5

Restaurator

Number 3

1972

C

RESTAURATOR

Verner W. Clapp

The story of permanent/durable book-paper, 1115–1970

international journal for the preservation of library and archival material supplement number 3 1972

Verner W. Clapp

The story of permanent/durable book-paper, 1115–1970

RESTAURATOR

5

Verner W. Clapp

The story of permanent/durable
book-paper, 1115–1970

international journal for the preservation of library and
archival material · supplement number 3 · 1972

restaurator press · copenhagen

RESTAURATOR, International Journal for the Preservation of Library and Archival Material . Supplement number 3

Editors:
A. D. BAYNES-COPE . London
POUL A. CHRISTIANSEN . Copenhagen
FRAZER G. POOLE . Washington, D.C.

Restaurator Press
Postbox 96
DK-1004 Copenhagen K
Denmark

ISBN 87 87220 01 6

The story of permanent/durable book-paper 1115–1970, is reprinted in a slightly revised form from Scholarly Publishing 2 (1971): 107–24, 229–45, 353–67

RESTAURATOR is indexed in:
Current Contents: Education
Library and Information Science Abstracts
Library Literature

Printed in Denmark by Vinderup Bogtrykkeri, Vinderup

Table of Contents

The story of permanent/durable book-paper, 1115-1970

VERNER W. CLAPP

The early development of book-paper and its progressive degradation since 1500 are followed to the nineteenth century in the first instalment of a two-part article

Litera scripta manet. That the written word endures may be assumed to be an article of faith with all whose interests meet in the pages of this journal. The fact is, however, that by itself the written word has no claims to permanence. For this it is wholly dependent upon the substratum upon which it is inscribed. Through the centuries the substratum has taken many forms – the face of a cliff, a marble shaft, or a tablet of clay; a papyrus scroll or an animal skin; a bronze plaque or a sheet of paper; and many more.

This recitation suggests that the choice of paper as a universally preferred writing material was not made on grounds of lastingness. The truth is that we ask many qualities in a writing material, and to some we give a higher priority than to its permanence.[1] Specifically, in its ability to accept a message readily and to render it faithfully, in its compactness, manipulability and portability, and perhaps above all in its cheapness, paper has proved itself so far superior to all its competitors that we are lucky if we obtained any permanence at all in the bargain. Actually, some permanence was thrown in, but not enough. If it had been an all-or-none proposition – if all paper had been permanent, or none – the matter would undoubtedly have been disposed of one way or another long ago. Instead, indeterminacy has exacerbated the problem for more than 850 years.

1115–1500 PAPER VS PARCHMENT

Paper entered the European scene with a black mark against its name, written – it may be suspected – on parchment. In 1115 parchment was achieving dominance in European chancelleries, having almost entirely superseded papyrus. Paper, introduced from Africa into Spain and Sicily by the Arabs, had been gaining ground for a century. We can only guess today the evidence on which parchment was preferred to paper in the twelfth century, but in 1115 Roger II of Sicily (then Count) renewed on parchment a charter which his father, Roger I, had granted the abbey of Santa Maria di Terreti in Calabria on paper only 25 years before.[2] Again, in an assembly in Palermo in 1145, Roger renewed on parchment four charters granted on paper to the Basilian monastery of St Philip of Fragala from 1102 to 1124.[3] The reason for the preference is not explained in either case.

The Emperor Frederick II (Roger II's nephew) was more explicit. In the constitutions which he ordained for the Two Sicilies in 1231 he required that all public documents should be written on parchment 'so that they may bear testimony to future times and not risk destruction through age.'[4]

Whether the parchment industry has ever erected a monument to this monarch, I do not know. It should most certainly recognize him as its patron, for Frederick's edict, which has worked greatly to its advantage, has lasted longer and more effectively than the acts of most lawgivers. (Perhaps because it was written on parchment!)

Thus, until very recent years, parchment has been specified for documents whenever permanence was in view. Not only were such national muniments as Magna Carta and the Declaration of Independence engrossed on parchment, but the walls of the western world have within human memory been papered with the certificates of educational achievement known as 'sheepskins.' By contrast the Charter of the United Nations is on paper, as are all but a very elite few of the current product of the diploma-mills.

Ironically, when parchment began to get expensive, it was discovered that a 'vegetable parchment' could be made from – of all things – paper, by dipping it into – of all things – sulphuric acid! This improbable material has taken the place of parchment for many documental uses, while 'parchmentized' paper is widely used for wrapping butter. All that would be needed to complete the irony would be to watermark this product with the figure of Frederick II!

In spite of the imperial discouragement, the manufacture of paper progressed amain over the centuries following 1231; so much so that it was able to support a very lively publishing industry when printing came into existence in the second half of the fifteenth century. It is true that fastidious book-purchasers continued to insist on parchment, and the Gutenberg Bible, c. 1455, was printed in parchment as well as paper copies. The next book, the Mainz Psalter 1457, was printed exclusively in parchment copies. But as the century wore on, the use of parchment became less and less frequent.

Of course, the printing press rang the knell of technological obsolescence on the scriptorium. The scriptorium did not, for that reason, immediately go out of business; it lingered for years. When it didn't have manuscripts to copy, it sometimes copied printed works, and Dr Curt Buehler of the Pierpont Morgan Library has amused himself by collecting instances of manuscript copies – sometimes slavish reproductions, colophon and all – of printed books.[5] Such copying required justification. One rationalization argued that copies printed on paper were perishable, and needed to be replaced by transcripts on more durable parchment. We owe to the formidable Johann Tritheim – theologian, historian, bibliographer, cryptographer, and director of a scriptorium in the Benedictine monastery at Sponheim where he was abbot from 1483 to 1506 – perhaps the best wording of this rationalization. 'If writing,' said he in *In Praise of Scribes*, 'is inscribed on parchment, it will last a millennium. But if on paper, how long will it last? Two hundred years would be a lot.' He consequently urged scribes 'to perpetuate in writing the useful products of the press.'[6]

1 / '*Permanence* is the degree to which paper resists chemical action which may result from impurities in the paper itself or agents from the surrounding air. *Durability* is the degree to which a paper retains its original qualities under continual usage.' (Report of the [Technical Association of the Pulp and Paper Industry] Committee on Permanence and Durability of Paper. *Paper Trade Journal* 97:4:33–6, 27 July 1933)

2 / J.-L.-A. Huillard Bréholles: *Historia diplomatica Frederici* II ... *imperatoris* (Paris: Plon, 1852–9), II, 440. This is a latin translation made by the magistrates of Reggio when reconfirming the charter in 1252. The expression for 'paper' used by the magistrates was 'carta papiri'; it would be interesting to know which of several available terms was used in the greek in which the charter was originally written.

3 / Roccho Pirri: *Sicilia sacra* (Panormi [i.e., Palermo]: Bua, 1633–1733) 4 (1649) 91–3. Again, this is a latin translation of the greek original, by Pirri, and we do not know the greek term for paper. The latin phrase used by Pirri, 'carta cuttunea,' means paper made from cotton according to C. du F. Ducange (*Glossarium mediae et infimae latinitatis* [Paris: Librairie des sciences et des arts, 1937–8], s.v. Charta cuttunea), but paper made from flax or linen according to Santifeller, 1953 (cited by G. Piccard: 'Carta bombycina, carta papyri, pergamena graeca,' *Archivalische Zeitschrift* 61 [1965] 46–74. p. 47). But would Pirri have distinguished in 1649?

4 / 'Volumus etiam & sancimus, ut praedicta instrumenta publica, & aliae similes cautiones, nonnisi in pergaminis in posterum conscribantur. Cum enim eorum fides multis futuris temporibus duratura speretur, justum esse decernimus, ut ex vetustate forsitan, destructionis periculo non succumbant.' *Constitutiones regum regni utriusque Siciliae mandante Friderico* II *imperatore per Petrum de Vinea ... concinnatae ... cum graeca earundem versione* (Neapoli: Ex Regia Typographia, 1786), Tit. LXXX (p. 81–2). The latin terms for paper in this title are 'charta papyri' and 'charta bombycina'; the corresponding term in the greek text is *χαρτίον βαυβακερον*.

5 / Curt F. Buhler: *The fifteenth century book* (Philadelphia: University of Pennsylvania Press, c. 1960), p. 15ff

6 / Johannes Trithemius: *De laude scriptorum pulcherrimus tractatus* (Mainz: Peter von Friedberg, 1494). Hain *15167 – the reference is to Ludwig Hain: *Repertorium bibliographicum* [*of books printed up to 1500*] (Stuttgart, 1826–38).

In spite of this distrust of paper, Tritheim was not averse to seeing his own works become useful products of the press He seems, however, to have taken the precaution that at least some copies of his books were printed on parchment. Of no fewer than 117 copies of just those of his works that were published before the end of the fifteenth century which have found their way into the collections of North American libraries, no fewer than nine are on parchment![7] I have not seen these parchment copies, all but one of which are in the Pierpont Morgan Library, but in the Library of Congress I have examined twelve copies of Tritheim's books and pamphlets – all on paper – printed before his death in 1516 as abbot of St. Jacob's in Würzburg.[8] Four of these publications are of book length. These are fine copies, showing little or no evidence of use in the way of annotations, and their paper is in excellent condition, with beauty and strength apparently unaffected by age. The other eight publications are pamphlets, most of which show evidence of some use, and several a great deal of use. The paper in five is good, in two fair, and in one (which appears to have been through a fire) quite brown and poor. Nevertheless, these books have all already more than doubled their author's expectation of life on their behalf, and seem (with the exception of the worst of the pamphlets) to have undiminished expectancy of further existence, given as good care as they have had for the past half millennium.

But the world heeded the warnings of the abbot no more than it had those of the emperor, and in retrospect the world appears to have been in the right. Certainly, there is no evidence of massive losses of paper records, manuscript or printed, from the fifteenth and earlier centuries from causes that would not have been equally destructive to parchment. On the contrary, hundreds of thousands of printed books from the second half of the fifteenth century and of manuscripts from the fifteenth and earlier centuries survive intact in libraries and archives. It may be conjectured that the combination of sound raw materials (clean linen rags), little or no chemical treatment (limited principally to retting the flax and bleaching the linen in sunshine), the minimum of mechanical treatment (pounding in stamping-mills which left the fibres long), and an abundance of clean water account for the resulting stable product. If to these conditions is added that the hard water likely to have been found in the mountain streams often sought by papermakers to operate their stamping-mills undoubtedly often contributed the mineral salts which account for the alkalinity of many early papers, then the principal elements conducive to permanence, as we

7/ Frederick R. Goff: *Incunabula in American libraries* (New York: Bibliographical Society of America, 1964), items T-433, 436, 439, 443, 444, 449, 451, and 457 (2 copies)

8/ *Ibid.*, items T-433, 434, 437, 438, 441, 446, 448, 452, 455, 456. Also: *De purissima et immaculata conceptione Virginis Mariae* (Strassburg: Matthias Hupfuff, 1406 [!]), 2 copies; and *Compendium sive breviarium primi voluminis Annalium* (Mainz: Peter Schoffer, 1515)

now know them, would have been present.

Accustomed as we are to a preponderance of less-than-fine book-papers, how do we account for the many fine papers of the fifteenth century? Without going into the organizational complexities of medieval trade and industry, it may simply be suggested that until about 1500 book-paper was competitive with parchment and was measured by the standard set by that product. By 1500, however, paper had won the day, and only a few nostalgics like Tritheim (who had, besides, a vested interest in an obsolete practice) still insisted on the more expensive material.

Then, freed from competition with parchment and facing only intra-industry competition, the inevitable happened. To meet the ever-increasing demand for paper, accompanied by a correspondingly severe competition for high-quality raw materials, manufacturers began to adopt improvements in manufacturing technique which too often led to degradation of the product, and in the use – made possible by technological advances – of inferior raw materials.

The processes of degradation were slow at first and not immediately apprehended; the effects, however, were cumulative. In the severity of the chemical and mechanical treatment of which it was the product, the paper of each century since the fifteenth has increasingly exceeded its predecessor, finally resulting in a product which could be called paper only by courtesy.

The steps down the slope of degradation are not all known, and many questions persist. However, we know a great deal more now than before William J. Barrow began his epochal work in 1957.

WILLIAM J. BARROW, 1904–1967

Barrow, a document-restorer of Richmond, Virginia, was in 1957 widely known as the inventor of a laminating process which had been adopted by principal archives and libraries around the world.[9] The development of this process is an integral part of the story of permanent/durable book-paper.

Barrow came into restoration work early in the depression, and he prepared himself for his new profession with characteristic thoroughness. At the Library of Congress he observed documents being repaired by the 'silking' or 'crêpelining' process and he was struck by the inability of this painfully slow and none-too-permanent method to cope with the vast quantities of documents needing attention, such as local land and vital records. He was attracted by the process of lamination with cellulose acetate foil with which the U.S. Bureau of Standards was currently experimenting. Because he could not afford the enormous steam-and-cold-

9/ Frazer G. Poole: 'William James Barrow,' *Encyclopedia of library and information science* (New York and London: M. Dekker, 1969–) 2:257–70. Also 'Death of William J. Barrow,' Council on Library Resources: *Annual report* XI (1967) 44–9 water-jacketed hydraulic laminating press that was the conventional equipment, he developed the comparatively simple and inexpensive but much more efficient cylindrical press that is known by his name. By early 1938 this had proved effective.[10]

But the results did not satisfy him. In the first place, the cellulose acetate foil added little strength to weak documents and was itself very susceptible to edge-tear. To supply the needed strength he added gossamer-thin sheets of strong, purified paper tissue to the laminate sandwich.

Meanwhile, however, he was becoming increasingly aware of the role of acidity in paper embrittlement, and his own observations from 1939 confirmed that deteriorated documents are indeed in general highly acid. He perceived the need of neutralizing this acid condition if the documents which he was laminating were not to continue to deteriorate and in addition to contaminate the cellulosic material which he was using to protect them. Some non-injurious method of neutralizing the acid prior to laminating seemed to be called for, but early experiments were discouraging because the acid condition tended to recur. However, the observation (for which he credited various U.S. agencies as well as W.V. Torrey and E. Sutermeister of the S.D. Warren paper company) that certain old papers probably manufactured in a limestone region owed their remarkable state of preservation to the presence of calcium carbonate, pointed the way to a successful method of deacidification making use of solutions of calcium hydroxide and calcium bicarbonate.[11] The Barrow laminating process, thus perfected by 1942, has withstood the test of time and has become the standard method.

As the result of this experience, Barrow gained great confidence in his ability to retard deterioration in ageing paper. He yearned to apply this ability to new paper.

