A Comparative Study of Six Writing Papers After Artificial Aging

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In tests on six writing papers commonly used in the creation of records, the authors show that some papers endure longer than others and that this does not necessarily reflect the claims of the manufacturers.

1. INTRODUCTION

The immensity of the task of conserving paper-based archival materials in governmental and public collections would be ameliorated if matters of archival potential were recorded *at the outset* on papers with a capacity to endure for long periods.

In this study, which was sponsored jointly by Australian Archives, the National Library of Australia and the Materials Conservation Section of the Canberra College of Advanced Education, three types of writing papers in every-day use by departments and agencies of the Australian Government, and three marketed as 'permanent/durable' papers were evaluated comparatively. Chemical spot tests were made for the presence of lignin, alum-rosin sizing and starch; and samples were scanned by irradiation from a black light tube to detect optical whiteners. After accelerated aging in a dry oven at 105±2° C for periods ranging from four hours to thirty-six days, samples were examined against preconditioned unaged controls for changes in brightness, folding endurance and pH levels.

Given the physical and chemical complexity of the substance, sophisticated and extended investigation is called for if the potential permanence of a paper is to be forecast with reasonable conviction. Based on the findings of this and similar studies, it is believed Government departments and agencies could, initially, go some way towards fulfilling their archival responsibilities by designating the types of paper to be used for specific record purposes. It is anticipated that further studies would enable such papers to be selected on the basis of a relatively simple set of tests.

2. EXPERIMENTAL PROCEDURES

2.1 Scope

The combination of physical and chemical methods used in the study was necessarily related to and limited by the facilities, time and competence available. It was not practicable, for example, to attempt artificial aging in humid atmospheres, a course which is widely, though not universally, advocated.

In a 1980 review[1] of the characteristics of the two methods of artificial aging, Wilson and Parks reported that different tests respond differently to moist and dry aging, but moist aging usually results in much greater and more rapid changes than dry aging. They found, for example, that accelerated aging in a moist atmosphere had a devastating effect on folding endurance even after one day of aging. Experience in the study now under report was that dry heat aging could likewise be powerful in its effects; indeed, three of the six test papers lost virtually all fold retention in a matter of hours.

Wilson and Parks reported also that huge amounts of acid are generated during extended accelerated aging at 50% relative humidity; little acid is generated during dry aging; and that large amounts of acid did not develop during 36 years of natural aging in the set of papers which was the focus of their study.[2] It might be inferred from those findings that dry heat aging better simulates natural aging in respect of changes in pH levels.

In their summary of the state of the art Wilson and Parks conclude that accelerated aging is useful if employed only to rank the stability of papers relative to each other.[3] It has been employed here in that context.

The range of measurements and tests undertaken is shown in Table 1.

Table 1. Measurements and Tests

Characteristic	Number of Tests
Basis Weight	10 of each type of paper
Thickness	15 per sample sheet
Chemical Spot Tests:	
Lignin	1 of each type of paper
Aluminium ions	1 of each type of paper
Rosin	1 of each type of paper
Starch	1 of each type of paper
Folding Endurance	5 per sample sheet
Brightness	2 per sample sheet
Optical Whiteners	1 of each type of paper
pH Levels	2 per sample sheet of controls and of sets aged for 1, 12, 24 and 36 days

2.2 The Test Papers

The six types of paper selected by the AustralianArchives Conservation Laboratory for evaluation are listed in Table 2. All were A4 size (210 × 297mm).

Table 2. The Test Papers

Test Code Number	Name	Basis Weight As specified g/m²	Basis Weight As measured (mean of 10) g/m²	±	Thickness (mean of 15) mm	±
Standard Grades:						
1	Burnie Bank (130-R)	44	43.8	0.4	0.07	0.001
2	Canary Bank (217L) (yellow dyed)	44	44.7	1.4	0.07	0.002
3	Dry Process Copying Paper	80	78.9	1.1	0.11	0.002
'Permanent/Durable' Papers:						
4	Permalife Bond	73	72.7	1.3	0.12	0.002
5	Plus Fabric Bond	70	69.4	1.8	0.11	0.002
6	Archive Text	85	82.9	1.9	0.11	0.001

Thickness measurements were made by hand-held micrometer and, because of the limitations of this method, are used in this study for characterization purposes only.

