all traces of chlorine by washing the pulp, and as the oxidizing effect of the chemical is harmful to paper, machine-made paper from coloured rags has an inherent disadvantage.

1.2.2 Paper made from wood pulp (industrial production)

The growing demand for paper was difficult to satisfy with the traditional materials, that is, with rags.

The search for new sources resulted in the manufacture, in England, of very durable paper from esparto, a grass yielding slender cylindrical fibres.

However, it was Koller's discovery that wood could be used for papermaking that led finally and irreversibly to the replacement of rags with wood.

Logs, stripped of bark and cut up, became the basic material of paper in the middle of the nineteenth century. Depending on the methods used, the end product is paper made from mechanical pulp, from chemical pulp or from semi-chemical pulp.

1.2.2.1 Paper from mechanical pulp

In the production of mechanical pulp, the logs are first barked and then ground by pushing against large grindstones made of carborundum or other abrasive materials. By this process, the separate fibres of the wood are dissociated. These are then washed and drained in the hollander beater where the pulp-forming process takes place. At the same time chlorine bleach and alum-rosin based size are added.

Composition

Unlike rags, wood contains substances other than cellulose, among them hemicellulose, which is similar to cellulose in composition, lignin, resin, pectin, etc. None of these substances are removed during the production of mechanical paper which, because of the rough grinding process, has short and irregular fibres.

Rosin is obtained from turpentine. It renders water-resistant paper receptive to ink. Its use in sizes together with alum, which facilitates its adherence to fibres, largely accounts for the acidity of modern papers.

Lignin is a complex organic acid which surrounds and impregnates the cellulose fibres. Its function in plants is not fully known. Lignin is easily oxidized, highly polymerized and insoluble in water but can be removed by chemical processes.

The poor quality of mechanical pulp is due to the continued presence of chlorinating agents which have not been completely removed after the bleaching of the dark fibres, a process that improves their appearance but not their quality. Such paper is commonly used for newsprint, i.e. for media in which the urgent transmission of news is more important than the durability of the material.

1.2.2.2 Paper from chemical pulp

The cellulose in pulp obtained from wood could easily be as pure as that derived from rags if only it could be rid of extraneous matter. In 1863, B.C. Tilghman patented a process in the United States of America for converting wood into cellulose by cooking it with sulphite or lime under steam pressure. Mellun in France, C. Watt and others in England obtained cellulose by boiling wood shavings in a solution of caustic soda. Currently, the so-called sulphate process (usually involving a mixture of caustic soda and a sulphur compound) is the most widely used of all.

The caustic soda and sulphate processes are alkaline. The second, of German origin, produces a pulp known as 'Kraft' (strength), an indication of its quality. Its dark colour makes it unsuitable as a writing support, though bleaching can in fact make it fit for that purpose - at the cost of reduced durability.

The sulphite process, on the other hand, is of the acid type due to the presence of sulphur dioxide, and this is the case even when carbonates and other alkaline compounds are added as neutralizers.

Composition

Chemically treated cellulose is free from such substances as lignin. However the pulp is of poorer quality (as is mechanical pulp) because of the presence of alum, rosin and traces of chlorine.

1.2.2.3 Paper from semi-chemical pulp

For economic reasons, the above processes were rarely carried to the point of yielding pure cellulose pulp which would have meant the loss of a large percentage of basic material (wood). Instead a semi-chemical pulp was obtained by mechanical wood-splitting followed by chemical treatment.

Composition

Semi-chemical pulp is not as pure as chemical pulp but purer than mechanical pulp, having a smaller quantity of lignin and other non-cellulose matter.

1.2.2.4 Recycled paper

Paper can be obtained indirectly from wood in the form of recycled paper. The material is of poor quality, has a very low cellulose content, very short fibres and contains all the deleterious substances associated with wood.

1.2.2.5 Classification

Industrial paper-making processes produce many different types of paper, unlike the old rag-converting methods which yielded a much more homogeneous article. This diversity is due to the inclusion, during the refining stage, of various chemicals, dyes, pigments and varying amounts of water.

Of the different types of paper obtained as a result, we distinguish, besides newsprint and paper made of mechanical or semi-chemical pulp with a high percentage of lignin and recylced paper, paper that poses special conservation problems, namely coated art paper and more particularly sulphurized paper either of the vegetable type or of the so-called permanent/durable type.

Art paper. While various substances used to be added to the pulp for reasons of economy since paper used to be sold by weight, more recently there has been a growing demand for less adulterated or more special types of paper. One such is art paper coated with a mixture of China clay which fills the gaps between the fibres and gives the paper an opaqueness and a smooth, compact surface eminently suited for the printing of illustrations. This explains its use in luxury editions, art books and other texts whose main importance lies in their visual impact. Unfortunately, the fibre base of such paper is often of very low quality. The high solubility of the additives poses serious restoration problems, especially when the paper has been wetted and the pages have become stuck together.

Sulphurized vegetable paper. For many years before the advent of polyester paper, sulphurized vegetable paper was widely used for architectural and engineering drawings and plans. The transparency of this paper is due to the action of sulphuric acid on the cellulose fibres, which are almost completely broken up. The highly hygroscopic nature of the paper, due to the presence of the sulphuric acid, causes serious and irreversible deformation under damp conditions.

Permanent/durable paper. This type of paper, although made from wood, equals the quality of paper made from rags because of the resistance and length of its fibres and the slightly alkaline character of the pulp, resulting from the absence of acidic additives.

Permanence and durability are two prerequisites of sound preservation. The first refers to the ability of an object to maintain its original characteristics; the second to resistance to wear and tear. Permanence affects the material characteristics of the object; durability its function. Without permanence there can be no durability, and while it is possible to have permanence without durability, it is of little use to preserve something that, for lack of durability, cannot fulfil the function for which it was created.

Permanent/durable paper was first produced as a superior substitute for paper sized with alum-rosin, which lacks these qualities.

Almost at the same time as Illig invented machine sizing with alum-rosin, Sutermeister was able to show in the United States that paper made by Illig's process but with the addition of calcium carbonate, deteriorated much less quickly, the alkaline salts acting as buffers against attacks by acids.

The subsequent work of W. Barrow confirmed this hypothesis, and in the 1850s led to the industrial production of permanent/durable paper at first in the United States, and later in some European countries as well. The basic material for this paper is wood pulp of good quality and strong fibres treated with an adhesive made of synthetic resins instead of the traditional alum-rosin and containing carbonates as an alkali reserve.

Recent studies have shown that in the United States 25 per cent of all books are printed on paper of this type. The European percentage is very much lower; in any case, its use is confined to non-illustrated texts. All methods of dyeing, loading and coating paper involve the use of alum in acid suspensions, and the reconversion of the paper to an alkaline state costs more than the paper industry is, at present, willing to pay for the sake of more effective preservation.

For the rest, this type of paper is more often used for printed books than for archival records.

The conservation of the latter will not benefit substantially from the use of permanent/durable paper until it becomes more economical.

1.3 Paper from synthetic fibres

The depletion of our forestry stocks in the wake of the growing demand for paper has encouraged the search for alternative sources of supply.

First and foremost among them are the synthetic materials (plastics) discovered at the end of the last century. The oldest of these substances are cellulose nitrate used in the first rolls of film, cellulose acetate still used in cinematography and microfilming, and polyester. The last is of particular interest to us because of its adoption by cartographers, who have been using it in preference to vegetable or sulphurized paper since the fifties, and also because of various attempts to use it for illustrated texts.

Polyesters are thermoplastic resins obtained from the synthesis of polyacids and polyalcohols or glycols.

Polymerization is a chemical reaction that takes place at about 2000°C and as a result of which various molecules of low molecular weight (monomers) are combined into larger molecules or macromolecules known as polymers.

Because polyesters are stable in the presence of external degrading agents and also because of their physical strength, they may well be the paper of the future. However as they are petroleum by-products derivatives and as petroleum prices have gone up dramatically, research into their application to the printing of documents has been held back, their present use being confined to the printing of cartographic material and architectural or engineering plans.

CHAPTER 2

INKS, THE GRAPHIC ELEMENTS OF DOCUMENTS

2.1 General

The abstract nature of ideas and concepts has encouraged their graphic representation by means of more or less conventional symbols and characters on a medium more durable than the human voice or memory.

To that end, the material on which such symbols are recorded usually had its surface modified (modelling, engraving, cuneiform writing, raised dots of the Braille system etc.), by perforation (punched, cut and trimmed cards) or by the addition of extraneous matter or energy (inks, photo-sensitive layers) or magnetization and electrification (sound tracks, magnetic wires or tapes, etc.).

Of all this great variety, the graphic element most widely used is ink and we shall now turn our attention to it.

2.2 Inks

Inks are fluids or pastes used for writing, printing and drawing with the help of techniques and instruments appropriate to each of these activities.

Since ancient times, inks have been of three distinct types, namely vegetable, animal and mineral. The precise ingredients have varied considerably, especially during periods when their selection was based on trial and error. At present, except for those inks which are obtained directly from natural sources, the majority are mixtures or compounds whose quantitative and qualitative composition cannot always be specified even with the most advanced analytic techniques.

2.2.1 The composition of inks

The quality and properties of inks are determined by their constituents. Here we distinguish between basic and complementary ingredients.

2.2.1.1 Basic ingredients

Colouring matter. Pigments and dyes provide the characteristic colour of inks and can be of natural or synthetic origin.

Solvents. Solvents are fluids in which the ingredients of inks are dissolved and diluted. They ensure the smooth flow of ink over the writing material.

The most common solvents used in calligraphic and typographic inks are water and oil respectively.

Adhesives. Adhesives are substances that bind the colouring matter to the paper.

The most common are: gum arabic, Senegal gum, dextrin, sugar, molasses, shellac and starches, among the carbohydrates; gelatine, casein, albumen, fish glue and various synthetic substances among the proteins.

Mordants. Some inks contain mordants, chemical fixatives instead of adhesives with a mechanical action. These are usually acid compounds and are essential ingredients of the so-called metallo-acid inks.

2.2.1.2 Secondary ingredients

These are added to the ink to give it certain defined characteristics. Among the most common are: Thickeners. These are used to control the density of the ink (sodium carbonate, heavy spar, or white barium). Humidifiers. These are used to control the speed of the drying process and hence the binding properties and flexibility of the ink (glycerine, glycols). Antiseptics. These inhibit microbic activity (phenol, borax, mercuric bichloride, thymol, salicylic and boric acids, oil of cloves, thyme or lavender, alum, naphthol). Scents. These are substances that give ink a pleasant odour or reduce disagreeable smells (essence of musk, ambergris, terpineol). Brighteners. These add shine and lustre to ink (sugar, coffee, alum, rosin, shellac, beer). Penetrants. These facilitate the absorption of ink by the writing support (alcohol).

2.2.2 Classifiation of inks

Based on their respective uses, inks may be classified as follows: Writing inks. Used for manuscripts and typescripts. Printing inks. Used in printing processes. Lithographic inks. Used in art work. For purposes of conservation, we distinguish between stable and unstable inks.

Stable inks maintain their physico-chemical balance in spite of environmental fluctuations and are neutral with respect to the paper.

Unstable inks, by contrast, contain elements that, directly or indirectly, cause their own alteration or that of the paper.

It is worth stressing that certain inks known commercially as 'permanent' belong to the unstable group. For although they are permanent in contact with water, i.e. virtually insoluable, their chemical instability can have a corrosive effect on the paper causing serious and irreversible damage. In general such 'permanent' inks are of the metallo-acid type which we shall be examining below.

2.2.2.1 Writing inks

Although fluidity is a classical characteristic of all-writing inks, they vary in respect of viscosity, hardness, etc. as witness the inks in ball point pens which must be included in this section.

Among these inks, the most important are made of carbon, which is considered the oldest ink-making substance. Carbon-containing inks come in various forms depending on the source of the carbon (lampblack, vine shoots, bones, China, India).

They are the most stable inks because their basic colouring matter, carbon, is unchanged by acids or alkalis, light, water or microbiological agents. Their origins go back to the third millennium B.C. (China and Egypt).

Methods of production.

The oldest method of preparing ink was the incomplete combustion of organic matter, preferably resinous wood, which was then ground and mixed with the soot produced by the fire.

The resulting powder was mashed with various glues or gums, moulded into sticks and allowed to dry. The sticks were mixed with water to yield ink. On occasion, the ink was also obtained by dissolving the powder directly in water to which some adhesive had been added.

The quality of the ink depended on the fineness of the powder. The preferred system of obtaining high-quality inks was to collect the soot adhering to surfaces near a flame, for examples the sides of oil lamps.

This process was improved by the construction of special ovens or kilns in which the smoke produced by the slow combustion of selected materials was led through chimneys fitted with filters and small chambers, retaining particles of different size carried up with the smoke.

The fuel used was resinous spruce, vine shoots, grape skins (left after pressing), fruit pips and stones, ivory, bone, animal fats and vegetable oils, and more recently hydrocarbons and natural gas.

The most common adhesives used are gum, gelatine, rhinoceros horn, ox hooves and fish glue, etc. depending on time and place.

From the nineteenth century, a mordant was added to render erasure more difficult.

Sepia. Genuine sepia ink is an extract obtained from the molluse *Sepia officinalis* containing mineral and organic substances which are insoluble in water and not as commonly believed the blackish secretion of certain cephalopods (cuttlefish, squid, etc.), which despite its inky characteristics is not suitable for use as an ink. It is prepared by diluting the extract in acid, followed by neutralization, and further dilution in a mixture of water and adhesive.

This ink is less stable than carbon-based ink, reacts with chlorine which turns it orange and is not fast to light.

Bistre. Bistre is made by boiling the soot of wood and has a brownish-yellow colour. It is of inferior quality to ink made from lampblack even though its components are similar. It is not fast to light.

Metallo-acid inks comprise all inks containing a colour made up of a metal and an acid. The latter acts as a combined oxidizing agent and mordant, that is, as a substance with the ability to fix colours. Examples are inks containing gallic acid, logwood, alizarin and vanadium.

Ferro-gallic inks. All iron gall inks contain an acid compound and an iron salt.

The oldest description of such inks was given by Pliny (first century) who has described the method of preparation and the resulting intensely black liquid, widely used by the Romans.

At one time, the acid compound (tannic acid) was obtained by boiling oak galls in hot water, and the iron salt (ferrous sulphate) by the action of sulphuric acid on iron.

A mixture of iron sulphate and tannin produces a ferrous tannin that has little colour and hence does not yield a high-quality ink. However its colour gradually improves as the ferrous tannin is transformed into ferric tannin by the action of atmospheric oxygen and turns dark brown. Usually lampblack is added as well.

Another characteristic of these inks is that they do not need adhesives because they are fixed to the writing material, not by a binding substance, but by the chemical action of the mordant, in this case, an acid compound. However, they normally contain a thickener to increase the density of the ink and reduce the settling out of the insoluable ink particles. Commercially these inks are called 'permanent', which simply refers to the fact that, not being soluble in water, they cannot be washed away. For the rest, they are chemically unstable and responsible for a great deal of damage.

That damage is largely caused by the acid which reacts with the ferrous sulphate to produce sulphuric acid and corrodes the paper. Though the sulphuric acid can be partly neutralized by the alkaline components of the paper or by the other components of the ink, it does produce strips of damaged paper and later causes damage to surronding areas a well.

This destructive effect is increased by the presence of iron which, in addition to damaging cellulose by oxidation, has a catalytic effect on atmospheric sulphur dioxide. The latter readily combines with atmospheric moisture to form sulphuric acid.

Thus both the content of the ink and the catalytic effect of the iron render it highly acidic, and this in proportion to the amount of acid and iron originally present in it.

Hence ink, which is a fundamental component of written and printed documents, is also a cause of their deterioration.

Ink made from logwood [Haematoxylon campechianum]. H. campechianum is a leguminous tree (family: Papilionaceae) with heavy reddish-brown wood that yields the dye haematoxylin upon boiling. The latter becomes oxidized into haematin, and makes an excellent ink.

The boiled logwood has a reddish colour which can be changed to blue-black by the addition of various salts.

In general, logwood fades when exposed to light or to bleaching agents. By nature it is acidic, easily oxidized and water-resistant like other metallo-acids.

Ink made from alizarin. Alizarin is a red dye derived from Rubia tinctorum (madder) and should not be confused with the ink synthesized by Leonhardi in 1856 from indigo, to which he gave the name 'Alizarin'.

The difference between ink made from alizarin and ferrogallic ink is that in the latter the colour comes from a fine powder dispersed in a suspension by a thickener, while the colour in alizarin inks, which also have an iron tannate base, is kept in solution by the addition of an acid that keeps the ferrous salt diluted until it becomes oxidized on paper into ferric salt. As a result the originally greenish-grey colour is changed into black.

Ink made from vanadium. In 1832, Berzelius suggested the substitution of vanadium for iron in tannic inks, because ammonium vanadate in acid solution produces a particularly deep black colour.

These inks are unaffected by acids, alkalis and chlorine unless these are newly applied. In the presence of alkalis they turn yellow; with chlorine, bromide and potassium permanganate they lose some but by no means all intensity. They have a corrosive effect on paper by virtue of their acid content.

Aniline inks. Aniline is an oily liquid, moderately soluable in water and obtained by the reduction of nitrobenzene derived from coal or coal tar, although in the past it used to be derived from indigo. It is toxic, colourless when freshly made and turns a dark yellow in the presence of oxygen.

It came into general use as a base for synthetic or artificial dyes in 1856 with the advent of fuchsines, dyestuffs that dissolve in water to form violet, and Bismarck-brown solutions.

Most aniline inks are covered by industrial patents so that their precise composition is not known. Their common additives are water, alcohol, glycerine, gum arabic, alum, phenyl, oxalic, tartaric, salicylic and sulphuric acids, sodium sulphate, sodium chloride, sodium carbonate, disodium phosphate, dextrin, urea and traditional adhesives.

Early aniline inks were very sensitive to exposure to light and air. The higher quality of the modern varieties gives them greater strength and stability.

Identification of aniline-based inks is facilitated by the fact that, unlike other tar derivatives, they turn black on calcination. They are easily attacked by chemical agents, lack durability and are generally neutral.

Typewriter ribbon inks. These inks are solutions of dyes and pigments in water to which various wetting agents have been added.

Colouring matter: lampblack, aniline (violet: methyl violet; blue: methyl blue; red: aniline red, powdered cochineal).

Wetting agents: glycerine, castor oil, vaseline, linseed oil, wax.

Solvents: alcohol, water, organic solvents.

Mordants: acetic acid (in very small quantities).

These inks are very similar to printing inks and carbon-paper inks.

Carbon-paper inks. These inks are emulsions or coatings on special paper.

Colouring matter: lampblack, aniline.

Additives: wax, glycerine, molasses, glucose, linseed oil, vaseline.

Very unstable in light.

Ballpoint pen inks. These inks consist of aniline dispersed in oils, resins, etc. They are soluble in alcohol, glycol and organic solvents, and lack penetrating power.

Labelling inks. These inks are made of aniline dispersed in alcohol. They are soluble in glycol.

Fountain pen inks are usually made of aniline, and free of iron salts that could damage the pen by oxidization. They are soluble in water and bleach, and their colour is very fast to light.

Duplicating (stencilling) inks are made from saturated or unsaturated hydrocarbons of suitable viscosity.

Stamping pad inks are made from aniline (methyl violet, fuchsine, nigrosine) dispersed in glycerine, alcohol, acetic acid, water, castor oil, cod liver oil, turpentine or linseed oil.

2.2.2.2 Printing inks

Printing inks differ from writing inks in that they contain a varnish instead of the aqueous solvent.

This varnish differs from the household variety in that it serves as a vehicle for transferring the colouring matter to the paper. It used to be obtained from boiled, thinned and purified linseed oil but is now usually prepared with synthetic resins. The first printing inks were based on other vegetable oils, especially walnut.

The combination of varnish with various solvents, drying and setting agents determines the type of ink, each ink being of distinct viscosity, penetrating power, drying rate, stability, etc.

There is a variety of inks to meet a variety of printing needs, styles and applications. They can be broadly divided into:

Letterpress inks. These are divided into inks for newspapers and those for better quality printing. The first use low-quality ingredients which satisfy the short life-expectancy of this medium of communication. The main vehicles are mineral oils and resins to which are added fast-acting drying agents appropriate to the absorbing power of newsprint. The main constituents are carbon black, lampblack, animal charcoal and soot, and the commonest additives are rosin and coal tar. Typographic inks for use on engraved or other high-quality printing not only contain more carefully selected colouring materials but also highly refined linseed oil varnishes. The preferred additives are rosin and molasses.

Inks for colour work are made with natural or synthetic pigments, soluble in water, thickened with glycerine, and mixed with adhesives (dextrin, gum arabic, etc.).

Lithographic and zincographic inks. These inks include lampblack dispersed in linseed oil to which a greasy substance has been added in order to reduce the adhesion of this ink to the stone or metal plates. Wax, animal fat, grease, olive oil, etc., are commonly used. Mastic or putty and lacquer are added for greater body.

The same substances are also used to make lithographic pencils used for drawing on stone and for tempering the 'mordant' effect of acid on metal.

Photo-engraving inks. Inks used in photogravure differ from lithographic inks in that they include an aromatic compound, generally benzol. Occasionally this solvent is replaced with water, alcohol or vegetable oil.

Offset inks. These inks include a linseed varnish base, a very fast drying agent and a solvent that makes them free-flowing and quick-drying.

Softground etching inks differ slightly from typographic inks. The linseed or nut-oil varnish is boiled less intensively so as to obtain a clear, strong and greasy ink.

The most common colouring materials are Frankfurt black (wine sediment), peach black (peach stones) and German black (mixture of the preceding but not thinned).

2.2.2.3 Coloured inks

The enormous variety of these inks makes it difficult to describe them in detail so that we must confine ourselves to the basic colouring materials and other points of special interest.

The complexity of the mixtures, tones, intensities, etc. is such that it is impossible to quote authors, works, periods, etc.

The introduction of synthetic colours and especially of aniline dyes, greatly complicates their direct identification, particularly as many components are patented. Their chemical structure is nevertheless identifiable by analysis.

Among the most common traditional and modern inks or pigments, we distinguish:

Black

from charred animal bones (ivory black; antiquity);

from carbon and smoke, similar to the writing inks described earlier, but of varying degrees of liquidity and viscosity (antiquity);

from graphite, an allotropic form of carbon but of a less shiny greyish-black (metallic) colour;

from aniline dyes made of nigrosins and indophenines.

Red

from iron oxide also known as red ochre (antiquity);

from cinnabar, a sulphide of mercury very stable at higher temperature but darkened by light (antiquity);

from lead oxide, also known as minium or red lead. Reacts with hydrogen sulphide and acids. Not very fast to light (first century);

from Tyrean purple obtained from marine gastropods of the genus Murex (antiquity);

from cochineal, a crimson substance obtained from the crushed bodies of cochineal insects. Not fast to light; soluble in ammonia (fifteenth century);

from vermilion or mercuric sulphide. Turns black in light and reacts with acids (antiquity);

from alizarin, also known as red madder, obtained from the root of the madder. Soluble in ammonia;

from chrome derived from lead chromate. Reacts with acids;

from aniline dyes, eosin, erythrosin, cyanosin, etc.

White

from white lead (cerussite or lead carbonate). Darkened by hydrogen sulphide and bleaching powder. Turns yellow when heated (antiquity).

from gypsum (hydrated calcium sulphate);

from talc (hydrated magnesium silicate);

from chalk (calcium carbonate);

from kaolin (hydrated silicate of aluminium);

from titanium (titanium dioxide) (1920);

from zinc (zinc oxide and zinc sulphate); reacts with acid (1832);

from lithopone prepared by the coprecipitation of zinc sulphide and barium sulphate (1874).

Yellow

from chrome (lead chromate); unstable in light and acid;

from barium (barium chromate) (1809);

from cadmium (cadmium sulphide); reacts with acids and moisutre (1829);

from cobalt (potassium cobalt-nitrate) (1861);

from zinc (zinc chromate); reacts with acids (1850);

Indian yellow. A calcium or magnesium salt derived from xanthic acid. Discovered in 1400 in Persia whence it passed to India. Used in oriental miniatures.

from aniline, methanol, benzidine, etc.