10/ For this statement and those in the next two paragraphs see W.J. Barrow: 'The Barrow method of laminating documents,' *Journal of documentary reproduction* 2:147–51, June 1939; W.J. Barrow, 'Restoration methods,' *American archivist* 6:151–4, July 1943; W.J. Barrow: *The Barrow method of restoring deteriorated documents* (Richmond, Va.: The author, 1965); W.K. Wilson & B.W. Forshee: *Preservation of documents by lamination* ([Washington:] National Bureau of Standards, 1959)

11/ W.V. Torrey and E. Sutermeister: 'A brief study of some old papers,' *Paper trade journal* 96:21:45–6, 25 May 1933. The authors analysed a number of tiny specimens of papers from the tenth to eighteenth centuries. They found the ash of several to be alkaline and to contain calcium. But they did not speculate about limestone regions; Barrow was reading his own thoughts into their writings. Also M.B. Shaw and M.J. O'Leary: 'Effect of filling and sizing materials on stability of book papers,' *Journal of research of the National Bureau of Standards* 21:671–695, November 1938. This work was cited by Barrow presumably on account of one of its less emphasized findings, that calcium carbonate pigments in paper had a protective or inhibiting effect on deterioration during heat-ageing.

In the libraries to which he was a frequent visitor he found the custodians worrying about the deteriorating collections over which they were presiding and to which they were daily adding more material similarly destined to deteriorate. He was sure that this was unnecessary. In 1957 came his chance to do something about it.

The Council on Library Resources had been established in late 1956 with the paper-deterioration problem high on its list of priorities for action. Early in 1957 it was agreed between the council and the Virginia State Library (where Barrow maintained his restoration shop) that, as a first step in an attack on the problem, the library should contract with Barrow to attempt to find out just what had happened to the book-papers of the first half of the twentieth century.[12] To do this he was to test for physical and chemical characteristics the papers of 500 nonfiction books published in the United States, ten for each year of the period 1900–1949.

Barrow's first step was to appoint an advisory committee so chosen as to assure himself access to talents in polymer and paper chemistry, physics, statistics, and library administration, as needed in the study. Though in a sense a solitary worker, Barrow (whose standing in the community was high) never lacked expert advice.

In the course of the study Barrow examined more than 40,000 test strips. As testing proceeded he rejected a number of usual tests – viscosity, copper number, bursting strength – but retained three as being most indicative of those qualities of paper in which he was interested: folding endurance, tear resistance, and acidity/alkalinity. His results were shocking: they showed that the paper from the average nonfiction book published in the United States in the first decade of the twentieth century had by 1957 lost 96 per cent of the strength that (by comparison with new papers) it possessed when manufactured; that papers of 1940–9 had already lost 64 per cent of their original strength; and that most books printed in the United States in the first half of the twentieth century would probably be unusable in the twenty-first. He found deterioration among the tested papers to be proportional to their acidity.[13] It must be remembered that at this time Barrow did not own a pH meter (for measurements of acidity/alkalinity) and that he had to commission pH readings from a commercial laboratory on a selective basis. He learned from this experience, however, that the ability to measure acidity/alkalinity precisely was essential to his interests, and as soon as he could afford an instrument (the following year) he purchased one.

From these findings concerning book-papers of the first half of the twentieth

12/ Council on Library Resources: *Annual report 1* (1957) 21–2.

13/ W.J. Barrow and R.C. Sproull: 'Permanence in book papers,' *Science* 129:1075–84, 24 April 1959. Randolph C. Church, ed.: *Deterioration of book stock: causes and remedies; two studies on the permanence of book paper conducted by W.J. Barrow* (Richmond: Virginia State Library, 1959) century Barrow went on, as will be discussed later, to develop a permanent/durable book-paper. But he realized that he had only examined the tip of an iceberg and that much unexplored paper history lay beneath. As soon as possible, therefore, he returned to the investigation of old papers.

His previous investigations had been conducted in the confined quarters of his restoration shop at the Virginia State Library; to continue them, with assistance from the Council on Library Resources, he acquired in 1960 in the fine building of the Virginia State Historical Society a laboratory superbly equipped for investigations into the permanence/durability of the book. Here he conducted a number of important studies, publishing the results in a series entitled Permanence/Durability of the Book.[14] In 1964 he reported on 21 writing papers, 1425–1900, and in 1967 on 500 book-papers, 1800–1899. For the last he had added tests for chlorides and sulphates and a procedure for distinguishing flax from cotton fibres. At the time of his death in August 1967 he was pushing his examination back to the eighteenth, seventeenth, and sixteenth centuries.

The Barrow Laboratory continues today under the direction of Dr Robert N. DuPuis, formerly director for research of General Foods Corporation. The examination of sixteenth- to eighteenth-century papers has been completed under his direction with the use of additional tests for alum and rosin, which have also been applied to the twentieth-century papers first tested. The results are now being readied for the press.

1500–1900 THE ROAD TO AVERNUS

Pending publication and interpretation of these data, some important dates in the chronology of the degradation of book-paper – its *fasti nefasti* or *un*holydays – can be identified as follows.

1650–1675 THE FIRST STEP: THE INTRODUCTION OF ALUM

By the mid-seventeenth century it was standard practice to size book and writing papers to prevent feathering and penetration of ink. The principal agent for this purpose until the nineteenth century was animal gelatine or glue obtained from cartilaginous material. The finished and dried sheet of paper was dipped into a tub containing a dilute solution of glue, the process being known as tub-sizing.

Alum (potassium aluminum sulphate) was brought to the assistance of tub-sizing about the mid-seventeenth century. Alum appears to have some sizing value of its own, but it was found to be useful for hardening the gelatine and to keep it from putrefying in the indefinitely replenished tub.

The principal use of alum in the arts is as a mordant in dyeing, and so important is it for that purpose that wars have been fought over it.[15] It was not until after the mid-seventeenth century that England developed its own reliable domestic source in the schists of Yorkshire, and it is then that it first appears in the literature of English papermaking. In 1678 the diarist John Evelyn visited a paper mill at Byfleete which he found making a coarse white paper. 'First they cull the raggs (which are linnen for White paper, Wollen for browne).' After the paper is made they 'ply & dry it on strings, as they dry linnen in the Laundry, then dip it in allume water, lastly polish and make it up in quires: ec: note that the[y] put some gumm in the water in which they macerate the raggs into a pap.'[16] It seems more likely that the gum and the alum were together in the sizing tub.

Once admitted to the paper mill, alum became the papermaker's fast (but often false) friend, and the librarian/archivist's worst enemy. To the papermaker alum became a catholicon; as late as 1954 the well known paper chemist, Dr Edwin Sutermeister, called it 'one of the most generally used cure-alls in the mill,'[17] and even more recently the research director of the S.D. Warren Company, leading manufacturers of book-paper, termed it 'the papermakers' panacea.'[18] But to the librarian/archivist (and to the users of libraries and archives) its significance lies in its acidity, and its consequent injurious effect upon paper strength. In his study of writing papers, 1425–1900, Barrow found that the papers of the second half of the seventeenth century were a horrifyingly 16 times as acid as those of the first half (i.e., their median pH values had fallen from 7.0 to 5.6).[19] At the same time their strength, as

14/ *Permanence/durability of the book*. (Richmond, Virginia: W. J. Barrow Research Laboratory, 1963– .) W. J. Barrow: [I] / *A two-year research program* (1963); II/ *Test data of naturally aged papers* (1964); III/ *Spray deacidification* (1964); IV/ *Polyvinyl acetate* (PVA) *adhesive for use in library bookbinding* (1963); V/ *Strength and other characteristics of book papers, 1800–1899* (1967); VI/ *Spot testing for unstable modern book and record papers* (1969)

15/ Charles J. Singer: *The earliest chemical industry; an essay in the historical relations of economics and technology illustrated from the alum trade* (London: Folio Society, 1948). James Sheridan Muspratt: *Chemistry, theoretical, practical, analytical, as applied to the arts and manufacturers* (2 vols, Glasgow and New York: McKenzie [1860]) I: 149–176

16/ John Evelyn: *The diary*, ed. E. S. de Beer (Oxford: Clarendon Press, 1955), IV: 141–2, s.d. 24 August 1675

17/ Edwin Sutermeister: *The story of papermaking* (Boston: S. D. Warren Co, 1954), p. 146.

18/ Joseph J. Thomas: Alkaline printing papers: promise and performance. *Library quarterly* 40:99–107. p. 100.

19/ pH is a measure of acidity/alkalinity on a scale of 0–14 in which 1 represents extreme acidity, 7 is the neutral point, and 14 represents extreme alkalinity. For example, the pH value of caustic soda is 14, of chalk 9, of pure water 7, of cow's milk 6.5, of spinach 5.5, of bananas 4.5, of sauerkraut 3.5, of hydrochloric acid 0.1. Because the pH scale is logarithmic, each unit difference represents a ten-fold difference in acidity/alkalinity. Thus pH 4.5 represents a condition ten times as acid as pH 5.5. For pH measurements of paper a liquid extract is required. Barrow used cold-extraction, which he believed better represented the situation than hot-extraction.

measured by folding endurance, had dropped by two-thirds (i.e., from 840 to 289 folds, median values). Barrow attributed the increased acidity to alum.[20]

But in the seventeenth century alum had only begun its work of paper-degradation. We shall meet it again, triumphant, in the nineteenth century.

1680 THE HOLLANDER

Paper pulp was originally prepared from the raw material by hand with mortar and pestle. But as early as 1151 there was invented at Xativa in Valencia a stamping-mill operated by water power, and this device served for five centuries as the papermaker's principal mechanical aid. But stamping was slow. Accordingly, about 1680 an unknown Dutch papermaker invented the machine known as the Dutch beating-engine or Hollander or beater. In this device the fibrous raw material, immersed in water, is made to circulate in a tub through a chopper that lacerates, macerates, and rapidly reduces the material to pulp. The Hollander gradually spread from the land of its birth. In 1725 the Hollander in Freiburg (Germany) was reported to furnish as much pulp in one day as an eight-hole stamper could do in eight days. In spite of this superior productivity it did not oust the last of the stamping mills until the mid-nineteenth century. At least one reason for this was that the stamping-mills beat the raw material rather than cut it and furnished a longer-fibred pulp giving a stronger and more durable paper.[21]

The Hollander beater, improved in capacity and speed, is still in use, but has been supplemented and often superseded by the Jordan, a device invented in 1858 by Joseph Jordan, an American. This is a rotary fibre-reducing mill operating on the same principle as the coffee-grinder It is even more efficient at reducing fibre to pulp than the Hollander.[22] There seems to be little doubt that paper made with these machines is not generally as strong as that prepared with the stamping-mill. Comparative length of fibre, degree of fibrillation (breaking-down of the main fibre into smaller fibres) and doubtless other factors are involved.

In his study of writing papers Barrow found that the folding strength continued to fall at a shocking rate into the eighteenth century: from a median folding strength of 289 folds for nine specimens for the period 1651–1700 to five folds for 109 specimens for the period 1701–1800, a drop of 98 per cent.[23] It would be difficult to prove the attribution of any specific share in this degradation to the Hollander, but on the evidence of its characteristic performance it may be supposed to have played its part in the decline.

20/ Barrow: ref. 14, II: 37, Table 6
21/ Dard Hunter: *Papermaking* (2d ed. New York: A. A. Knopf, 1947), p. 107, 153, 163
22/ Sutermeister, ref. 17, p. 135ff.
23/ Barrow, ref. 14, II: Tables 6–8

1666–1814 THE BURYING IN WOOLLEN ACT

For centuries the raw material for paper in Western countries consisted of linen – and latterly of cotton – rags. These had to be collected, piece by piece, in door-to-door solicitation through the countryside, and there seems always to have been a shortage of good materials. In consequence, the right to collect rags was often a monopoly conveyed by governmental patent. Householders, too, were urged in various ways, including even watermarks in paper (these must have been the original 'hidden persuaders'!) to save their rags.[24]

In England, for 148 years from 1666 to 1814, the Burying in Woollen Act made it a penal offense to bury a corpse in any 'shirt, sheet, shrift or shroud' made of other than sheep's wool.[25] The stated intent of the law was originally to encourage domestic manufacture of wool and discourage importation of linen. When the law's teeth were sharpened in 1677 an intent to encourage the manufacture of paper as well was added retroactively. Dard Hunter reports that the law effected a saving of 200,000 lbs. of cotton and linen annually, but gives no authority for the statement.[26] (Significantly, while the law specifically prohibited cerements of flax, hemp, silk, gold, or silver, it made no mention of cotton.) Matthias Koops (of whom more later) reported in 1800 that out of a total annual consumption of 24 million pounds of raw materials for paper, Great Britain had imported 6.3 million pounds of rags from the Continent during the previous year, and he opined that the Burying in Woollen Act might save 250,000 pounds of rags annually.[27] But when the Act was repealed in 1814 the Judge Advocate General (Charles Manners-Sutton), who introduced the repealing bill, stated that he had 'never heard that the woollen manufacturers had ever thought it necessary to enforce this law,' which he stated was harder on the clergymen who were required to report violations than on the deceased whose estate was to be fined.[28] (Manners-Sutton, the son of an Archbishop of Canterbury and himself later Viscount Canterbury, was always soft for clergymen.)

1684–1800 PROPOSED SUBSTITUTES FOR RAG

In any case, the chronic shortage of raw materials for paper stimulated a continuous flow of suggestions for substitutes for rag. Dard Hunter devotes a chapter in his history to them, listing suggestions for some 135 substitutes beginning with asbestos

24/ Hunter, ref. 21, p. [309]
25/ An act for burying in wool only, 18 Charles II, c. 4, 1666; reenacted as An act for burying in woolen, 30 Charles II, c. 3, 1677 and 32 Charles II, c. 1, 1680; repealed by 54 George III, c. 108, 1814
26/ Hunter, ref. 21, p. 311, 482
27/ Koops, ref. 33 (1800), p. 74
28/ 'Parliamentary intelligence,' *The Times* (London), 5 July 1814, p. 2, col. 5

in 1684 and concluding with straw in 1800.[29] In 1876 Edward Knight of the U.S Patent Office cited references in the literature to 402 substances which had been used or suggested up to that time for use as raw material for paper.[30]

Three of these early suggestions deserve mention here, because they were later realized in practice and played a part in the story of the permanence/durability of book paper.[31] The first of these was made by the French scientist, René Antoine Réaumur, who in 1719 called to the attention of the French Royal Academy the ability of the North American (especially the Canadian) wasp to make paper from wood, and suggested that this creature might show the way to overcome the scarcity of rags. The second was Jacob Christian Schäffer, a German evangelical clergyman in Regensburg, who among other prodigious accomplishments published in 1765–71 a six-volume work on substitutes for papermaking, listing 95 of them with examples of paper made from each, including wasps' nests, old wooden shingles, and straw.[32] The third was Matthias Koops, 'of Queen Street, Ranelagh, in the county of Middlesex, gentleman,' who published in London in 1800 a book on the predecessors of paper, itself printed 'on the first useful paper manufactured soley [!] from straw,' with an appendix 'printed upon Paper made from Wood alone, the produce of this country, without any intermixture of rags, [etc.].'[33]

Of the three, Koops was the only one to attempt to commercialize his suggestion. He organized a company for making paper from straw, but went bankrupt in a year.[34] The fact was that by 1800 the need for rag substitutes was deferred for half a century by the two developments next to be described.

