MANUFACTURING AND ENVIRONMENTAL FACTORS AFFECTING THE PERMANENCE OF PAPER

A. J. Watson

Paper and products derived from paper are used for a multitude of purposes but in very few of these are we looking to the paper to have a long service life. Newspapers, notices and the like are required to convey information of immediate interest to the recipient. Packaging and wrapping materials have served their purpose once the goods have been delivered. Even objects such as books and office records are in the majority of cases of interest over only a relatively limited span of years. However, there are instances where certain documents, books and other records committed to paper are of direct or potential interest to future generations and the question of their preservation can be a matter of major importance to the person or organization entrusted with their custody.

The problems associated with the preservation of such documents are often accentuated because in many cases there was no thought at the time of preparation that the material would be of archival interest. In such cases little attention was given to paper quality with the result that the paper may have a relatively short life before showing obvious signs of deterioration.

In cases where it is recognized that some degree of permanence is required attempts are usually made to select a grade of paper which experience has shown will last for a long time. There is, however, only limited information as to what constitutes a permanent paper and because of technological changes introduced into pulp and paper manufacturing procedures, past experience is not always a reliable guide.

One of the difficulties in assessing just what constitutes a suitable paper is confusion between the term 'permanent' and 'durable' as applied to paper. Although sometimes considered as synonymous they describe two different functions. A durable paper is one which will withstand frequent and even rough handling without failure but it is not necessarily a paper which will retain its properties over a long period of time. An ideal permanent paper would be one which showed no change in its properties with ageing. It would have properties appropriate to a specific end use and would continue to exhibit these properties indefinitely. Durability is usually of secondary importance as most paper documents where permanence is the main consideration are stored on bookshelves, in folders or in some type of wrapping to protect them from mechanical damage, and handling is minimal.

It is the intention here to discuss factors influencing the permanence of paper. These may be associated with the type of pulp used, impurities remaining in the pulp after processing, materials added during papermaking and to the climatic and atmospheric conditions to which the finished paper is subjected during storage.

Pulps Used in Papermaking

About 95 per cent of all papermaking fibre is derived from wood. The remainder is made from a variety of materials such as sugar cane bagasse, bamboo, straws, reeds, grasses and other fibrous agricultural crops. All of these, together with the various types of pulpwood, may be classed as lignocellulosic materials and have to be subjected to pulping procedures to reduce them to a fibrous pulp suitable for papermaking.

Small quantities of paper are also made from pulps prepared from rags, cotton linters, and old hemp ropes. These materials are already in a fibrous state and are mainly cellulosic in nature. After treatment to remove waxes, dirt and other impurities they are in a form suitable for processing into paper. Rag pulps were once considered essential for the manufacture of permanent papers but it is now recognized that good quality chemical wood pulps can be equally satisfactory.

Wood pulps are prepared by a number of different processes. The yield and the papermaking properties of these pulps differ widely depending on the pulping process. These range from full chemical pulps in which practically all the non-cellulosic materials have been removed during the pulping operation to give fibres which approach cotton cellulose in general chemical composition, to pulps which are made simply by reducing the wood to a fibrous state by the application of mechanical energy. In between are a range of semichemical pulps produced by a combination of chemical and mechanical treatments.

Pulps which are to be used for the manufacture of white grades of paper have to be subjected to bleaching treatments. These differ in degree and kind for different types of pulp and on the degree of brightness (whiteness) that is desired. In all cases it is important that the bleaching operation be carried out in such a way as to minimise damage to the pulp fibre. Damage to the fibre by overtreatment during the bleaching operation or retention of bleach liquor residues in the pulp due to inadequate washing will adversely affect the strength and brightness of paper made from the pulp. Such effects will become more pronounced with ageing of the paper.

Paper Manufacture

Prior to the beginning of the 19th century all paper was hand made but now practically all paper is made on machines. Various operations are carried out on the pulp prior to papermaking. The pulp fibres are beaten to make them more flexible and improve their bonding properties and, depending on the end use, sizing materials, dyes, pigments, fillers and the like are added prior to formation to impart or improve certain desired properties in the finished paper. The nature of the pulp furnish and many of the materials added prior to or during the papermaking operation can influence the permanence of the paper.

As already indicated rag pulps were once considered as essential for papers where a high degree of permanence was required but bleached chemical wood pulps can be expected to be equally satisfactory providing the pulping and bleaching operations do not degrade the cellulosic fibres. The permanence of papers made from

these pulps will be influenced mainly by non-fibrous components added during manufacture.