Blue

from blue pigment obtained from lapis-lazuli (antiquity);

from Egyptian blue. A compound of copper. Reacts with acids (antiquity);

from azurite. A hydrated basic copper carbonate (antiquity);

from indigo, extracted from the stems and leaves of the leguminous plant Indigofera tinctoria. Of Indian origin. The Romans called it indicum (antiquity);

from Prussian blue derived from ferrocyanides. Sensitive to light and alkali (1710);

from cobalt (cobalt aluminate). Insoluble in acids and alkalis. Fast to light (1802);

from cerulean, obtained from cobalt stannate. Not fast to light, but cerulean obtained from cobalt oxide and alumina is stable in the presence of acids, bases and light. Short-lived (1860);

from aniline, induline, metaphenylene, benzole, italocyanine.

Green

from basic copper carbonate. Is turned black by hydrogen sulphide and discoloured by alkali (antiquity);

from chrome. Various types from hydrated or dehydrated chrome oxide and lead chromate. Reacts with acids (1862);

from cobalt, zinc oxide and cobalt protoxide (1780);

from emerald (copper aceto-arsenate). Sensitive to light and moisutre (1860);

from verdigris (basic copper acetate). Very corrosive and toxic.

Gold

from gold powder dispersed in wine and gum arabic or albumen. Also prepared in a mixture of walnut oil, salts, vinegar, gum arabic, cresilic and sulphuric acids, borax and alcohol;

from gold purpurite. Bronze, copper or brass in a mixture of potassium iodide, lead acetate and lead iodide.

Silver

from silver powder dispersed in the same substances as gold powder;

from silver purpurite. Prepared from tin, mercury, aluminium, magnesium or zinc. Additives: honey, gum arabic.

CHAPTER 3

CAUSES AND EFFECTS OF DETERIORATION

3.1 General

Paper conservation is a complex subject; it involves many factors and structural changes cannot always be assigned to specific causes because destructive analytical tests are, of course, ruled out. Besides, different causes can produce similar effects, while different effects can sometimes be produced by similar causes.

The deterioration and destruction of paper can be caused by inherent (internal) or by environmental (external) factors of a physical, chemical or biological nature. They may act jointly or severally, regularly or sporadically (during floods, fires, wars, earthquakes and other catastrophes).

In each case the deterioration is increased by factors that a determined preventive policy could largely have eliminated (we cannot, of course, eliminate the material nature of the object we intend to preserve and without which there would be nothing to deteriorate).

It is impossible to fit the causes of deterioration into neat compartments: all internal causes and symptoms can be reinforced by the simultaneous action of external causes and symptoms and vice versa.

The ultimate proof of the presence of a cause of deterioration is the appearance of its effects on the paper. Quite often, the cause or causes can be determined by direct inspection.

The conventional system of classification distinguishes between generalized and local or limited effects.

The first, without doubt the more serious, affect the whole or nearly the whole of the paper because they attack the structure of its basic constitutents. The effect of the second are limited to specific areas and not to the overall structure of the paper.

3.2 Internal causes of deterioration

These causes reside in the natural properties of paper and the substances (additives) used to convert it into pulp.

Deterioration can also be caused by occasional factors to which paper may be exposed during the manufacturing process (impure water, oxidation of metals, etc.).

The oxidation of some inks is another internal cause that cannot be dissociated from the paper and that may cause irreparable damage.

Attachments and special formats needed to store documents and books in libraries are further internal factors that may have a deleterious effect on their conservation.

3.2.1 Natural properties

Handmade paper obtained from rags will not, as we saw when we examined its composition, deteriorate from inherent causes but is subject to the destructive action of external agents.

Occasional factors triggering local effects can, in certain cases, act as catalysts for further destructive processes.

Quite different is the behaviour of paper containing lignin or such additives and sizes as alum, rosin chloride, bleaches, disintegrating products of an acid character, etc.

All these additives, reinforced by external agents, may cause acid reactions that generally tend to break up (hydrolize) the cellulose chains and hence to reduce the mechanical strength of paper, as can be demonstrated by folding endurance and tear resistance tests. The oxidation of lignin and rosin will, moreover, cause the paper to turn yellow.

Recent studies, although still in an experimental stage, have shown that the fragility of paper must be attributed not only to loss of resistance in fibres following the break-up of cellulose chains, but also to changes in inter-fibre linkages and the increased crystallization of the fibre walls(1).

Acidity or the chemical activity of an acid (the most active of all acids being sulphuric acid) is the most serious cause of deterioration and particularly affects paper made from wood pulp. W. Barrow's methods of identification and correction constitute an important landmark and, during the fifties, when they were first presented, opened up new and more effective paths in paper-conservation methodology.

The acidity of paper, like that of other materials, is expressed in terms of the concentration of hydrogen ions (pH), which can be read off from a pH meter with a scale from 1 to 14, the first figure indicating maximum acidity and the second the highest degree of alkalinity, the neutral state having pH 7. For purposes of conservation, the logarithmic nature of this scale is particularly useful when it comes to measuring very small differences in acidity.

Acidity is a mobile and hence a contagious state. Thus if neutral paper or paper with an alkaline reserve is brought into contact with paper that is acidic or protected by a container with acidic characteristics, it will turn acidic in its turn.

The effects of acids are hard to detect in time; often they do not become obvious until the paper has reached a point where it will crumble at the slightest pressure.

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(1) A. Koura and T. Krause: Effect of altering fiber and sheet on the durability of paper. A new method for conservation and restoration of paper.

3.2.2 Inks

Inks are internal elements, inseparable from the paper, and occasionally the causes of its deterioration. For the rest, they provide the graphic component without which paper would have no bibliographic or documentary value.

Under the heading of harmful inks we can combine all those we have defined as metallo-acids.

The acid component used as a mordant to fix the ink to the salt whose metallic component acts as a catalyst, liberates sulphuric acid, that is an acid with the greatest corrosive effect of all. As a result the ink 'bites' the paper to the point of piercing it, burning up whole lines and pages of text. Even adjacent blank sheets can become contaminated.

Similar effects may be caused by verdigris ink which is used for maps and plans. Its oxidizing action is second to none, even though it causes less damage since it is confined to drawings rather than whole pages of written text.

Corrosive inks may have a more or less general effect on a sheet or sheets of printed paper. It is not uncommon to find works in archives and libraries in which the only usefully conserved parts are the blank margins, the text having been destroyed or converted into a blackish carbonized mass which crumbles into dust on the slightest movement of the sheet.

3.2.3 Accessories and special formats

Accessories that are not easily separable such as seals, bindings, fastenings, although not causing general harm to a document or book can produce local damage (spots, tears, cuts, etc.).

The abnormal format of such documents as maps, plans, large volumes, may cause storage and handling problems and may therefore be another internal factor with adverse effects on conservation.

3.3 External causes of deterioration

Obviously, it we could keep our documents, especially those in a fragile condition, untouched, in an inert atmosphere and with controlled lighting, conservation would pose no problem to the archivist and librarian.

However, such conditions exist so rarely that we can safely ignore them. It could not be otherwise. Books are there to be read, moved and handled. They are not like museum pieces. Their conservation must be based, not on static, but on dynamic considerations, and these inevitably involve deterioration and destruction.

External causes of alteration are due to normal, natural or everyday events that fall into four large groups: mechanical, environmental, chemical and biological, or else to extraordinary circumstances such as fire, earthquake, flood, war, etc.

Whatever the original cause, it is usually complemented with others, be they internal or external. For that reason our division into groups is not quite straightforward and should merely be considered an attempt to put some order into the complex subject of conservation. Hence when we call the large shape or bulk of a map or book an intrinsic cause of alteration, it should be understood that damage could equally well be caused by such external factors as the friction produced by moving a book from its shelf or the dimensions of a filing cabinet which make it necessary to fold a map and so forth. Moreover, the effects of one cause can, and in fact do, produce a whole chain of effects.

The various causes of deterioration do not therefore act independently. Irrespective of their origin, all have a damaging effect on documents, reducing their mechanical resistance to tearing, folding, stretching, etc. and hence their permanence and durability.

3.3.1 Mechanical causes of deterioration

These causes include manipulation, defective storage, knocks, friction, compression by studs and other metallic binding items, etc. The result could be the ripping of sheets, the appearance of greasy fingermarks when a document is in frequent use, the tearing of the edges of a sheet clamped down too tightly or in too small a cover, the fracture of a binding through the continual opening and shutting of a book in the course of reading, photocopying, etc. All these are occasional causes of localized deterioration.

3.3.2 Physical causes of deterioration

These causes are related to the climate, or more precisely, the microclimate in which books and documents are kept. There are three basic environmental factors affecting paper conservation: humidity, temperature and light.

3.3.2.1 Humidity/temperature

In general, humidity is the amount of water contained in the atmosphere. In this book, we refer to it in terms of relative humidity, that is the mass of water vapour present in the air (absolute humidity) expressed as a percentage of the mass that would be present in an equal volume of saturated air at the same temperature. As the temperature rises, so the mass of water needed to saturate a fixed volume of air rises as well, with the result that the relative humidity is greatly reduced. On the other hand low temperatures reduce the saturation point and consequently increase the relative humidity of the atmosphere. A rapid fall in temperature can cause a loss of water from the atmosphere, because its saturation point has been lowered. The result is condensation and the formation of drops of water.

As we have said earlier, paper needs a certain amount of humidity if the cellulose fibres are to retain their flexibility. Excess humidity causes decomposition through hydrolysis, aids the formation of sulphuric, hydrochloric and other acids derived from salts and othe products used in paper production or ink making, and softens the sizes and glues of bindings. The combination of a high relative humidity and a high temperature encourages the spread of micro-organisms (fungi, bacteria) and insects harmful to paper. A dry atmosphere will rob the paper of moisture thus reducing the interfiber links and render the cellulose more fragile. Dryness and high temperature are two factors accelerating the natural ageing of paper and causing the cracking of adhesives.

Sudden and continual changes in temperature and relative humidity which are practically inseparable, subject paper to great tensile and compressive strains and destroy its structural links.

3.3.2.2 Light

Light poses no problems to the conservation of paper, provided its intensity is kept within bounds. Moreover light has a deleterious effect on certain harmful micro-organisms and insects. Excessive exposure to light and above all some radiations are nevertheless important causes of the deterioration of documents and books.

Sunlight is made up of visible as well as of invisible rays (infra-red and ultra-violet) the last being the most harmful to documents.

Ultra-violet rays have a short wavelength. Given that the speed of light is constant and a product of the wavelength and the frequency, the shorter the former the greater is the latter and hence the energy of the emission. When light meets an object, that object absorbs part of the light energy, and the resulting chemical reaction (photolysis) changes its molecular structure, above all if the object is an organic compound. Light discolours inks and acts on the ingredients and impurities of paper by setting of photo-mechanical reactions and oxidation. The products of this reaction weaken cellulose by rupturing its molecular chains. Light has a bleaching effect on good quality paper, but turns paper containing lignin yellow and then darker.

In terms of the ultra-violet radiation it contains, the most harmful light is sunlight, fluorescent light, and incandescent light, in that order.

Unlike humidity and temperature, light has no harmful effect on documents stored in files, boxes, folders and bindings.

3.3.3 Chemical causes of deterioration in the atmosphere

In addition to water which determines its humidity, the atmosphere contains a series of chemical elements such as oxygen, nitrogen, ozone and carbon dioxide. These elements are responsible for the combustion, fermentation, hydrolysis and the oxidation of books and documents. As they sustain life on our planet, they cannot be kept out of archives and libraries.

The atmosphere, especially of industrialized zones, also contains a series of impurities (the results of pollution or contamination) which undoubtedly do the greatest harm to documents.

Of these, we need merely mention carbon dioxide, nitrogen dioxide and, above all, sulphur dioxide, by-products of industrial combustion which, catalysed by metals, react with water to form acids. The most important of these is sulphuric acid. We have mentioned its effect as an internal contaminant of paper; when its source is external, its effect can be highly localized. Thus our libraries contain many books whose paper has turned dark and fragile at the edges, that is, in those areas not protected by the binding while the protected inner areas seem to be perfect. Rag paper, though it has no internal acid-producing elements is no less susceptible to attack by sulphuric acid in the environment.

The atmosphere also contains aerosols, small solid particles (dust) of various origins (spores of micro-organisms, carbon, metal fragments, salt in maritime areas) which have abrasive, catalytic and biological contaminating effects on paper.

3.3.4 Biological factors

Many biological factors affect the conservation of documents, human intervention being just one of them. Rodents, insects, fungi and bacteria leave the most obvious tell-tale marks.

3.3.4.1 Rodents

Rodents have a destructive mechanical effect on paper. They tend to live in old buildings and there is a large number of poisons to exterminate them.

3.3.4.2 Bibliophagous insects

This term covers some hundred book-consuming species, all of which infest archives and libraries. They can be divided into two main groups: regular and occasional residents. The first feed mainly on paper (cellulose, paste, glue); the second are xylophagous, that is, feed mainly on wood, but may also attack paper.

The life cycle of a normal insect consists of several distinct stages: egg, larva, pupa or nymph, and adult. The greatest damage is done at the larval stage, which is when most of the perforations in paper are made.

The presence and growth of all insects is encouraged by a warm and humid environment, darkness and poor ventilation.

Cockroaches, voracious nocturnal insects of the suborder Blattaria feed on vegetable and animal matter (paper, leather, parchment). They produce a blackish excrement which leaves stains.

The silver fish is a small wingless insect of the genus Lepisma. It lives mainly on paste, glue and photographic gelatine, and lays its eggs in dark places, e.g. in the cracks of bindings.

'Bookworm' is a very apt generic name for the larvae of many bibliophagous insects. The adults lay their eggs fairly near the surface of books which the larvae then pierce, secreting a gummy substance that sticks sheets of paper together. They also excrete a finer substance which can be found covering the shelves of contaminated books. The pupae emerge from the shelves as adults, and the life cycle then starts all over again.

Beetles, insects of the order Coleoptera are counted among the bookworms and are common inhabitants of archives and libraries in humid of temperate zones (e.g. the Mediterranean). Under adverse conditions, they are capable of living as pupae for many years.

Booklice of the order Psocoptera are tiny insects which lay their eggs on or in the spines of books. They are almost omnivorous, but feed particularly on pastes, glues and paper-infesting fungi. The larvae and adults hardly differ in appearance, except that the adults are a somewhat brighter colour.

Termites merit our special attention. They are xylophagous and capable of destroying the woodwork of buildings (beams, shelving units) no less than the documents and books inside. These isopterous insects, also known as white ants, although they are neither white nor look like ants, are common in tropical countries where they are a real scourge. Some species also occur in temperate zones. All avoid the light and like warmth and humidity. They are highly social insects: the winged king and queen are responsible for the reproduction of the species; the asexual workers, which alone are capable of digesting cellulose, feed the rest of the colony and guard the nests of the young larvae; the soldiers, also asexual, are responsible for the defence of the colony. They dig passageways through the timbers and thence proceed into books and papers. Termites breed prolifically, the queen being capable of laying an egg every two seconds.

Termites cannot tolerate fluctuations in humidity or temperature; a drop in either can kill off a whole colony. However, they have their own defence mechanism: workers responsible for transporting water from underground levels maintain the necessary degree of humidity, which is very near to saturation point. A uniform temperature level is maintained by the termites' own body heat, while veritable 'plantations' of fungi throughout the colony act as additional sources of heat.

The dark conditions in which they operate often makes it difficult to detect the presence of termites before they have done irreparable damage: hollow beams, books that are no more than paste ...

3.3.4.3 Micro-organisms

For our purposes, micro-organisms can be divided into two groups: fungi and bacteria. Both infest documents and books.

Fungi. Fungi are cryptogamous plants, i.e. plants that do not produce seeds. Some live on inert organic matter and are said to be sacrophagous. Others feed on living matter and are said to be parasitic; a third group lives together with their hosts to the benefit of both (symbiosis).

All fungi reproduce their kind by means of spores, which germinate to give rise to a mass of branching filaments (mycelia) with a cellular structure.

Among cellulose-attacking fungi, the most common are Aspergillus (yellow or black) and Penicillium.

Bacteria. Bacteria are primitive, unicellular organisms that multiply very rapidly. Their spore-like structure enables them to survive even in unfavourable conditions. We distinguish between aerobic and anaerobic bacteria; the latter, through their enzymatic activity, are often used in industrial fermentation processes. The most abundant genus is that of the bacilli (Bacillus cereus, Bacillus circulans, Bacillus subtilis).

Mottling or foxing. Papers and books in our archives and libraries are often covered in brown specks, whose origin is not fully understood. Their presence is generally attributed to an as yet unidentified micro-organism which releases organic acids that react chemically with metallic impurities (iron, copper, etc.) in the paper. What is certain, is that the appearance of such specks requires less extreme conditions of humidity and temperature than is demanded by other micro-organisms.

The seriousness of the damage caused by insects depends on the degree of infestation and is reflected in the number of perforations in the paper. On the other hand, insects do not set off chemical reactions that may alter the structure of paper. Insects generally attack paper of good quality, that is rag paper and neutral or alkaline paper.

It is quite common to find 'corroded' documents in archives and libraries. This damage is due to the oxidizing effect of metallo-gallic inks on documents subsequently attacked by insects in just the (blank) margins. Papers made from wood pulp is not usually attacked by insects, and it is often possible to determine the quality of paper by the amount of insect activity on it. This is no consolation of course, just a demonstration that nothing is safe from the risk of destruction: the only thing that varies is the cause.

The action of micro-organisms (fungi and bacteria) leads to weakening of the paper in the affected areas, which begin to look woolly and eventually crumble away, while pigments produced by the various micro-organisms leave marks ranging from deep black to white, through red, violet and brown. Some micro-organisms also attack inks, causing discoloration.

Micro-organisms have a phyiscal and, on occasion, a chemical effect on paper. The cellulose becomes weakened, although the paper may retain its folding endurance, unlike paper attacked by acids. The degree of pigmentation is not a measure of infestation: some micro-organisms do not produce pigments, which explains why their presence may remain undetected until the damage they cause become irreversible.

3.3.5 Extraordinary (catastrophic) causes

The destruction of documents by catastrophes is a very serious and spectacular matter. Floods and fires are among the most dramatic of these causes, and the damage they produce is often compounded by the means and methods used to combat them.

This explains, inter alia, why more and more countries have drawn up contingency plans to cope with situations of this type.

3.3.5.1 Floods

The flooding of the Arno in Florence and of the Po in Venice in 1966, which affected archives and libraries in both cities, and the flooding of the Tagus in Lisbon in 1967 which damaged the treasures of the Gulbenkian Foundation, show how great the need for appropriate countermeasures has become, the more so as the experience gained from the first two disasters helped to avoid grave errors during the second. Beyond that, the response to these tragic events has given proof of international solidarity and has led to spectacular advances in restoration methods.

Minor inundations, too (burst pipes, blocked gutters, leaks, etc.) can cause serious if less extensive damage.

The main effects of flooding on books and documents are the running of inks, the caking and crumbling of sheets of paper, the disintegration of adhesives, the discolouring and collapse of bindings, the appearance of spots and stains due to mud or any other matter the water may leave behind. Later, if the salvage operation is not run properly, or the number of documents and books is too large for immediate treatment, the growth of fungi may be encouraged by the humid atmosphere and the sudden rises in temperature resulting from attempts to speed the drying process. This biological risk can be avoided by freeze-drying (lyophilization), a method increasingly used during recent years.

3.3.5.2 Fires

Fire is an ancient scourge of archives and libraries as well as of other buildings constructed of or containing combustible material. Early electrical wiring methods greatly increased this risk, so much so that many countries have passed special legislation concerning the use of electrical installations in the national archives.

Fire needs the combined presence of three factors: (a) combustible matter; (b) matter that supports combustion; and (c) a high enough temperature to allow the formation of a flame (ignition point). The first two factors are unavoidable in libraries and archives (paper is combustible and oxygen, the agent which supports combustion is inevitably present in the atmosphere), so that all preventive efforts must be aimed at eliminating the third factor.

Damage caused by fire ranges from minor injury to total destruction. To this damage must be added that caused by fire extinguishers, many of which spray water with effects of the kind we have already discussed.

3.3.6 Other causes

Man is a direct or indirect cause of all the deteriorating processes we have been discussing, but on the other hand he also contributes to conservation, indeed is the ultimate reason for conservation.

The need to read documentary and bibliographical material with all the handling, even the most careful, it involves, is one of the inevitable causes of deterioration. Only to the extent that we can avoid the direct examination of original documents can we hope to preserve them indefinitely. Reprographic techniques correctly applied can effectively aid conservation, though, for years to come, if not always, they will have to remain confined to a relatively small percentage of the sum total of our documentary material. The best results will be achieved by libraries with a policy concentrating their conservation efforts on rare manuscripts, books and early editions, rather than on modern editions which can easily be replaced.

Improvized repairs, trial-and-error restoration methods and even some more scientific techniques that recent scientific advances have shown to be obsolete, if not positively harmful, also figure among the causes of paper impairment.

Cases in point are adhesive strips used to repair small tears, but causing the oxidation of glues and hence producing indelible marks in valuable books and documents; reagents to revive faded inks; the indiscriminate lamination of documents.

Ownership marks printed on valuable books and documents as a guarantee of identification in case of theft can cause serious damage, quite apart from their unaesthetic effect and the often careless method of application. In particular, the indelible inks needed for such marks clash with an essential requirement of good taste, namely discretion(1).

All in all, fear of theft has always preoccupied archivists and librarians as much as fire has often been the cause of serious damage.

In particular, strong boxes used for storing the most valuable items of an archive or library, but designed to hold inert matter, and hence lacking a controlled environment, may, when they are opened after some time, reveal shocking evidence of deterioration.

The number of factors that threaten the conservation of paper is very large. We have confined ourselves to those which, because of their recurrent or catastrophic nature, are the most common and the most serious.

(1) Lampblack inking pads have recently been introduced to solve the problem. See Marking Manuscripts (Preservation Leaflets, Library of Congress, No. 4, 1978).

CHAPTER 4

PREVENTIVE METHODS OF CONSERVATION

4.1 General

Because of their permanent cultural importance there is a need to conserve books and documents and to pass on the information they contain. Archivists and librarians bear a great responsibility in taking appropriate action in both spheres and in keeping a balance between them, that is between conservation, restrictive in character and designed to protect the material side of books and records, and communication which should be completely free if the cultural values or ideas contained in books and records are to be generally available.

Conservation means maintaining objects in good physical condition so that they may fulfil the function for which they were designed. It tries to prevent the deterioration or destruction of these objects and to repair any damage that may impede or threaten their function. This first objective is attained by preventive methods, the second by curative methods (restoration).

Preventive methods seek to create an ideal habitat which, as far as possible, puts objects out of harm's way and preserves their chemical and physical integrity, that is their permanence and durability. The effectiveness of the preventive approach depends on knowledge of the characteristics of the objects and of the causes of deterioration and of the uses of materials and techniques to stem it.

The need for preventive and restorative measures is inversely proportional, intensification of the one implying a relaxation of the other. 'Prevention is better than cure', applies in this field no less than it does in health care.

There seems to be a general consensus on the preventive aspects of conservation, as witness a growing number of guidelines and norms published in many countries. Views on restoration, by contrast, vary considerably, largely because of the effects of the techniques and products used.

The preventive conservation of documents depends mainly on the availability of protective measures against the many forms of deterioration we have described in earlier sections. Such measures include proper care of the building in which the documents are kept (archives), adequate storage facilities, direct physical protection, and appropriate environmental and other controls.

4.2 Buildings

In what follows 'archive' refers to the place or building intended to store a coherent body of documents and the services needed to look after them.

The function of an archive is to protect the documents kept in it against all risks, to provide a comfortable working environment for the officials and easy access for those who wish to peruse the documents. The suitability of archives should be judged from three points of view: location, architectural features and internal layout.

4.2.1 Location

If we were able to choose the ideal location for an archive, our knowledge of detrimental causes would lead us to eliminate a number of sites on the following grounds: the danger of rising damp, the risk of infestation by paper-eating insects, low terrain and not very porous soil likely to be flooded during torrential downpours, proximity to dangerous industries and to potential war targets, etc.

Because of the cultural objectives of an archive, ease of communication, access and proximity to other academic and cultural centres which complement its own function, and suitable distance from extremely noisy areas, are other factors to be considered in the choice of location.

4.2.2 Construction

Economic considerations and the wish to conserve buildings of historic interest are responsible for the housing of many archives and libraries in suitably converted old buildings. As far as the physical security of the documents is concerned, there can be no objections, provided only that the buildings are or can be suitably secured.

However, purpose-built new constructions can obviate many problems and frequently save money.

The layout of archives is governed by many considerations: style, planning policy, geological conditions, climate, geography, dimensions and economics.