1774 CHLORINE BLEACH

Anciently, cloth was bleached by exposing it to sunlight and air, while sprinkling it frequently with water. The process was slow; it might take several months. This

29/ Hunter, ref. 21, Chapter XI, 'Papermaking materials,' p. [309]-40
30/ Edward H. Knight: *Knights' American mechanical dictionary* (3 vols, Boston: Houghton, Mifflin & Co. [c, 1876]), *s.v.* Paper
31/ They are all discussed at greater length in Hunter, ref. 21.
32/ Jacob Christian Schäffer: *Versuche und Muster ohne alle Lumpen oder doch mit einen geringen Zusatze derselben Papier zu machen* (6 vols, Regensburg, 1765–1771)
33/ Matthias Koops: *Historical account of the substances which have been used to describe events and to convey ideas from the earliest date to the invention of paper. Printed on the first usefull paper manufactured soley [!] from straw* (London: T. Burton, 1800). In the Library of Congress copy the straw paper is a very acceptable book-paper, not too dark though with numerous specks. The wood paper of the appendix is almost as yellow as the straw paper. Both are in excellent condition. In the Library of Congress copy of the 2d edition (London: Jaques, 1801; apparently Dard Hunter's 'another printing') the straw paper has fewer specks and the wood paper is lighter in colour than in the 1st edition. Again, both are in excellent condition.
34/ Hunter, ref. 21, p. 333-40

art was practised with especial skill in the Netherlands, and the fine resulting products were called Hollands in England. With the advent of the industrial revolution the art of bleaching was gradually improved in both effectiveness and speed by employing various increasingly powerful chemical agents. In 1749 a method of 'bucking and crofting' was introduced in Scotland; the cloth was bucked, i.e., soaked in a mild alkaline solution such as extract of wood ashes, then crofted, i.e., spread out to air on the grass; after this was repeated five or six times the cloth was soaked in a 'sour,' i.e., a mild acid such as sour milk, and hung in a loft to air and dry. When, shortly thereafter, the sour was concocted of oil of vitriol, i.e., sulphuric acid, the time was cut in half, but it may be conjectured that the fibre lost strength in the process.[35]

However, in 1774 the Swedish chemist Karl Wilhelm Scheele discovered chlorine, and this led quickly to the development of chlorine bleach, which was capable of much faster and more effective whitening as well as decolourizing of dyed cloth. It rapidly came into use in papermaking where it made acceptable much dyed and discoloured rag which had not previously been suitable for book-papers.[36]

Many of the early attempts to use chlorine bleach were disastrous, resulting in rapid embrittlement of the paper. John Murray, 1829, speaks of bleaching – at whatever stage – the rags, the pulp, or the finished paper – as the 'chief source of the disintegration of modern paper' and he mentions a royal octavo Bible in his possession, printed at the Oxford University Press in 1816, which was 'crumbling literally to dust ... before ever the book was used.' A lecturer on chemistry by profession, he concludes that '[t]his destructive agent [chlorine] is too generally clumsily, or incautiously, and unwarily employed.'[37] Murray's testimony is corroborated by other witnesses: Thomas Hansard (he of the *Parliamentary Debates*) spoke of '[w]hole piles of quired stock, meaning books unbound ... crumbling to dust in the warehouses of

35/ Knight, ref. 30, s.v. Bleaching. Also Francis Howe, M.D.: *Experiments in bleaching. To which are added ... directions for the preparation of the sours made of oil of vitriol and of the lyes made of bleaching-ashes with the addition of quicklime* [by David Chambers McBride] (Dublin: T. Ewing, 1771). 'The milk [sours] take many days to perform their task, but the vitriol sours do it in as many hours; nay, perhaps in as many minutes' (page 57). 'The milk sours are very dear ... but the vitriol are cheap' (*Ibid.*)
36/ [C.] Pajot des Charmes: *The art of bleaching ... rendered more easy and general by means of the oxygenated muriatic acid ... to which are added ... the discoveries of the author in the art of bleaching paper* (London: C. G. & J. Robertson, 1799). Procedure for bleaching brown rags to substitute for white rags in papermaking, using oxygenated muriatic acid (an aquaeous solution of chlorine), p. 268. The same for dyed rags, using also sulphuric acid, p. 269–70. 'the new methods ... will greatly contribute to prevent the want or dearness of paper,' p. 270.
37/ John Murray: *Practical remarks on modern paper* (Edinburgh: W. Blackwood; London: T. Cadell, 1829), p. 75, 80–1

booksellers,'[38] and more than half-way through the nineteenth century it was recalled that '[w]ithin the recollection of my father, it was not at all an uncommon occurrence for a parcel of paper to become so completely perished from the circumstances of its not having been thoroughly washed after bleaching that an entire ream, composed of 480 sheets, might be as readily snapped asunder as a piece of rotten wood ...'[39]

Papermakers have, of course, long learned to control the worst excesses of bleaching. The fact remains, however, that chlorine is a strong oxidizing agent, capable of uniting with moisture to form hypochlorous acid with potential damage to the cellulose fibres. Dr Sutermeister notes (1954) that excessive bleaching is often practised for the sake of a little additional, perhaps even undesired, whiteness in the paper; that high temperatures used to hasten bleaching weaken the fibre; that high pH, though desirable from the point of view of paper strength, is avoided because it may increase bleaching-time materially; and that the use of 'anti-chlor' to stop the bleaching action sets up an acid condition.[40] In short, as stated in 1967 by Barrow, chlorine bleaching has since its introduction been one of the factors that must be reckoned with when considering the behaviour of paper.[41]

1794 THE COTTON GIN

In its hunger for raw materials, the paper industry must often have looked hopefully toward America, not for wasps' nests, but for that purest natural form of cellulose, cotton. But until the invention of the cotton gin by Eli Whitney in 1794 the availability of cotton was limited by the difficulty of separating the fibre from the seed. Released from this restriction, its production increased by leaps and bounds.[42] In the chronology of the degradation of paper the development is important in that it delayed for fifty years the need of the paper industry for other raw materials than flax and cotton, in spite of the rapidly increasing literacy and an enormously increasing consumption of paper. Matthias Koops' bankruptcy may well have resulted, without his knowing why, from Eli Whitney's invention. There is a sardonic quality in the reflection that this invention enabled slaves in American cotton fields to contribute to the spread of literacy and to fan libertarian movements in Europe.

38/ Thomas C. Hansard: *Typographia* (London: Baldwin, Craddock & Joy, 1825)
39/ Richard Herring: *Paper & paper making, ancient and modern* (2d ed., London: Longman, Brown, Green & Longmans 1856), p. 97
40/ Sutermeister, ref. 17, p. 112, 120, 125
41/ Barrow, ref. 14, v: 15
42/ U.S. Bureau of the census: *Historical statistics of the United States* (Washington, DC, Government printing office, 1960). Cotton production in the United States in thousands of bales (p. 302): 1790, 3; 1793, 10; 1800, 73; 1810, 178; 1820, 335; 1830, 732; 1840, 1,348.

1803 THE FOURDRINIER OR PAPERMAKING MACHINE

The first machine adapted to the making of usable paper was set in motion in 1803 at Frogmore Mill, Waters, Hertfordshire. It was named for the Fourdrinier brothers, London stationers, who had funded its development but who profited from it no more than did the inventor of the basic mechanism, the Frenchman Nicholas-Louis Robert.[43] Lacking the fourdrinier, the present age of paper could not exist; it made possible the enormous quantities of paper of uniform quality, having a finish suitable for modern high-speed presses, and in roll rather than sheet form, facilitating rapid handling. Against these virtues must be set several characteristics of the fourdrinier which militate against the longevity of its product by contributing to its initial weakness. One is that the fourdrinier works better with short- than with long-fibre stock. Another is that because the fourdrinier does not shake the pulp at the moment that the sheet is being formed as uniformly as the hand papermaker shook his mould, the machine-made paper is not equally strong in both directions. Symptoms of this are its tendency when wetted to expand and curl more in one direction than another, and its preference for tearing in one direction over the other. Still another is that because the pulp is agitated until it is fed to the endless wire-screen belt where it becomes paper, it is easy to add various materials to the pulp such as sizing and fillers. For all these reasons John Murray in 1829 stated that the introduction of paper machines forms 'another era in the deterioration of the paper manufacture; for by means of them an immense quantity of inferior paper was thrown into the market.' He emphasized that he was not hostile to machines, and he allowed for the possibility that paper machines might one day surmount all objections.[44]

1807 MORITZ FRIEDRICH ILLIG AND ALUM ROSIN SIZE

The history of modern paper is in large part the history of alum rosin size. There is no doubt that, for good or evil, the invention of this ingredient in the manufacture of writing and printing papers will have left its mark indelibly on an epoch which has, indeed, not yet closed.

Moritz Friedrich Illig, 1777–1845, was the descendant of papermakers, but – although he made one of the most significant contributions of all time to the papermaking art – he did not stay in the business himself. His contemporaries knew him instead as a 'profound master of mechanisms (mechanikus); a scientific clockmaker.'[45]

In 1807 Illig privately published in Erbach a pamphlet describing a 'safe, simple

43/ Hunter, ref. 21, p. [341]-73
44/ Murray, ref. 37, p. 66-70. See also Lee E. Grove: 'John Murray and paper deterioration,' *Libri* 16 (1966) 194-204.
45/ 'Diefdenkender Mechanikus, wissenschaftlicher Uhrmacher,' *Allgemeine deutsche Biographie* (Leipzig & München, 1875-1912) 50: 667-8

and cheap' method of sizing paper 'in the mass,' or – as we would say, 'engine sizing.' By this is meant the introduction of the size into the engine or beater where the pulp is worked into a slurry.[46] Illig's invention was (or should have been) simplicity itself; it consisted in adding rosin, boiled with soda to make a soap (sodium resinate), to the beater, followed by alum. The rosin is precipitated on the paper fibres as aluminum resinate. This gives the finished paper sufficient water-repellancy to be written on with writing ink. A similar process can be used to size wax cups.

The advantages of alum-rosin size from the papermaker's point of view are obvious: it made sizing a part of the preparation of the pulp instead of a separate subsequent operation. It made use of inexpensive, stable ingredients instead of the putrescible contents of the sizing vat. In addition, papermakers have used alum to reduce foaming, enhance rattle, and improve retention of filler, setting of colour, and handling of sticky stock.

But for the librarian/archivist (and the user of libraries and archives) Illig's invention was catastrophe. For the alum-rosin sizing process is not only an acid process in itself (it works best at pH 4.5 to 5.0),[47] but it encourages deliberate excess acidity in the papermaking operation,[48] and – most important – it leaves, as a by-product of the reaction between the alum and the rosin soap, free sulphuric acid. Barrow concluded that 'it is because of this reaction that the introduction of alum-rosin size contributed more to the deterioration of paper than any other development in papermaking of the 19th century, a contribution that persisted into the present century.'[49]

Although apparently revealed to friends in 1807, Illig's invention was slow to reach the United States. Dard Hunter states that it was introduced there in 1830, but Barrow, out of 86 U.S. books tested for the period 1830–49, found only one containing rosin; it was published in Philadelphia in 1845. Three decades later, however, he found alum-rosin size in practically universal use in American books.

But worse was to come. The high price of potassium alum (potassium aluminum sulphate), which was increased in the United States by a protective tariff dating from 1816,[50] stimulated the search for alternative sources and for substitutes. For the history of paper the most important result of this search was the invention of 'papermaker's alum' (aluminum sulphate). This is made by a process of treating bauxite with sulphuric acid, developed in the United States about 1876. The product was sold as 'concentrated alum'; it gave the papermaker twice as much aluminum for his money as did potassium alum, where the potassium sulphate and the water of crystallization, constituting 64 per cent of the total, were 'simply spectators' in the sizing process. Unfortunately, papermaker's alum, as stressed by the literature from 1878 to 1942, is prone to contain residual sulphuric acid from the process of its own manufacture.[51]

Thus, to the already excessively acidic process used to manufacture book-paper, there was added about mid-nineteenth century the additionally acidic alum-rosin sizing process, and then, at about the three-quarter mark of the century, the acid ingredient of the size was replaced by one still more acidic.

The results were soon to appear. Libraries and archives are living with many of them yet.

46/ *Anleitung; auf eine sichere, einfache und wohlfeile Art Papier in der Masse zu leimen. Als Beitrag zur papiermacher Kunst* (n.p., 1807) Vorrede signed 'Erbach im Januar 1806. M. F. Illig.' The text was reprinted in *Papier-Zeitung* 12: 1161–2, 1197–8, 1229–30, 1261–2, 1369–70, 25 August, 1, 8, 15 September, 13 October, 1885, with a facsimile of the title-page in the first instalment.

47/ P. M. C. Cobb in E. Sutermeister: *Chemistry of pulp and paper making* (3d ed., New York: Wiley, 1941), p. 310

48/ 'As a surplus of alum cannot do any harm unless it contains free acid, the safest way is, to use too much ...' Carl Hofmann: *A practical treatise on the manufacture of paper* (Philadelphia: H. C. Baird, 1873), p. 91

49/ Barrow, ref. 14, v: 17

50/ J. Leander Bishop: *History of American manufactures from 1608 to 1860* (Philadelphia: E. Young & Co, 1866)

51/ Hofmann, ref. 48, p. 89 91. G. S. Witham: *Modern pulp and paper making* (New York: Reinhold, 1942), p. 332. Singer, ref. 15, p. 289. Williams Haynes: *American chemical industry* (New York: Van Nostrand [c. 1954]), I: 287.

1829 – 1900 SUBSTITUTES FOR RAG TAKE OVER

Matthias Koops had been both before and behind his time. If he had started to make paper without rags ten years earlier, before the invention of the cotton gin, or thirty years later, after the increased supply of rag stimulated by the cotton gin had in its turn become insufficient, he might have succeeded. As it was he possibly never knew what hit him.

In any case the ever-increasing demand for paper was such that the supply of rag, whether of linen or cotton, was again insufficient, and papermakers again began to seek elsewhere. Dard Hunter reports that the manufacture of printing paper from straw began on a commercial basis in the United States in 1829.[52] In the 1840s the groundwood process, traced by Dr Sutermeister to Charles Fenerty of Halifax, N.S., flung the forests of the world open to papermakers as sources of raw materials.[53] Groundwood is still a principal component of newsprint (the impermanence of which is notorious) and some magazine papers, and – to the dismay of librarians – of the official publications of the less well developed countries. Groundwood papers are weak because their method of preparation produces very short fibres in clumps, scarcely fibrillated, and associated with much non-fibrous material such as lignin and hemicelluloses. They are impermanent because the non-cellulosic materials break down into acidic compounds, the breakdown of the lignin being triggered by light.

52/ Hunter, ref. 21, p. 394–6, 545

53/ Sutermeister, ref. 17, p. [49]

Their impermanence may also be hastened by size or other additives in the course of manufacture.