Papers such as newsprint and other grades which contain high percentages of mechanical and semichemical pulps often have poor colour stability. Loss of brightness is relatively slow when such papers are stored in the dark but exposure to strong light may cause browning within a few days.

As has been indicated papers are often made from blends of different types of pulp. This has become much more common in recent years and paper grades that once would have been made solely from a bleached chemical pulp may now contain substantial amounts of bleached semichemical and mechanical pulps. Papers are manufactured for various specific end uses and the papermaker's objective is to make them from the available pulps as economically as possible. The fibre composition of a specific grade of paper may vary depending on pulp prices and availability. Consequently, unless a requirement for permanence is included in the specification, papers which are nominally the same may show different characteristics on ageing.

Non-fibrous Components

Some of the non-fibrous components added during the manufacture of the paper can have a marked influence on its ageing characteristics. Of these the one which is of major interest is papermakers' alum. This is a form of aluminium sulphate which, in aqueous solution, has a mildly acid reaction. It is used to precipitate rosin size onto the papermaking fibres to make the paper slightly water resistant and in other papermaking operations where pH control is required. Over a period of years even mild acid conditions have adverse effects on the cellulose fibre. The paper tends to become brittle and some strength properties such as folding endurance and tearing strength may be substantially reduced (see Table 1).

Alkaline and neutral sizing agents are available and may be used for speciality papers where the acidity from rosin-alum sizing is objectionable. Such papers show little reduction in strength on ageing, and alkaline sizes are recommended where permanence is a prime requirement.

The type of filler used during paper manufacture can also influence the permanence of paper. Fillers are usually inert materials such as clays and chalks which are added to the paper during manufacture to improve opacity and sometimes to increase brightness and surface smoothness. If a filler such as calcium carbonate is used in conjunction with an alkaline sizing agent the paper will have a slightly alkaline reaction. Most pulps have a slightly acid reaction even when alum is not present. The presence of the calcium carbonate counteracts this effect and also tends to neutralize any acidic materials that the paper might absorb from the atmosphere.

Coatings such as starch and gelatine sizes which are applied either to partly or fully finished papers to improve their surface properties can increase the probability of biological attack during storage. Fungicides are sometimes added to reduce this effect. These coatings are also prone to insect attack.

Environmental Factors

While an appreciation of the way in which the manufacturing processes may influence the permanence of paper can be of some assistance to the archivist, he has little or no control over these operations. Material coming into his hands will be from a variety of sources and range from newsprint to high quality rag papers. However, the precautions that should be taken during storage are common to all types of paper and under suitable conditions most papers can be stored for long periods without showing serious signs of deterioration.

Light: As already mentioned papers containing appreciable quantities of mechanical or similar high yield pulps darken on exposure to light but all types of paper suffer from degrade. Exposure also leads to embrittlement and loss of strength. With papers such as newsprint care should be taken to limit their exposure to light to the absolute minimum.

Temperature: Paper ages more rapidly at higher temperatures and every effort should be made to avoid storage under such conditions. It is also desirable that the temperature remains constant within a few degrees (cf.—relative humidity). Storage temperature within the range 15 to 25°C should be aimed at.

Humidity: Paper is very hygroscopic and rapidly comes into equilibrium with the surrounding air. These changes in the moisture content of the paper are accompanied by dimensional changes within the paper which over a long period of time are reflected in reductions in some strength properties. Temperature and humidity are inter-related and both should be controlled within fairly narrow limits to give good storage conditions for paper. Relative humidity control within the range 30% to 65% would be satisfactory but, as with temperature, it is desirable to restrict the variation as much as possible.

Under conditions of high humidity (>65%) and especially at higher temperatures there is a very real danger of fungal attack. This leads to discolouration and staining and in more extreme cases to weakening of the paper. Humidity control is the most effective way of preventing this but fumigation of storage areas with fungicides is also used. Little information is available as to whether such treatments have adverse effects on the permanence of the paper.

Atmospheric Pollutants: The air contains traces of acidic materials (mainly sulphur dioxide and oxides of nitrogen), the actual concentration depending largely on the amount of industrial activity in a given region. Cellulosic materials exposed to such atmospheres and, particularly under high humidity conditions, tend to absorb these constituents. This increase in acidity contributes to the degrade of the paper during storage.

Handling: In addition to atmospheric factors paper may also suffer degrade during printing and converting operations depending on the type of ink, surface sprays, adhesives and the like that might be used and from perspiration during handling. Most of these effects are evident only after the paper has been held for long periods. The archivist usually has no control over the converting operations but he can ensure that care is taken when handling documents in his possession.