2.3 Sample Sizes

A sample set of 10 sheets of each of the 6 papers for 9 oven aging periods (540 sheets) was selected for test purposes by a random extraction from 5 reams of each type of paper. A control set of 10 sheets of each type (60 sheets) was also randomly drawn from the same source. Randomness in the selections and in the allocation of rack positions in the aging oven was ensured by recourse on each occasion to distributed random number lists generated by a Texas Instruments TI 59 calculator incorporating an applied statistics module.

Errors in samples were calculated as 99% interval estimates using Students' 't' Statistical Tables.

2.4 Standards

The Standards of the Technical Association of the Pulp and Paper Industry of the USA (TAPPI) were used where appropriate in the context of the facilities and time available.

2.5 Test Environment

Apart from chemical spot tests and brightness measurements, all investigations were carried out in an environment of controlled temperature and relative humidity. TAPPI Standard T402 os-70 calls for an atmosphere for paper testing of 50±2%RH and 23±1°C. The temperature stipulation was met; the facility used was not designed to hold to such limited variance in relative humidity levels, but performed within the range 50±5%RH.

Throughout the study the test specimens were maintained in the controlled environment (except during brightness measurements, which were made elsewhere after the completion of all other tests).

2.6 Method

2.6.1. Preconditioning

To minimise hysteresis the control samples were preconditioned in a closed chamber until the ambient relative humidity fell to 17% (TAPPI Standard T402 os-70) and were then conditioned for a minimum of three days in the controlled environment room before testing.

2.6.2 Oven Aging Procedures

Specimens were artificially aged in a Qualtex Solidstat mechanical convection oven (Model OM3672). Temperature distribution within the oven was ascertained, beforehand, by the insertion of thermocouples connected to a Bausch and Lomb 10mv VOM5 recorder with the reference electrode in ice. Readings from three thermocouples at central and peripheral locations in the ovens revealed a maximum temperature variation of 0.5°C.

TAPPI Standard T453 su-70 requires that oven temperature be maintained at 105±2°C. Temperature was monitored three times daily throughout use and the specified limits were met.

Nine oven aging periods were undertaken in two series, these being for 1, 3, 6, 9 and 12 days; and 18, 24, 30 and 36 days respectively. The shorter interval of three days in the first series was adopted because it was expected there would be early manifestations of change. In the event, three of the papers (Burnie Bank, Canary Bank and Plus Fabric Bond) virtually lost folding endurance after 1 day of oven aging. New samples of these papers were then subjected to a supplementary aging series for periods of 4, 8 and 16 hours.

2.6.3 Chemical Spot Tests

An aluminon test for aluminium ions and the Raspail Test for rosin were run in accordance with the procedures described by the W.J. Barrow Research Laboratory.[4]

Two tests were made for the presence of lignin:

- a Phloroglucinol Test which also followed the Barrow prescriptions; and
- an Aniline Sulfate Test undertaken in accordance with Grant.[5]

Starch was detected by the appearance of a blue spot following the application of a drop of a solution consisting of 2.54g of iodine and 6.00g of potassium iodide dissolved in 1 litre of water.

2.6.4. Folding Endurance

Folding endurance measurements were made on a Toyoseiki MIT-type machine at a tension of 1kg. A set of standard weights was used to calibrate the tension and to ensure that the plunger friction load was kept within 25g (TAPPI Standard T511 su-69).

Five folding strips of 15 x 110mm were cut from each of the 10 sheets of each type of paper in the control state and each of the aged states, giving a sample size of 50 for each sample set. TAPPI Standard T453 su-70 stipulates a sample size of 20; the larger number was taken in this investigation because of the wide variability of the fold test reported by, amongst others, Roberson[6] and Browning.[7]

Strips were folded across the machine direction. Results are reported as a mean of 50, together with standard deviations.