In the chemical wood processes of papermaking, the non-cellulosic material is separated from the fibres by cooking. When these are carefully purified, they can be made into a paper at its best scarcely distinguishable from the best traditional paper. The soda process, which uses caustic soda as the cooking agent, was introduced in the 1850s. The sulphite process, which uses a cooking solution of calcium bisulphite with an excess of sulphur dioxide, was introduced in the 1870s and 1880s. The sulphate (also known as the Kraft) process, in which sodium sulphide is the principal agent, was developed at the end of the nineteenth century.[54]

It is obvious that the effort of the chemical processes to separate the cellulose fibre of the wood from its other constituents, and to bleach and purify this fibre sufficiently to make it into acceptable paper involves treatment many times harsher than that which flax or – *a fortiori* – cotton (the purest natural form of cellulose) require. That fine paper *can* be made from wood and that so much *is* made, is a triumph of chemical industry.

In Europe an early substitute for rag was esparto grass, used for papermaking since the mid-nineteenth century.

Let us conclude this inventory of the principal elements which entered into the making of a nineteenth-century book-paper with a wry observation. We noted previously that Eli Whitney's invention of the cotton gin made it possible for Negro slaves in American cotton fields to contribute – indirectly and quite unvoluntarily, it is true – to culture and libertarian movements by increasing the supplies of the rags needed as raw materials for paper. The cotton gin simultaneously, as is widely recognized, promoted the spread of Negro slavery in the United States. Seventy years later, by a turn of the wheel, a great Civil War provoked by that slavery cut off those supplies of cotton and thereby hastened the adoption of non-rag raw materials for papermaking!

The process by which nineteenth-century book-paper cumulated within itself the effect of the errors of its own and previous centuries, and became in fact what John Murray had called it, 'that miserable substance known as paper,' are all too clear to us today. But until 1967, when Barrow published the results of his study of 500 nineteenth-century book-papers, speculation and folk-lore substituted in large measure for knowledge of what had actually happened. To his study we now turn.

54/ *Ibid.*, p. 59ff.; Barrow, ref. 14, v: 19–20

The story of permanent durable book-paper, 1115-1970

VERNER W. CLAPP

The detection of acidity as the principal culprit in paper deterioration, and the glossing over of that discovery for decades, are recorded in the second instalment of Mr Clapp's historical survey

The first instalment of this article recalled how – though denounced for impermanence by emperor and abbot – paper emerged from the Middle Ages as the principal vehicle of recorded information, with qualities of permanence that have been amply demonstrated over more than half a millennium; and how during the next four centuries the insatiable demand for this indispensable material led to its steady degradation through the increasing use of inferior raw materials and of short-cuts in manufacture – both made possible by advancing technology. Reference was made to the work of William J. Barrow, the document-restorer of Richmond, Virginia, whose systematic studies of old papers have illumined a number of dark places in paper history. The instalment concluded with a listing of the factors which cumulatively affected nineteenth-century book-paper. The effects of these, as reported by Barrow, are now to be presented.

BOOK-PAPER IN THE NINETEENTH CENTURY

The success of his first systematic study of book-papers 1900–49, previously described, had made Barrow eager to pursue the investigation into prior centuries, and he soon began to collect books for the purpose. In 1963 he made a selection of 500 nineteenth-century nonfiction books, 50 per decade and all but a few published in the United States, and commenced testing them. The results were published in 1967[55] and an extract of some of the most important data is presented in Table 1. The significance of these may be summarized as follows:

In the first place it is apparent that the papers dating from 1800 to 1849 are all-rag. Those of the first decade, 1800–9, are the weakest; this may reflect the conditions of

TABLE I

500 book-papers, 1800–99, by decade: fibre content, presence of rosin, acidity, folding endurance

decade	total specimens	all-rag content: specimens	all-rag: % with rosin	all-rag: acidity (pH)	all-rag: folding endurance	part-rag content: specimens	part-rag: % with rosin	part-rag: acidity (pH)	part-rag: folding endurance	no-rag content: specimens	no-rag: % with rosin	no-rag: acidity (pH)	no-rag: folding endurance
1800–9	50	50	—	4.6	18	—				—			
1810–9	50	50	—	4.7	22	—				—			
1820–9	50	50	—	5.2	27	—				—			
1830–9	50	50	2	5.8	35	—				—			
1840–9	50	50	10	5.4	35	—				—			
1850–9	50	46	28	5.1	17	4	75	4.9	6	—			
1860–9	50	42	36	4.8	10	7	71	4.9	6	1	100	6.1	3
1870–9	50	10	100	4.5	5	23	91	4.6	4	17	82	4.5	2
1880–9	50	—				19	95	4.6	4	31	90	4.6	2
1890–9	50	—				32	97	4.7	2	18	83	4.6	1

NOTES:

The part-rag papers represent a great variety of mixtures of wood and straw fibres with rag.

The no-rag papers were mostly made from chemical wood pulp, with occasional admixtures of groundwood and straw.

The pH data were taken from uninked areas of the pages, cold extraction, median values.

The folding endurance values are expressed in the number of folds made by an MIT fold tester at 0.5 kg tension across the lines of print but in uninked areas, median values.

Adapted from Barrow, ref. 14, v: Tables 3 and 6

which John Murray and Thomas Hansard complained. Through the next four decades, 1810–49, increasing strength suggests that papermakers were adjusting to the industrial revolution in their art. (Also, of course, these papers are progressively of decreasing age.)

Nevertheless the strength of these papers, which at its highest (35 folds, median values, for the decades 1830–49 when tested in 1963–5) does not rise above the strength of new newsprint and is only 4 per cent of the median strength (840 folds) of the six writing papers of 1601–50 previously mentioned, is very far from what might be expected of all-rag papers. Barrow attributed this weakness to excessive acidity, pointing out the correlation between diminishing acidity and increasing strength over the period, and also pointing out that the papers of the period having the least acidity (pH 6.1–8.0) still retained high folding strength (217–978 folds).[56]

As for the cause of the acidity, Barrow believed that alum, used as a hardener and preservative in connection with the glue size, was indicated.

Beginning in 1850, Table I records a violent transition. Within three decades the number of all-rag book-papers declined from 50 to 0 per decade, their places being taken by part-rag and no-rag papers. The strength of all papers shows a catastrophic decline from a median of 35 folds (1840–9) to 2 folds and 1 fold (1890–9), an all-time low for book-papers, not even exceeded by the papers of the first decade of the twentieth century which had inspired Barrow's ominous prediction in 1960. Things had come to such a pass that the pages of one of the most widely circulated British journals of the late 1890s are even reported to have 'smelt very vilely.'[57]

The disastrous condition of paper in the second half of the nineteenth century is of course notorious, though it had never before been documented as Barrow documented it. It has been the cause of librarians' nightmares for three-quarters of a century.

Because the rapid decline in paper strength after 1850 coincided with the conspicuous substitution for rag of wood, popular belief has condemned wood pulp as impermanent and has made all-rag a symbol of permanence. Barrow's findings point to a different conclusion. They show that the decline in strength from 1840 to 1899 was parallelled by a sixfold increase in acidity (from pH 5.4 to 4.6). This might be expected (as we know now) to result in lowered strength. And it is hardly necessary to speculate as to the source of this acidity, for, corresponding with its increase, an increasing number of papers, from 10 per cent in 1840–9 to 97 per cent (of part-rag paper) and 87 per cent (of no-rag paper) in 1890–9 are found to have been using alum-rosin size.

In this precipitous decline the all-rag papers did not suffer quite so badly as the part-rag and no-rag papers, but their degradation is only barely distinguishable from that of their rivals. From the 1840s to the 1870s the proportion of all-rag papers containing rosin increased from 10 per cent to 100 per cent, their median acidity fell from pH 5.4 to 4.5 (an eightfold increase in acidity), and their median

55/ Barrow, ref. 14, v

56/ *Ibid.*, v: 21–4

57/ R. Irvine and G. S. Woodhead: 'On the presence in paper of residual chemicals used in its manufacture,' *Journal of the Society for Chemical Industry* 13:131–3, 28 February 1894 folding endurance from 35 to 5 folds.

It appears, therefore, that popular opinion tagged the wrong chief culprit for the great second-half-of-the-nineteenth-century degradation of paper. The villain was not so much wood pulp as alum-rosin size. This is, of course, not to underrate the importance of other factors contributing to the degradation such as an increasing use of excessively short fibres (Barrow found a decrease in good fibre length of from 84 per cent to 22 per cent between 1840–9 and 1890–9),[58] or to overlook the fact that, in spite of their terrible deterioration, all-rag papers were still stronger than the non-all-rag (5 folds compared to 4 for the part-rag and 2 for the no-rag papers in the 1870–9 group).

1829 – 1960 PROTEST

It might be supposed that the nadir reached by book-paper in the 1890s might have occasioned shrieks of public protest so clamorous as to compel reform. Shrieks were indeed occasioned; but reform was uncompelled.[59]

It must be remembered in the first place that the paper which Barrow found in the 1960s to be practically unusable was still new and sufficient for its immediate purpose in the 1880s. To foresee at the time its rapid loss of strength required a 'feel' for paper derived from the kind of association with older papers typically enjoyed only by custodians and users of libraries and archives. Frederick II may have been such a person; John Murray certainly was. After the mid-nineteenth century the roster of protesters grows very long and only a few of its best-known names can be mentioned: Adolf Martens, Royal Material Testing Bureau, Charlottenburg (1888), Rossiter Johnson, American editor and encyclopaedist (1891), J. Y. W. MacAlister, City Librarian of Leeds (1897), John Russell Young, Librarian of Congress (1897), Harry Miller Lydenberg, Director, New York Public Library (1915, 1924, 1931), Norman Parley, Messrs. Percy Lund Humphries & Co, Ltd, London (1928), Robert C. Binkley, Chairman, Joint Committee on Materials for Research (1929), Virginia Gildersleeve, Dean Emeritus, Barnard College, New York (1960).

The paper deterioration problem was the subject of the first annual report rendered by the new Librarian of Congress after occupying the Library's new and magnificent building in 1897.[60] It was the subject of landmark studies published by the Society of Arts, London (1898), and the U. S. Bureau of Standards, Washington

58/ Barrow, ref. 14, V: Table 3

59/ For numerous citations to the literature of this protest see: Lee E. Grove: 'Paper deterioration – an old story,' *College & research libraries* 25:365–74, September 1964; Richard D. Smith: 'Paper impermanence as a consequence of pH and storage conditions,' *Library quarterly* 39:153–95, April 1969; Edwin E. Williams: 'Deterioration of library collections today,' *Ibid.* 40:3–17, January 1970

60/ The Librarian's proposed solution for the problem was to require that copyright deposits be printed on permanent paper!

(1933, 1934, 1937). It has stimulated many organizations to conduct experimental and other inquiries leading to the development of specifications to assure the selection of permanent paper and the avoidance of impermanent paper; among these were the Royal Material Testing Bureau, Charlottenburg (1886, 1892), the U. S. Department of Agriculture, Washington (1906), the Joint Committee on Printing of the U. S. Congress, Washington (1911), the Swedish Government Testing Bureau, Stockholm (1925), the International Institute of Intellectual Co-operation of the League of Nations (1928), the Library Association, London (1930), and the Carnegie Institution of Washington (1935). It has been reckoned to have been the subject of 290 investigative reports and articles from 1885 to 1939,[61] increasing to 479 by 1963.[62]

How could such a weight of protest and investigation have failed to bring reform? The answer lies partly in economics, partly in the state of chemical knowledge, and partly in communication.

ECONOMICS

As a question of economics, the matter was comparatively simple. Even if alum-rosin size had been identified as the real culprit in paper deterioration (and although it was suspected, it was not proved guilty for many years), the alum-rosin process was so much the cheapest method of sizing that it was not to be dislodged merely by alarmist predictions of calamity a century hence. Even after the relationship of alum to deterioration had been demonstrated, it kept on conveniently slipping from notice.

The same economic argument that protected the alum-rosin size process also deprived manufacturers (and consumers) of advantages which they might have had by 'going alkaline.' An interesting example of this was recently reported.

In 1901 Edwin Sutermeister, then a young chemist with the S. D. Warren [Paper] Company, made an experimental paper using as a filler calcium carbonate (an alkaline by-product of the soda wood pulp process for which it was very desirable to find a profitable use). Over the years this experimental paper tested stronger and whiter than acid papers made at the same time. But its pH (8.9) was much too high to allow it to be alum-rosin sized, and the company had to forgo advantages in strength, brightness, opacity, and printability which an acid-free technique might have provided, until such time as an alkaline-compatible size became available.[63]

61/ M. S. Kantrowitz & others: *Permanence and durability of paper: an annotated bibliography of the technical literature from 1885 A.D. to 1939 A.D.* (Washington: U.S. Government Printing Office, 1940)

62/ Jerry Byrne & Jack Weiner: *Permanence* (Appleton, Wis.: Institute of Paper Chemistry, 1964)

63/ Thomas, ref. 18, p. 100–3. Also [S. D. Warren Company:] *concerning paper permanence* [Boston, October 1960], p. [11]

As a question of chemical knowledge, the matter is less simple. Today every schoolboy knows that acidity in paper is incompatible with its stability, and he assumes that this has always been a matter of common knowledge. It has and it hasn't.

It is true that in 1829 chemist John Murray used tincture of litmus as a test of a 'genuine' (i.e., sound, stable) paper; he used it to detect the effects of his bugbear, chlorine.[64] It is true that in 1873 paper scientist Carl Hofmann knew that alum should not be contaminated by free sulphuric acid.[65] It is also true that in 1898 the Committee on the Deterioration of Paper of the Society of Arts (London), discussing the cause of the deterioration which it had observed in both rag and non-rag papers, said that 'the disintegration may be generally referred to acidity.'[66]

In spite of these and other evidences of comprehension, the fact was, as the committee stated, that the art of papermaking had far outrun its science, and the science was only beginning to catch up. For example, the coarse measurements of acidity that it was possible to make with litmus (which turns red at pH 4.5 and blue at pH 8.3) were much too crude to provide adequate control over processes employing such powerful chemical agents as does modern papermaking, or to detect the small variations in acidity that can make all the difference. Even the improvements of nineteenth-century analytical chemistry proved, as we shall see, insufficient.

Systematic study and testing of paper commenced at the Royal Material Testing Bureau in Charlottenburg in the 1880s. Here in 1886 four grades of paper were established for governmental use on the basis of fibre content – I, all-rag; II, rag and cellulose (i.e., chemical wood, esparto, and straw pulp), with ash less than 5 per cent; III, any material except groundwood, with ash less than 15 per cent; IV, other (especially groundwood). These categories have persisted with little modification to the present day. At Charlottenburg also, in 1887, Adolf Martens tested for fibre content the paper of 97 scholarly German periodicals and predicted that 59 per cent of them would be unusable in a century and 29 per cent within a generation.[67]

For four and a half years from 1904, the U. S. Department of Agriculture, under the direction of F. P. Veitch of the Leather and Paper Laboratory, conducted an investigation of papers with special reference to their suitability for government use, involving the testing of some 5,000 papers. The result was an elaborate report on the testing of paper, with specifications for papers for all general governmental purposes.[68] But whereas Veitch used almost all the physical tests for papers that were being used thirty years later (fold, tear, etc.) almost no chemical tests were used, specifically not one for acidity. By the same token, although the specifications controlled fibre content, folding strength, and even rosin content, they did not control acidity – or even alum, which might indirectly have controlled acidity. Conscious of the impermanence of most of the papers specified, the departmental committee transmitting the specifications recommended that a part of the edition of each government publication of lasting value be printed on durable paper for deposit in great libraries.[69] Of curious interest is the committee's recommendation that very white papers be avoided as being decidedly injurious to eyesight and often productive of headache.