The traditional archive, built above ground level on a small number of floors, is the most common type. Since the last war, however, many underground depositories have been added for security reasons. They involve the creation of artificial environments (light, humidity, temperature) which, though they undoubtedly help the conservation of documents, do so at a high economic cost, not always justified by the nature, or within the modest means, of the archive concerned.

Properly controlled architectural and environmental conditions and installations are however absolute necessities for archives in tropical zones and those subject to the action of violent atmospheric and/or geological fluctuations.

While there is no need for luxury buildings, it is essential to choose materials, systems and equipment that, though as economical as possible, do not endanger the security and function of the building.

A building intended to house an archive should meet a series of building standards together with a number of storage conditions which we shall be examining below.

All the materials used for the foundations, the walls and the roofs should be fire-proof and the dimensions or regional features of the building chosen accordingly. To that end different standards have been laid down in various countries.

The area of the building and of its surroundings must also meet certain standards of thermal and acoustic insulation.

Last but not least, the structure of the building will have to meet the need for housing large storage areas and restoration, binding and reprographic laboratories.

4.2.3 The areas of an archive

There are four main areas in an archive: storage, internal services, public services and maintenance.

4.2.3.1 The storage area

This is the most important part of an archive, not least for purposes of conservation, as it is meant to house a stock of documents almost in perpetuity.

Siting. The siting of the storage area must have absolute priority over the siting of all other departments.

Orientation. The storage area should not face directions receiving maximum sunlight or face the prevailing winds which might carry aerosols or elements detrimental to conservation.

Separation from other departments. The distinction between storage and other areas should be clear. The location of the storage area above, below or beside the other areas is determined by the architectural characteristics of the building and the site, and does not usually affect conservation, although it is common practice to store the documents on a series of floors adjoining the other departments.

Fire security. The storage area should be isolated from the rest of the building by fire-proof doors and walls in conformity with national safety regulations.

Communications. For reasons of fire safety, the vertical connections between floors (stairs, lifts) should be built outside the storage area, with special fire-proof bays giving access to each floor.

Emergency exits. The safety regulations of most countries also stipulate the construction and distribution of emergency exits, though they normally do not make special provision for the saving of documents. Emergency spiral staircases with angles of descent suitable for personnel but certainly not for inert matter that has to be evacuated in a hurry, are still common sights outside many archives. Chutes are considerably more effective.

Dimensions. The dimensions of the storage area should be calculated in terms of the existing stock of documents and foreseeable growth within a reasonable number of years. On average an area measuring $100m^2$ and having a height of 2.30m can house a run of 600m of documents in seven open shelving units arranged in bays.

Division. For safety and also to facilitate localized fumigation treatment, the storage area should have a maximum floor area of $200m^2$ and a minimum floor area of $150m^2$.

Height of ceilings. Ceilings should be placed at the height that allows access to books or documents on the top shelf without the use of ladders (2.30m-2.50m).

Insulation. The various storage areas should be separated by fire-proof metal walls and doors. The doors are normally made of two laminated plates with insulating material between them. They must have enough room to expand without becoming jammed.

Roofs. The roof of the storage area and the rest of the building intended to house archives is usually constructed more with an eye to style than to practicability. Flat roofs have recently become quite fashionable, and not only for this type of building.

The rendering of flat roofs completely and permanently water-proof poses a problem that has not yet been satisfactorily solved.

For archives in climates with continual or heavy downpours it is preferable in most, if not in all, cases to use ridged roofs, which not only facilitate the rapid draining away of rain water but also create a large air pocket which acts as an excellent hydrothermal insulator.

Mechanical resistance. The storage area has to support a considerable weight, i.e. the documents and their containers or shelves. This fact must be taken into account when laying the foundations and calculating the stresses. On average, an acceptable limit is $1,000kg/m^2$ for floors with a height of 2.50m and with traditional metal shelving units having 75cm wide aisles between each.

Compact shelving systems need stronger foundations.

Protection against environmental agents and abrasives

Humidity. In order to minimize the accumulation of moisture through capillary action, infiltration or condensation the storage area should be sealed off against rising damp. No water pipes should be laid inside the area and all walls, ceilings and floors should be treated with waterproofing material not susceptible to oxidation.

Temperature. To minimize the influence of fluctuations in temperature and external humidity, thermal insulators should be used in the construction of the storage area.

Light. Except in special atmospheres and climates, the presence of limited amounts of natural light in the storage area does no harm and may even be biologically beneficial (insects, mirco-organisms).

In that case, the external openings should not exceed more than 15 per cent of the wall surface, should be watertight and insulated against heat and capable of filtering excessive sunlight.

Dust. In order to avoid dust produced by the crumbling of flooring due to people walking about, to the mechanical transport of documents, etc., all flooring should be of hard-wearing material and have a minimum number of joints. Thermostable plastics are most suitable.

Communications. The storage area is the nerve centre of an archive. Its communications with other sectors should be simple and direct for functional reasons as well as for conservation purposes.

There are two essential communication routes from the storage area: one to the internal service areas (reception of documents, restoration and reprographic workshops), the other to the areas open to the public (reading rooms and exhibitions).

4.2.3.2 Internal service areas

These areas are not usually open to the public. They include rooms for the reception of records, for disinfection, for disinfestation, for cleaning, for classification, for copying, for reprographic work, for binding and restoration and for the allocation of work to various staff members.

Although all of these rooms play their part in the preservation of documents, which is the main concern of this study, the only ones with which we need concern ourselves here are the disinfection and disinfestation (fumigation) and cleaning rooms. This is because several monographs are currently being devoted to the rest.

The cleaning and fumigation departments should be on the ground floor near the unloading bays so that incoming documents can be treated before being subjected to any other manipulations.

Cleaning rooms. These rooms, with a surface area of about 10m^2 and normal ceiling height, are set aside for the manual and mechanical removal of dust and dirt from documents in need of such treatment.

Mechanical dust removal involves spraying or blowing. In the second case, an extractor fan is an essential requirement.

Fumigation rooms. Fumigation rooms measure approximately 5m^2. They can be bought in the form of vacuum or pressure chambers, but a sealed and watertight room capable of supporting a vacuum and/or an excess pressure of 0.25 would do perfectly well and be far more economical.

Gases from this chamber or room should be expelled from the highest point of the building or through the sewers.

4.2.3.3 Service areas open to the public

These areas include the administrative offices (reception, information, secretariat), the reading rooms, and the exhibition and conference halls. Only the reading rooms and exhibition halls are directly relevant to this study.

Reading room. The reading of documents calls for increases in the intensity of natural and/or artificial light to values that would not be acceptable in storage areas (500-700 lux). At the same time, the temperature and relative humidity are raised above acceptable limits, although not to the same extent.

Hence it is in the reading room that the two main concerns of the archivist - conservation and communication - come into direct conflict.

The dimensions of the reading room depend on the number of readers normally accommodated. The estimated average surface area per reader is $5m^2$.

The room should have comfortable tables, lecterns for propping up manuscripts and valuable books and hence minimizing the need to handle them. For the rest, the staff has to be exceptionally vigilant to ensure that no documents are mishandled.

Exhibition halls. From a purely conservationist point of view, exhibitions are a nuisance but since, like reading rooms, they are needed to provide public access to treasures that owe their continued existence to their historical and cultural importance, they have to be put up with.

Here we shall not consider permanent exhibitions.

The use of brightly lit glass showcases causes the greatest harm. The best form of lighting is by fluorescent tubes placed outside the showcases and used in conjunction with filters that reduce the intensity of ultraviolet light. The tubes should be switched off or dimmed to suitable values when the exhibition is not being attended.

Hydroscopic substances, for instance, silica gel (1.3kg per m^3 depending on watertightness) can absorb enough moisture in glass or transparent plastic showcases to avoid condensation.

Documents put on display should not be pinned down and any sticky tape used should be of high quality and contain rustproof adhesive components.

4.2.4 Old buildings adapted for archive use

Old buildings have to be specially converted and adapted to provide the conditions needed to guarantee proper conservation and the same could be said of older archives constructed on lines very different from those used nowadays. It is quite common to find many large doors and windows opening in the walls of old buildings because of the understandable fear of fire. In these cases, curtains, Venetian blinds or shutters should not be used to keep the sun out as they cannot be regulated with any degree of accuracy. When there are no planning or architectural objections to them, adjustable sun-blinds made of fabric solve the problem. Otherwise, there is a large variety of glasses, films and varnishes that filter heat and light radiation (UV) without altering the appearance of the facade.

The need to include combustible materials (beams, flooring) in the structure of such buildings for historical and artistic reasons makes it necessary to fire-proof them and to treat them with insect repellants.

4.2.5 Archives in tropical countries

To the measures recommended for the more temperature zones, several others must inevitably be added in arid and humid tropical areas. Their common characteristic is intense sunlight. For that reason buildings used to store documents should have their largest facade facing north or south, depending on whether they are north or south of the equator, this minimizing the effect of incident or reflected sunlight.

Another important factor in these zones is the wind. Wind, and sea breezes in particular, can be beneficial in arid zones by helping to cool the air and in humid zones by helping to dry the atmosphere. But winds can also cause sandstorms or harmful precipitations.

It is a good idea to plant trees round the building, placed at a suitable distance lest the roots undermine the foundations. When choosing trees, it is essential to avoid those that harbour a harmful fauna as well as those that produce large quantities of pollen.

All in all, therefore, the construction of archives should be based on the following considerations:

4.2.5.1 Buildings

To minimize the harmful effects of external agents, the size of the building should generally be as small as possible in relation to the volume of documents to be stored. Tall buildings are advisable in humid zones because they have a relatively small roof area, and roofs can be very troublesome.

4.2.5.2 Foundations

In humid zones the foundations should be surrounded by a drainage system of large capacity and capable of coping with a high water table.

4.2.5.3 External walls

These should be of great thickness and high thermal inertia to absorb and hence even out the considerable diurnal temperature fluctuations in arid zones. In savannahs, the outside walls must have strongly insulating properties and in humid zones they must be designed to discourage condensation.

4.2.5.4 Windows

If possible, windows should be placed on the less sunny side of buildings. On the sunny side, they should occupy less than 10 per cent of the total wall area in arid zones, less than 15 per cent in savannahs and less than 20 per cent in humid zones. On the other sides they must never exceed 30 per cent of the total wall area, especially in arid zones. Windows facing the direction of sandstorms should not open. In any case, an effective method of ventilation control must be provided.

4.2.5.5 Roofs

Ridged roofs are the most suitable. With flat roofs the usual arrangement of the components should be reversed, the thermal isolation being placed above the permeable layer. The whole roof should be designed to withstand pressure as much as suction caused by winds. In zones with a risk of torrential rains, gutters and drainage pipes should be larger than usual.

4.3 Storage of documents

Documents are normally stored in a series of shelving units or more specialized fittings such as filing cabinets and map holders for larger documents.

4.3.1 Shelving units

The advantages of metal shelving units over more traditional wooden ones are twofold: the shelves are not combustible and they are insect-proof.

Shelving units can be designed as part of the building, the uprights serving as load-bearing members. In that case, the external walls of the building act purely as a shell, all the weight being carried by the metal posts. This type of construction can be put up very quickly and cheaply but is unsuitable for very tall buildings or for administrative areas because the metal posts restrict the size of individual offices to a maximum of about $9m^2$.

The risk of the metal posts buckling in the event of fire, with the consequent collapse of the entire structure can be minimized with electrical fittings and sensible precautions against fire and storm. In case of war, the risks are no greater than in more traditional buildings. The shelving-post method of construction is used in several countries both for attaching storage areas to existing buildings and also for adapting the interior of old buildings, the walls of which cannot bear the weight of masses of books or documents. Metal shelving units are of two types: the traditional open and fixed shelves and the movable compact shelves, so called after 'Compactus' the firm which introduced them some 30 years ago. These shelves can be rolled or pushed close together and separated at will. The choice between the two types does not so much depend on taste, although taste is often taken into consideration as well, as on the nature and dimensions of the storage area.

4.3.1.1 The compact system

In general, this system is used in rooms of small dimensions in which a large number of documents have to be stored. The concentration of weight on a small surface area makes it absolutely essential to have solid foundations as we have already stated. The shelves are packed so close together as to reduce the amount of air needed for the preservation of paper and to encourage condensation. This poses no problems if humidity, temperature and air flow can be controlled (that is, if air conditions are fitted) but may cause physical deterioration if they cannot.

We believe that this system should not be used indiscriminately, i.e. for purely stylistic reasons.

4.3.1.2 The traditional system

The open or traditional shelving system is chosen by most archives and libraries, because the shelves come in a variety of shapes and sizes. Archive shelving is usually deeper than library shelving because the dimensions of documents and their containers are usually larger than those of books.

An open shelving unit is a module formed by two vertical members carrying several fixed or movable horizontal members. Such units have a standard width of 99-108cm, a standard height of 216-240cm and a depth of 30-40cm.

Several modules of shelving units linked together by their frames constitutes a row. If the modules are attached back to back, they form a double-sided shelving system. This type is very popular because it saves a great deal of space.

Installation. In the storage area of archives, the shelving units are normally double-sided and run in parallel rows of various lengths, with aisles between them so that every module (usually ten units) is easily accessed. In addition, there are other rows running at right angles to, and separating, successive modules of the first type. The aisles between the first type of row at 70-80cm wide, those between the second type are 1m wide.

Characteristics. The metal shelving units, open and fixed or compact and mobile are among the few components industrial companies manufacture almost exclusively for archives and libraries. Needless to say, not all of them combine all the technical features needed for the solid, secure and convenient storage of documents and their containers.

Solidity. Since one running metre of archive documents normally weighs about 60kg, and with some materials up to 80kg or more, the metal shelving must be capable of bearing a linear weight of about 100kg/m.

Security. The metal shelving units should be treated with anticorrosive paint and enamel to prevent oxidation of the contents and to remove any sharp or rough surface capable of damaging the documents.

Shelving units should not be placed directly against a wall, which might curtail ventilation and encourage condensation.

Convenience. The highest shelf of any unit should be within the reach of a person of normal height, without the use of a ladder. This means that it should be about 2.10m high.

Location of containers and documents. The lowest shelf should be at least 6cm from the floor. There must be large enough a gap between successive shelves to allow a clearance of 1-3cm between the top books or containers and the shelf above. This is to ensure an adequate flow of air.

The depth of the shelves should be such that neither records nor containers protrude and be rubbed against or damaged.

The number of shelves in a shelving unit and their depth depend on the size of the documents and the arragements of their containers. If the documents are stored with their shorter side parallel to the front of the shelf they will take up less space across and hence the number of shelving units needed will be smaller. On the other hand if they are stored with their longer side parallel to the front of the shelf, the number of shelving units will have to be greater.

4.3.2 Planfiles

In accordance with standard procedure, documents in archives are stored in boxes that do not vary greatly in size and fit neatly and easily into shelving units.

Of course there are records that have in addition to the usual causes of deterioration an unusual shape and hence pose special storage problems, for instance cartographic, architectural and engineering drawings and plans.

There are two possible solutions namely suspension (transverse) and horizontal filing systems.

4.3.2.1 Suspension systems

This is the most modern and probably the most effective solution. It was first used by architects and engineers for filing plans drawn on lightweight material (vegetable paper, polyester, Ozalid paper). The filing cabinet has a system of combs or pegs to which the plans can be clipped, or a system of hooks on rails, to which special hinges clipped to the plans can be attached. The vertical storage of historical documents in archives and map libraries poses various special problems:

tears may be caused by the very weight of maps, generally lined or otherwise reinforced;

the additional chore of attaching the hinges;

the attaching material and the glues in it may not be stable enough;

the structure of the filing system itself may be harmful to the physical integrity of the documents;

the system takes up more space than the horizontal system in which boxes can be piled up on top of one another.

4.3.2.2 Horizontal storage

This is the traditional and most widespread solution. The system consists of metallic modules, each a series of superimposed boxes designed to store plans horizontally.

The commercial versions of these storage units are not always capable of coping with the variety and unusual shapes of documents - something that is equally true of suspension systems.

The main drawbacks of this system are:

the fact that several plans have to be stored in one and the same box which makes it necessary to remove some in order to get at others;

to reduce the number of objects in any one box, smaller boxes have to be used thus increasing the total number of boxes and hence the weight and cost of the whole system. In some archives metal boxes have recently been replaced with plastic (perspex) boxes designed for horizontal storage. They are much lighter and can also act as a means of transport for conveying maps and plans from the storage area to the reading rooms.

4.3.3 Other systems

When the dimensions of a plan exceed the maximum capacity of a planfile, special units have to be built at extra cost, or other steps must be taken. These involve folding, cutting or rolling up.

Folding maps. Folding can weaken paper to the point that it comes apart.

Cutting maps up. This is a drastic measure, but undoubtedly the best for purposes of conservation. It can only be used when a map is made up of several sheets of paper. These can be separated and if a gap of one millimetre is left between them, they can later be rejoined and folded without damage. Specialist staff is needed to perform this delicate operation, especially when the maps or plans are very carefully marked or scaled.

Rolling maps up. This is probably the oldest form of storing maps. It causes problems with maps filed away at the back of the shelving unit. Recently some institutions have introduced the compact system with cylinders affixed to the shelves. This system makes it possible to store and remove rolled-up maps individually.

Direct protection of maps. Regardless of the system used, maps must be isolated from other maps and from the atmosphere. Paper or plastic sleeves will do very well. Rolled-up maps can, moreover, be kept in cardboard or plastic tubes. These look neat, but the maps inside them may prove hard to extract.

Whenever possible, maps should be reproduced photographically thus minimizing the need for direct handling.

4.4 Covers

Archival documents other than books are usually kept in covers of various types.

4.4.1 Covers

For centuries folders were the basic unit of archival conservation. However the two cardboard covers and the string or cord used to tie them round documents was not and is not an effective way of avoiding deterioration, friction, dust, etc. Even so, it must be remembered that folders, with all their shortcomings, have helped to preserve masses of documents that had lost their administrative usefulness (the main reason for storing them), by acting as a psychological barrier against the systematic destruction that might perhaps have been ordered before they were saved by administrative fiat.

Nevertheless folders are far less effective containers than boxes.

4.4.2 Boxes

Filing boxes are usually made of cardboard. Until recently, the only factor taken into account was their physical strength, but the discovery that acidity militates significantly against the conservation of paper has added the further demand that filing boxes must be made of alkaline or neutral material.

To increase the strength of filing boxes it is now common practice in many countries to reinforce their corners and edges with rustproof metal strips.

Putting documents in or taking them out of their containers can tear them or expose them to unnecessary friction. For that reason boxes that open on the side are not recommended. The lid should be completely removable so that the contents can be lifted out without being rubbed against the sides.

Boxes are usually slightly larger in size than the documents they contain (34 x 26 x 15cm is one of the most usual sizes) and the volume of the documents should be compatible with that of the boxes used. That volume should not be so small as to cause excessive movement or so big as to make it hard to shut the boxes.

Neutral or alkaline properties are also demanded of folders, paper sleeves, envelopes, wrappers, etc. used to separate and protect small archival units (dossiers, etc.).

Plastic meets the demands of strength and lack of acidity better then cardboard. Morever, commercially available plastic containers now have a greater degree of thermal stability than cardboard containers.

CHAPTER 5

CONSERVATION CONTROLS

5.1 General

Closely related to prevention and cure, and bound up with them is the control of those agents whose mere presence, or presence in such quantities as exceed tolerable limits, renders their elimination or repair essential.

Since these agents are known, an efficient control policy should be based on equipment designed to detect and quantify their presence and the consequent correction or elimination of their harmful effects.

These agents are: light, temperature, humidity, atmospheric pollution, biological contamination and fire.

Now, whereas, all these factors are undoubtedly taken into account during the construction and equipment of archives, the incorporated controls are not usually enough to cope with endemic situations.

Air conditioners normally solve most of the problems caused by temperature, humidity, pollution and biological contamination but because they are difficult to install and costly they are not within the means of many archives nor are they always essential.

Only in cases where environmental conditions render them indispensable should they therefore be fitted, and even then within narrow economic and technical limits.

5.1.1 Light

Obviously the storage area of an archive needs no more light than is absolutely necessary for moving documents in and out. This demand is met by a light intensity of 50 lux.

Even where natural light is available, there is a clear need for additional electric lighting to cope with fluctuations in daylight or the uneven distribution of light.

5.1.1.1 Electric lighting

Electric lighting has now ceased to be the source of concern it used to be years ago when faulty wiring often caused fires. The use of circuit-breakers, independent supply lines to various parts of the archive and the protection of electric cables with fireproof steel tubes, have largely helped to allay such fears.

There are two types of electric lighting: incandescent and fluorescent. Each has advantages and drawbacks.

Incandescent light is the older of the two. It emits a great amount of infra-red radiation and heat.

Flourescent light emits a greater amount of ultra-violet light and less heat.

Incandescent light emits less than 75 Mw/lm (microwatts per lumen) of ultra-violet radiation, the maximum figure permissible for light sources in archives, museums, etc. Fluorescent light emits 400 Mw/lm.

However, fluorescent light provides much the better illumination with the same wattage. Thus while a 40 watt fluorescent lamp produces 1,700 to 3,450 lumens, a 40 watt incandescent light bulb produces just 360 lumens.

Fluorescent light therefore saves electricity. Its negative aspect, the high emission of ultra-violet rays, can be corrected with special filters or by the use of fluorescent lamps producing ultra-violet radiation of less than 75 Mw/lm but still maintaining an adequate luminous intensity.

This fact, together with the lower running costs, justifies the more widespread use of fluorescent lighting in reading rooms and exhibition halls.

Only in the storage area where intense sources of light are not needed, is it still reasonable to weigh up the disadvantages of the heat output of incandescent lamps against the low cost of fluorescent lights and to choose accordingly.

Neither natural nor electric light should be allowed to fall perpendicularly on documents or containers.

5.1.1.2 Meters

The illumination of storage areas can be determined with the help of photometers. These instruments should be capable of registering fairly low values (25-20 lux) with reasonable accuracy.

Ultra-violet photometers are also available at reasonable prices.

Neither type is necessary once the storage area has been built and equipped and the natural and artificial luminous intensities have been checked and found to be within acceptable limits.

5.1.2 Humidity/temperature

For purposes of climatic control, it is necessary to consider these two factors in conjunction, as their effects are interdependent. Both can cause serious damage to cellulose.

The only effective way of controlling their harmful effects is to keep them within tolerable limits, i.e. within the limits of the so-called optimum climate. The latter is devoid of strong fluctuations in humidity or temperature. An optimum climate can be provided by natural or artificial means.

5.1.2.1 The natural system

The effects of this system depend completely on climatic conditions.

The optimum natural climate is computed from average measurements taken in previous years. Let us suppose that the average relative humidity and temperature over the last three years have been 58 per cent, 62 per cent, 60 per cent and 24°C, 20°C, 22°C respectively. The average for these three years will therefore be 60 per cent and 22°C. The optimum climate is defined as being 5 points above or below the average humidity and 3 points above or below the average temperature. In other words, the optimum climate would have a relative humidity of 55-65 per cent and a temperature of 19°C-25°C.

The optimum climate can be obtained and maintained in various ways.

In the first place, the building should be erected on a elevated site thus avoiding rising damp; the storage area should face the direction of the prevailing winds and be protected from the heat of the sun; all rooms should be insulated with double walls, floors and ceilings; and natural ventilation should be maximized by optimum channelling of air currents inside the storage area.

The advantages of the natural system become clear when we recall that organic material responds well to it and suffers the less damage the smaller the fluctuations and the fewer the number of sudden changes threatening structural ability.

Only when the average natural climate exceeds the normal temperature limits of between 18°C-22°C (± 3°C) and relative humidity limits of 50 per cent to 60 per cent (± 5 per cent), should artificial systems be used.

5.1.2.2 <u>The artificial system</u>

This system makes it possible to control relative humidity and temperature fluctuations of unusual amplitude. It involves the use of devices for adding or abstracting humidity, cold or heat. The most satisfactory are air conditioners.

Theoretically this is the ideal solution, but the high cost of installation and maintenance, the risk of temporary breakdowns due to electrical or mechanical failure militates against their general use.

For the conservationist, intermittent operations - to save energy and reduce costs - are totally unacceptable because they produce a constant structural disequilibrium in the paper and end up by destroying it. In other words, the misuse of air conditions destroys rather than prevents destruction.

Of far less interest are dehumidifiers or humidifiers, which can only be put to use in small areas.