2.6.5. Brightness

Brightness was measured on a Pye Unicam SP1700 spectrophotometer incorporating an SP890 diffuse reflectance unit. The instrument was operated at 457nm. Twenty replicate tests were made of each of the six sample papers in the preconditioned control state and after conditioning following oven aging for 1, 3, 6, 12, 18, 24, 30 and 36 days at 105±2°C.

As facilities for calibration using the magnesium oxide or barium sulfate standards were not available, the spectrophotometer was calibrated before each day's use against 10 randomly drawn samples of Hollinger Bond paper. This method was adopted in the circumstances as adequate for comparative evaluation of the six types of paper.

Results are given as percentage reflectance values, mean of 20 in each instance, with standard deviations.

2.6.6. pH Cold Extraction Values

Cold extraction pH values were ascertained in accordance with TAPPI Standard T509 os-77 except that, for consistency, all readings were taken one hour after the solutions had been prepared (TAPPI allows a latitude of up to four hours) and two minutes after each immersion of the electrode.

Measurements were made with a Beckman 4500 pH Meter calibrated daily against 4.01pH and 9.18pH buffers. Two cold extractions were run from each of the 60 control samples and from each of the 60 papers (10 of each type) which had been artificially aged for 1, 12, 24 and 36 days. Results are displayed as a mean of 20 for each type and state of paper, with standard deviations.

To provide a check of pH variations in the distilled water supply, two additional cold extractions were carried out at the end of each test run using unaged pure cellulose chromatography paper as the sample. The test for presence of alkaline impurities prescribed by TAPPI Standard T509 os-77 yielded a cold extraction value in both samples of pH6.8 in the permitted range pH6.2 to pH7.3.

3. RESULTS

3.1 Chemical Spot Tests

Table 3 sets out the reactions to chemical spot tests for lignin.

Table 3. Results of Spot Tests for Lignin

Paper	Phloroglucinol Test	Aniline Sulfate Test
Burnie Bank	pos.	pos.
Canary Bank	inc.	inc.
Dry Process Copying Paper	pos.	pos.
Permalife Bond	neg.	neg.
Plus Fabric Bond	pos.	neg.
Archive Text	neg.	neg.

('pos.' = positive; 'neg.' = negative; 'inc.' = inconclusive)

Since both test solutions were acidic and the yellow dye in Canary Bank is acid-sensitive, no results for that paper could be adduced.

Though three papers reacted positively to the phloroglucinol test, the evidence of lignin was only slight; consequently no attempt was made to quantify or rank the results.

Table 4 shows the results of spot tests for aluminium ions, rosin and starch.

Table 4. Results of Spot Tests for Aluminium Ions, Rosin and Starch

Paper	Aluminium ions	Rosin	Starch
Burnie Bank	pos.	pos.	pos.
Canary Bank	pos.	inc.	pos.
Dry Process Copying Paper	pos.	pos.	pos.
Permalife Bond	neg.	nt.	pos.
Plus Fabric Bond	pos.	pos.	pos.
Archive Text	neg.	nt.	pos.

('pos.' = positive; 'neg.' = negative; 'inc.' = inconclusive; 'nt.' = not tested)

Starch indications were only slight in all instances. As Permalife Bond and Archive Text gave a negative response to the test for aluminium ions, they were not checked for rosin (which can be deposited as a size only when alum is present to act as a mordant).

3.2 Folding Endurance

The folding endurance data are displayed in Appendix A and Figure 1. In the latter the numerical fold values (mean of 50) have been plotted against days aged on standard axes and the points connected by lines.

Figure 1 on page 122

Burnie Bank, Canary Bank and Plus Fabric Bond (papers 1, 2, and 5 respectively) lost virtually all their folding endurance after only one day of oven aging; indeed, their scores of 1 to 3 folds probably represent no more than the initial momentum of the oscillating head of the testing machine. To explore their behaviour further an additional set of 30 sheets of these papers were oven aged for periods of 4, 8 and 16 hours (10 sheets of each paper per aging period). The results are shown as an Inset at Figure 1. Plus Fabric Bond with a basis weight of $70g/m^2$ and which is marketed as a 'permanent/durable' paper exhibited a similar folding endurance performance (despite its greater weight) to those of the standard grade papers Burnie Bank ($44g/m^2$) and Canary Bank ($44g/m^2$). The remaining standard grade paper — Dry Process Copying Paper (paper 3) — retained a greater measure of strength; its fold scores remained significant until it had been subjected to 30 days of oven aging.