The next two decades saw tremendous advances in paper science, through research conducted in governmental testing bureaux, university departments of chemistry and paper technology, and the laboratories of individual paper companies. By their end, special training had been made available for paper chemists and engineers; professional associations and journals had come into being; and the enormous resulting literature was controlled by elaborate bibliographic services. The principal characteristics of paper which define its suitability for various uses had been identified; testing devices and procedures for measuring them had been invented, tested, and standardized; and explanations of paper behaviour in chemical and physical terms had been intensively explored. Paper chemistry and technology benefited, too, from the development of other industrial uses of cellulose – rayon, photographic films, lacquers, etc. By the mid-1920s paper science had so far advanced as to make a technical discussion of permanence at last fruitful.

In 1925 S. Köhler and Gösta Hall of the Swedish Government Testing Bureau in Stockholm published the results of investigations into the durability of paper, undertaken with the original purpose of setting paper standards for official use.[70] Summaries of the research were quickly reported in the paper trade journals of the world. In the same year the authors wrote an article for an American journal, describing their new method of determining the acidity of paper,[71] and in the

64/ Murray, ref. 37, p. 112
65/ Hofmann, ref. 48, p. 90–1
66/ Society, ref. 81, p. 3 (or 599)
67/ Society, ref. 81, Abstracts 5, 15, 40, p. 7, 10–12, 20–21

68/ F. P. Veitch: 'Paper specifications,' in H. W. Wiley & C. Hart Merriam: *Durability and economy in papers for permanent records* (Washington: Government Printing Office, 1909), p. 13–51
69/ Alas! the copy of their report which I have consulted in the Library of Congress is at the lower limit of usability.
70/ S. Köhler and G. Hall: *Undersökningar över finpappers håll barhet med särskild hänsyn till Svenska statens normalpapper. Investigations into the durability of paper* (Stockholm: Statens provningsanstalt, 1925). (Meddelande 28). Summary in English, p. 81–4
71/ S. Köhler & G. Hall: 'Acidity in paper,' *The paper industry* 7:1059–63, October 1925

following year Hall, who was by that time working in the United States, read an important paper describing the findings of the research before the Paper Testing Section of the Technical Association of the Pulp and Paper Industry.[72] For the permanence of paper this was a crucial investigation.

Köhler and Hall fully appreciated the significance of their findings, which Hall described as opening 'a new phase of paper testing – testing for relative permanence.' He did not exaggerate.

It appears that the Swedish Government Testing Bureau, like the German before it, had found evidence of distressingly rapid deterioration in record papers, whether of rag or of chemical wood composition, after even careful storage for 11 to 12 years. An investigation was launched to seek the cause and to prevent recurrence.

An immediate need was for some method of simulating in a few hours or weeks the effects of years of natural ageing. For this purpose two methods were adopted, both used only occasionally until then – ageing by exposure to direct sunlight for periods up to 100 days, and ageing by baking in an electric oven at 100° C for periods up to 125 hours. After it was ascertained that the effects of both methods were similar, the sunlight method was abandoned in favour of heat-ageing.

Upon submitting a number of papers to this accelerated ageing procedure, the investigators found that those with the greatest rosin content suffered the greatest loss of folding endurance. (The investigators had found the fold test to be the most sensitive indicator of physical change in paper.) This fact called attention to the possible role of acidity in the deterioration of these heavily sized papers, and it became in consequence necessary to measure their acid content. But no method of measuring acidity could be found sufficiently accurate for the purpose, and the investigators were compelled to develop their own, basically an improved method of titration.

This consisted in fluffing the paper in a special grinder or disintegrator, extracting it up to seven times in boiling water, and measuring the acid by the number of cubic centimetres of dilute alkali required to neutralize it, using phenolphthalein as the indicator because it changes from colourless to red at approximately the neutral point. The method was sufficiently sensitive to make it possible to grade the eight experimental papers described below on a scale extending from 1.6 (for unsized paper) to 44.2 (for an especially heavily sized paper), and to distinguish between the effects of 'internal' (engine) and 'external' (tub) sizing.

Armed with this new laboratory procedure, Köhler and Hall were quickly able to show that the papers with high rosin content were indeed the most acid. Because the fibre content of these papers was good, they concluded that it was the acid that was responsible for their rapid deterioration. To confirm this conclusion they made up eight lots of paper from an identical beater charge but with differing proportions of alum-rosin size and with widely-spaced measurements of acidity as described above. After the samples were heated at 100° C for 125 hours, the losses in their folding endurance were found to be relative to the amounts of size and the acidity ratings. Hall concluded that it could be considered proved that acidity caused by rosin sizing affects permanence and needs control. For the first time, the relation of alum-rosin size to paper permanence was demonstrated empirically.

In spite of this finding, Köhler and Hall did not condemn rosin outright. They concluded that it might be permitted in papers of which a high degree of permanence was required, provided that the rosin be restricted to 1.0–1.5 per cent of the paper weight and alum (aluminum sulphate) to 0.8 per cent of the rosin, presuming also that the paper was to be tub-sized.

Köhler and Hall were also concerned with the comparative permanence of various fibres. At first they found no significant difference between rag and wood (sulphite) fibre; but later they encountered evidence that tipped the scales in favour of rag. Accordingly, to make a paper 'of the highest possible permanence' they recommended one with all-rag content; such a paper, sized in accordance with their recommendations, should, they said, be able to withstand a heat-ageing test of 20 hours at 100° C without loss of original strength as determined before tub-sizing.

The Köhler-Hall investigation exerted an immediate impact with respect to its innovations in paper research procedure and its findings regarding the causes of paper deterioration. The U.S. Bureau of Standards promptly commissioned a paper-disintegrator and adopted the Köhler-Hall method of acid measurement, which it continued to use for much of the next decade until this method was displaced by electrical measurements on the pH scale. The Bureau also adopted heat-ageing as a laboratory technique for use in paper research and greatly developed its usefulness.

Immediate attention was similarly paid to the Köhler-Hall findings regarding the role of alum-rosin size in the deterioration of paper. In 1928 W. H. Hoffman of the Northwest Paper Company independently confirmed the causal relationship between acidity and deterioration after testing 70 papers of three types from several mills. He, like Köhler-Hall, however, concluded that acidity was compatible with permanence, provided that it was held at pH 4.7.[73]

The fact seems to have been that both for Köhler-Hall and for Hoffman, the drink was too bitter. The evidence that alum-rosin size contributed to deterioration was

72 / Gösta Hall: 'Permanence of paper,' *Paper trade journal* 89:14:32–8, 8 April 1926. Also in *Technical Association papers* 9:92–8, June 1926

73 / W. F. Hoffman: 'Effect of residual acid on rate of deterioration of paper,' *Paper trade journal* 86:9:58–60, 1 March 1928

plain, but alum-rosin size had to be preserved or paper could not be made. In consequence, the minimum of acidity needed for the alum-rosin size reaction had to be permitted; Köhler-Hall put this at pH 5.0–5.5, but Hoffman allowed more leeway and put it at pH 4.7.

In 1929 the U. S. Government Printing Office similarly placed limits to acidity in its specifications for all-rag papers, but these limits were again not incompatible with alum-rosin size.[74]

Corroboration of the role of alum in the deterioration of paper continued to come in at intervals during the next decade,[75] but little heed was paid to it. Attention had been diverted by the discussions of the role of alpha cellulose in paper permanence.

Alpha cellulose is unmodified cellulose, identified by its ability to resist solution by a strong alkali. When, in the late 1920s, it was found that alpha cellulose was present in varying proportions in both rag and chemical wood pulps, hopes were raised that sufficient purification of wood pulp might raise its alpha cellulose content to the point at which it could be made into paper as strong and permanent as rag paper. Accordingly, in 1928, Royal H. Rasch of the Brown Company launched an investigation as an associate at the U. S. Bureau of Standards into the suitability of purified wood fibres as papermaking materials, using heat-ageing to test stability as measured by retention of alpha cellulose and folding endurance. He found that the purified wood pulps and papers, though inferior in initial values to the best rag pulps and papers, quite equalled them in stability.[76]

In 1931 Rasch, with others, reported a continuation of this study, testing papers made from a commercially available, highly purified chemical wood pulp. They found it possible to make bond papers exceeding in strength the government requirements for the highest grade writing papers, and to make currency-type papers in which the strength requirements for United States currency were exceeded. When acidity was held to pH 5.0, a highly stable, well-sized paper was produced.[77]

One of the effects of this investigation was to focus attention on the validity of heat-ageing as a predictive test. The resulting studies are of the utmost importance for the development and identification of permanent/durable paper.

74/ M. S. Kantrowitz & R. H. Simmons: *The technical status of permanence and durability of paper* ([n. p., 1954]). (Reprinted from *Proceedings of Graphic Arts Technical Conference, Washington, D. C., 1936*), p. 9

75/ Cf. Kantrowitz, ref. 61, nos. 29, 53, 70, 82, 119

76/ Royal H. Rasch: 'A study of purified wood fibers as a paper-making material,' *Bureau of Standards journal of research* 3:469–506, September 1929

77/ Royal H. Rasch & others: 'Highly purified wood fibers as paper-making material,' *Ibid.* 7:765–82, November 1931

A more immediate effect, however, was to direct attention from the effects of processing, including sizing, to the comparative effects of the use of different kinds of fibre on the permanence of paper. As a result, the role of acidity was almost entirely lost to view. In 1937 the Committee on Permanence and Durability of the Technical Association of the Pulp and Paper Industry said in its annual report, in reference to the relationship of acidity to deterioration, that, 'This has of course been known for some time but little emphasis has been placed on it.'[78]

But four years before this, Torrey and Sutermeister had brought the debate to a temporary conclusion by their report on old papers that has been previously cited. These authors objected to the claims being made for alpha cellulose, which they contested with evidence from papers from AD 998 to 1800, given to them by Dard Hunter. They argued that the permanence of paper is related not merely to its fibre but to all its characteristics, and they suggested that 'a much more complete study of very old papers would throw much light on this problem.'[79] It was Barrow who – as we have seen – took up this gage.

COMMUNICATION

The communication of the findings was a still more difficult question. Even to the extent that alum-rosin size (or the other enemies of permanence resulting from the manufacturing processes) had come under suspicion by the technicians, the idea seems never to have penetrated to the consuming public or even to that part of it that had professional responsibilities concerned with the longevity of paper. Instead, even that part of the public was allowed to believe that paper deterioration came in with rag-substitutes and could be avoided only by a return to rag; and, moreover, that the worst enemy of paper was polluted urban atmosphere. That these beliefs were not wholly consistent did not seem to disturb their adherents. And, of course, there has been no lack of evidence to support both of them. But, unfortunately, the atmosphere has been used as a scapegoat for harm for which it was not primarily responsible, and all-rag paper has been given a status of panacea which has obscured the real problems of permanence in paper.

The condition of industrial urban atmosphere in the age of gas-lights and soft-coal stoves exposed it only too readily to the charge of causing deterioration. And so, when Michael Faraday in the course of a popular lecture in 1842 exhibited some leather-bound books from the Athenaeum Club of which the binding was 'completely gone,' and expressed little doubt that the effect was due to the vapour and

78/ 'Report of permanence and durability committee,' *Technical Association papers* 20:296–8, June 1937

79/ Torrey, ref. 11

heat produced by illuminating gas,[80] the imputation stuck. But no one seems to have asked Faraday whether there were not other bindings in the Athenaeum library which had not 'completely gone.' Knowing what we do today about the degradation of nineteenth-century leather bindings, we may be permitted a suspicion that there were other influences at work than just the gas-lights.

In May 1898, however, the imputation came to roost on book-paper in a report which was to exert great influence on popular and professional opinion for many years to come.[81] In June of the preceding year the Society of Arts (London) had appointed a committee to investigate statements which had been current for some time to the effect that paper was not what it used to be, exciting 'more than a suspicion' that many of the papers made from the newer materials might be deficient in qualities of permanence. The committee, which had a distinguished and expert membership, circularized librarians, papermakers and others interested, and heard shocking tales from some custodians of book stocks. It found instances of disintegration in all kinds of paper – rag as well as chemical wood and groundwood. In spite of the evidence it concluded that 'the danger has been overestimated.'[82] It found that all papers are liable to extreme chemical change resulting in disintegration and it attributed the disintegration which it had observed to change caused by 'acid bodies' of internal or external origin. But the only specific origin which it suggested for such bodies was illuminating gas, which it mentioned three times in the course of its report. It named this gas as a possible cause of discoloration in paper (an effect which it believed to be independent of, though often concurrent with, disintegration) and then, almost as an afterthought, it mentioned as a conclusion warranted by the evidence that discoloration of chemical wood paper in storage is proportional to its content of rosin size. The emphasis was unmistakably on polluted atmosphere, and the reference to rosin was almost unnoticeable.

However, the committee was not neglectful of its principal charge, which was to give attention to standards of paper quality. If it had trusted its own diagnosis of the cause of deterioration, these standards should have been related to removing or countering the effects of polluted atmosphere. But no such logic prevailed. Instead, after general exhortations against the excessive use of any paper additive, the committee stated that it found little fault with existing trade practice, and that it was satisfied to limit its findings to the specification of a 'normal standard of quality' for book-papers required for publications of permanent value, namely, that they should be not less than 70 per cent rag, with not more than 2 per cent rosin size nor 10 per cent ash (filler).

80 / M. Faraday: 'On light and ventilation,' *The repertory of patent inventions and other discoveries and improvements* 2:174–81, 238–50, September, October 1843

81 / *Society for the Encouragement of Arts, Manufacturing & Commerce. Report of the Committee on the deterioration of paper. With two appendixes: 1. Abstracts of papers on German official tests, 1885 96. 2. Précis of correspondence.* (London: Printed by W. Trounce, 1898). The report was also printed, without appendices, in *Journal of the Society of Arts* 46:597–601, 20 May 1898.

82 / 'Report of Council ... xv. Committee on the deterioration of paper.' *Ibid.* 46:698–9, 1 July 1898

Then the report delivered a stinger. For written documents, it said, 'it must be evident' that nothing less would do than all-rag paper, 'pure' (no additives), and with gelatine (not rosin) size: all imitations were to be carefully avoided.

The effect of this final flick was completely to undercut the authority of the 'normal standard' which had just been enunciated. It was obvious that when the committee had *real* permanence in view, its own 'normal standard' was not good enough.