Fans and extractors do help to circulate and renew the air provided external conditions are favourable. In any case, all these systems and devices must maintain the humidity and temperature range of the optimum climate. The greater the deviations from it, the worse the service the equipment will provide, the greater the costs and also the danger of damage from breakdowns or power cuts. Although the ideal climatic conditions for the conservation of organic matter are low temperature and low humidity, it must be remembered that archives and libraries provide a service to the public who demand a certain standard of comfort. A compromise must therefore be found. One solution is the use of intermediate exchange systems through which paper can safely be passed from the climate of the storage area to that prevailing outside and vice versa without suffering damage.

Measuring devices. Temperature is measured with thermometers of various types:

bimetal strips (invar steel and brass);

gas (nitrogen);

vapour pressure (methyl chloride, ether, alcohol, etc.);

mercury or alcohol.

The most widely used methods of graduating a thermometre are the Celsius (centigrade) and Fahrenheit scales. The first is converted into the second by the following formula:

$$(°C) = \frac{(°F) - 32}{1.8}$$

Humidity is measured with:

Hygrometers, instruments that register the contraction or expansion of an element sensitive to moisture.

Wet and dry bulb hygrometers psychrometers. These instruments consist of a pair of similar thermometers one having its bulb wrapped in a damp wick. The rate of evaporation from the wick and the consequent cooling of the wet bulb depend on the relative humidity of the air which can be obtained from readings of the two thermometers. Psychrometers are more accurate than hygrometers.

Thermo-hygrographs measure humidity and temperature simultaneously and register variations.

5.1.3 Atmospheric pollution

Atmospheric pollution is caused by waste products - from industrial or natural processes - which accumulate in the atmosphere. These products include:

Aerosols, made up of solid or liquid particles (dust) dispersed in the air; smoke (condensation of the fumes of solid matters or produced by chemical reactions) and fog (liquid particles suspended in the air).

Vapours, gases released by solids or liquids due to changes in pressure or temperature. Most of these products are potentially harmful as they carry substances that can damage paper (acids, grease, chemical reagents, dirt, etc.).

In addition to these pollutants, the atmosphere contains gases (oxygen, ozone, nitrogen, water vapour, etc.) that, although needed for the maintenance of life, have a negative effect on cellulose products. They cannot be kept under control in the absence of special vacuum or pressure chambers filled with an inert gas (helium, Freons, etc.).

The effects of atmospheric pollution can be reduced by a system of filters that shut out harmful particles. The best of these systems are made of cellulose fibre, activated charcoal, oil, water, potassium chloride, etc. and have to be cleaned and replaced periodically.

Storage areas without external windows or doors are, of course, the easiest to control.

5.1.4 Biological contamination

The presence of bibliophagous insects in archives and libraries is encouraged by two main factors, namely the availability of food (cellulose) and a microclimate favourable to their growth.

The first of these causes is inevitable and all that can be done is to provide paper with some means of self-defence, either during its production or through subsequent treatment. The normal procedure is to treat documents with microbiological remedies, which we have already discussed.

For that reason we need merely dwell on the problem of the environmental and climatic factors favourable to the proliferation of bibliophagous insects. These are:

high temperature and humidity;

poor ventilation;

absence of light;

dust and dirt;

corners and hidden areas;

absence of perturbations;

direct access to the outside;

contaminated materials;

failure to make periodic checks;

failure to take preventive steps.

While these factors continue unchecked, there is always a danger of the presence of and invasion by these pests. The control of biological contamination must be based on:

Low temperature and humidity. All living creatures need an ideal climate. As a general rule, although the resistance and adaptability of species varies, microfauna favours temperatures of between 25° and 30°C, and a relative humidity above 65 per cent (few species can support a relative humidity greater than 85 per cent). Particularly undemanding insects can survive within very wide limits, but most prefer dry and temperate climates. In view of the deleterious effects of high temperatures and humidity on paper, it is therefore advisable to keep temperatures low and to maintain what we have defined as the 'optimum climate'.

Good ventilation. Stale air in badly ventilated places favours the presence of insects and the characteristic musty smell of enclosed storage areas is an obvious sign of the presence of micro-organisms. Natural or artificial ventilation should be kept at a constant and regular level, ideally at a replacement rate of 0.25 litres of air per second per square metre.

Lighting. Most micro-organisms are weakened or destroyed by light and many insects cannot tolerate it. This is due to the germicidal and vibratory effects of light rays, especially those of shorter wave length. A modest amount of general illumination (+/-50 lux) in storage areas helps to limit the activity of a large number of bibliophagous species.

Cleanliness. Dirt encourages the presence of bibliophagous insects and other pests which in their turn create more dirt. The removal of dust and refuse is therefore an elementary hygienic precaution, and should be complemented with more thorough cleaning methods involving special products (detergents, bleaches, etc.).

Unobstructed areas. Corners and hidden areas encourage the accumulation of dirt, no less so than lack of ventilation. The correct shape of rooms and the proper siting of furniture can help to avoid these problems.

Noise, vibration. Silence and under-use will encourage the activity of insects and micro-organisms. Noise and vibration by contrast - as long as they cause no damage to paper - disturb the activities of bibliophagous and other parasites in storage areas.

Direct access to the outside. Doors and windows can provide easy access for micro-organisms and insects. More harmful by far are water pipes and electricity cables, for these often provide uncontrollable passages for insects. All types of unnecessary direct access should therefore be avoided. This means stopping up and carefully checking all indispensable conduits.

Use of uncontaminated material. Often the records themselves introduce bibliophagous elements into the storage area and hence to the rest of an archive. To prevent this from happening, all documents brought into the storage area, especially fresh material, should be carefully inspected and disinfected.

Periodic checks. It is absolutely essential to make periodic checks of documents, furniture, of specially exposed zones (e.g. zones in which there may be an accumulation of moisture), etc., for bio-degrading factors. These checks should take place at times - generally spring and summer - when the threat of contamination is greatest.

Preventive treatment with antiseptics. The ideal complement to all the steps we have described is the creation of an environment repellent to and uninhabitable for harmful species. This is best done by means of antiseptics (insecticides, disinfectants) applied periodically and in larger or smaller doses depending on climatic conditions.

Antiseptics can be applied by sublimation or by spraying, depending on the choice of solid or liquid. Both have more lasting effects than gases.

5.1.5 Fire

The first step in fire control is the elimination of all structural elements, furniture, electrical installations, etc., that may cause or feed fires. If this is not possible, corrective steps must be taken. Since archives are filled with easily combustible matter, it is essential to have methods of detection and extinction that respectively give early warnings of fires and help to put them out.

5.1.5.1 Detectors

These devices react to the presence of gases, smoke, flames or heat given off by burning matter.

The best such detectors for archives and libraries are smoke and gas detectors, particularly of the ionization type. All detectors incorporate alarms that can be connected directly to the fire brigade or to automatic fire extinguishers.

5.1.5.2 Extinguishers

Besides more or less improvized methods of fire fighting, there exists a whole series of extinguishers specially adapted for dealing with various materials.

These act chiefly by cooling or smothering (asphyxia) and can be applied by means of fixed (manual or automatic) or portable equipment, although both should be available for joint use.

There are liquid extinguishers (water and foam), solid extinguishers (normal or polyvalent powders) and gas extinguishers (carbon dioxide, halogens). The most highly recommended in view of the highly combustible nature of cellulose material are polyvalent powders among the solids, and halogens among the gases. Water should only be used when all other methods have been exhausted.

CHAPTER 6

RESTORATION

6.1 General

A look at the recent past will show that over the past 50 years there has been a great change in all aspects of the conservation of books and records, and especially in the field of restoration.

From what for centuries was a carefully guarded secret craft, largely in the service of private collectors, restoration has become an authentic science whose advances have been based on rapid technical progress reinforced by an increased awareness of one of mankind's noblest objectives: the conservation of works that have immortalized their author - man - by bearing witness to his achievement and progress, and that should be available, without let or hindrance, to all students of history.

The concept of restoration is closely bound up with the preservation of the integrity of documents, an idea based on respect for their metaphysical as well as their material value.

The metaphysical or spiritual value reflects the intangible aspects of the work: the spatio-temporal conditions, the motives or influences that have determined its form, style, etc., but above all the message that its author wished to transmit giving physical expression to the timelessness of his thoughts. In more concrete terms, they provide such information as renders the work the tangible abstraction of an idea based on the activity of its author in the society to which he belongs.

The material value involves the physical and functional aspects of the work. On the one hand there is the individual nature of the elements that make up the work, and on the other there is the form these elements take the better to fulfil the function for which they were combined and selected.

The value of a document is the greater the more complete its integrity. Now, that integrity depends directly on the metaphysical value which in turn depends on the state of material preservation. Thus physical deterioration causes functional incapacity, that is, the mutilation and hence the destruction of the message every work carries as part of its particular and inseparable integrity.

For that reason, and because every printed work is a unique means of communication across the generations, the current approach in conservation recognizes the need for preserving this very aspect and of handing it down unchanged.

In the past, failure to appreciate the importance of the integrity of books and documents and of saving them for future generations was responsible for confining conservation to the repair of the most obvious damage with no other stipulation than that this work be entrusted to reasonably skilful hands.

The result was a craft riddled with secrets and occult formulas, ingenious as much as empirical, reserved for a few wizards who tried their best to obscure the real problems.

In any case, even though they undoubtedly had some positive achievements to their credit, the main feature of their work was its utterly unsystematic character. In these circumstances it is easy to understand that, their good intentions notwithstanding, they should have caused irreversible damage. As a reaction, all curative activity was suspended, and restorers contented themselves with doing what they could to help damaged works to survive in their existing condition.

It is easy to understand the enormous responsibility that falls on restorers; they are the sole repairers of damaged texts but they must also ensure that their intervention does not cause further deterioration, immediately or in the future.

The appreciation of this fact was responsible for the growing professionalism of those involved in the work, reinforced by more and better academic training, experience, fundamental research, and above all by the acceptance of those precepts which, as a matter of professional ethics, respect the value of documents and eschew any sort of manipulation or approach that might cause harm.

These precepts constitute the criteria of restoration and have acquired near-doctrinal status thanks to their universal applicability, their compliance with standards that put an end to anarchic conditions and their termination of many uncertainties. All of them are based on knowledge acquired during earlier periods combined with the results of modern, strictly scientific investigations.

6.2 Restoration criteria

The aim of restoration is to reinstate the physical and functional integrity of an object by repairing the effects of alteration and damage.

Restoration means resurrection of the original condition largely by recourse to retrojection and by methods that make good partial damage but do not prove detrimental to the whole.

Restoration involves direct intervention as the only means of repairing damage or correcting the influences that have modified or altered the object to be restored.

The use of restorative methods places an enormous responsibility on the restorer because of the risk of compounding the existing damage with the wrong manipulations or methods. In other words, restoration does not allow of errors that require further restorative treatment. Hence it is essential to abstain from any act of doubtful efficacy and from any manipulation that might introduce new alterations.

Above all, restoration should be based on respect for the total and absolute integrity of the object concerned because only in that way is it possible to preserve what the author created and tried to convey.

Based on these principles, the restoration criteria can be formulated as follows:

6.2.1 Abstention

from any manipulation that may involve real or apparent modifications of the authentic and particular documentary character of the object.

This obviously precludes any intervention that may lead to further deterioration.

Primum non nocere. The first principle is not to cause damage, is a medical axiom that applies equally well to restoration. It implies respect for the physical, functional and metaphysical integrity of the work. To that end, it may be necessary to consult specialists (archivists, librarians) who will be able to tell what information is needed to make the necessary diagnosis and hence to determine what if any treatment is humanly and technically possible.

6.2.2 Elimination

of all external matter impeding the historical or artistic interpretation of documents.

This implies not only to the removal of dirt and dust detracting from the aesthetic appeal of the object, but also the removal of patches, inexpert repairs, etc. Naturally, any additions that are an integral part of the history of a document should be left alone, or at least some traces of them should be preserved. Thus, if certain passages of a book have been blanked or covered over by censors, the complete removal of these additions would mean loss of such proofs of authenticity. In that case, as in that of engravings coloured in after printing, the restorer must not remove indiscriminately, but, on the contrary, leave clear proof of the intention to erase, patch up or colour in which, though it was not part of the original document, is an inseparable part of its history.

6.2.3 Stabilization

and consolidation or neutralization of the degraded elements instead of their removal of replacement.

6.2.4 Reincorporation

of fragments once they have been clearly identified as an integral part of the whole.

6.2.5 Reconstruction

of missing elements (including inks), no longer extant but identifiable from the available documentation. Such reconstructions should be in the original style but executed with different techniques and materials so that they cannot be mistaken for original material.

6.2.6 Inclusion

of unidentifiable elements provided their presence is necessary for the understanding or physical maintenance of the document. This must be done in a neutral style and with materials as distinct as possible from the original, so that they cannot possibly be mistaken for integral parts of the original document.

These headings cover the common problems of reconstruction and reintegration of the support as well as of the graphic element (ink). All are controversial because of the difficulties in assembling the precise data needed for successful restoration in accordance with the most up-to-date standards, and also because of occasional pressure to hide any alterations by adopting methods that come close to falsification.

6.3 The resotration process

All acceptable restorations must be based on an overall methodology.

That methodology eschews every kind of improvization and ensures safety by a series of steps in accordance with strict rules for particular cases.

The various steps must be in sequence and compatible with one another. They are determined by the character of the document to be restored and, once chosen, their order may only be changed if it is absolutely certain that the change is beneficial.

The steps involved are:

control

identification, diagnosis and choice of treatment

photography

pesticides

dismantling

cleaning with

- mechanical agents
- non-aqueous solvents (dry-cleaning)
- aqueous solutions (washing)
- bleaching agents

deacidification

regluing and resizing

drying

pressing

hygroscopic stabilization

repair of cuts and tears

reintegration of missing areas in paper

reintegration of inks

lamination

assembly.

The first two steps (control: identification, diagnosis and choice of treatment) are essential preliminaries to any restoration work. The final drying and pressing should be done at the end of all the other steps. Moreover, the final neutralization of acids should not be applied until it is absolutely certain that no subsequent treatment will diminish its effects.

6.3.1 Control

Under this heading we include all administrative steps involved in the restoration process.

Whatever the location or capacity of the laboratory or restoration workshop, it must perform a series of complementary tasks amongst which we distinguish: identification, record of arrival and release, internal circulation of data.

First of all, a good control system must prevent backlogs of items waiting for treatment: the acceptance of new items should be geared to the availability of laboratory capacity. The alternative means running the risks connected with the prolonged storage of untreated items and earning a reputation for slowness and inefficiency.

Once an item has been accepted, a record card should be opened and anything that may help to produce a detailed history should be listed.

The record should contain the registration number of the item together with the date of admission, origin (details of ownership, place, etc.), name of author, date of execution, dimensions, techniques and materials, special features, etc.

All these data, together with those entered during the restoration process, will ultimately constitute a useful history and description of the item. The information should be easily available to all interested parties.

Another aspect of control is the efficient circulation of items between various areas of the laboratory, so that similar tasks can be performed together. This makes for greater efficiency: laboratories generally achieve better results when the items to be treated present similar problems and/or are made of the same material.

While one record card should list all data needed for the physical identification of a document, another should list all the restoration work done, not only for future reference, but above all as evidence of the methods and procedures used.

It does not matter what sort of record card is used; the only important thing is that it should document all the activities and manipulations to which the item in question has been subjected.

6.3.2 Identification, analysis and diagnosis

Before any conservation work is begun, it is absolutely essential to make a correct identification and assessment of the item itself and of the alterations to which it bas been subjected. Failure to do so might have catastrophic results.

Intuition and improvization, crucial factors in earlier periods, have now been replaced with scientific procedures that have little of the hit-and-miss character associated with the empirical stage.

Naturally, the experienced restorer has a fund of accumulated knowledge that, on many occasions, enables him by direct inspection to make a rapid assessment of the state of preservation of a document and the extent of any possible damage. However his very experience has taught him about the serious consequences of hasty diagnosis or mistaken interpretations even in cases that seem to present no problems.

It cannot be repeated too often, therefore, that restoration is a highly responsible task and needs to be shored up with prolonged study and great expertise.

For all these reasons, restoration work must start with a preliminary diagnosis as part of the following analytical scheme:

6.3.2.1 Analysis

Identification and evaluation of the document as a whole:

identification of its documentary characteristics;

fixing the date and place of its execution and of possible additions;

objective assessment of any physical or functional changes it has undergone;

identification of its material characteristics and properties;

structural analysis of all its parts.

6.3.2.2 Diagnosis

Diagnosis of the state of conservation for the purpose of determining:

the causes of any changes;

the physical and functional damage.

6.3.2.3 Choice of treatment

Choice of treatment to be given in keeping with the above.

All these steps are essential for the correct assessment of the meta-physical and functional intergrity of the item and, consequently, for assessing its historical value and future importance.

The technique used in making an item facilitates its identification. Thus a manuscript, a print, a drawing or an engraving whose author cannot be identified by his personal signature, may nevertheless be shown to reflect a certain style which allows us to attribute the item indirectly to a person, school, group, etc., which, in turn, facilitates the determination of its date of origin and also the motives for its creation. These data then make it possible to identify or at least to infer any possible additions or modifications.

This information is often totally unknown to restorers who confine themselves to repairing the damaged part of an item, and who may therefore make mistakes when dealing with some doubtful element. For that reason, it is essential to consult a specialist (archivist, librarian) who can decide what elements should not be replaced or changed, irrespective of the state of preservation.

Structural analysis

This type of analysis involves destructive and non-destructive tests, the former involving the sacrifice of some element of the document.

Needless to say, non-destructive tests are always preferable to destructive tests, but on occasion, the latter are unavoidable, in which case the smallest possible quantity of material should be sacrificed and then only such areas as will not be greatly missed or whose removal causes no substantial damage to the whole.

Non-destructive tests should be both harmless and reversible.

Included here are simulation and aging tests which involve recreating the problem in identical conditions and with similar materials. Howeover, on occasion the original may have to be used and any possible damage discounted.

Physical analysis

Solubility of inks;

Main direction of fibres;

Obverse and reverse differences: gloss, porosity;

Density and weight;

Consistency of support:

resistance to stretching;

resistance to folding;

resistance to explosion (bursting);

Colorimetry;

Accelerated aging;

Light stability;

Stability under atmospheric pollution.

Chemical analysis

pH analysis (acidity);

Pulp analysis;

Fibre analysis;

Filler analysis;

Adhesive analysis;

Ink analysis.

Biological analysis

General contamination rate;

Environmental contamination rate;

Identification of bibliophagous species.

Once the characteristics of a document are known, i.e. the structural materials and the causes and effects of their impairment, it is possible to decide on the best methods and procedures to restore it to its original state.

The choice of methods and procedures is therefore dictated by the results of prior studies.

6.3.3 Photography

Photographs are used in restoration to provide security copies, records of the current state of repair, and as aids for research and teaching, to mention only a few.

6.3.3.1 Security copies

It is obvious that any restorative manipulation entails risks - even with the best methods it is impossible to guarantee that no accidents will happen. True, these risks are, or should be, minimal, but it is almost inevitable that some inks should deteriorate and that fragments of paper should be lost during some operations. The unpredictability of such accidents, even with all the precautions one can take, makes it advisable, even necessary, to photograph items in such a way that their general appearance as well as characteristic details are recorded before restoration is begun.

The coloured or black-and-white photographs must be very sharply focused, and it must be possible to enlarge them so as to capture the smallest detail or to reduce them for storage on microfilm in the case of very large items.

6.3.3.2 Photographic records of the state of conservation

These records should satisfy two requirements: they should be able to complement the security copy as evidence of deterioration and they should also serve as records of the conservation work performed on the item concerned.

In other words, they should cover all the physical and functional aspects of the original and of the alterations and, by means of general or sectional views depending on the nature of the problem, provide maximum information. To that end, the following lighting should be used:

Overhead lighting. This type of lighting provides the most detailed information on inks, marks, cracks and lost areas of the support.

The light sources are placed at right angles to the plane on which the document has been laid.

Side lighting. This provides maximum detail of such surface deformations as creases, rucks, and any other factors that appear in relief.

The lights are placed to the side of the item to be photographed, at a distance and angle such that the shadows cast help to identify and locate possible faults rather than obscure the problem.

Back lighting. Used for optimum detection of cracks, lost areas, superimpositions, patches, etc.

Back-lit objects must have a smooth and transparent surface behind or underneath which lamps can be placed in such a way as to produce an even distribution of light.

Though the item concerned will provide evidence of the restoration work done on it once that work has been completed, its dossier should contain a series of before-and-after photographs as evidence of what has been done and with what measure of success. If the photographs, however artistic, fail to bring this out, their documentary value is negligible.

The final set of photographs must be obtained by the same methods (type of film, lighting, etc.) as the first set, and above all, cover the same area seen from the same angle.

6.3.3.3 Investigation

Photography is an essential tool in the restorer's hands, particularly for the corroboration of the results of physical, chemical and biological investigations.

Microphotography. With this method it is possible to take photographs of objects invisible to the naked eye. The image is greatly reduced and therefore requires special optical enlargement for viewing purposes. The method is used for the analysis of fibres, for mycological studies, and for examining pigmentations, spots, etc.

Macrophotography. This method is used to obtain views of aspects that, although visible to the naked eye, need magnification for more accurate interpretation. Such views are obtained with close-up lenses and provide useful information on graphic elements, fibre structure, printing and drawing techniques, etc.

Photographs can be taken not only in natural or artificial light, but also in light beyond the visible part of the spectrum. Such photographs reveal normally invisible features of objects or features that are not shown very clearly by normal methods.

Infra-red photography. This technique reveals the presence of superposed layers of pigments which, because of chromatic assimilation are not easily identified with the naked eye.

Ultra-violet photography. This technique helps the detection of elements invisible to the naked eye, either because they are too slight (faded texts) or else because of their chromatic affinity with the support.

In short, infra-red photography reveals surface elements while ultraviolet photography reveals elements below surface levels that are not visible in ordinary light.

X-rays reveal the shapes adopted by structural elements. They are not of great practical use to the paper restorer since the material with which he works, is too thin and of small absorptive capacity.

6.3.3.4 Education

Photography in the form of printed positives or of slides provides restorers with a valuable educational tool.

At meetings, congresses, discussion groups, conferences, etc., they can use these visual aids to emphasize many points they wish to present.

For that reason, they would do well to assemble a specialized photographic library covering such areas as the causes and effects of deterioration, materials, techniques, instruments, etc. This demands a complete photographic laboratory with colour enlargers, slide projectors and viewers, a variety of lighting equipment, including spotlights with heat-absorbing reflectors, and so on.

6.3.4 Methods of protecting paper during the restoration process

During their progress through the various phases of restoration, some predictable factors are likely to arise and pose special risks to the material cohesion of documents.

Experience has shown that accidents in restoration occur mainly during the various intervals between successive phases of the work, and also during the drying process, during local treatment and especially during washing and rinsing.

The damage can be minimized by:

6.3.4.1 Protection during intervals between successive phases

From the moment it is received in the workshop to the moment it leaves, the item to be restored is subjected to periods of waiting: before the treatment begins, during intervals between successive phases of treatment and finally, from completion of the work to the final dispatch.

In any of these situations, accidents can happen (tears, spots, rucking and even loss) and this the more so when there is a backlog and a lack of proper control. During waiting periods, therefore, items sent in for treatment should be stored in cupboards, filing cabinets and shelving units whose dimensions and structural characteristics make them suitable containers for holding documents under conditions that obviate accidents through negligence.

Individual items such as books and special documents are best kept in cases, bags, boxes, envelopes, folders, etc. that serve as individual receptacles during storage and provide protection during transport.

Needless to say, all materials used in cupboards, etc. or in individual containers should be of a quality suited to their purpose.

It would be absurd if the storage areas of the workshops and laboratories were to be causes of deterioration through lack of proper equipment.

6.3.4.2 Protection during drying

If documents are to be dried in warm air, and provided there are no draughts or other forms of turbulence, they need merely be placed on smooth shelves, thus minimizing damage from sharp projections.

This precaution must be kept very much in mind when drying books that have suffered flood damage or similar exposure, lest serious deformations appear on sheets, book spines, covers or jackets. In order to avoid such damage, additional supports should be used which, without impeding the flow of air, prevent accidents.

On the other hand when air is applied directly through a jet or suction pump, the document must be protected by a rigid or flexible mesh whose texture should match the state of preservation of the item being treated. The mesh can be of simple gauze or thin fabric or, best of all, of plastic.

6.3.4.3 Protection during local treatment

Here the best method is to protect the rest of the item with an impermeable, semi-rigid sheet and thus to spare it the procedures described below.