TABLE 1

Changes in paper properties produced by artificial ageing for six commercial grade papers.

(From Wilson, W. K. and Herbert, R. L.—see bibliography.)

(Papers heated at 90°C. and 50% relative humidity.)

Types of paper and furnish

1. Newsprint.
2. 100% white ledger (100% new rag pulp—glue and rosin size).
3. Chemical wood white bond (bleached wood pulp—starch and rosin size).
4. Alkaline bond (hardwood kraft and soda pulp).
5. Bond (20% bleached kraft softwood, 80% bleached NSSC hardwood—neutral size).
6. Bond (25% bleached kraft softwood, 5% semi-bleached softwood, 70% bleached NSSC hardwood—acid size).

Ageing time hr.	Paper Type 1	2	3	4	5	6
			Double Folds—MIT Instrument			
0	74	9130	1290	2710	4280	1730
6	26	6430	74	2800	3560	85
12	23	4800(1)	3	2710	1870	40(1)
18	6(2)	4290(1)	1	2290	1350	1
24		4190	1(1)	2150(1)	1430	0
			Internal Tearing Strength g			
0	22	102	55	68	60	47
6	19	96	38	75	60	27
12	19	96(1)	25	72	54	24(1)
18	13(2)	95(1)	69	71	59	12
24		95	11(1)	69(1)	55	10
			Bursting strength p.s.i.			
0	7	59	32	27	62	27
6	6	58	22	29	51	17
12	6	57(1)	15	27	51	16(1)
18	5(2)	55(1)	14	17	50	10
24		53	12(1)	26(1)	47	9
			Brightness (% of white standard)			
0	55	83	75	83	84	82
6	44	74	69	76	64	71
12	47	71(1)	63	74	64	72(1)
18	39(2)	70(1)	63	74	62	66
24		66	62(1)	75(1)	61	65
			pH of Original Paper (measured on cold water extract)			
0	4.73	5.40	4.95	7.20	6.30	4.80

(1) Values obtained by interpolation from original data.

(2) Ageing time 15 hours.

Testing of Paper for Permanence

Attempts have been made to ascertain the changes taking place in paper during natural ageing by comparing the strength and brightness of papers some years after manufacture with results obtained on the same paper soon after it had been made. Such results give only a general indication as test equipment and procedures change with the years and measurements made at different periods may not be comparable. Accelerated ageing tests have been developed to assess whether a paper will retain its properties over a long period of time. These test procedures all make use of storage of the paper for a period of days at elevated temperatures to simulate the ageing process. There is general agreement that the heat treatment does bring about changes of the same general nature as those that occur over a period of years at room temperature but it is difficult to establish any precise correlations.

The tests that may be applied when studying the ageing characteristics of papers have been directed mainly towards measuring strength properties and discolouration. Folding endurance is very sensitive to ageing and is frequently used in such studies but any of the commonly-used strength tests may be used. Reduction in paper brightness can be particularly marked with some grades of paper.

The Paper Evaluation Section of the U.S. Bureau of Standards measured the relative stability of a number of papers after laboratory ageing at 90°C and 50% RH for various periods. The results obtained for some of these papers using a range of tests are given in Table 1.

It will be noted that the papers differ widely in general properties prior to ageing (zero time) and also behave very differently during ageing. Paper No. 4 (an alkaline bond paper) changed relatively little with ageing. This paper had an alkaline reaction while the other five all showed some degree of acidity probably due to the presence of traces of alum. Paper No. 2 (100% new rag pulp) showed only a small amount of degrade. It is also of interest that the newsprint with its high percentage of groundwood showed quite good resistance to ageing. The papers containing a high percentage of semichemical pulps (Nos. 5 and 6) differed widely in their behaviour. Here also the paper with the lower acidity gave the better results.

These results serve to demonstrate the complex nature of the ageing process. Paper stability is clearly influenced by the fibre furnish and materials added during manufacture. Papers with an acid reaction were more liable to degrade than neutral or alkaline papers but here also factors such as furnish and storage conditions play an important part. Accelerated ageing tests are still at the stage where although they may be able to rank papers in order of permanence they can give only a general estimate as to whether the paper could be expected to have a storage life of decades or centuries.

Literature References

There is a considerable literature on the various factors associated with paper permanence, on accelerated ageing of paper and on tests used in assessing the changes in paper properties associated with

ageing. Several of the more important publications, reviews and bibliographies that have appeared in recent years are given below.

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