To any but the most careful and sceptical reader the lesson of the report was plain: the principal cause of paper deterioration was polluted atmosphere; the only real cure was all-rag paper; if you could not afford all-rag, the 'practical adjustments which rule the [paper] trade' would take care of the situation 'with little fault' 'in the majority of cases.' The extent of this 'little fault' became apparent in 1960 when Barrow published his study, previously discussed, of 500 book-papers, 1900–49.

The committee's exaggerated emphasis on the role of polluted atmosphere as a principal villain of paper deterioration became part of the folklore of paper, with folklore's usual resistance to correction. In this case, the alarm regarding polluted atmosphere was sounded with sufficient frequency to keep the belief alive.

The outstanding example of this was provided in 1934 by the report of the U. S. Bureau of Standards on four years of research 'to determine the causes of the deterioration of paper in libraries and similar depositories, and to find means of minimizing or eliminating this deterioration.'[83] (The research had been funded by the Carnegie Corporation on behalf of the American Library Association.) The report discussed as causes of deterioration polluted air, light, ventilation, paper quality, insects, and writing inks, in that order. The first of these was given more than twice the space allowed to any other, and the discussion contained the statement that 'it has been definitely established that sulphur dioxide is one of the principal factors governing the deterioration of paper.' Alum-rosin and acidity are mentioned only in passing in the discussion of paper quality, where fibre is the topic of principal interest, and where there is no allusion to the findings of Köhler and Hall or their successors. The 'Recapitulation of Recommendations' similarly does not allude to the subject. The emphasis of the report is in consequence quite correctly represented

83 / A. E. Kimberly and B. W. Scribner: *Summary report of Bureau of Standards research on preservation of records* (Washington: U. S. Government Printing Office, 1934)

in the headline under which it was reviewed in *Printing & Paper Digest* – 'The Enemies of Paper, Polluted Air and Uncontrolled Light.'[84]

(The 1934 report was updated and reissued in 1937. The most significant change with respect to paper deterioration consisted in removing the phrase 'no doubt' from a statement that paper quality had improved.)

With this kind of assistance from scientists for the 'polluted urban atmosphere' theory of paper deterioration, it is not to be wondered at if even Harry Miller Lydenberg of the New York Public Library, who fought for good paper longer and more consistently than any other layman of his generation, and at whose suggestion the Bureau of Standards investigation had been undertaken, made no reference to alum or to acidity in his own manual of book-care, even when he was discussing sizing. Instead, he warned his readers that 'the air we breathe may be one of the worst enemies of the books we collect.'[85]

Of course, the 'polluted urban atmosphere' theory, which is part of the truth, was much more comfortable than the whole truth. To be able to charge paper deterioration to polluted atmosphere let the manufacturers off the hook but it also laid the blame on burners of coal, illuminating gas, and fuel oil, i.e., on all of us. Under the circumstances, nothing could be done. Had we known the whole truth we might have been compelled to take some action.

Meanwhile the companion to the 'polluted urban atmosphere' theory of paper deterioration, the 'all-rag' theory of paper permanence, continued with like stubbornness to obstruct the road to the improvement of book-paper.

The first experimental demonstration of the superior stability of all-rag paper was provided by Köhler and Hall in 1925. But popular preference for rag did not require such evidence. It rested upon the reputation of rag paper for demonstrated centuries-old permanence.

That this reputation was open to question was not considered. Yet the source of fibre in modern rag book-paper is almost exclusively cotton, whereas the rag paper of the age of the Gutenberg Bible and the First Folio Shakespeare, with which modern rag paper so likes to be compared, was typically derived from flax. Indeed, so far from being the traditional source of fibre for the paper of the Western world, cotton is – in terms of centuries – not much less of a newcomer to papermaking than straw, esparto, and wood.[86] Again, the oldest papers of all, those of China, appear to

84 / [Review by] William Bond Wheelright, *Printing & paper digest*, December 1936, p. 8

85 / H. M. Lydenberg & J. Archer: *The care and repair of books* (New York: R. R. Bowker, 1931), p. 21, 60. So in 2d ed., 1933, p. 21, 60, and 3d ed. rev., 1945, p. 17, 61. But the 4th ed., 1960, was revised by a new editor in the light of Barrow's work.

86 / Barrow's findings suggest that cotton rag played second fiddle to linen rag as a source of fibre for book-paper until after mid-nineteenth century. Cf. Barrow, ref. 14, v: 12, 15 6, 23

have been made from some kind of grass, while Japanese papers, which Veitch recognized to be superior to any available to him, are made from various reeds and barks. The truth is that the behaviour of rag paper in the run-of-the-mill book of the second half of the nineteenth century was, as we have seen, only a little less disreputable than that of its rivals – but this, of course, could not be known until later.

In any case, for lack of experimental evidence, the Society of Arts committee had based its preference for rag paper in 1898 upon an unspecified 'practical experience' (supporting, it said, chemical theory).[87] With a similar lack of evidence, Veitch in 1909 expressed a similar preference, stating that although examples of paper made from properly prepared chemical wood fibre had endured since the introduction of that material, yet the fifty years in which it had been in use were insufficient for exact knowledge of its durability.[88] With similar lack of evidence, too, H. M. Lydenberg in 1924 was pleading that [89]

> *Some one, every one, connected with books – users, readers, producers, makers, distributors – must insist, in season and out, that books of permanent value and interest must be printed on paper that will last, honest rag stock with never a trace of wood pulp in it.*

In August 1928 the International Institute of Intellectual Co-operation of the League of Nations (the forerunner of Unesco) approved the recommendation of a committee of experts that, for fear of deterioration of records in libraries and archives due to inferior paper, preference be given to unbleached rag paper; but it added the proviso that the preference relate solely 'to the printing of a few copies intended for preservation in libraries and archives.'[90]

Whereupon the (British) Library Association, finding the situation regarding the deterioration of paper threatening to become 'extremely grave,' appointed a committee to look into the matter and requested the co-operation of other library groups and of the Paper Makers' Association, all of which, it noted, had passed similar resolutions.[91]

This committee (which had received wide co-operation from the Paper Makers' Association, the Publishers' Association, H.M. Stationery Office, and others, and held consultations with organizations in Holland, Germany, Norway, Canada, and the

87 / Society, ref. 81, p. 4 (or 600–1)

88 / Veitch, ref. 68, p. 14–15

89 / H. M. Lydenberg: *Paper or sawdust, a plea for good paper for good books* (New York: [Paper Manufacturers' Education Association], 1924), p. 8

90 / *Library Association record* n.s. 6:170–2, September 1928

91 / 'Council notes,' *Ibid.* n.s. 6:262–3, December 1928

United States) rendered an elaborate and informative report in December 1930.[92] Its desire for a testing station to identify permanent papers had been dashed, together with its hope that publishers would be willing to print library editions on special paper. There was left to it only to propose specifications for paper for use in publications of permanent worth. This it did with zest.

The committee accepted without criticism the by-then-traditional but inaccurate assertion that where 'absolute' paper permanence was in view there was no evidence in favour of any materials except cotton, flax, and hemp, 'of which all old and surviving papers are exclusively made.' And it drew the by-then-traditional conclusion that for permanent papers only such materials should be used. But it went even further and emphasized that for the 'best' books the paper should be *hand-made* and *tub-sized* (describing the latter technique inaccurately, with the word 'alum' omitted from the sentence in which it should have been included), and with a pH of 5.5–6.0 'in situ'; for such papers 'alone confer practical immortality.' However, the committee conceded that machine-made rag, part-rag, and chemical wood fibres might be used to achieve 'as long a life as possible' where cost was a consideration.

The trouble with such specifications was that they were counsels of perfection. What publisher could employ hand-made all-rag papers? Or even the machine-made variety? Few indeed. (When they did so, they could easily be bilked, as was the Library of Congress in 1906 when it issued an important publication on rag paper from a respected mill, only to watch it deteriorate almost to unusability in less than 25 years.[93]) And while the counsel of perfection was almost as unrealistic as though the committee had advocated (as some have done) printing on sheets of stainless steel, the alternatives were not really useful, because by definition they were for impermanent paper giving the purchaser no assurances making them worth the trouble of seeking them.

At this point the paper industry took a hand. Stimulated by consumer interest in paper permanence and by suggestions contained in the work of Köhler, Hall, Hoffman, and Rasch that a method for predicting the behaviour of paper might be impending (or threatening), the Technical Association of the Pulp and Paper Industry established in May 1929 a Committee on Permanence and Durability of Paper.[94] The committee consisted of five members, two from rag mills, two from

92 / *The durability of paper. Report of the special committee set up by the Library Association.* (London: The Association [1930], 24 p.)

93 / V. W. Clapp: '"permanent/durable" book papers,' *ALA* [*American Library Association*] *bulletin* 57:847–852, October 1963, p. 848 ftn.

94 / A committee had been called for in 1928 by T. C. Bentzen (*Technical association papers* 11:119–20, June 1928) and in 1929 by W. F. Hoffman, who was anxious to establish the causes of deterioration (*Ibid.* 12:81–2, May 1929).

chemical wood mills, and one neutral person, and its reports were required to be unanimous.

In its first report (1930) the committee stated positively that 'under present circumstances no one is justified in drawing definite conclusions as to the probable life of a given paper.'[95] In 1933 it reported that accelerated ageing tests, as employed for predicting the probable life of a paper, had not been confirmed by natural ageing, and that their use in paper specifications was of questionable value, whereas '[t]ime has proven that permanence is insured by the use of new white or unbleached cotton, flax or hemp fibers, carefully processed, in the manufacture of a paper which is stored under average conditions.'[96] In 1935 the committee was still unable to endorse any specifications for the permanence and durability of paper.[97] In 1937, in view of general ignorance of the facts of deterioration, the committee recommended a 50- to 200-year study of paper permanence and laid out a program, listing the papers to be tested, the tests to be applied, etc., with a budget for the first century of $41,430.[98] This seems to have been the committee's last act.

95 / 'Committee on permanence and durability of papers,' *Ibid.* 13:1:24–5, May 1930

96 / Quoted in Carnegie Institution of Washington *Year book* 34 (1934–5), p. 376 and Kantrowitz, ref. 74, p. 7

97 / 'Permanence and durability committee report,' *Technical association papers* 18:470–2, June 1935

98 / 'Report of permanence and durability committee,' *Ibid.* 20:296–8, June 1937

The story of permanent durable book paper, 1115-1970

VERNER W. CLAPP

Earlier instalments traced the problem of permanence/durability in book-paper from the late Middle Ages to the opening of the 1930s. This third and last instalment brings the story down to within recent months

In the mid-1930s, a decade after Köhler and Hall's prediction of a 'new phase of paper testing – testing for relative permanence,' four American organizations summarized the situation with respect to the permanence/durability of book-paper, each from its own point of view.

In 1935 the first of these organizations, the U. S. National Bureau of Standards, was asked by the Carnegie Institution of Washington to advise on the selection of a permanent book-paper. The Bureau's response summarized its energetic investigations of paper over the previous seven years. Because it had found that paper permanence could not be guaranteed by the specification of a particular fibre, the Bureau had developed specifications based on purity, strength, and stability, and it had found that papers suitable for permanent record use can be made from wood as well as rag fibres. In its specifications purity was defined in terms of a high content of alpha cellulose (unmodified cellulose), a low copper number (indicating freedom from degraded cellulose), the absence of unbleached fibres and groundwood, and low rosin and ash content. The strength requirement varied with the prospective use of the paper, that for writing paper being higher than for book-paper. Stability was measured in terms of small losses of alpha cellulose and folding strength and small increases in copper number after heat-ageing for 72 hours at 100° C. By varying the proportions of the various elements, the specifications provided for 'permanent' paper, for papers expected to have minimum lives of 100 and 50 years, and for papers suitable for current use only.[99] These specifications were identical with those which Dr B. W. Scribner, chief of the Bureau's Paper Section, had proposed in 1930; they had held up under the Bureau's further investigations since that time.[100]

In the following year the technical director and associate chemist of the second of these organizations, the U. S. Government Printing Office, collaborated in a critical review of 'The technical status of permanence and durability of paper.'[101] They introduced the discussion with the usual statement which we now know to have been an incomplete representation of the facts: 'The introduction of wood pulp as a substitute for rag pulp in the manufacture of paper soon revealed to librarians and those in charge of archives and records that papers made from rag pulps withstood the ravages of time while those made from wood pulps did not.' They quoted the 1933 report of the Tappi committee on the unreliability of accelerated ageing and the time-proved permanence of rag fibres mentioned above,[102] and they concluded, unsurprisingly, that permanent book paper must be made of '100 per cent new white, cream, or unbleached rags,' with pH not less than 5.0, limits on rosin and ash, minimum folding and bursting strength, but with no requirements for alpha cellulose and copper number because of the time needed to test for them.

The effect of these conflicting views on a contemporary consumer is interesting to observe. The third of our four organizations was a consumer to whom cost was not the overriding consideration in the purchase of paper, the Carnegie Institution of Washington.

In 1934-5 the Institution undertook a review of its decision, taken early in the century, to use in its publications nothing but all-rag book-papers of best grade, made to special order. For this review it sought advice from a scientific publisher (who recommended a part-rag paper), from the National Bureau of Standards, and the Government Printing Office. Each of the latter offered the views which have been described above. The Institution concluded by noting that apparently all parties were agreed as to the satisfactory behaviour of rag paper of good quality (which accorded with its own experience with its publications), and that investigations to date had not sufficiently demonstrated an equal expectancy for chemical wood papers to justify any change in its policy.[103]

So simple a decision was not possible for a consumer to whom cost was of much more moment than to the Carnegie Institution. In 1936 there appeared Robert C. Binkley's epochal *Manual on methods of reproducing research materials*, prepared for the fourth of our organizations, the Joint Committee on Materials for Research of the Social Science Research Council and the American Council of Learned

100 / B. W. Scribner: 'Permanence standards for printing and writing papers,' *Transactions of the American Association of Mechanical Engineers* 52 (2): P121-5, 1930

101 / Kantrowitz, ref. 74

102 / W. L. Wehmhoff, Kantrowitz's predecessor as technical director at GPO, had been a member of the committee in 1933, and both were members in 1935 and 1937

103 / Carnegie, ref. 96, p. 371-6. I am informed that the Institution has since changed its policy.

Societies.[104] This work, which brought together the results of seven years of inspired investigation of the economic and technical obstacles to making the raw materials and products of scholarship accessible, devoted a chapter to 'A study of paper permanence.' It is still the best thing of its kind. It showed a knowledge of paper technology and the paper trade quite uncommon in laymen's writings. It had been submitted to the National Bureau of Standards and to the Permanence and Durability Committee of Tappi. The latter body had indeed adopted much of the chapter with certain important additions and omissions (including among the former the passage quoted above) as its own report for 1935. Professor Binkley carefully listed and compared specifications for permanent papers from principal standardizing authorities, including papermakers, and indicated the availability of papers conforming thereto. He recognized that to be assured of permanence it was insufficient to specify rag content alone; that there was no single test for permanence, and that high price was no guarantee of quality; that the distributing trade had little knowledge of the problems of paper permanence and durability or of standards intended to assure these qualities, but continued to sell its products as 100 per cent rag, 50 per cent rag, etc., and to induce the purchaser to believe that the more he paid the greater would be the probable longevity of the paper; that printers not only sought other qualities than permanence and durability in paper but were not in any case equipped to judge of them; that there was no agreement on specifications for a permanent paper other than through the use of the highest grade of rag; that the economics of publishing prevented the publisher from tying up capital in unsold stocks of expensive paper, and that special library editions on permanent paper would merely introduce new problems and costs to the publisher.[105] There remained but one solution – that the permanence level of all book-papers be raised, without greatly increasing prices. 'The buyer must be induced to demand what the technicians are able to make, a rag or purified chemical wood pulp paper manufactured for permanence, and sold at a moderate price.' Professor Binkley gave no prescription how this might be done.