The sheet should have no sticky surfaces or carry static electric charges, in which case it might pick up or loosen pigments, particularly in charcoal and pastel drawings. One solution is a 5mm thick metacrylic layer with several spacers that will kept it just clear of the document. This system is most useful for the mechanical cleaning of maps, plans, engravings, drawings, etc. with erasers, etc.

6.3.4.4 Protection during washing

Washing is undoubtedly an extremely risky cleaning procedure as it involves the exposure of documents to a medium for which they are, in principle, not adapted and which, in consequence, can lead to unpredictable deformations, tears, ink smudges, etc.

Thus, despite the accumulation of a great deal of knowledge, it is essential before washing documents with any kind of liquid, to make certain that the paper and the inks are stable enough.

The paper has to be protected in all cases, for though it responds well to the liquids commonly used in restoration, most of these liquids upset its equilibrium temporarily. Thus while organic solvents harden it, water weakens it sometimes to the point of exfoliation, the loosening of fillers and the appearance of cracks and tears.

To prevent lasting and irreversible damage, the documents must be suitably protected during treatment, and that means placing them in or on special supports.

These supports can be single or double (sandwich) i.e. in contact with just one side of the document or with both. For the rest, they can be rigid or flexible, permeable or impermeable.

By far the most widely used supports are of the flexible-permeable type, which is easiest to handle and very versatile. One of the best is the so-called 'woven-non-woven' type made of synthetic fibres (polyester, polyamide) which is marketed, among others, under the names of Reemay (Nos. 2014 or 2016 by Dupont) and Cerex (by Monsanto).

Its consistency does not vary even in the smallest sizes, and among its advantages are resistance to most of the products used in restoration, to attack by micro-organisms even after spending a long time in damp conditions, and to the action of cheap adhesives.

It is also possible to use woven fabrics which should be close-meshed (linen, tulle, etc.) even though that entails periodic washing and ironing to prevent the transmission of stains, creases, micro-organisms, etc.

Also very practical is rust-proof mesh made of metal or of synthetic materials (nylon, polyester, etc.). Care must be taken to keep it free of creases lest it damages the documents it is meant to protect. The use of drying or filter paper is not recommended because it loses its strength when wet.

Such flexible or impermeable supports as paraffin or silicone paper are not recommended because they become deformed when wet and may also stain documents by the release of dyes contained in their water-resistant surface.

Sheets of polythene, Teflon, or polyethylene terephthalate (Mylar) of various sizes and transparencies are much more stable.

Sheets of cellulose acetate have instabilities similar to those of silicone paper and lack strength in the usual, smaller sizes.

Rigid permeable supports are usually constructed of more or less fine-meshed rust-proof wires or synthetic fibres, fixed in a frame that lends them smoothness and rigidity. This type of support can take the form of a folder designed to hold documents whose instability prevents all forms of handling. In any case it is a good idea to interpose a flexible folder and to place the document inside it which makes it easier to lift it out later and avoids possible erosion by the mesh.

Among rigid permeable supports special mention must be made of transparent metacrylic or PVC plates. Although very useful for certain types of work, they may cause the document to stick to the plate so that lifting it out presents serious difficulties. For that reason, this type of support should be combined with a flexible cover, for instance a folder.

It may also prove helpful to use boards made of wood, cork or similar material whose floating properties make it possible to keep the document at a fixed level below the surface, so that paper attached to it will be immersed automatically.

Glass and similar supports should be avoided because their fragility can cause accidents.

Perforated metal sheets are not recommended either, because the perforations may cause damage.

6.3.4.5 Immersion in and extraction from the bath

Experience has shown that these two operations, and especially the second, are responsible for most of the damage caused by the restoration process. A wet document loses its normal strength, so that the slightest handling mistake can produce a tear. This sort of mistake is particularly common when the restorer plunges large numbers of sheets into the same bath, or when the washing process has to be interrupted quickly upon the detection of some anomaly in the inks or in the paper.

To avoid such accidents, it is essential to remember that the very simplicity of the operation makes it all the more dangerous. The danger can be avoided by the use of a rigid, permeable support of the folder type and by exercising with due care.

Most supports in common use are flexible and permeable but rigid enough to keep the documents safe.

Immersion. By far the safest method of immersion is to place the documents between two flexible and permeable covers and to lower this sandwich into the bath at an angle of about 45°. In that way the document will enter the liquid without creating air pockets or air bubbles that can cause distortion and tears.

This method of immersion also avoids possible swellings that occur when the document is suddenly soaked over its entire surface. Instead, it is wetted gradually and is not tilted into the horizontal position until it reaches the bottom of the bath or ends up on top of another sandwich.

If a floating platform is preferred, the sandwich is attached to it, whereupon the platform is tilted until the surface of the liquid reaches the document and soaks it completely or over the required area.

Extraction. In order to remove the document from the bath, the sandwich is seized by its sides and, without allowing the document to slide about, is lifted out at the same angle at which it was immersed. In that case, the edge of the bath can be used as a sort of drain through which much of the water trapped in the sandwich can run off.

Once the entire sandwich has been taken out and, providing that the document is held firmly between the two protective layers, the remaining liquid can be drained off by holding the sandwich at right-angles just above the bath. Provided that operation is performed gently, it should pose no problems or danger.

Obviously the last method must not be used with fairly heavy documents or when the gripping power of the supports is too greatly reduced by the sudden loss of liquid. In that case, the sandwich should be placed on a flat surface and left there until it has dried off.

6.3.4.6 Methods of protecting inks or other sustained elements during the restoration process: fixatives

The first step here, which presupposes a great deal of preliminary experience, is to determine the stability of inks under dry or wet treatment.

The choice between these two methods can only be made after tests for stability in particular liquids. If these tests prove positive, i.e. if there is destruction, dilution or dispersion of ink, then the treatment must either be avoided or the ink must be protected with fixatives after a careful evaluation of their advantages and potentially deleterious side effects.

These effects can be changes in the texture of charcoal, pastel or similar drawings due to amalgamation of pigments and blurring; in particular they can lead to the creation of haloes that alter the appearance and colour of the original. With the passage of time they can also cause the surface to turn yellow, generally through oxidation. All these effects vary in intensity with the amount of fixative used. For that reason the minimum amount of fixative should be applied, and removed once it has done its work.

Fixatives must stand up to the proposed techniques and procedures; cause no harm to the document and be reversible in media that must cause no harm to the document in their turn.

On occasion it may be best not to remove fixatives, especially when they are needed for lasting protection. In that case the risk of possible side effects will have to be discounted.

In any case, fixatives are extraneous to the original document and should be applied with care, the restorer always leaving evidence of their use in case subsequent treatment should be needed.

Most traditional fixatives act as new ink adhesives or as new coatings, i.e. their action is mechanical unlike that of some more recent and rather unsuccessful fixatives based on chemical electroastatic processes.

It is of the utmost importance to choose a fixative whose effects will not be nullified by the subsequent restoration process, or worse still which will give rise to stains or blotches.

Fixatives are applied locally or as a protective coat over the whole surface. They should be sprayed (those containing inflammable solvents must be kept away from sparks or flames) or brushed on.

The concentration varies greatly and depends on the porosity of the support and the required adhesive power. For that reason and also because the vehicles of most fixatives are volatile solvents, it is impossible to lay down specific concentrations, the less so as evaporation greatly increases the concentration of the solvent and is difficult to control. It is therefore common practice to prepare a high concentration and to dilute it as and when required.

The most common fixatives and their solvents are:

Laboratory gelatine prepared by dissolving 30g of gelatine per litre of water at 40° C in a bain-marie.

Naturally, this fixative must not be used on documents requiring both treatment and in tepid water in particular. On the other hand, it is eminently suitable for use with non-aqueous solvents and it can be left permanently on the paper as it is one of its natural elements.

Laboratory gelatine (3%) hardened with formaldehyde (1.5%). The inclusion of formaldehyde in the gelatine preparation allows the use of this fixative even with bath treatments. The formaldehyde hardens the gelatine irreversibly. It should, however, be borne in mind that excess of it can cause a dangerous hardening of the paper itself which may then split. In some cases a small amount of treacle or of a similar substance, e.g. glycerine or glycol can be added to increase paper flexibility.

Cellulose acetate dissolved in acetone. This fixative forms a strong protective film. It should not be used when the atmospheric humidity is excessive or dissolved in acetone containing a great deal of water, or it may produce a whitish coat.

Polaroid dissolved in potassium nitrate solution, xylene or toluene.

Soluble nylon dissolved in warm alcohol. Should be applied at moderate temperature.

Mowilith dissolved in acetone, xylene or toluene.

Commercial fixatives. Many commercial fixatives are particularly suitable for use with drawings. Most are acrylic resins sold in spray form for ease of application. It is best to choose one that is reversible and produces the smallest degree of yellowing in aging tests. The most popular are Fixer Spray (Pelican), Taker, Krylon, Krilac and Regnal.

Pencils. Sometimes it is possible to cover fine ink marks by running the tip of a greasy lead pencil over them. The new marks are easily erased and rarely need solvents for their removal.

A great many other substances also have special characteristics that make them eminently suitable for use as fixatives.

6.3.5 Insecticides, disinfectants, sterilizers

Ever since organic substances were first used as writing supports, bibliophagous insects and other vermin have been among the worst destroyers of this part of our cultural heritage.

Even in ancient archives, it was therefore common practice to place documents in ceramic containers or in wooden boxes impregnated with balsam and hence shunned by harmful insects.

Later, mineral substances (lime, mercury, sulphur) which alchemists prepared in accordance with more or less set formulae, were added, their effectiveness being boosted further by special supplications in or on the first pages of books.

In the nineteenth century scientific research led to the emergence of new techniques and methods that have since given rise to a whole pesticidal industry, and the manufacture of a wide range of products for waging microbiological war on a host of pests.

Bibliophagous species can be fought by chemical, physical and biological methods.

6.3.5.1 Chemical methods of pest control

Chemical pesticides can be organic, inorganic or synthetic compounds. They include a range of bacterecides, fungicides, insecticides and rat killers and act in different ways (ingestion, contact or inhalation).

Ingested and inhaled poisons act on individual pest while contact poisons affect a whole community. In either case the action of the poison may be immediate or delayed and may either undermine the function of individual organs or else lead to coagulation or oxidation of all the protoplasm.

The drawback of these products is the danger of their indiscriminate use, the dosages used being wasteful or ineffective and, in either case, potentially harmful to man.

In view of this danger, all toxic products should be handled and applied exclusively by specially trained staff.

Chemical pesticides can be applied by sublimation, spraying or fumigation, depending on whether the poison is in solid, liquid or gaseous form. Solids in solutions or dispersions remain active over a longer period but have a relatively low exterminating capacity.

Solids that sublime have limited powers of penetration and unless applied in high concentration create unpleasant atmosphere with small lethal effect. The most common are:

paradichlorobenzene (225g/m^3)

thymol (30g/m^3)

paraformaldehye (5-6g/m^3).

These solids are deployed in receptacles placed at strategic points of the room, shelving unit, cupboard, etc.

Others, for instance orthophenyl phenol or sodium slat (1.5% in alcohol or water), can be incorporated in natural adhesives or other substances attractive to insects or micro-organisms.

Liquids are more effective when used for impregnation, especially against xylophagous insects which attack furniture or structural timber. Commercial products have an oily appearance due to the solvents in them and should be applied carefully lest they stain documents.

The most common for the protection of documents are:

formaldehye

applied throughout the building: 100-150cc/litre of water/100m^3. Must be left for 48 hours

in a closed room: 250g/m^3 at 30° C; relative humidity of 60 per cent. Must be left for 24-48 hours

pentachlorophenol sodium salt: 10.50g/litre of water/100m^3

phenol: 2.5g/litre of alcohol/100m^3

parachlorometacresol: 50g/litre of ethanol and 50 per cent water/100m^3

paradichlorobenzene: 225g/litre of alcohol/m^3.

All can be applied directly or sprayed into the air, preferably with industrial sprayers equipped with automatic controls.

Gases and fumigants act quickly and are the most drastic agents of biological warfare.

If the bibliophagous species to be exterminated is xylophagous as well and nests in the woodwork, gas and liquids can be combined to obtain a rapid and complete annihilation of both adults and larvae. The most common fumigants are:

ethylene oxide which acts as a combined insecticide, fungicide and bactericide. It is also a sterilizer;

methyl bromide: insecticide.

For application in undiluted form these fumigants must be applied in vacuum or pressure chambers with special characteristics (see 4.2.3.2), especially ethylene oxide which explodes in contact with air.

Both fumigants are highly toxic and should be used with great care (masks, special clothing, etc.).

Ethylene oxide (more effective than methyl bromide) loses its explosive capacity when used in a commercial mixture of 10 parts of ethylene oxide to 90 parts of carbon dioxide or Freon.

This preparation is suitable for use in fume cupboards or any other hermetically sealed containers or in rooms that can be sealed off with putty or with special adhesives designed for the job.

It is essential to take precautions against the formation of pockets of gas which could create a potential risk. In addition, anything capable of producing sparks or flames should be removed.

The normal dosage is 1-3kg of this mixture per $10m^3$. It is applied directly from the commercial cylinder which has a manually controlled escape valve.

Duration of treatment is from 48 to 72 hours and it is very important that the environmental temperature should be above 15° C as, below this figure, the gas loses its effectiveness. The ideal temperature is 18°-21° C and the temperature should not be allowed to rise above 30° C.

Once fumigation has been completed, the room and the documents should be ventilated before being returned to the storage area for use by the public or staff.

It must be remembered that this type of fumigation is purely curative and that preventive measures must be used to avoid the return of bibliophagous species. This danger arises because the pupae of these insects are immune to the fumigants described, and after a few days when the effects of the gas have worn off, resume their cycle of devastation.

Moreover, there is always a chance that new species will invade areas cleared of competitors.

Hence it is advisable to repeat the treatment every 15-30 days.

6.3.5.2 Physical methods of pest control

This group is very heterogeneous, most physical methods having a perturbatory rather than lethal effect (see section 5, under cold, heat, vibration and light).

This leaves us with two physical methods with great lethal power. Neither can be recommended unreservedly as both can damage cellulose.

Irradiation. The penetrating power of gamma rays and of X-rays can be harnessed to the destruction of bacteria. Though these rays have to be applied with special equipment and by trained staff, they may prove useful in certain cases provided exposure is not too long, i.e. is stopped before the degrading effect on cellulose becomes patent.

High frequency electric fields. High frequency microwaves have an insecticidal and disinfectant effect, but because they raise the temperature of the objects they strike, they may set paper on fire.

6.3.5.3 Biological methods of pest control

Many bibliophagous species are preyed upon by non-bibliophagous species. Thus some spiders, ants and fungi attack silver fish in the same way in which wasps, cockroaches and beetles attack certain fungi.

This situation, although not yet exploited may in the near future be used to ward off invasions of bibliphagous insects. It may, of course, become necessary to destroy the predators in turn, but that is a much simpler task as the species concerned are not adapted to life in archives and libraries.

6.3.6 Cleaning

This heading includes all attempts to get rid of dirt or additives that detract from the appearance or originality of a document or book.

For centuries, cleaning was the most common, indeed the sole, form of paper restoration, as witness the large number of methods, products and 'formulae' handed down to us. These methods, together with more recent recipes, can be divided into four groups, namely mechanical cleaning, cleaning with non-aqueous solvents, washing and bleaching.

The choice of cleaning method depends on the degree and extent of dirt and stains (solid particles; greasy substances; aqueous suspensions or solutions; oxidation products; micro-biological pigmentation).

It is very important to identify and distinguish the nature of these soiling elements, because each requires specific treatment, and mistaken diagnoses can increase damage through the prescription of the wrong cure.

Stains caused by solid particles (contamination, wear, etc.). Such stains are easily distinguished because they are located on the surface or sides of the paper. They can be detected by simple touch (particles can be picked up by moving a finger gently over the surface) or by using a gentle abrasive such as an ordinary eraser. This sort of surface dirt should be removed by mechanical cleaning methods, not by treatment with water or other liquids that might help to soak the particles into the paper and so make them more difficult to remove.

Grease stains. These stains can be recognized by their uniform dark brown colour and by their blurred edges. They are round and show up on both sides of the paper, but more strongly on the side that has been soiled. The grease oxidizes in time and turns into solid particles that are not soluble or dispersable in what would normally be suitable solvents. In that case, the only method of removal is bleaching or saponification.

Stains caused by aqueous suspensions. These stains can be divided into two groups:

Stains caused by running ink. In general, such stains affect one side of the paper only, as their own density prevents their total absorption. They have clearly defined edges and, on being moistened, may be seen on the reverse side of the paper because water dissolves and increases the penetrating power of ink.

Stains caused by water (floods, drips, etc.). These 'damp' or 'water' stains have a characteristic method of advancing: their rim gradually spreads and, once it has dried out again, leaves an area cleaner than the surface not attacked by the damp. This effect is due to the capillary displacement of dirt particles on and inside the paper.

Such stains affect both sides of the paper, their colour depending on the particles in the water.

In both cases washing is the best remedy.

Stains produced by the oxidation of metallic elements, of cellulose or of other organic substances incorporated in the paper, as well as by microbiological pigmentation (fungi and bacteria). These stains can be distinguished by their dark yellow colour. If they appear on the whole surface of the paper, they are the result of structural acidity, but if they are small and mottled with maximum intensity in the centre, they are caused by metallic particles and their oxidizing effect. When the mottling is of microbiological origin it will occasionally assume the velvety appearance of the micro-organism itself. This is clearly visible in larger stains which comes in a variety of colours depending on the pigmentation of the fungus or bacterium responsible.

Such stains are neither soluble nor can they be dispersed. All that can be done to remove them is to reduce their surface concentration by mechanical cleaning methods followed by bleaching.

A document can acquire a whole series of additives (patches, secondary supports, reinforcements, etf.) or spots due to solid or dissolved pigments or to chemical and biological agents, etc.) which require special treatment, namely:

6.3.6.1 Mechanical cleaning

This is invariably performed with dry substances and its aim is to remove solid matter from the surface of the paper.

Typical concentrations of solid matter are due to dust, atmospheric pollution or disintegration of the paper. They can also be caused by rubbing, or wear or by solid pigments.

In this type of cleaning, the affected area is treated and great care must be taken not to damage the writing or other areas covered by the stains. Since the cleaning agents are fairly abrasive, the rest of the document needs special protection.

The most usual methods of mechanical cleaning involve the use of:

Cleaning rooms, fume cupboards or cleaning tables. Given that mechanical cleaning loosens solid particles encrusted in the document, all such particles must be eliminated before they contaminate the area in which the cleaning operation is performed. For that reason, the cleaning should be done in a special area from which dust can be expelled by special extractors.

In closed rooms or fume cupboards extraction should ideally take place through the floor as well as through the walls and the ceiling.

In the case of cleaning tables fitted with additional suction apparatus, a special aperture to absorb scattered dirt obviates encrustation of the other side of the paper.

Dust extraction or removal can be done by:

Vacuum cleaners. This is a good method, providing that the document is sound enough to stand up to the action of the vacuum cleaner.

Less hardy documents are best protected with nylon, metal or similar mesh, which makes it possible to extract the dirt without the risk of damaging the document.

Compressed air blowers. The use of compressed air is not generally advisable because it stirs up dust. However, on occasion it may prove the best method of cleaning bindings or documents made of strong material. The operation should be performed in a fume cupboard equipped with an extractor.

Brushes. Brushing is a good way of removing dust. Brushes come in a large variety of sizes and degrees of hardness.

Abrasive methods

Erasers in bar, granulated or powder form. Erasers provide one of the best methods of removing surface dirt. They can be of different degrees of hardness but must not stain or have greasy characteristics. It is possible to determine whether an eraser has these effects, by rubbing it on a piece of white paper and sprinkling a little pastel or carbon dust over the rubbed area. If the dust particles stick to that area, then the eraser contains grease.

A combination of soft and hard erasers will remove most surface stains caused by solid particles. The hardness of the eraser and the intensity of the operation should be matched to the sensitivity of the paper.

Erasers in powder form (powdered rubber) usually come in perforated bags that are rubbed over the surface of the document. Their action is very gentle, and as the rubber granules get dirty - evidence of their cleaning action - they should be scraped off the bag. By gentle tapping, the bag can be made to release fresh powder. The bag itself should not be allowed to become dirty or it will soil clean areas of the document.

Large surfaces are best cleaned with erasing machines, small motors with a spindle carrying cylindrical areasers of chosen hardness.

Glass or nylon fibre brushes. These brushes are highly abrasive and very effective in removing surface dirt. Their action is similar to that of sandpaper. They come in pencil form or mounted on a spindle.

Clay powder (Fuller's earth). This power, very soft to the touch and consisting of small particles, serves to remove semi-hard surface stains. Its abrasive action is very gentle and easily controlled.

Self-adhesive tape and absorbent erasers. The adhesive powder of these tapes makes it possible to use them for removing surface dust or dirt. They should be applied directly, gently and without excessive pressure so as to avoid complete adhesion.

Scrapers. Some surface stains caused by accumulations of solids can be scraped off providing that the operation is performed skilfully enough not to cause any serious damage.

A scalpel or knife may be an effective means of removing stains of this type, and so is sandpaper of a fine grade.

6.3.6.2 Cleaning with non-aqueous solvents

Stains caused by non-aqueous substances are very common on paper and can be removed with dry-cleaning solvents, so called because their volatility causes rapid drying, which must occasionally be checked to avoid excessive dehydration of the paper.

The cleaning power of this type of solvent goes hand in hand with a number of negative characteristics which should be remembered if poisoning, fire, incompatibility, etc. are to be avoided.

The solvents can be applied generally in a bath or locally with a paint brush or even better, with wads of cotton wool or absorbent paper, or in a paste of talcum, lead or paper pulp.

Generally local treatment is applied first followed by a bath. The solvent is more effective at higher temperatures, but then there is the risk of fire or even of an explosion. This work must never be done in the presence of a flame or a spark, and is best confined to a gas chamber or fume cupboard, as the majority of these solvents have toxic effects. The safest method of heating is in a bain-marie, a bath holding hot water in which vessels can be heated slowly.

The following table lists the most common solvents and their sphere of application.

Stains	Solvents
Varnish	Ethyl or methyl alcohol, acetone
Mud	Water and ammonia
Tar	Petroleum ether
Wax	Hexane, petroleum ether, toluene, chloroform
Self-adhesive tape	Chloroform, dichloromethane, acetone, alcohol, petrol
Grease	Trichloroethylene, perchloroethylene, petroleum ether, essence of turpentine, dimethylformamide, tetrachloromethane
Rust	Freshly prepared oxalic acid (3%)
Lacquer	Acetone, alcohol, xylene, toluene
Aniline ink	Alcohol
Ball point ink	Diethylene glycol, alcohol
Ink-pad ink	Acetic acid, ethanol

6.3.6.3 Washing

Many stains on documents are caused by particles in aqueous suspension or solution. They can only be removed in water baths which help to disperse or dissolve them. In other words, they have to be washed off, notwithstanding the risk of weakening the paper or diluting the ink.

Washing must always be coupled with appropriate protective measures to prevent mishaps. It should only be used if it is certain that, when dry, the paper will have a better appearance and, above all, greater physical strength thanks to better chemical linkage of the fibres following the destruction of extraneous elements.

However, not all types of water are suitable; the best is hard water containing large amounts of calcium but devoid of iron, copper and chlorine. This type of water acts as a pH regulator. Neither distilled nor de-ionized water will do, as both remove ions from the paper to compensate for those lost during distillation or de-ionization and hence weaken or upset the structure of the paper. The correct mixture is obtained by dissolving bicarbonate or calcium hydroxide (0.1 to 1 per cent) in the water.

The duration of baths is directly related to the quality of the paper and the temperature of the water.

Paper of normal quality may remain stable during prolonged immersion in a water bath at a low temperature, but the ink may be dispersed or dissolved. The stability of both decreases with rises in the water temperature, i.e. as the adhesives are softened and the interfibre links weakened.

Except in special cases, it is not advisable to work at temperatures lower than 15° C. The ideal temperature is the average temperature of the surroundings. To avoid fluctuation during treatment, it is best to use thermostatically controlled tanks or baths in which the water is continually renewed. This method is particularly suitable for intensive rinsing treatments.

The action of the water can be augmented with detergents, colloidal agents or enzymes.

Detergents. Detergents are substances that, by reducing the surface tension of water, increase its wetting effect and emulsify oils and grease, thus facilitating their removal. Dirt due to atmospheric pollution consists of solid or other particles, coated with greasy substances that lend these particles their water-repellant quality and hence render them insoluble in water.

To counteract this effect, the water must be provided with agents that destroy the greasy coating and hence allow the particles to be dispersed or diluted.

In addition to this degreasing action, detergents surround the now grease-free dirt particles with a water-repellent emulsion that prevents their sticking together and makes it easier to get rid of them in the final rinse.

Soaps are detergents containing alkaline salts of fatty acids which can damage cellulose. Hence only those proved to be harmless should be used - the so-called neutral soaps - and even then it is necessary to remove residues by thorough rinsing in clean water.

The dosage of detergents varies according to the quantity and resistance of the stains, but a 10 per cent solution can be used for test purposes and can, if necessary, be strengthened.

The most common detergents are: Lissapol N, Teepol G, Tergitol, Triton 100, Nekalin and Tween 60 and 80.

Colloidal agents. Certain solids, dispersed and dissolved in water will attract and retain particles of dirt loosened in the bath. They also prevent dirt from returning to the document.

The dosage of these agents cannot be specified but it should be remembered that they are present in many detergents.

The most commonly used are: bentonite, saponin, soft soap and especially methyl cellulose and carboxymethyl cellulose.

Enzymes. Enzymes are proteins produced by living cells. They are chemical catalysts and, in paper restoration, are used to 'weaken' natural adhesives (glues and pastes). For that reason they are eminently suited to the separation of sheets that have become stuck together and to the removal of stains caused by adhesives.

The whole document is immersed in a bath containing the enzymes or else the preparation is applied locally with a nylon brush (enzymes damage natural bristle).

The treatment should be quick and performed at a fairly high temperature (30-40° C). When the work is finished, the sheets of paper are transferred to a bath of cold water, frequently renewed.

The most frequently used enzymes are: pancreatin (5 ionization litre of water at 40° C) amylase and protease (1g per litre of water at 37° C). The last two enzymes can be applied jointly or severally, the amylase always being used first. All of them work best in solutions with a slightly alkaline pH.

Enzymes should be kept away from light and stored in a cool and preferably dry place.

6.3.6.4 Bleaching

Some stains have or acquire characteristics that do not respond to mechanical cleaning, washing or the application of solvents. In that case the only solution is bleaching which, for many years was the most widely used of all restoration techniques, not surprisingly so since, though very simple to apply, it can produce spectacular results.

The same empirical approach that made bleaching so popular, also revealed that it weakens cellulose appreciably, sometimes to the point of complete disintegration, especially in the case of modern documents.

Chemical analyses have since shown that bleaching is based on oxidation, and the oxidation of cellulose triggers off a process of acidification that breaks up the molecular structure of the cellulose and hence weakens the paper.

Modern paper is particularly sensitive to bleaching because it tends to be acidic.

For all these reasons, bleaching is nowadays considered the potentially most harmful form of cleaning. Its use should be limited to very special cases and then always with the strictest controls. In particular, bleaches should be added to baths in weak solutions, renewed for each new treatment, and immersion should be quick. For local use, it is better to use higher concentrations.

With chlorine compounds, potential damage can be reduced and even completely eliminated if the document has an alkaline reserve (pH 8-10) and thus escapes the harmful oxidation that occurs in acid media. Thus before starting the bleaching operation, it is essential to wash and de-acidify documents. After that operation, the secondary effects of the bleaching agent must be offset with a new wash and antichlor treatment (neutralization). Finally a de-acidifier should be applied, leaving the paper with a suitable alkaline reserve.

It should be remembered that the bleaching of stains releases organic and other acids, all of which reduce the pH of the bleaching bath. For that reason it is best to regulate the pH by the addition of alkalis that will stabilize it at between 9.5 and 10. That way, the damage will be minimized and it will also be possible to control the rate of bleaching.

Bleaching can also be done with the help of gases, for which purpose special chambers must be used. However baths are more effective. Other methods include spraying (not greatly recommended) and local application with a brush, cloth or a paste made from a mixture of colloids and bleach.

The most commonly used bleaches are:

Hypochlorites. The best-known are sodium hypochlorite and calcium hypochlorite, due to their ease of handling and low cost, although uncontrolled use can be highly dangerous, as witness the fact that, because of their great bleaching power, hypochlorites are the only chemicals to remove stains produced by micro-organisms.

Both types have similar effects although sodium hypochlorite (thanks to its sodium hydroxide content) penetrates the fibres and bleaches them completely while calcium hypochlorite merely acts on the surface.

Sodium hypochlorite is slightly more risky to use - although more effective - than calcium hypochlorite which, moreover, leaves the paper with a more natural appearance.

Sodium hypochlorite should be made up into a 2 per cent to 10 per cent acqueous solution. For local treatment this percentage can be raised to 30, depending on the type of stain and the strength of the paper.

As we have said, it is the most widely used bleach, because of its sweeping effects.

Calcium hypochlorite is also known as bleaching powder and can be used either in solution or else in powder form.

When used in solution it is prepared at the rate of 5g per litre of water, then left to settle or filtered. The final solution should have pH 9-10.5.

When used as a paste it lends itself to local application although its action is slow.

Generally, bleaching powder can be recommended for its effectiveness and low degrading effect.

Chloramine T and chloramine B. These are two organic chlorine derivatives with similar characteristics and applications although the first is the better known.

Their behaviour in aqueous solutions is comparable to that of sodium hypochlorite but slower because they take longer to hydrolyse.

Both should be neutralized as soon as the paper has been bleached enough, as otherwise they will continue to act and attack the paper.

Neutralization calls for the use of antichlors because the chloramines cling to cellulose and washing is not enough to eliminate their residues, which become converted into compounds insoluble in chloramine.

In their natural state - white powders - they are very unstable and should be kept away from light and moisture. All in all, they have no real advantages over hypochlorites, for not only are they less potent but they can have very harmful side effects.

Chloramines are usually applied in 5 per cent aqueous solutions.

Sodium chlorite. This compound which comes in crystals or a white powder will, in the presence of some acids (formaldehyde and sulphuric acid) release a yellow gas with bleaching properties.

This gas is chlorine dioxide and can be applied in aqueous solution or directly.

It makes an effective bleach and its degrading effect on paper is very low.

Sodium chlorite is toxic and an irritant and, if used incorrectly, may cause explosions and fires. For that reason it should only be handled by experienced staff following the manufacturers directions to the letter.

Dissolved chlorine dioxide. This bleaching agent must be applied in a fume cupboard equipped with a gas extractor. The expelled gases must, moreover, be quickly dispersed to prevent the formation of toxic and incendiary gas pockets.

The bleach is prepared from an aqueous solution of sodium chlorite (20g of sodium chlorite per litre of water (2%)) to which a solution of 25ml of formalin (37-40% aqueous formaldehyde solution) is added. This mixture immediately turns yellow as a sign of the formation of chlorine dioxide, the active bleaching agent.

The document to be treated is immersed in a bath and kept there until the stain disappears (the maximum immersion period is 10 minutes). The document should then be washed in a water bath. Antichlor is not needed, as the chlorine dioxide escapes without leaving any residue. Dissolved chlorine dioxide makes an excellent bleach, not only because of its effectiveness but also because of its low degrading action.

Identical effects can be obtained when the formalin is replaced with 2N sulphuric acid, the acid being allowed to drip into a 10 per cent aqueous solution of sodium chlorite. This preparation can be diluted as required.

All things being equal, however, it is preferable to use formalin, which is easier to handle than sulphuric acid.

Chlorine dioxide in gaseous form. This method should only be used in a special chamber as described by various authors (see bibliography: 41-A by Otto Wachter).

The document is placed inside the chamber and the gas released in high concentrations.

The method seemed unlikely to lend itself to large-scale applications, but the idea has had to be revised because, on the one hand, the gas is poisonous and explosive and, on the other, the spectacular results turned out to be transitory - the stains reappear after a short interval. Moreover, the document has to be moistened before treatment and the gas cannot be applied indiscriminately as it discolours inks containing organic compounds, turning black ink into brown.

Nevertheless this gas provides a useful means of bleaching stains on pastel, carbon and wax drawings.

Chlorous acid. This acid is obtained from sodium chlorite by slow acidification down to pH 3.6. The pH must be maintained at about that level since, if it is allowed to drop to 3, the resulting acid will decompose and release chlorine dioxide. If that happens, the solution will acquire the yellow colour characteristic of that gas. At pH 3.6 by contrast, the solution is colourless.

This bleach has a gentle and slow action. As a precaution against the scape of chlorine dioxide, it is best to work with a chamber or fume cupboard equipped with a gas extractor, taking the same precautions as with chlorine dioxide in aqueous solution.

Chlorous acid is applied in an aqueous solution of sodium chlorite no higher than 5 per cent (50g per litre of water) to which acetic acid is added drop by drop until the solution has pH 3.6. The solution can then be applied in a bath or locally. After bleaching, the document should be washed and neutralized to remove all traces of the acid.

Potassium permanganate. This bleach is rarely used nowadays although in earlier times it was very popular because of its spectacular results. Its oxidizing power makes it one of the most paper-degrading of all bleaches. Its bleaching action is due to the manganese dioxide released by aqueous solutions of the permanganate. It has a pronounced reddish brown colour which stains the paper and makes it impossible to determine the degree of bleaching attained until a decolorant is applied. The treatment may therefore have to be repeated several times until a satisfactory result is obtained. For that reason it is best to work in short bursts.

The bleach is prepared by dissolving 5g of potassium permanganate in a litre of water. After treatment, the document is immersed in a 5 per cent sodium metabisulphite solution until the reddish-brown colour disappears. The sodium metabisulphite solution can be replaced with a 3 per cent oxalic acid solution.

In any case it should be reiterated that the use of potassium permanganate as a bleaching agent is not recommended because of its pronounced degrading effect on cellulose.

Sodium horon hydride. This is a bleach that has not been fully tried out but gives good results especially as it is a strong reducing agent.

In aqueous solution it behaves like the sodium metaborate which acts as a pH regulator, but, after hydrolysis, it forms caustic soda which can seriously weaken cellulose. It has the best bleaching effect at pH 9.

During hydrolysis it releases hydrogen which may explode in contact with air. For that reason it should be applied in a chamber or fume cupboard fitted with a gas extractor, and extreme care should be taken when dissolving it in water, with which it reacts violently, giving off large amounts of hydrogen.

As it can cause accidents (explosions) at high temperatures and/or degrees of humidity, it is best not to store it in large quantities.

Sodium boron hydride should be applied in solutions containing 1g of the compound for every 100g of paper to be treated. The document is immersed in a bath until it has been bleached enough, when it should be washed and neutralized.

Hydrogen peroxide. Hydrogen peroxide is a vigorous bleaching agent but has a marked degrading effect on cellulose containing iron or copper, elements that it readily oxidizes.

It is suitable for local treatment but, whatever method of application, should only be used with paper having an alkaline pH, or it may cause major damage.

Hydrogen peroxide can be applied directly, in various aqueous solutions (using commercial 20 volume h_2O_2 mixed with ethyl ether or ammonia, in which case its bleaching action is combined with pH regulation.

Sodium perborate. This boron compound is not a very effective bleaching agent because of its extreme mildness and slowness. It is usually made up in a 1.2 per cent aqueous solution and its effect is improved by exposure to sunlight.

Ozone. Ozone though a powerful oxidizing agent, has no appreciable bleaching effect.

Sunlight. Solar radiation or, in its absence, light sources with similar properties (e.g. xenon arc lamps), can be used to bleach stains on documents, but as all these radiations can have harmful side-effects (photo-oxidation), the paper must be protected with the help of a considerable alkaline reserve and by careful screening of those areas that are not to be bleached.

This method usually works well with yellow stains caused by acids, providing the paper is not made of wood pulp, which sunlight darkens by oxidation of the lignin and alum.

The main disadvantage is that the paper has to be exposed for very long periods, which may prove awkward.

Optical bleaches. These fluorescent substances used by the paper industry to improve the appearance of paper are not recommended because they are not fast to light and insoluble in water.

Antichlor. The need to regulate the action of chlorine bleaches calls for the use of certain products that also destroy their harmful residues. They are called antichlors because a large number of bleaches are derived from chlorine, but they also work with most non-chlorine bleaches.

Before antichlors are applied to it, the document should be given a good rinse or wash in circulating water to remove as much of the bleach as possible. If this is not done, and a highly alkalkine substance is brought into contact with a highly acidic one, there will be a violent reaction with consequent damage to the cellulose, a change in the colour of some inks and even the disintegration of graphic characters.

The most common antichlors are sodium thiosulphate, sodium bisulphate and sodium metabisulphate, in 2.5 per cent aqueous solution. Their residues can also cause deterioration especially in the form of stains. For these reasons it is best to supplement antichlors with strongly diluted aqueous solutions of weak acids, which help to remove traces of chlorine with the minimum of trouble.

6.3.7 Deacidification

Deacidification, a method not used by restorers until a few decades ago, is a not very spectacular process because, unlike other treatments, its results are not visible. However, it is of enormous importance in paper conservation.

Its aim is to remove the harmful effects on paper of acids introduced by internal and external agents of various origin. Acids destroy molecular bonds, destabilize the cellulose structure and trigger off a slow degenerating process that ends in the total disintegration of the paper. Their harmful effects on the physical-mechanical properties of paper may be compared to the continuous erosion of the structural elements of a building which, after a period of time, causes total collapse.

Degradation of paper by acidity is reflected in the appearance of the yellow tone characteristic of this process, accompanied by increasing fragility, as a result of which the paper is transformed into a very brittle substance that crumbles at the slightest touch.

Deacidification does not cure the effects, but aims at the removal of their original cause: acidity. It can be effected by dilution and by buffer solutions.

Treatment by dilution has limited effects and even then on some soluble acids only. Moreover, it is not lasting enough to prevent the formation of new acids, even in a short space of time.

Buffer solutions, by contrast, transform acids into harmless elements by chemical means and create an alklaine reserve which impedes the formation of new acids, at least in the same conditions as helped to produce them in the first place. Because of their chemical action, buffer solutions belong to the group generally known as neutralizers, though because of their specific function they are more correctly defined as deacidifiers.

On occasion, paper may be damaged not by acidity but by its very opposite, i.e. excess alkalinity, which is as dangerous as acidity but less common, and can be treated by acidulation (in a bath).

In any case the pH of paper must be stabilized between 7 and 8, with the rider that paper of a more acidic type should have a pH closer to 7, because if highly acidic paper is put in a highly alkaline pH environment, the result may be grey or brown discoloration.

Deacidifiers can be applied in gaseous or in liquid form.

Gaseous deacidifiers make it possible to treat documents 'en masse', that is, without having to separate them or even having to remove them from the storage area.

The results so far, however, though very promising, have not yet proved to be effective or permanent enough, and there are serious technical and economic difficulties. There is a keen need to find the best answer to the serious problem posed by thouands and thousands of books and selected documents on the shelves of libraries and archives awaiting treatment for this 'cancer' of paper.

Liquid deacidifers already produce permanent, if limited, results of proved effectiveness.

We distinguish between aqueous and non-aqueous types, depending on whether the deacidifying agent is soluble in water or in an organic solvent.

The most common deacidifers are:

6.3.7.1 Aqueous deacidifiers

Water. Water is an excellent solvent of soluble acids such as polyglucuronic acid, formed by the photochemical degradation of cellulose or of other by-products such as sulphates which are capable of turning into acids. Water has no buffer effect and does not create an alkaline reserve; even if it is very hard (350 ppm) due to the presence of carbonates, its alkalinity is insigificant.

Magnesium and calcium carbonates. These carbonates are not water soluble, and even when in very fine suspension lack penetrating power and cannot serve as deacidifying agents.

To turn them into such, they must first be transformed into bicarbonates - by passing carbon dioxide into a solution of the carbonate in water. The resulting compounds are soluble in water and able to penetrate paper. They later surrender their carbon dioxide and change back into solid carbonates which have a stabilizing effect on paper by creating an alkaline reserve.

Of the two carbonates mentioned, calcium carbonate is the more widely used in restoration, although both produce excellent results. Sometimes they are used in conjunction.

The simplest method is to dissolve 1 to 3g of the carbonate per litre of water in a vessel into which carbon dioxide can be blown. The resulting bicarbonate is transferred into a tank in which the document can be immersed for one or two hours. Next the document must be aired to allow the bicarbonate to be reconverted into a carbonate.

During the bath, the pH should be checked and the solution changed or adjusted in case it is found too excessively or insufficiently alkaline. The final pH of the paper should be between 8 and 9.

If the document cannot be immersed in a bath, a solution of these bicarbonates in alcohol can be applied with a brush or spray.

Barrow has developed an apparatus with rows of spray nozzles fixed over a work bench on which the pages of a book can be treated in succession.

It is important to ensure that the distance of the nozzles or high temperatures do not produce carbonate deposits on the surface of the paper, in which case a white film will appear. The latter must then be removed with slightly acidulated water.

Another variant of this method has been developed by Cunha, who obtains the bicarbonate from soda water: he drops in the carbonate, shakes the mixture and then pours it into the tank in which the document is being treated.

The bath should be covered with plastic and the temperature kept low to reduce the escape of carbon dioxide. The bath must take 20-30 minutes.

Sodium and potassium carbonates. Though these carbonates are water soluble, their use is not recommended because they are very powerful alkalis and hence degrade cellulose. If the pH rises above 10, they will darken the paper and diminish its mechanical resistance.

Calcium and magnesium hydroxides. When brought into contact with paper in a bath, these hydroxides (soluble in water) react with atmospheric carbon dioxide and change into carbonates (insoluble solids) which stabilize the alkaline reserve they create.

Of the two, calcium hydroxide is the more effective, for which reason magnesium hydroxide is not used very often.

Calcium hydroxide (lime-water) is the most practical of all aqueous deacidifiers, because of its low cost, ease of preparation and excellent results.

It is prepared by suspension in water until saturation point is reached (approx. 1.5g per litre of water). The mixture is decanted, and the supernatant liquid, which should be completely clear, is poured into a bath which should be administered for about 10 minutes. Next the document should be aired to activate the carbon dioxide before final pressing.

Sodium and potassium hydroxides. These two compounds are not recommended because their high alkalinity has a degrading effect on cellulose. Of the two, potassium hydroxide is the less harmful.

Sodium tetraborate. This compound, also known as borax, owes its deacidifying action to the fact that during hydrolysis it breaks up into boric acid and sodium hydroxide, which latter is the actual deacidifying agent.

Its additional fungicidal powers contributed greatly to its popularity, but nowadays it is not normally used because calcium hydroxide gives better results.

Borax should be applied at 25g per litre of water.

6.3.7.2 Non-aqueous deacidifers

Barium hydroxide (octohydrate). Its effectiveness as a deacidifier and its solubility in methanol together with its low cost and simple preparation, have made barium hydroxide the most widely used non-aqueous deacidifier.

Barium hydroxide is converted into barium carbonate by atmospheric carbon dioxide (much like calcium and magnesium hydroxides).

Made up in a solution of 10-20g per litre of methanol it is administered in a bath for 15-30 minutes. As barium carbonate and methanol are slightly toxic they should be applied in a chamber or fume cupboard with a gas extractor.

Baynes-Cope, Santucci and John Williams have described the positive effects of this compound.

Calcium, barium and magnesium acetates. All these acetates are transformed into carbonates in the presence of atmospheric carbon dioxide.

Calcium acetate is not directly soluble in alcohol and must first be diluted in water (2g per 20ml of water). Ethyl alcohol is then added to make up a litre. Once prepared, the solution must be used within three days. The document should be bathed in the solution and then aired, when it gives off the characteristic odour of acetic acid. That means that the acetate is being converted into a carbonate. The reaction - which releases the acid - proceeds faster as higher temperatures, but it is best not to accelerate the process.

Barium acetate has no special advantages over calcium acetate. It is prepared in a 5 per cent methanol solution.

Magnesium acetate, which is prepared in a 1 per cent ethanol or methanol solution, degrades cellulose.

Magnesium methoxide. This compound, introduced by R.D. Smith, is formed by the reaction of alcohols with certain metals that combine with water to form hydroxides. When applied to paper, these are transformed into carbonates.

Magnesium methoxide is very sensitive to water, whose presence accelerates its precipitation. Before it is applied, the paper should therefore be carefully dried as the magnesium methoxide will otherwise solidify and its positive effects will be nullified, while its negative effects will have to be counteracted. Magnesium methoxide is applied in a 1 per cent methanol solution either in a bath or through a Freon spray.

It produces good results and does not affect the mechanical properties of paper.

Methyl magnesium carbonate. This compound, obtained by the carbonization of magnesium methoxide, is very stable in water, and hence more effective than magnesium methoxide.

As developed by the Library of Congress, it is applied by saturating an 8 per cent magnesium methoxide solution in methanol with carbon dioxide at 25° C for two hours. The methanol is then allowed to evaporate, leaving the carbonate in the form of a white solid.

6.3.7.3 Gaseeous deacidifiers

Ammonia (vapour). Ammonia vapour is alkaline and hence a good deacidifying agent.

The documents to be treated are placed in the drawers or shelves of a cupboard at the bottom of which ammonia is poured into an open vessel. The resulting vapours pervade the cupboard, penetrate the paper, and turn it alkaline. Exposure should be continued for from 12 to 48 hours at an even temperature.

Unfortunately the ease of application is not matched by the stability of the results, as the ammonium sulphate formed lasts for just a few days, when the acidity reappears. Moreover, the paper is discoloured in the process.

Morpholine and water vapour. The use of morpholine as a deacidifying agent was developed in the laboratories of Virginia State Library (United States of America). It must be applied in a vacuum chamber.

The treatment lasts for only about 10 minutes and before opening the chamber, its contents must be ventilated and the fumes pumped into the drainage system to eliminate the toxicity and bad smell of the mopholine.

Morpholine is an alkaline amine that slightly distends cellulose, and is therefore able to penetrate it more fully than other agents that act superficially. It does not affect the mechanical properties of paper but can cause the darkening of paper made from mechanical pulp.

Cyclohexylamine (CHC). Cyclohexylamine is an amine whose carbonate gives off a deacidifying alkaline gas on sublimation. The gas lacks penetrating power so that the entire surface of the paper must be exposed to it. It is not stable, and its volatility increases with the temperature. It has a disagreeable smell, is toxic (maximum concentration of 1 ppm in the working area), and affects the mechanical characteristics of paper by weakening and turning it yellow. For all these reasons, its use cannot be recommended.

A variant is Vapor Phase Deacidification (VPD), as developed by Langwell. It is marketed in the form of paper or bags impregnated with CHC. These are respectively placed between the pages of a book or sealed in containers with the documents to be deacidified. The treatment must be continued for six to eight weeks and, according to Langwell, its effects last for at least seven years. Great care should be taken with this gas, as it is toxic and irritates the skin and respiratory tract.

Zinc diethyl (vapour of). Zinc diethyl is a highly reactive, explosive and irrtant liquid that must be applied in a special vacuum chamber.

In the system currently being developed in the United States, 1.3-1.8kg of zinc diethyl is applied to every 45kg of paper, which must be very dry. To complete the treatment, which lasts three to eight days, the paper should be moistened and aired to remove the smell of the gas. It gives good results and is ideal for bulk treatment, but its widespread use is prevented by the high cost of the method.

Besides the deacidifiers we have described, there are others of limited use or doubtful effectiveness. These include: aqueous solutions of sodium pyrophosphate and of various other phosphates and borates used to neutralize iron particles in paper; magnesium sulphate, strontium bicarbonate, strontium hydroxide, potassium acetate and diglycolamine. There is little to choose between them.

6.3.8 Consolidation: adhesives

Consolidation restores the lost strength of degraded or fragile paper. Without it, conservation is risky, since paper lacking strength cannot be handled without serious danger of rupture or even of total disintegration.

Consolidating agents are substances that play a protective and curative role. Their action serves to unite the fibres and the other structural elements to which paper owes its strength, and which ensures its consistency. Consolidation can be achieved by chemical (water) and/or mechanical means (adhesives).

6.3.8.1. Chemical means: water

At first sight, it seems absurd to include water among paper-consolidating agents. However, it does play a 'soldering' part by helping to join the fibres together, so much so that the strength of the earliest papers used to depend largely on their absolute humidity (6-8 per cent).

It is well known that paper becomes extremely brittle when dehydrated by high temperatures, acidity, etc. However, most types of paper regain their flexibility and strength after immersion in water. Unfortunately, in the process they also lose strength and run the risk of disintegrating through defibration.

All in all, therefore, lack of moisture and excess of moisture alike have adverse effects on paper. On the other hand, water can, in certain cases, have a positive effect by enhancing the flexibility and strength especially of hardened and brittle paper, so that it must be included among the consolidating agents.