But we must now return to W. J. Barrow. The 'polluted urban atmosphere' theory of paper deterioration must have left him unconvinced. After all, the papers that came to him as document-restorer in the Virginia State Library were largely local courthouse records that had deteriorated in the pure country air of rural

104 / Ann Arbor, Michigan: Edwards Brothers, Inc 1936

105 / For references regarding these special library editions (*Brooklyn Eagle*, London *Times*, *New York Times*, Sydney *Morning Herald*, *Sears-Roebuck Catalog* and scientific publications of the University of California Press), see Kantrowitz, ref. 61, nos. 58, 155, 176, 182, 185, and 192; also Grove, ref. 59

Virginia.[106] Yet he was not immediately prepared to fly in the face of received popular opinion. Accordingly, in his 1942 paper before the Society of American Archivists he cautiously mentioned 'conditions of storage' as at least equal to and even perhaps slightly more important than 'changes within the paper itself' as the causes of acidity.[107] By 1959 he knew more about old papers than any other person alive, and he bluntly stated that his study of 500 book-papers 1900–49 had sought to redress the imbalance of attention given to polluted atmosphere on the one hand and to internal agents on the other, concluding that the probable cause of the acidity in these papers was principally in the agencies of the second kind, namely chlorides from the bleach and alum from the size.[108]

Neither was he sidetracked by the 'all-rag' theory of paper permanence. By the time that he entered paper work there was enough evidence (of which the layman was in general quite unaware) that permanence was not fibre-bound to free him from the popular delusion. Whether or not he ever encountered Binkley's chapter, the conclusion of his own *Science* article sounded the same note, holding out genuine prospect of help to the custodians of collections of paper, both with respect to their existing collections and to collections yet to be formed:

> *While the present study describes a procedure for stabilizing initially unstable paper, much more remains to be done if relatively stable papers are to be made for books of lasting value. There is evidence that this is possible – that such papers can be made from certain types of chemical wood fibers at but little additional cost. But more research is needed, and the cooperation of the scientist, papermaker, printer, publisher, and librarian will be required to assure permanent books for the future.*

SPECIFICATIONS FOR PERMANENT/DURABLE BOOK-PAPER

Barrow could hardly wait to take the next step, for which his investigation of old papers had been merely the curtainraiser. This was to demonstrate the possibility of making a book-paper with good prospects of durability combined with stability, yet capable of competing in price with other commonly used book-papers on the market.[109]

106 / He surely did not know that James Strachan was saying at the time in England that '[a] good deal of nonsense has been written with regard to the attack on books and paper of the polluted atmosphere' in 'The preservation of books and papers. 1. Paper,' *The paper-maker and British paper trade journal* 92: TS 97–8, 1 July 1936

107 / Barrow, ref. 10 (1943), p. 151

108 / Barrow, ref. 13, p. 1079, 1084

109 / Church, ref. 13, p. 49–63, 65–7

The price factor dictated that the proposed paper be made of materials and by processes not significantly more expensive than those that generally went into the making of 100 per cent chemical wood paper.[110]

The first step was to establish the criteria for a 'durable' (or – as it soon came to be called – a permanent/durable) book-paper. Here Barrow's instinct for the essential declared itself, and the resultant specifications constitute in a sense the heart of his achievement.

In his studies of old papers, Barrow's interests had hitherto been to measure residual performance and explain the differences between the behaviour of those that had retained good usability over long periods of time and that of those that had lost it. But to measure the performance of old papers was one thing; to predict the performance of new papers at some specified time in the future was quite another.

For want of a predictive test, the Royal Material Testing Bureau in 1885, the Society of Arts in 1898, Veitch in 1909, the Library Association in 1930, and the U.S. Government Printing Office in 1936 all specified a particular fibre source (e.g., rag) or a particular fibre (e.g., cotton, flax, or hemp) in order to assure permanence, relying upon received opinion regarding the previous behaviour of these materials. By contrast, the Swedish Government Testing Bureau in 1925 selected particular fibres (it found cotton and linen to be equivalent) on the basis of their demonstrated stability under a heat-ageing test which it felt 'in all probability' simulated the effects of natural ageing. It required, furthermore, that the papers made from these fibres should themselves withstand a heat-ageing test without significant loss of original strength.

The U.S. National Bureau of Standards had pushed both principles toward logical conclusions, producing the specifications for permanence, previously described, based on purity and strength. In doing this it had relied heavily for indications of relative permanence upon the heat-ageing test, which Rasch had reported in 1929 and 1931 as having arranged various pulps and papers in the same order of stability as would be expected of natural ageing.[111] So important did this test seem that in 1931 Rasch prepared a separate report on it.[112] But its value was strongly challenged, as we have seen, on the grounds that it had not been confirmed by natural ageing, and the Bureau was under pressure to explore such confirmation. In 1933 Rasch and

110 / W.J. Barrow: *Improvement of permanence and durability of book papers; a progress report to Council on Library Resources* [Richmond] 15 September 1959; unpublished. Also Randolph W. Church, editor: *The manufacture and testing of durable book papers, based on the investigations of W.J. Barrow* (Richmond: Virginia State Library, 1960)

111 / Rasch, refs. 76, 77

112 / Royal H. Rasch: 'Accelerated aging test for paper,' *U.S. Bureau of Standards journal of research* 7 (1931) 465–75

Scribner, and in 1939 Scribner alone, reported on four- and eight-year re-examinations of the 1929 test-papers and confirmed the validity of the heat-ageing test.[113] Finally, in 1955, Dr William K. Wilson and three colleagues in the U. S. National Bureau of Standards published a report comparing the chemical characteristics of the 29 surviving papers of the 1929 report at 22 years, and their physical characteristics at 26 years, with the findings of the original heat-ageing test.[114] They concluded that although the results showed a 'fair correlation' between the results of natural and heat ageing, no quantitative conclusions could be drawn because of defective planning of the experiment in 1928 due to insufficient knowledge at that time. Nevertheless, the graphs by which they summarized the experimental data reflected an equivalence of approximately 16 years of natural ageing to 72 hours of heat-ageing at 100° C for rag papers, and of 19 years for sulphite papers.

Regretfully, the experiment stopped there, because although it was intended that the test-papers be stored for still further work, they are reported to have been accidentally discarded. However, the Bureau was more fortunate in this matter than the Royal Material Testing Bureau where, in 1904, Dr Wilhelm Herzberg had planned a fifty-year research project which contemplated the testing at ten-year intervals (including heat-ageing at 60° C) of some 300 papers, but the project failed for lack of industry support.[115]

In any case, the National Bureau of Standards' validation of the heat-ageing test was essential to Barrow's thesis. Always impressed by the predictive possibilities of the test, he made it his own following the Wilson report in 1955 and employed it as a tool of daily use, improving the methods of plotting and interpretation associated with its use. For working purposes he equated 72 hours of heat-ageing at 100° C with 25 years of natural ageing, and he had no hesitation in using multiples of the basic test in order to extend the range.[116]

With the aid of the heat-ageing test, Barrow's 'tentative' specifications for a

113 / Royal H. Rasch & B. W. Scribner, *Ibid.* 11 (1933) 727–32. Also B. W. Scribner, *Ibid.* 23 (1939) 405 ff.

114 / William K. Wilson & others: 'Accelerated aging of record papers compared with normal aging,' *Tappi* 38: 543–8, September 1955

115 / W. Herzberg: *Papierprüfung*, 7th ed. (Berlin: Springer, 1932) p. 281 ftn. However, work on the validity of heat-ageing as a predictive test has continued. A. H. H. van Royen in 1957 found that 72 hours at 100° C is equal to 28 years of natural ageing at 20° C (68° F) (*Assoc. Techn. Ind. Papetière* Bull. 6 (1957) 223–6; *De papierwereld* 12:219–22, 225, April 1958). B. L. Browning and W. A. Wink in 1968 confirmed the principle of heat-ageing and while stressing that the number of variables makes precise prediction of paper life impossible they calculated a theoretical equivalence of 72 hours in a ventilated oven at 100° C to 37.1 years at 20° C (*Tappi* 51:156–163, April 1968).

116 / Church, ref. 110, p. 15.

'durable' (i.e., a permanent/durable) book-paper became the most simple offered so far, because they were essentially limited to two requirements: 1 / specific values for initial strength, and 2 / a test for stability intended to assure full usefulness of the paper for at least 300 years with diminished usefulness beyond that.[117]

Each of these requirements was empirically derived. The basic presumption – useful life for at least 300 years – rested upon the advice of his library consultants who informed him that the greatest use of a typical reference book takes place in its first 50 years of life and that it is little used after 300 years. The strength and stability requirements were based upon the actual performance of two groups of book-papers, one old, the other new. The old papers came from seven books published from 1534 to 1722, still in good condition although already 237 to 425 years old in 1959. The new papers consisted of 19 commonly-used chemical wood book-papers.

The old papers ranged in folding endurance from 87 to 813 folds and tear resistance from 30 to 46 grams (both weaker directions). The new papers had a range in folding endurance from 13 to 409 folds and tear resistance from 28 to 96 grams (both weaker directions). Barrow consequently set the initial strength requirements at 300 folds and 60 grams as being not beyond the ability of modern chemical wood papers to meet, yet sufficiently close to the characteristics of the old all-rag papers to make a substantial degree of durability probable, if stability could be assured.[118]

The test for stability similarly rested on the record of performance of the old papers. To obtain this, Barrow submitted them to a heat-ageing test of 24 days' duration (the approximate equivalent of 200 years of natural ageing) and found that they retained 49 per cent of the folding endurance and 89 per cent of the tear

117 / 'Tentative specifications for durable, non-coated, chemical wood book papers, based on 25″ × 38″ size at 60 lbs. per ream: 1 / The paper must be free of ground wood and unbleached fibers. 2 / On the basis of a minimum of 15 test strips, from 15 different sheets selected at random from a ream, initial folding endurance of conditioned strips shall average not less than 300 folds in the weakest direction as measured on the MIT tester at 1/2 kilogram tension. 3 / On the basis of a minimum of 12 test strips (selected as in 2) and tested by 5 tears through 4 strips initial tear resistance of conditioned strips shall average not less than 60 grams in weakest direction as measured on the Elmendorf tester. 4 / After artificial aging at 100° C ± 2° the average of strips (selected and tested as in 2 and 3) shall not show less than the following fold and tear for the days of aging indicated: 12 days, 200 folds, 53 grams tear; 24 days, 140 folds, 48 grams tear; 36 days, 100 folds, 43 grams tear. 5 / The pH of the paper shall not be less than 6.5 at time of manufacture, and after heat aging (as in 4) for 3 days shall show no sharp decline. 6 / Opacity of the paper shall not be less than 90. 7 / Procedures for testing shall follow TAPPI unless otherwise indicated.' (Church, ref. 110, p. 31)

118 / Barrow's folding endurance measurements were made on the MIT fold tester at 1/2 kg tension and his tear measurements on the Elmendorf tester.

resistance (median values, weaker directions) that they possessed at the beginning of the test.

The 19 new papers were similarly heat-aged but the purpose in this case was to discover the pattern of loss of strength. Paper deterioration typically proceeds at a diminishing rate, and it was found that the pattern followed by these papers could be best interpreted semi-logarithmically for the fold endurance and semi-reciprocally for the tear resistance.

Barrow now built these data into the stability requirement of the specifications, using the proportions derived from the old papers (expressed in terms of fold and tear instead of percent) and the rates of deterioration derived from the new papers.

There remained several minor items, and one major. The specifications were explicitly limited to non-coated chemical wood papers; Barrow was not prepared to go further as yet. Similarly, he explicitly excluded groundwood and unbleached fibres; this was a reasonable precaution sanctified by common experience. Finally, however, he required that the initial pH should not be less than 6.5 and after the heat-ageing test should show no sharp decline. This figure, too, he based on the behaviour of the seven old papers whose median pH was 6.7 before heat-ageing and 6.3 after it. Although not a specification of performance, pH was a predictor of stability so important as to be indispensable. The fact is that it is the single most important predictive characteristic of the stability of paper that can be ascertained quickly; few are willing to wait for 36 days for the completion of a heat-ageing test in order to judge the relative permanence of a paper.

When the new papers were evaluated by these specifications it was found that none could meet the ageing requirement. However, after they had been soaked in a solution of magnesium and calcium bicarbonates for two hours before heat-ageing, decided improvement was effected, and two of the papers even met the specifications completely.

MANUFACTURE OF A PERMANENT/DURABLE BOOK PAPER

Not altogether surprised at the results of his tests, Barrow turned with growing confidence to the production of a chemical wood book-paper that would meet his own specifications, enlisting for the purpose the experimental paper mill of the Herty Foundation in Savannah. The first trial run of paper was made on 6 May 1959.

Barrow had intended in any case to avoid the use of alum-rosin size, which would not have worked at that time in any case at the pH that he was specifying. He seems to have had some hopes of making an unsized paper that would be suitable for letter-press printing, since sizing is not needed for the inks used in printing to the same degree as it is for writing ink.[119] If this had not proved possible (but his experimental unsized papers were found by printers to be far from unacceptable), he still had options for sizing with starch, gelatine, etc. However, by a fortunate coincidence there came on the market just at this time an engine size (Aquapel-Kymene, made by the Hercules Powder Company) compatible with alkalinity. Barrow adopted it with alacrity.

The first experimental paper, both sized and unsized, substantially exceeded the minimum specifications, both for initial strength and for ageing, and was found to have good printability as well. Its furnish consisted of 50 per cent Swedish sulphate pulp for the sake of strength, 50 per cent soda pulp to provide a cushion for printing, and calcium carbonate to assure mild alkalinity and serve as a buffer against possible future acid. Additional papers were run in July and September 1959 to test other blends of pulp as well as the ability of the formula to run on a full-scale commercial machine. In all, three of the experimental papers fully met the specifications.[120]

The time had now arrived when the process could be taken into a commercial mill. In consequence, on 11 December 1959, using a furnish consisting of one-third each of sulphate, sulphite, and soda pulps, with 10 percent each of clay and calcium carbonate, and with technicians from the manufacturer standing by to advise on the working of the size, the Standard Paper Manufacturing Company of Richmond produced five tons of a fine 60-pound book-paper, the first paper deliberately manufactured as a strong, stable ('permanent') paper for general use at a competitive price. The paper exceeded the absolute specifications for both before-and-after heat-ageing by from 28 per cent to 67 per cent, its pH remained well on the alkaline side, from 8.9 to 8.5, and it could be priced in the medium range of 100 per cent chemical wood papers.