This effect is due mainly to the fact that water helps to bind together the cellulose fibres to which paper owes its structure, i.e. water ensures interfibrillar cohesion.

This mechanism is based on a chemical process, complex at first sight, but simple to demonstrate: a sheet of paper will cling to other, moist sheets, but separate from them again as soon as the moisture drops below a certain level.

Water derives this adhesive power from the interposition of its own molecules between the cellulose molecules, and to their reaction with the oxygen and especially with the hydrogen atoms in the cellulose molecules.

In reality, this process is rather more complicated, but it is always present in matter capable of holding water, such as cellulose and protein. Chemically it is known as a 'hydrogen bridge'.

For that reason, early paper which was rich in cellulose did not need to be reinforced mechanically with glues - its strength was derived directly from the chemical process we have been describing and from the intertwinement of fibres which in its turn improves contact between the cellulose molecules.

All in all, therefore, the strength of paper in general, but more especially of older paper, is linked to the presence of hydrogen bonds. In addition, moisture has a direct influence on its flexibility and consistency.

In more modern paper, poor in cellulose, this chemical linkage is less effective, so that glues have to be added. They not only facilitate the chemical union of fibres, but also helps to bind the filling agents responsible for the specific qualities of modern papers.

For the rest, a simple bath, administered with all the precautions needed for the handling of documents, can clearly restore the strength of paper.

6.3.8.2 Mechanical processes: adhesives

The mechanical union of the structural elements of paper is obtained by the action of special glues which, in time, lose their adhesive power through a variety of causes (damp, chemical reactions, microbiological agents, etc.). As a result, the paper becomes weakened and runs the risks of disintegration.

When paper begins to show signs of weakness, therefore, it has to be resized.

That means an overall coating once the entire surface of the document is found to be deteriorating. However, there are occasions when partial sizing of a given area alone is indicated.

Adhesives are normally applied with brushes, but for total resizing it is best to immerse the paper in an adequately sticky solution of the selected glue.

A variety of adhesives is available for this task, and also for the repair of cuts and tears, the choice depending on the restoration process.

Adhesives may be natural or synthetic.

Natural adhesives. These adhesives (of vegetable or animal origin) attract insects and micro-organisms, which find them an excellent source of food.

Natural adhesives also lack stability and lose their physical and adhesive properties when the temperature or atmospheric humidity is high. In the first case they become dehydrated, lose their flexibility, and turn into a granular substance which drops off the paper.

Excessive moisture again weakens them to the point of dissolution, causing loss of adhesive power and leaving spots on the paper. To prevent these (biological and mechanical) effects, antiseptic agents (ortho-phenylphenol, formol, pentachlorophenol, etc.) or emollients (molasses) and wetting agents (glycerine, glycols) must be added to the adhesives at the time of preparation.

Adhesives of animal origin. The best of these adhesives are gelatine or fish glue, both of which come in various grades of purity.

Gelatine, which has been used since antiquity, is a magnificent sizing agent and gives good results. It can be hardened with formaldehyde (roughly 1/16 of the weight of the dry gelatine) and so rendered insoluble.

Casein and albumen are used much more rarely.

Adhesives of plant origin. The most common adhesives of vegetable origin are starches derived from rice and wheat, and also gum arabic. The literature also mentions potato, maize and rye starches, as well as gums obtained from cherry, morello cherry, apricot and plum trees and from tragacanth.

Closely related and of great interest are semi-synthetic adhesives derived from cellulose. They lack some of the negative features of starches and are very stable and easily applied. Some of the most important for restoration work are methyl cellulose (Culminal, Tylose MH), carboxymethyl cellulose (Cellofas, Tylose CB), hydroethyl cellulose, hydroxymethyl cellulose and hydroxypropyl cellulose (Krucel). A large range of types and varieties can be found on the market. All are water-soluble and some can also be dissolved in organic solutions and are therefore extremely versatile.

The advantages of these cellulose derivatives make them indispensable aids in modern restoration work, and quite particularly in the repair or consolidation of all types of paper.

Synthetic adhesives. Synthetic adhesives are either thermostable or else thermoplastic. The first, once they have set, are resistant to further applications of heat, while the second are not and can, moreover, be restored to their original form by various solvents.

Thermostable (thermosetting) adhesives (e.g. epoxy resins) cannot be recommended in this branch of restoration, their use being reserved for special bindings and sigillography.

Thermoplastic adhesives are used more frequently than thermosetting adhesives because they come in a much wider range, including particularly:

Polyvinyl acetates, reversible in toluene, acetone and alcohol (Mowilith, A34 k 3, Vinavil, etc.);

Polyvinyl alcohols, reversible in water (Mowiol, Vinavinol, Gelvatol, Rhodoviol);

Polyamides (nylon), reversible in tepid alcohol (Calaton, Maranyl);

Acrylates, reversible in toluene and derived from petroleum and acetone (Paraloid, Primal, Plexigum, Plexivol, Plextol).

In addition, there are the synethetic rubbers and polyvinyl acetals. At present none of these are used in the restoration of cellulosic material.

The respective functions of these adhesives as consolidating agents, fixatives or simple pigments depend on the degree of concentration of the respective solvents. Thus a highly diluted product will act as a consolidating agent while it can serve as a fixative at a higher concentration and as a pigment when the viscosity is greater still.

For some applications it is possible to obtain compatible mixtures of synthetic and semi-synthetic adhesives, e.g. methyl cellulose and polyvinyl acetate.

6.3.9 The repair of cuts and tears

Cuts and tears are among the most common alterations of printed documents. The normal, household cure is to cover the tear with a transparent strip of tape or a patch to prevent it from spreading. This method, however, can lead to the appearance of stains. A far better solution is to stick the broken edges together with a suitable adhesive (see 6.3.8: Consolidation), if possible making use of loose fibres but taking care to position them correctly when drawing them across the torn surface.

If the edges cannot be made to meet, it may be possible to use a strip of fine tissue paper of maximum transparency, placing it in such a way that its two sides overlap the tear by about 2mm. The edges of this strip should be defibred before it is put in place or, if applied to the edge of the torn sheet of paper, evened off with a scalpel once the adhesive is dry.

Another method is to apply a fine layer of adhesive directly along the line of the tear. Covered with a piece of tissue, it should then be dried in a press to ensure the evenness and smoothness of the treated part. Then with the help of tweezers, the excess tissue is removed by moistening it with a fine brush along the line or area of proposed separation. The water weakens the tissue which comes away easily, for which reason it should only be moistened very lightly and in the exact place. Finally the edges should be smoothed with a scalpel or fine sandpaper. If necessary, fibres obtained from the defibring of long-fibred paper can also be used. The fibres are mixed into a paste with an adhesive (methyl cellulose, gelatine, etc.), and the tear is covered in such a way that the fibres provide the maximum resistance to further tearing. The job is laborious but gives good results, especially when a final pressing is added.

The method can also be used for filling cracks, in which case the paste is applied with a brush and pressed down with an electrically heated and thermostatically controlled spatula.

Tears in thick paper (cardboard), usually leave large flaps which greatly facilitate the repair work. If such paper has a cut, it should not be covered with a patch like fine paper, but an unprinted area of the cut piece should be shaped with a scalpel or with sandpaper into a wedge with its vortex below the line of the cut. A piece of cardboard of the same thickness should then be cut out to fit round the wedge, whereupon both pieces are glued together and dried under pressure. All rough surfaces and projections are smoothed with a scalpel or with sandpaper. If necessary, the repair work can be reinforced with tissue on the other side.

In all these cases, it is likely that the line of the break will eventually darken, even if a perfect join has been made. The darkness is caused by accumulations of dirt along the edges and staining by the adhesive. A light bleach may help but does not usually give lasting results. It is best not to dirty the edges of the tear in the first place or to clean them gently with a brush, eraser, etc., making certain that no further smudges are added.

6.3.10 Paper reintegration

Through wear, misuse, fire, and above all the activity of bibliophagous agents, paper is only too often marred by gaps, tears and holes, all of which spell the partial loss of the document concerned. The damage affects the printing as well as the strength of the paper.

Reintegration involves filling the missing areas with strips or patches of new paper (grafts) that fit perfectly into the gaps.

Traditionally, restorers have taken great pains with this operation, whose aesthetic quality is concrete evidence of their virtuosity.

Modern methods of reintegration are of two kinds: manual and mechanical.

6.3.10.1 Manual reintegration

The first step in manual reintegration is choosing the grafting paper with the required characteristics (texture, colour and, above all, structural quality).

Because of a growing demand for different types of grafting paper, the restorer must have access to a wide range to satisfy the changing needs of different documents, an essential factor on which the final outcome of the whole work depends.

The use of grafting paper stronger than the original causes deformation of the rest of the sheet, and the use of grafting paper weaker than the original will have the opposite results. Hence it is essential to strike the correct balance. On most occasions it is better to use two sheets of fine paper rather than one fairly thick sheet.

With machine-made paper, the fibres of the grafting sheet should run in the same direction as those of the paper to be repaired, lest differences in tension cause unpredictable distortions.

Manual reintegration takes a variety of forms, reflecting the customs of individual workshops, the training of restorers, the methods available, etc.

The most widespread methods are:

Pin-point method. The area to be reintegrated is traced on the grafting paper with a soft pencil. A narrow margin, about 1mm wide, is left round the pencil mark and pricked with a pin of a thickness appropriate to the paper.

The operation is performed on a flat pad of semi-hard foam, and once the edge round the drawing has been perforated, the area inside can be pulled away like a postage stamp. The perforated edge left behind constitutes a good contact surface for the grafting paper to which it is glued. If necessary, once the graft has been put in place and is dry, the edge can be bevelled off with a scalpel or fine sandpaper.

The operation requires some skill but for the rest it is easy to perform and especially suitable for very fine paper.

Indentation method. Once the area of the graft has been outlined and a thin rim left round it, it is indented with a punch or similar instrument. An incision is then made along the line of indentation. The paper may be dry or moistened with a fine brush which facilitates the operation. The rim is then placed over the grafting paper and glued to it.

Bevelling method. With this method, the edges of the hole in the paper are bevelled with a scalpel (on the side or area not covered with writing), leaving an edge of a width that varies with the thickness of the paper. The work is done on a light-table for better control of the scalpel. Next, the outline of the area to be filled in is traced on the grafting paper and a line approximately 5mm in width is drawn round this outline. The paper is cut along this second line, and then the 5mm edge round the original outline in the grafting paper is bevelled to produce a perfect match with the bevelled edge of the hole in the document. Once this has been done, glue is applied to the bevelled edge of the graft, which is then placed on the original. The join should be perfectly smooth.

Brush method. The document to be reintegrated is placed over a sheet of grafting paper so that both lie completely flat. Glue is brushed over the edges of the hole in the paper. A layer of flexible and permeable material is placed over the two sheets for purposes of drying and pressing. Once dry, surplus material in the top paper is removed with a scalpel or by simply wetting the outline and pulling it out with forceps. The fibrous edge left along the contours of the grafting paper should be given another coat of glue for extra strength.

In a variant of this method, glue is applied to all the grafting paper that can be seen through the hole. Then another sheet of grafting paper is placed on top. In that way, two pieces of grafting paper will be stuck together round the hole.

In this type of 'double grafting', very fine paper must be used, the thickness of the two grafting papers being equal to that of the original. The job is completed by the removal of surplus paper from the two grafts.

Lamination grafting. With this method, the document is placed over a sheet of grafting paper and the glue is applied with a soft brush over the entire visible surface, that is, over the whole document and over the grafting paper seen through the holes in the paper to be reintegrated. Next, a transparent sheet (tissue) is placed over both for purposes of lamination (see 6.3.13). A dry polish is then applied to the whole.

After dry polishing, all surplus grafting paper is removed. For greater strength and even tension, it is advisable also to laminate the side carrying the grafting paper.

Filling with paper pulp. Small holes can often be repaired with paper paste applied with a syringe or brush. The pulp is pressed down and dried with a heated spatula, if possible thermostatically controlled. This operation is best performed on a suction table.

6.3.10.2 Mechanical reintegration

The vast number of documents needing reintegration and the slowness and laboriousness of manual operations have led to the development of mechanical methods of reintegration, based on early systems of paper manufacture. The results obtained by this method are as positive as they are spectacular and rapid. All the holes and lost areas are reintegrated simultaneously and the whole process takes no more than three minutes.

This operation, called 'leaf casting', is performed by specially designed machines (Vinyector, Recurator, etc.).

Briefly, the document is placed on a grid across which an aqueous dispersion of paper pulp is passed. As it passes, the water is forced through the holes in the paper and as it runs off the fibres are trapped in the grid where they accumulate until the holes are 'plugged' completely. The amount of pulp used should be proportionate to the volume of the lost areas.

The whole mechanism is very simple: the very speed of the suction prevents the pulp spilling over on to the paper - that only happens when drainage is slow or when there is an excess of pulp. Sometimes that is brought about intentionally to laminate the back of very weak documents.

The pulp used should be matched to the paper treated, both in respect of colour and also of weight and quality.

Some methods involve the use of gluing agents, while others rely on interfibre chemical links.

6.3.11 Reintegration of the sustained elements (inks, etc.)

6.3.11.1 Standards

The accepted standards for the restoration of graphic and sustained elements include respect for the integrity of documents, and especially of manuscripts, which are unique.

No attempt should ever be made to reconstruct lost or incomplete texts without adequate documentation.

When a facsimile, photograph or exact description of the lost graphic element is available, the restorer has a number of options:

Modified reconstruction of the form but not the material of the original. This amounts to copying the original by methods and procedures differing from the authentic ones. Ink, colour and even the instruments used should be distinct from the original, and lost areas must be reintegrated in such a way as to leave no doubt about the status of the reconstructed version. The sources on which the reconstruction is based should be carefully recorded;

- Another method of providing information about the original is to append a sheet of identical size, different quality and more modern type and to use it solely for reconstructing the lost text, faithfully reproducing the type, technique and colour.

If this reconstruction is done on transparent paper the reconstructed text can be placed neatly over the original, thus conveying a good idea of what it looked like.

Experts disapprove of graphic reintegrations performed on the original document. Their attitude deserves respect, and in any case militates against fraud or mistakes.

For reasons of scientific propriety as well as convenience it is advisable to make a copy of the source of information and append it to the original document.

6.3.11.2 Faded texts

On no account should a faded document be touched up to enhance its colour, an operation that could cause irreversible damage. For greater ease of reading, it is far better to use ultraviolet lighting which brings out marks that may remain hidden in ordinary light.

With special film, it is even possible to take photographs in ultraviolet light. To protect original documents, it is always preferable to provide students with photographs and facsimiles, providing of course that both have been carefully checked against the originals.

The ability of some chemical reagents to intensify the colour of faded texts was discovered many years ago. They usually act by oxidation, and their effect is the greater, the greater the number of particles that can be oxidized. Unfortunately the effect is short-lived and when it is over the oxidized particles are rapidly destroyed.

For that reson, the use of these reagents cannot be recommended, but if they have to be used for some extraordinary reason, safeguards must be used against the possible degradation of inks and paper.

The method described in the last section is equally applicable to the restoration of faded texts and is much to be preferred.

6.3.11.3 Reintegration of works of art: engravings and drawings

In this branch of restoration different standards apply, for while printed works convey detailed textual meanings, the effect of works of art depends on their overall harmony which can be impaired if the lost areas are presented separately, i.e. out of their original artistic and chromatic context.

It follows that documents of predominantly aesthetic value must be repaired by methods that meet these requirements but that must nevertheless not be allowed to degenerate into camouflage or falsification. Thus visual harmony should never be bought at the price of hybrid insertions.

The restoration of works of art can take one of several forms:

Integral reintegration. The document is completely reconstructed but with ink that differs from that of the original and with grafting paper of obviously different quality from that of the original support.

Dot reintegration. In this method, the image is reconstructed by means of a series of dots whose colour blends with that of the work. It is a simple procedure and produces a good effect, but must not be used when the original was produced with similar techniques

Line reintegration. This method, like the last, produces a good effect but is more difficult to apply. A series of uniform parallel lines is drawn in the colours of the original, their length, thickness of design and superposition providing a finish that is clearly distinguishable from that of the original while not spoiling the visual effect. The lines should run in a vertical direction, regardless of the direction of the original lines. In that way they will not disturb the balance of the whole.

In any of these options and generally in all reintegrations of either the graphic element or the paper, no tones should be used that, alone or in combination, clash with the authentic ones, lest the reintegration divert attention from, and even diminish the value of, the work.

In principle, the reintegrated area should have 2/3 less chromatic intensity than the original. In practice that means using subdued tones which add harmony rather than discord.

6.3.12 Drying and pressing

Drying and pressing are two operations whose simplicity is deceptive, as the perfect finish required for restoration causes a number of problems.

All wet paper expands due to swelling of the fibres and the other hygroscopic substances it contains, with consequent distension of the cellulose and fillers. Theoretically all should regain their original size after drying, and the paper resume its original dimensions.

In practice, however, when the fibres and other deformed elements surrender their water they spread into different areas. The resulting deformations must be corrected by pressing.

If strong pressure is applied, the fibres and other substances will become trapped and the paper, when dry, will reveal this anomaly in the shape of irregularities and an appreciable increase in size.

If the paper is to recover its original dimensions, the removal of water must be slow enough for the fibres to spring back without the kind of pressure that upsets their recovery.

It goes without saying that it is virtually impossible to restore the original form completely - after drying all wet paper will have suffered a change of dimensions over its entire surface. That increase is most appreciable in the direction at right angles to the fibres and the deformations are in proportion to the hygroscopicity of the material, and the more or less inevitable strains imposed upon the paper in its manufacture.

6.3.12.1 Natural methods

These should begin with the airing of the wet paper. The paper is removed from the bath and placed on a smooth surface that will not impede the contraction consequent upon the evaporation of water. The paper is left in place until it is nearly dry. Airing should not be speeded up with point sources of heat or draughts. The best way to use shelves in a room or area where environmental conditions facilitate a gradual drop in the humidity of the paper, but not too slowly because, if there is microbiotic contamination, the rapid spread of micro-organisms will be encouraged.

After airing, when the paper has recovered its original dimensions as far as possible, it should be placed between two protective covers (flexible and permeable) on which gentle pressure can be exerted while the drying process is completed. Manual presses do this job perfectly well.

The quality of these (glossy or matt) covers is very important as they communicate their own texture to the paper. They should therefore be as alike as possible to the document.

The greater danger of distortion, the greater are the pressure and the degree of humidity and the shorter the time taken for complete drying.

To sum up, drying through airing should be a slow process, adapted to the surroundings, careful heed being paid to the possible presence of micro-organisms, the running of inks, and the appearance of lumps and other surface irregularities such as exfoliation.

Books damaged by flood must be dried in what opened position will cause the least deformation. If paper and ink allow it, they can also be immersed in alcohol which, on evaporation, will accelerate the drying process by abstraction of water.

In any case, the best method of drying books is by natural or artificial aeration, at temperatures below 25° C in order to reduce damage caused by high temperatures and by micro-organisms. The process is helped by inserting layers of materials, absorbent but not likely to dissolve inks, between the pages (these layers must be changed periodically).

When the uniform drying process has been completed, the books should be closed and gently pressed.

6.3.12.2 Other methods

In addition to natural drying and pressing, there are a number of complementary or independent methods, some manual and some involving mechanical assistance.

Manual methods:

Placing the paper between absorbent layers (drying or filter paper). Only recommended for final drying and pressing.

Use of permeable and flexible supports (Reemay). Ideal for airing as their transpiration aids drying. This method is highly recommended if the general precautions listed above are observed.

Suspension. This method is dangerous because of the risk of tears, and should only be used for very strong paper, and then only with strict precautions and constant surveillance.

Mesh covers. These are very practical and they also facilitate the handling of the document during baths. Moreover, they need not be removed during the subsequent airing. Mesh covers should be made of rustproof material, such as nylon.

Drying between wooden boards. Practical for large documents.

Drying under glass. Only recommended if the document has to be constantly watched, in which case it should be protected by flexible, transparent (serigraphic) covers.

Bathing in a volatile solvent. Very practical in all cases in which a slight speeding up of natural drying and airing is required.

Mechanical methods

Manual or hydraulic presses. These are needed in all restoration laboratories for use in final pressing.

Thermostatically heated presses. Only recommended for use during the final drying stage, and then only at a low temperature and light pressure.

Suction tables. The use of suction tables can be recommended provided the pressure is not excessive. The paper adjusts favourably under contraction and the support leaves no imprint on the wet paper. The combination of suction with volatile solvents helps to dry very irregular surfaces evenly.

Vacuum chambers. Vacuum chambers are highly recommended for large-scale drying operations especially for thawing books that have been treated by freezing methods after floods.

Kilns. The use of kilns is not advisable since, after drying, the paper has usually to be wetted again before final pressing.

Centrifuges. Their use is not recommended.

Infrared radiation. The irradiation of paper with a sequence of incandescent lamps is not recommended.

Dielectric drying. This method has recently been adopted by the paper industry and can produce excellent results in restoration work. It is based on the conversion of electric energy into heat depending on the amount of moisture in the paper. It facilitates the regular and uniform drying of the entire surface of the sheet being treated.

6.3.13 Lamination

The purpose of lamination is to offset the fragility of a document. To that end, a reinforcing sheet is applied to the surface of the paper, lending it greater strength and restoring its lost function.

Lamination can be single or double, i.e. applied to one or both sides of the paper. For papers with little body, it is usual to laminate both sides since, if just one side is stregnthened, the paper will tend to roll up due to differences in tension.

The covering layer should be very thin, of minimum opacity and maximum consistency (Jap tissue). Thicker paper, for instance that used for engravings, drawings, plans, etc., can be covered with thicker tissue, provided there is no printing or drawing on the reverse side.

Lamination is basically a curative method and should not be used on a large scale or indiscriminately. It should be strictly reserved for documents that, because of fire, acidity, insects, micro-organisms, etc., are in such a fragile state that they cannot be restored by other means.

However, even in these extreme cases, lamination must be preceded by special measures to obviate harmful effects and, above all, by the removal of dirt, acidity, micro-organisms, etc. Lamination itself cannot cure these ills; on the contrary, it will aggravate some of them, for instance acidity.

In other words, before resorting to lamination it is essential to eradicate the degrading factors (causes and effects) present in the document itself. If that is not done, these factors will be incorporated in the lamination and even increase, thus rendering this system of restoration useless and counterproductive.

Acidity must be eliminated first and foremost - no paper should be laminated before this cause of deterioration has been removed.

Lamination can be manual or mechanical.

6.3.13.1 Manual lamination

All that is needed for manual lamination is a smooth, preferably horizontal, surface on which a flexible support (Reemay, Teflon, polyethelene) is placed. The document to be laminated is moistened with a spray or soft brush to relax the fibres and help the action of the adhesive about to be applied evenly with a roller or brush.

The reinforcing sheet is laid on the glued surface, having also been moistened first, and once it has been fitted, another, impermeable, support is placed on top. A roller is used to apply light pressure before the whole is put in a press.

Although permeable holders (Reemay type) are normally used for this operation if, for any reason, an impermeable holder (Teflon, polyethylene) has to be substituted, it should be replaced with a permeable one during the final drying stage. That stage must never be speeded up by the local application of heated plates, as this method can cause uneven drying due to compression of the fibres in the document or in the laminating paper.

Manual lamination methods can be adapted to the solution of a great many special problems. For example, the adhesive can be applied directly to the laminating paper, the whole operation being performed on a suction table, etc.

Perhaps the variation of greatest interest is the replacement of aqueous adhesives with adhesives soluble in organic solvents. This is the only way out when a document or its graphic elements cannot be treated with water. In such cases, the most commonly used adhesive is cellulose acetate in foil form. The adhesive foil is spread out between the document and the laminating paper and acetone is applied lightly with a cotton pad. This method has the drawback of rendering documents more rigid following dehydration caused by the solvent.

6.3.13.2 Mechanical lamination

Mechanical lamination involves the use of adhesives that are applied in so-called laminators or thermostatically heated presses. Here two hotplates soften the adhesive by transmitting heat under pressure. On cooling, the adhesive hardens and bonds the papers, because it penetrates the surface with which it is in contact as soon as it melts. The process involves the following steps:

First, a flexible, impermeable support of Teflon (a thermosetting plastic) is laid down, followed by the sheet of laminating paper (tissue), the film of thermoplastic adhesive and the document. If the lamination is single, another support identical to that of the bottom of the sandwich is applied. If the lamination is double the final step is preceded by the application of a second thermoplastic film and reinforcing layer.

The whole is protected by two semi-rigid boards and passed through spring-loaded and heated metal rollers. Temperature and duration of the operation depend on the characteristics of the adhesive which hardens as it cools.

The thickness of the adhesive foil varies between 0.025 and 0.05mm. The foil should be completely transparent and should not need temperatures that might damage the paper. Moreover, it must be reversible in certain harmless solvents so that it can be removed if the treatment is unsuccessful.

The most common of these foils are made of:

Polyethylene. Temperature approximately 110° C. Solvent: Tri-perchloroethylene at about 50° C.

Polyamide (nylon). Temperature approximately 85° C. Solvent: heated alcohol.

Cellulose acetate. Temperature 150° C. Solvent: acetone.

With all these products, the treatment lasts for about 35 seconds.

Adhesive foils can be replaced with other thermoplastic adhesives (Paraloid, Primal, etc.) which can be applied directly to the laminating paper. The covering tissue must be pressed against the document and temperature and pressure applied as with adhesive films.

In all double laminations, whether manual or mechanical, it is wise to leave an outer border measuring about 2mm, for the purpose of sealing off the entire sandwich. Without this precaution, the sheets may work loose and micro-organisms might penetrate through the gaps at the sides of the document.

In double lamination, moreover, the direction of the fibres in the reinforcing papers must be taken into account: successive layers of fibre should be made to criss-cross. In that way, tensions and imbalances between successive surfaces are avoided and cockling is minimized.

If lamination is to be combined with grafting of destroyed areas, the work should proceed by two stages. The first is identical with that described for simple mechanical lamination, except that the grafting paper needed to cover all the gaps in the document is placed between its back and the final support.

During the first phase, the 'grafts' will have been joined to the covering tissue over the whole surface of the gaps, thanks to the presence of the adhesive. As a result, the back of the document will have been strengthened with the laminating tissue and the bits of grating paper will protrude in such a way that they can easily be trimmed back to the shape of the original gap. Once this has been done, the surface can be laminated by proceeding as for single lamination.

Though laborious, the method produces very good results, both in respect of paper strength and also of aesthetic appeal.

6.3.14 Bindings

For purposes of restoration, bound books fall into one of three categories, namely:

books whose bindings are of irreplaceable documentary and/or artistic value;

books that have lost their bindings;

modern books whose bindings are of indifferent quality and/or finish.

6.3.14.1 Standards and methods

These differ from one category to the next:

Bindings of irreplaceable documentary and/or artistic value

Obviously this category includes all antique or otherwise valuable bindings whatever their state of preservation. If they have been damaged and require restoration, the restorer must aim at maximizing the use and function of all the structural elements that have been preserved while skilfully reintegrating areas and materials that have disappeared or have lost their usefulness.

This double operation involves the dismantlement and reassembly of the book.

Dismantling. The dismantling of books whether for restoration of the contents or of the bindings calls for a careful analysis of the structural aspects.

That analysis bears on both the material and also on the function it fulfills or should fulfil. It is easy to fall into the error of trusting one's memory or logical sense for the reassembly of the dismantled elements, but so unmethodical an approach is bound to cause problems when the work has to be finished.

To avoid these, it is best, as with archaeological research, to keep a careful record of all items in the order of their removal and to add detailed functional descriptions.

In that way, there is built up a step-by-step locating scheme for every element and especially for those requiring restorative treatment.

The style of binding, the type of material used (leather or paper cloth), the method of dewing (raised or sewn in cords), the attachment and type of boards, the spine lettering, and the decoration (take rubbing when necessary) should all be carefully recorded on notes, drawings or photographs that will dispel any doubts about the presence and function of these elements.

Any omission or misinterpretation of data can cause irreparable damage.

The pages of the book should be numbered and a note should be made of any that are missing. There should also be clear diagrams of their sectional arrangement, whose regularity, especially in the oldest books, must not be taken for granted.

Since this operation is unlikely to be repeated with one and the same book in the foreseeable future, it is best to make a careful study of the special features of every binding and to profit from the cultural - scientific and technical - data this study can reveal.

To that end, it is best to record all the architectonic features of the original and to make a scale model for reference and also for further study.

Dismantling is therefore an operation of the utmost importance and should never the slipshod.

Rebinding. The rebinding of valuable books demands the maximum possible use of original material which once restored, should be reincorporated into the book.

If the elements to be restored must be replaced with others of similar type, it is essential to observe the rules against deliberate falsification.

It can easily happen that when he is about to reconstruct the binding of a recently restored book, the restorer notices that the covers are too small. That is because the book itself has increaed in volume because the paper has absorbed water during restoration and has not returned to its original size.

In that case it is also possible to enlarge the binding - a task that should not prove too difficult with material taken from the edges. If this solution is not possible, the only alternative is to separate the spine from the two boards along the join and then to attach these three parts to a new binding whose material and finish must be as close as possible to the original.

This solution is also recommended when the cover has missing areas that cannot or should not be reintegrated.

To prevent exfoliation, the edges and broken areas should be sealed with a thermoplastic adhesive or wax.

It often happens that the restorer is unable to reincorporate some original element in his finished work. In that case, it is common practice to attach a kind of envelope or pouch in which such elements can be safely stored and which show that they are part of the original document.

The inclusion of a simple note explaining the method of restoration, the file number and laboratory name provides any further scientific information that may be needed.

The most suitable materials for the restoration of bindings are:

tanned hides;

neutral cardboard or synthetic materials; metacrylate or PVC laminates;

wood treated with hardening agents, insecticides and fungicides;

good quality paper;

specially tinted end papers;

headband thread;

gold leaf or similar;

antioxidants for metallic elements;

linen or cotton cord;

synthetic or semi-synthetic adhesives.

It should be noted that, because of the instability of cardboard and wood in bindings of normal or large size, these traditional materials are often replaced with plates of metacrylate or PVC. Though the inclusion of the latter in traditional bindings may be anomalous, they produce good results and their presence is, in any case, hidden by covers and end papers.

Lost bindings

When bindings have disappeared, the character of the book in question must be fully investigated before any action is taken. In the case of modern books or any others whose intrinsic value lies in their contents, binding should merely aim at protecting and safeguarding these contents and at ease of handling. In that case and in keeping with the practice of the institution owning the book, it is usual to resort to what may be called functional bindings, always providing that the basic principles of conservation are observed.

Problems arise when a book, because of its age, rarity or some other relevant circumstance had an original binding of such singularity that an exact replica has to be made, either to restore the book's full value or for the simple reason that the binding and general appearance of the book detract from the importance of the document.

In such cases, the restorer may have:

Indirect information about the lost elements and binding methods either from photographs, drawings, descriptions or any other source. Having first dismantled the book, the restorer will proceed very carefully to its reassembly, making sure that the end product is as close as possible to the original in all technical respects.

The covers and final appearance will be an authentic copy of the lost features albeit produced with different techniques and materials, the restorer taking care not to prevent it as an original. In other words, while trying to recapture the original appearance, he will add a note about the period of history concerned and about the work as a whole.

In addition, he should also list in a final appendix or in a discreet but easily found place (envelope, pouch, etc.) any other relevant information, and the laboratory or file reference in which details of the circumstances of, and the reasons for, rebinding are recorded.

Lack of information about the original binding. If no information about the binding is available, the restorer should follow the style of the period or rely on what features of the book provide the closest possible information about its original appearance. As in the cases we have described earlier, he must imitate but not fake. The new binding should be accompanied with a record of the name of the laboratory or centre where the work was done.

Unserviceable bindings through faulty materials or poor manufacture. This problem, unfortunately quite common with modern books, is resolved with the help of simple, functional bindings, adapted to the use and nature of the book and to the requirements of the institution that owns it. The use of resistant and harmless materials is the only limitation placed on the work.

Quite often a new cover is placed over the new binding.

As a matter of principle, the restorer should always add a note on the state of the original binding and the reasons for its renovation.

6.3.15 Assembly and encapsulation

6.3.15.1 General

Once a document has been restored, it is essential to provide against the threat of new deterioration. To that end, it is essential to facilitate the handling of books and documents and to prevent external damage.

This section concentrates mainly on the first objective: ease of handling of items that, because of the use to which they are to be put or their physical state, require less drastic treatment than lamination.

Loose documents are best assembled in a pass-partout folder or by encapsulation.

Both methods provide reasonable protection against deterioration in the course of perusal, transport, display, storage, etc.

6.3.15.2 Folder construction

The passe-partout folder is made of two pieces of cardboard of identical quality. They must meet a series of very precise demands, namely:

lack of acidity (neutrality);

absence of metals or particles subject to oxidation;

resistance to exfoliation;

semi-glossy appearance;

low hygroscopicity.

When the two pieces of board have been chosen (they come in various thicknesses and colours) they are joined along one edge with adhesive tape to form a folder in diptych form.

Before joining the edges, a window should be cut in the top board, a few millimetres smaller than the document to be inserted. In that way, the two boards will press down on and smooth the document without impeding vision.

Normally the upper and side edges of this window are of the same width and the lower one slightly larger.

In the case of engravings and drawings, the inner edge of the window is bevelled to enhance the visual appeal (sometimes it is decorated with gold fillets or coloured bands in keeping with the document).

The document is fixed to the back board by means of two or three tissue paper hinges glued to the upper edge in such a way as to make it possible to turn the document over without causing damage.

In other models, the tissue hinges are replaced with double-sided adhesive tape or two or more lateral flaps of semi-rigid, transparent material (mylar) stuck to the card in such a way that they cover the edge of the document by a few millimetres and exert slight pressure on it.

Once the document has been inserted in this type of folder, a protective sheet can be added to minimize dust, light, friction, splashing, etc.). The best material for this protective sheet is a polyester - polythene terephthalate - known as mylar. It has a high degree of transparency and acts as a light filter. It is fixed to the back of the front cardboard so that it covers the whole window.

This arrangement allow for natural expansion and contraction without causing tensions beyond those exerted by the hinges. To reduce even these tensions, the hinges should be made of very fine tissue but strong enough to keep the document in place.

The folder can also be fitted with a double window which allows direct viewing of both sides of the contents. For this type of arrangement, two extra pieces of cardboard may be joined at one of their edges to provide an outside folder.

When a collection of items (engravings, drawings, plans) of the same size or different sizes is to be assembled in a passe-partout folder, the first thing to be taken into account is the size of the filing cabinet, of the plan file, the shelving unit, etc. in which the folders will be stored. The next step is to construct the folders in the most rational way possible so as to make optimum use of the storage equipment.

Passe-partout folders should also be used for framed displays of documents. The folder with its layer of mylar will keep the contents from direct contact with the glass and with the back of the frame, which is important since glass can have a whole range of damaging effects: fading of ink due to electro-static attraction; stains through oxidation or micro-organisms encouraged by condensation in the moist interior; cuts if there are breakages, etc. The back of the frame, too, can cause stains, deformation, acidity, etc., if it is of unstable material.

When the folder is placed between the glass and the back of the frame, the air in the window of the passe-partout helps to cushion the contents against fluctuations of temperature.

The arrangement will be even safer if the glass is designed to keep out ultra-violet radiation and if the inside is reinforced with a layer of metacrylate.

It is advisable to keep the frame slightly away from the wall to avoid the accumulation of harmful influences (humidity, dust, insects) at the back of the folder.

Perfect precautions would include providing the whole assembly with stable or at least a controlled internal microclimate obtained either by means of a vacuum or a neutral gas under excess pressure, or by placing dehumidifying and antiseptic agents in tiny receptacles inside the frame.

6.3.15.3 Encapsulation

Encapsulation is a system of preventive covering and consists of putting the document, without any adhesive, inside a flat, transparent and hermetically sealed sleeve.

It is ideal for the preservation of certain items (maps, engravings and other flat documents) which need special protection because of handling problems (exhibition, transport or storage).

Encapsulation, besides its resistance to normal wear and tear, impedes or prevents the deleterious action of external agents.

As with lamination, before beginning the process of encapsulation, the restorer must ensure that the document does not contain anything that could cause any foreseeable damage.

The most commonly used material for making the 'capsule' is polyethylene terephthalate (mylar). It should be heat-sealed or closed with double-sided self-adhesive tape.

The dimensions of the sleeve - formed by the superimposition of two layers - must not be much greater than those of the document. A proper fit will avoid movement and the consequent friction.

Encapsulation is also useful for the preservation of certain books that are not consulted very frequently. The drawback is that the 'wrapping' has to be renewed every time the book is taken out.

CHAPTER 7

SUMMARY

1. Paper as a support

Paper is the most widely used support of documents stored in archives and libraries. We distinguish two main periods in the manufacture of European paper. During the first, which continued until the middle of the nineteenth century, the basic materials were rags of vegetable origin (linen, hemp, cotton). The resulting paper was composed of cellulose, a substance found in plant fibres, a sizing of vegetable or animal glue, and a small reserve of alkali. The water molecules incorporated in the pulp during the process of paper making form bonds with the hydroxyl radicals of the cellulose, and hence serve as bridges (hydrogen bridges) between contiguous long-chain cellulose molecules.

Paper manufacture from rags was mechanized at the beginning of the nineteenth century and led to the production of continuous webs of paper (mechanical paper). In the eighteenth century, the growing demand for paper had already imposed the use of other than white rags for paper production. Chlorine compounds had then to be introduced as bleaching agents and natural sizes began to be replaced with a chemical size, namely alum, which unlike the natural product is added to the pulp before the formation of the paper. Both types of size cause acidity in the paper and decrease the durability of the fibre (sections 1.1-1.2.1.2, pp. 3-6).

Wood largely replaced rags in the production of paper in about the middle of the nineteenth century. Depending on the method of production, the pulp is called mechanical, chemical or semi-chemical. Paper made from mechanical pulp retains all the impurities of the wood.

Paper made from chemical pulp is obtained by treatment of the cellulose with various chemicals that eliminate the non-cellulosic elements of the wood. The resulting pulp is of poor quality, because of the presence of alum rosin and chlorine residues. At the end of the 1950s, permanent durable paper was introduced. Unlike traditional paper, obtained from wood, this paper is alkaline (sections 1.2.2-1.2.2.5, pp. 5-9).

Synthetic compounds such as polyesters are currently being used in the manufacture of paper for drawing and plans. Their inertia towards external agents and their physical resistance could make them the paper of the future (section 1.3, p. 9).

2. Inks

Inks are substances suitable for writing, printing or colouring. Their basic constituents are: colouring matter (dyes and pigments) and adhesives. Some inks contain mordants, chemical substances with the property of fixing the inks to paper and hence replacing the mechanical effects of adhesives (sections 2.2-2.2.1.2, pp. 11-12).

Carbon-based ink is stable: it neither changes chemically nor attacks the paper, though it can be affected by losses in the mechanical qualities of the adhesive.

Metallo-acid inks include a dye composed of a metal and an acid which acts as an oxidizing agent and mordant combined. The most important of these inks are the ferrogallic or ferrous types. Also included in the metallo-acid group are logwood, alizarin and vanadium inks.

The original aniline inks were very sensitve to light. Today they are of better quality and much more stable (sections 2.2.2-2.2.2.1, pp. 12-20).

Typographic inks differ from calligraphic inks in that the watery solvent normally used for the latter is replaced with an oily substance (varnish) in the former. The type of varnish used and its combination with various solvents (driers, thickeners, etc.) determines the suitability of such inks for particular printing techniques.

The introduction of synthetic dyes, especially aniline, has greatly complicated the identification of inks (section 2.2.2.2, p. 16).

3. Causes and effects of the degradation of paper

The causes of degradation can reside in the paper itself (internal causes) or in the environment (external causes). The most damaging internal causes are found in paper made from wood (lignin, alum, rosin, chlorine). Inks and metallo-acids must also be counted among the internal degrading agents of paper (sections 3.1-3.2.2, pp. 21-23).

External degradation can be mechanical, environmental, chemical or biological. There are three environmental factors that affect the conservation of paper: humidity, temperature and light. An excess of moisture softens the size and leads to the formation of acids derived from salts and other products used in the manufacture of paper or ink. Sudden and frequent changes in temperature and humidity subject paper to great strains that may rupture its fabric. The most dangerous radiations to which paper can be exposed are those of short wave-length (ultra-violet rays). The atmosphere of industrial areas contains a series of impurities that are harmful to paper (sections 3.3-3.3.3, pp. 23-26).

The most patent destroyers of paper are rodents, insects and micro-organisms. Special mention must be made of termites, wood-feeding insects, that can destroy the woodwork of an entire building and of all the books and documents stored in it.

Micro-organisms (fungi and bacteria) soften paper in the areas they invade, break up the surface sizing, and release pigments in the course of their metabolic cycle (sections 3.3.4-3.3.4.3, pp. 26-28).

It goes without saying that disasters (floods, fires, etc.) can have the most serious effects on documents. Floods can cause inks to run, pages to stick together, paper to rot, and glues to loose their adhesive power. In addition spotting and the growth of fungi is encouraged by the humid atmosphere and by rises in temperature caused by attempts to speed up the drying process. Fire can either mutilate or completely destroy records.

Other causes of deterioration are careless handling of documents, trial-and-error attempts at restoration, and inappropriate reagents used to restore faded inks, etc. (sections 3.3.5-3.3.6, pp. 28-30).

4. Preventive methods of conservation

Preventive methods of conservation aim at creating an ideal habitat for documents, one that puts them beyond the reach of harmful agents. Preventive conservation accordingly is concerned with location, installation, direct physical protection and environmental controls (section 4.1, p. 31).

A building intended to house an archive should satisfy a set of general building standards as well as a number of special conditions. Factors to be taken into account in choosing the location of storage area include: orientation of building, segregation from other sections of the archive, the need for fire-proof walls and doors, a rational lay-out of the surface area, mechanical resistance, protection against environmental dangers.

When old buildings are converted for use as archives, they must be modified to meet all the requirements of conservation.

For archives in tropical countries, construction standards should be particularly stringent; not only the outer walls and foundations but also the doors, windows and roofs should be in keeping with the climatic conditions (sections 4.2-4.2.5, pp. 31-37).

Metal shelving units are highly recommended: in the traditional and also in the 'compact' form they must combine solidity with safety and convenience.

Special storage problems are posed by documents of unusual shape or size (maps, plans, etc.; see sections 4.3-4.3.3, pp. 37-41).

The most usual containers of documents are boxes. Normally they are made of stiff and acid-free cardboard, but inert plastic boxes, which have obvious advantages, are beginning to replace cardboard (sections 4.4-4.4.2, pp. 41-42).

5. Conservation controls

Closely related to prevention and restoration is the monitoring of factors whose presence or imbalance can impair documents. The chief of these factors are light, humidity, temperature, pollution, biological contamination and fire.

The best natural climate is found in temperate zones where temperature and humidity rarely experience wide fluctuations. Artificial environments (air conditioners) make it possible to regulate humidity and temperature within even stricter limits (sections 5.1-5.1.2.2, pp. 43-46).

Atmospheric pollution is caused by the solid, liquid and gaseous waste products of industrial and natural processes. Limitation of biological pollution demands low levels of temperature, humidity and illumination, good ventilation, cleanliness, and periodic checks and preventive treatment.

Fire safety depends on the presence of adequate detection and extinguishing systems. Those based on ionization smoke detectors are the most suitable for archives (sections 5.1.3-5.1.5.1, pp. 46-49).

6. Restoration

The restoration of printed documents aims at the recreation of the physical and functional features of paper and ink lost through the passage of time, through handling or through an accumulation of adverse circumstances. Because of its special importance, this type of work must satisfy precise restoration standards which guarantee the preservation of the essence and function of the original documents, respect for their cultural integrity and concern about their transmission to future generations (sections 6.2-6.2.6, pp. 52-54).

The sequence of operations from the time a document arrives in the restoration laboratory to the time it leaves again, constitutes a series of links in a regular chain - the restoration process.

Restoration criteria require, before any restoration work starts, strict control - identification of the item's physical and cultural characteristics - and the opening of a file indicating the treatment given, the methods of application and any other details of general interest. The individual characteristics of each document and the diagnosis of the causes and effects of the deterioration suffered as well as the seriousness of the damage are determined by a series of physical, chemical and biological analyses. The appropriate treatment is determined from the results of the analyses and the value of the document as cultural property (sections 6.3-6.3.2.3, pp. 54-58).

Because of the structural fragility of paper and the instability of the materials it supports, restoration work should be carried out with sufficient safeguards to ensure its complete protection during the time it is in the laboratory or undergoing any other treatment throughout the restoration process.

In systems in which a bath is involved it is necessary to support the document while it is being handled. Inks etc. that are unstable or likely to be soluable must be protected with non-permanent fixatives applied locally or over the entire surface (sections 6.3.4-6.3.4.6, pp. 60-65).

Attack by micro-organisms and insects is a common cause of damage. Before introducing a document into a depository, therefore, it is necessary to disinfect it to prevent any likelihood of contagion. The installation and use of a room or area equipped for such a purpose is necessary in any archives or library (sections 6.3.5-6.3.5.1, pp. 65-68).

Patches, incrustrations, dust and dirt are removed by different cleansing treatments: erasers give good results in the removal of solid substances; ensymes are used chiefly to treat damage caused by natural adhesives; and organic solvents are applied to greasy and similar substances. The most stubborn stains can be removed only by bleaching, an operation with harmful side-effects that is advisable only for documents whose aesthetic appearance is important (sections 6.3.6-6.3.6.4, pp. 69-79).

The yellowish colour and friability of many papers may be due to excess acidity, which causes gradual degeneration. Deacidification elminates this cause and gives the document better protection. The creation of an akaline reserve with a pH between 7 and 8, according to the type of paper, is recommended as a preventive measure (sections 6.3.7-6.3.7.3, pp. 79-84).

Loss of body can be restored by means of protective and curative consolidating agents. Water helps to bind the fibres together. The most effective consolidating agents are adhesives, basically the increasingly widespread semi-synthetic adhesives (sections 6.3.8-6.3.8.2, pp. 84-87).

Fine tissue-paper of high transparency is used to repair cuts and tears. Gaps or missing areas are repaired by means of grafts, using either the manual or the mechanical process (sections 6.3.9-6.3.10.2, pp. 87-90).

Scientific considerations for the restoration of graphic elements demand that falsification of the reality of the mutilated part be avoided. In works of an artistic nature reintegration of the missing area, always using materials and techniques different from those of the original, must be in harmony with the whole (sections 6.3.11.1-6.3.11.3, pp. 90-92).

After aqueous treatments documents must be carefully dried in order to reduce the increase in volume that occurs in all cellulosic materials after immersion in water. The purpose of smoothing is to avoid deformations and restore, as far as possible, their original flatness and size. The best natural drying method after immersion is airing at room temperature and not too quickly, to avoid deformations. Documents are placed between two flexible and permeable covers on which gentle pressure can be exerted to complete the drying process and help to smooth them out (sections 6.3.12-6.3.12.2, pp. 92-94).

If a document is in such a fragile state that despite the consolidation treatment is still risky to handle it it should be laminated by applying to one or both sides a reinforcing sheet that will lend it greater body and functional strength. This operation can be performed manually or by special machines with heat and pressure controls. Lamination is a curative method and should not be used on a large scale or indiscriminately. Lamination must be preceded by the appropriate curative measures, especially deacidification (sections 6.3.13-6.3.13.2, pp. 94-97).

Other protective methods are applied to the restoration of bindings and the mounting or special protection of loose leaves or documents. For bindings of historical and/or artistic value the applicable criteria, as for all reintegration, are aimed at preserving the item in its integrity. When replacements are made the materials and techniques should avoid falsification and, while respecting the harmony of the original and reconstructing the missing parts, ensure that the old is clearly distinguishable from the new.

Binding entails dismantling and reassembling the entire volume if the leaves need treatment or if the binding has become weak. A careful record of the order and arrangement of each book is indispensable so as to avoid mistakes when rebinding (section 6.3.14.1, p. 97).

Loose documents should be protected, especially for the purposes of display, by being specially mounted in a passe-partout folder to preserve them. The materials used, like that used in other treatments (e.g. binding), must possess certain innocuous properties (e.g. chemical neutrality, absence of particles subject to oxidation and low or zero hygroscopicity). A transparent and impermeable sheet placed between the folder and document eliminates external risks.

Another method is encapsulation, a system of preventive covering that consists in putting the document, without any adhesivie, inside a flat, transparent and hermetically sealed sleeve and prevents or guards against the action of external agents. As with lamination, before encapsulating the document any agent that can cause foreseeable damage must be eliminated (sections 6.3.15.1-6.3.15.3, pp. 100-103).

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