The paper was sold to a number of interested parties and was used (*inter alia*) for the January 1960 issue of the *Virginia Magazine of History and Biography*, the *Annual Report* of the Virginia State Library, 1959, and for the reports of both of the investigations that had led directly to the making of the paper.[121] It seemed too hard to some, and in fact broke the needles of the sewing machine binding the *Virginia Magazine*

119/ In 1936 Strachan advocated abandonment of the use of alum and rosin in printing paper because '[s]izing of this type is not necessary for printing by means of inks having an oil basis.' Ref. 106, p. TS 98

120/ The initial tear resistance of the paper designated as 7C in Church, ref. 110, Table 5, was 78.8 grams; after 36 days of heat-ageing it was 55.1 grams; both in weaker direction. If the ageing specification for tear resistance had been written in percent retention instead of absolute quantities, this paper would have failed (70% retention instead of 72%). However, a second commercial run in March 1960 exceeded the minimum specifications for initial strength by 62% for the fold and 30% for the tear and exceeded the (unwritten) percentage as well as the (written) absolute specifications for retention after ageing. (Letter from D. D. Roberson, October 22, 1970)

121 / Church, refs. 13, 110

in 32-page sections; also its opacity left room for improvement, especially at a time when printers were demanding lighter-weight paper; on the other hand, one printer called it the best offset paper he had ever used. The fact was that, like any newly developed paper, it was capable of almost infinite modification.

It is difficult to overestimate the Barrow achievement. An essentially solitary worker lacking formal training for the task (though never without access to necessary technical advice), he dealt single-handedly with a problem of one of the greatest industries, itself the complex product of a violent industrial revolution in mechanical and chemical engineering that began even before the end of the Middle Ages, commanding tremendous resources, staffed with armies of trained specialists, and documented by an exhausting literature. Gifted with a sure instinct for the essential which not only drove him to question long-held beliefs but suggested the manner for doing so, and which led him to insist on empirical evidence for all predictions, he lost little time in penetrating the thicket of folklore and technical detail that had grown up about paper, picked up the trail that led to fifteenth-century quality through twentieth-century technology, and – devising his navigating instruments as he went – unfalteringly reached the goal that had eluded the centuries since the Emperor Frederick II and Abbot Tritheim – a paper not only beautiful but also dependable, yet not an article of luxury for the occasional need, but one for everyday use in the service of civilization.

P/D BOOK-PAPER SINCE BARROW

The story of permanent/durable paper (as Barrow's development was almost immediately called) after December 1959 is soon told. In September 1960 a meeting in Washington, attended by papermakers, paper chemists, book manufacturers, publishers, and librarians, to discuss the implications of the new paper, agreed on the significance of the development and on the need for further work to improve the paper in certain respects and to seek consensus on specifications and nomenclature.[122] A consumer-industry committee, suggested at this meeting, was subsequently established under the aegis of the American Library Association, but let the occasion slip, and the job still needs to be done.

In spite of that lost opportunity, both the manufacture and use of chemical wood papers of improved stability, and often of improved strength as well, has gradually spread. Given alternatives to alum-rosin size, of which Aquapel was the first, mills began to 'go alkaline.' One of the first was the Standard Paper Manufacturing Company of Richmond, which had been host to Barrow's first commercial run in 1959, and which since 1960 has continuously made book and writing papers far in excess of Barrow's minimum specifications.

In October 1960 the S. D. Warren Company, leading book-paper manufacturers, reported that all their book-papers were being made on an acid-free basis.[123] The following February, announcement was made of their new acid-free book-paper developed in collaboration with the Harvard University Press, which has a life-expectancy of more than 300 years.[124] There was a certain poignancy in this announcement to those who knew of Dr Sutermeister's early experience with an alkaline book-paper, described above.

From this point the manufacture of acid-free book-papers has spread gradually. By 1963 it was understood that such papers were being made by Crocker-Hamilton, Eaton, Ecusta, Fox River, and Meade as well as by Standard and Warren. Similarly with use: in 1963 some large publishing projects had adopted Barrow-specification papers or acid-free papers, among them the *Virginia Magazine of History*, the Adams Papers, the Madison Papers, the Centenary Hawthorne, the Illinois archives, and the reference works published by G. K. Hall.[125] In 1960 the McGraw-Hill Book Company announced a policy of printing all its books intended for library, reference, and scholarly use on permanent paper.[126]

Rag-paper manufacturers were among the earliest to 'go alkaline.' Although cotton fibre is the purest natural form of cellulose, requiring much milder chemical processing and generally producing stronger paper than wood fibre, it is no more immune to acidic deterioration than the latter, as was found by Barrow and the Society of Arts with respect to nineteenth-century papers and as has been repeatedly observed in the twentieth century.[127] Alkalinization of the rag-paper mills was an obvious step in order both to take advantage of special qualifications of the raw material and to support makers' claims of longevity. To dramatize these claims while commemorating the first manned moon landing in 1969, rag-paper manufacturers have developed a paper 'made to last 1000 years.'[128]

122 / *Permanent/durable book paper. Summary of a conference held in Washington, D. C., September 18, 1960, sponsored by the American Library Association and the Virginia State Library* (Richmond: Virginia State Library, 1960)

123 / Warren, ref. 63, p. [11]

124 / B. L. Stratton: 'A new paper is born,' *New England printer and lithographer*, February 1961, p. 58–9

125 / Clapp, ref. 93, p. 847, 851–2

126 / 'McGraw-Hill shifts to use of permanent paper,' *Publishers' Weekly* 194:1:85, 1 July 1968 [*Later:* increased demand for this paper led to higher prices, and in June 1971 McGraw-Hill withdrew its use in books (e.g., text-books) having lower claims to longevity.]

127 / Hall, ref. 72, p. 92. Also Scribner, citing Herzberg, ref. 100, p. 22; and Clapp, ref. 93, p. 848

128 / Cotton Fiber Paper Manufacturers, American Paper Institute: *'Payable to the bearer after 1000 years'* (New York, 18 March 1970). Press release describing certificates made from cotton fibre to last 1000 years. The release suggests no basis for the prediction other than that books such as the Gutenberg Bible and the First Folio Shakespeare [on paper made from flax?] have lasted half the length of time covered by the prediction.

P/D BOOK-PAPER CROSSES THE ATLANTIC

In 1962 permanent/durable paper crossed the Atlantic. In that year the H. W. Wilson Company of New York contracted with Balding & Mansell, British printers, to employ their unique abstracting camera (developed in connection with the printing of the British Museum's General Catalogue) in the printing of the third edition of the *Union list of serials in libraries of the United States and Canada*,[129] which Wilson was publishing on behalf of a joint committee representing the libraries of both countries. It was desirable to secure Barrow-specification paper for this enormous work, for which a long life of hard use was expected, but differences in testing procedures made it difficult to select such a paper in Britain. Finally Wilson brought paper from the Wolvercote Paper Mill at Oxford to the United States for testing. At 585 folds, 74 grams tear, and pH 6.87, initial values, with good retention after heat-ageing, it well exceeded the tentative minimum specifications and was adopted for use in the *Union list*, where a colophon in the last volume describes its characteristics in some detail.

In 1967 the situation was repeated. In that year the American Library Association (ALA) wished to take advantage of Mansell's abstracting camera for the printing of the 610-volume *National union catalog: pre-1956 imprints*.[130] The use of a Barrow-type paper was written into the printing contract. In order to widen the sources of supply for such paper (which was expected to be needed at the rate of 26 tons a month for 10 years) and to lay a basis for choice through testing, Barrow went to England at ALA's request in May-June 1967 to visit a number of paper mills and testing laboratories.

Visits to the first were very rewarding, but to the second less so, and he had to agree to do the testing himself. On August 15 he reported to ALA and Mansell that a paper made by the Guard Bridge Paper Company of Fife, Scotland, had tested at the high values of 1701 folds, 93 grams tear, and pH 8.9, initial, with excellent retention.[131] This paper was adopted for the *Catalog* and is similarly described in a colophon in each volume as meeting or exceeding 1200 folds, 73 grams tear, and pH 9.4, initial values.

P/D CATALOGUE CARDS

The permanence/durability of catalogue cards is of an importance to librarians second only to that of book-paper, because of the indefinite period of use for which their card catalogues are intended and the severity of the use. The present format

129/ (3d. ed., New York: H. W. Wilson Co., 1965), 5 vols

130/ ([London:] Mansell, 1968–   ), in progress.

131/ It was his last completed job. He died of a heart attack ten days later.

of the catalogue card (125 × 75 mm) is now about 80 years old, and deterioration has become a real problem with some of the older catalogues. In 1963, for example, 46 per cent of the 7.8 million cards in the catalogue of the New York Public Library, then about 70 years old, needed attention, and 30 per cent, amounting to 2.3 million, required immediate replacement.[132]

As early as 1960, therefore, the ALA's Library Technology Project contracted with Barrow to investigate catalogue cards with a view to improvements in permanence, durability, price, and such additional characteristics as erasability.

Barrow tested hundreds of cards, old and new, used and unused. He developed a new test, the diagonal fold, to correspond with the manner in which cards in catalogues are used, by bending the corners. In the old cards he found a distressing record of strength rapidly diminishing to zero over a span of 60 years, together with evidence of high acidity. In the new cards, while the greatest strength was reached by all-rag stock (1129 folds, compared with the greatest folding strength shown by chemical wood stock of 681 folds), he found that an appreciable number of all-rag cards were actually weaker than some chemical wood cards. Acidity in all was excessive except for the very strongest cards.

As tentative minimum specifications for cards for heavily used catalogues, Barrow recommended 800 folds with a pH of 6.0, values which were met only by all-rag specimens in his sample. For catalogues of moderate use he suggested 500 folds.[133]

This study resulted almost immediately in the manufacture and marketing of acceptable cards at prices lower than it was previously thought necessary to pay.[134] The reason for this was that it was soon found possible to manufacture cards from chemical wood fibre that equalled the performance achieved in the tests by only the all-rag stock, and greatly in excess of the recommended minimum specifications.

The Library Technology Project (now Program) did not let matters stand there; it took Barrow's recommended specifications to the American National Standards Institute which has written them into American Standard Z85.1.[135] This standard has been adopted by the Library of Congress which sells annually over 100 million printed catalogue cards to libraries.[136]

So successfully have Barrow's specifications for cards for heavily used catalogues been met that it has been found unnecessary to use his recommendation for cards for moderate use.

132/ Council, ref. 12, 10 (1966) 43

133/ W. J. Barrow: *Permanence and durability of library catalog cards* (Chicago: Library Technology Project, American Library Association [c. 1961])

134/ Council, ref. 12, 6 (1962) 20

135/ 'LTP news,' *ALA [American Library Association] bulletin* 63:1181, September 1969

136/ *Library of Congress information bulletin* 29:547, 15 October 1970

A principal reason for the slow rate at which permanent/durable book-paper obtains recognition is that it is not possible to distinguish a stable from an unstable paper by inspection.[137] It would be useful if book-papers achieving a certain level of permanence/durability showed an identifying watermark (like the watermark in U.S. Government bond paper indicating by the number of stars the percentage of rag fibre).[138] Lacking this, a number of publications printed on stable papers have taken pains to announce the fact. The colophons of the *Union list of serials* and the *National union catalog* were mentioned above, and there are others. In 1965 the University of Oklahoma Press began to insert a colophon in publications calling attention to the expected longevity of the book's paper.[139]

In spite of all evidences of use, however, the adoption of stable papers has been much slower than librarians would wish. They have considered, as one method of accelerating the process, suggesting the noting, in book-selection journals such as *Choice*, of the presence or absence of stable papers in the publications reviewed. Principal objections to this suggestion are that there is no standard, accepted or adopted by any responsible body, by which a permanent/durable paper can be identified; and even if there were, there is no source of the very considerable amount of expensive testing that would be required.

Barrow's specifications were expressly tentative; they were written before it was demonstrated that they could be met on a commercial basis by a chemical wood paper; and they were deliberately set low so as not to frighten paper manufacturers. They are now a decade old and there has been much experience in the manufacture and testing of stable papers since then, much of the latter by Barrow himself. It is felt by many that it is time for a new look in the light of this experience and for serious thought as to the manner in which paper can best be made to serve the interest of society – not only in libraries and archives, but in offices and homes as well.

A number of groups will be interested in assuring that such a new look is taken. In the United States, the ALA's Library Technology Program, the Association of Research Libraries, the Society of American Archivists, and the American Council of Learned Societies have all been involved to greater or lesser extent in the search for strong and stable papers. The National Archives of the United States has in

137 / In 1970 the Barrow Laboratory (ref. 14, VI) described spot-tests as a simple though crude method of identifying unstable papers.

138 / A watermark to identify permanent papers was recommended by the Library Association in 1930, ref. 92, p. 17

139/ E.g., T. G. Remer, editor: *Serendipity and the three princes* (Norman: University of Oklahoma Press [c. 1965])

recent years commissioned research in the field. Most recently, the Library of Congress and the Council on Library Resources have engaged the W. J. Barrow Research Laboratory to review the tentative specifications of 1960.

The prospect is that the written word will endure. But it is well to be not inactively optimistic. One recalls the simple trust of the Society of Arts in 1898 in 'the practical adjustments which rule the trade,' Rasch's belief in 1931 that general recognition had been reached of the dangers to good fibre from manufacturing processes, and Kimberly and Scribner's remark in 1934 that attention to paper permanence has no doubt been materially improved by 'the constantly increasing co-operation' (!) between papermakers, printers, and librarians (look mom, no publishers!) from which the 'no doubt' was stricken in 1937.

Here Binkley's adjuration comes to mind: the consumer must be induced to demand what the producers know perfectly well how to supply. How? Steps to this might consist in 1 / a review of the specifications for p/d paper such as is now taking place; 2 / acceptance of these specifications, in principle, as adequate to their purpose, by a responsible and interested consumer-producer group, perhaps of publishers and librarians;[140] 3 / a search for a watermark (B pierced by an arrow?) or other means whereby an acceptable paper may be recognized; 4 / a search for means of policing, by spot-check or otherwise, the use of the watermark; 5 / failing the adoption of a watermark, the policing of the paper in new publications through some book-announcement journal.

140 / Publishers stand to gain from improved book-paper comparably with librarians, for the latter are now spending many millions on 'preservation' of deteriorating materials that ought to be going into new books. But the right mix may be difficult to get. In 1930 the Library Association concluded that some agency, to be endowed with authority, should take the initiative to carry out its recommendations; the suggestion predictably fizzed. The consumer-producer committee established by the American Library Association in 1961 on the recommendation of a consumer-producer group to forward the cause of p/d paper, mentioned earlier, similarly died upon the midnight, with a fizz maybe worth an anecdote. Next time should learn from these examples.