The other 'permanent/durable' papers — Permalife Bond and Archive Text (papers 4 and 6) — registered far higher fold scores over longer oven aging periods than any of the standard grade papers and Plus Fabric Bond. Both had retained approximately 15% of their control fold scores after 30 days of aging; at 36 days Permalife Bond held 12% and Archive Text had 9% of initial fold value.

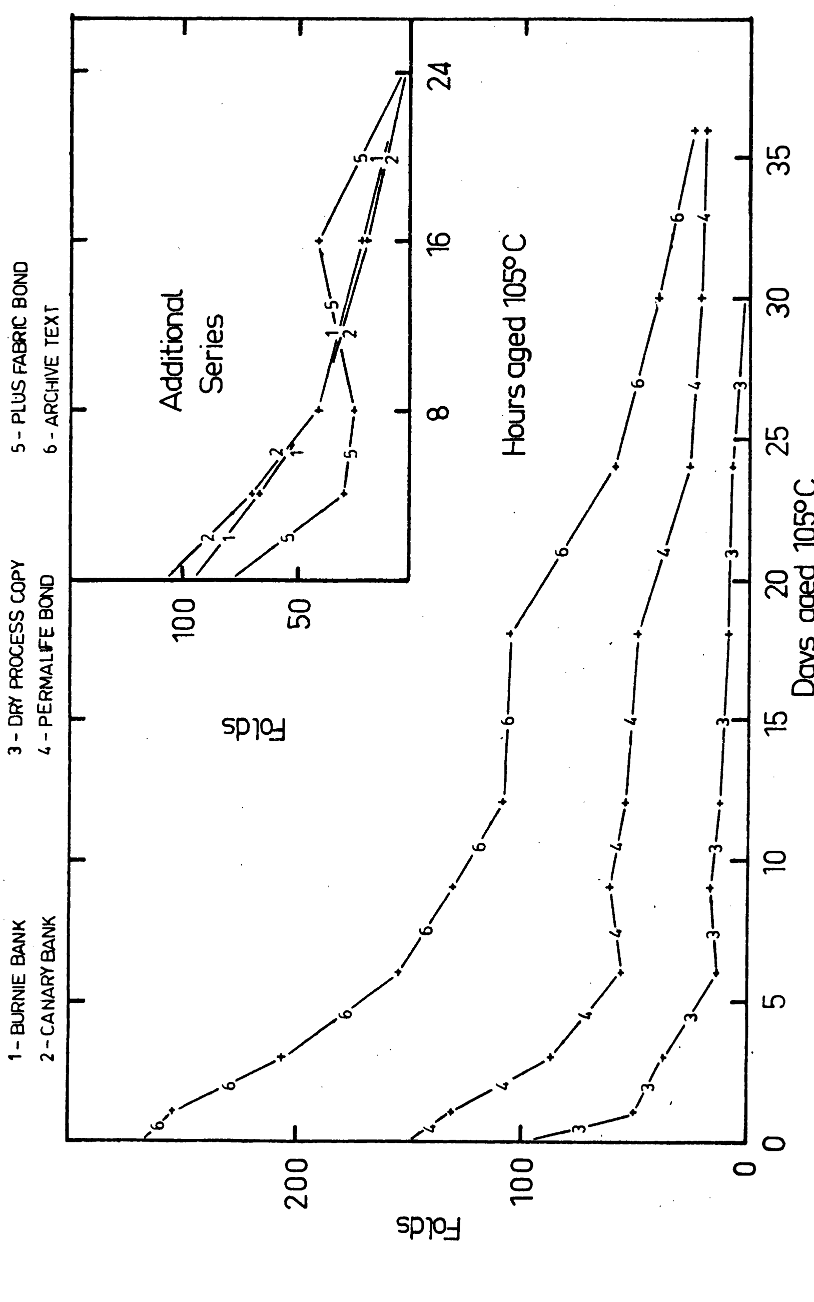
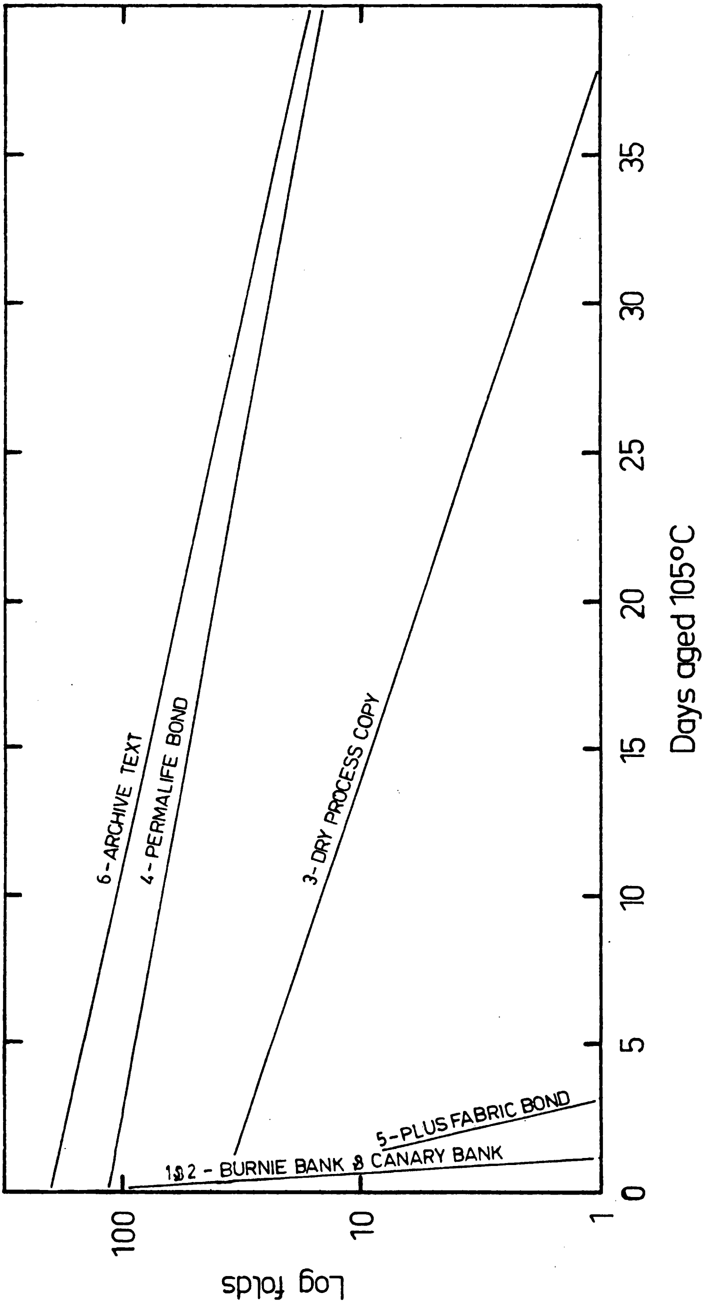


FIG. 1 : PAPERS 1 - 6 - FOLDING ENDURANCE vs AGING

FIG.2 : PAPERS 1 - 6 LOG FOLDS vs AGING

Lines of best fit



It will be evident from Figure 1 that the ranking by initial fold score did not change materially throughout the oven aging periods. Plus Fabric Bond (paper 5), which started with a slightly lower score than Burnie Bank (paper 2), momentarily registered a superior score at the 16 hour oven aging stage (see Appendix A); but the three papers with the lowest initial scores had all collapsed after only one day of oven aging.

The other three papers — Dry Process Copying Paper (paper 3), Permalife Bond (paper 4) and Archive Text (paper 6) — retained their relative positions throughout the entire series of tests.

In Figure 2 the fold values have been expressed as log folding endurance versus time oven aged. Data were processed by a Texas Instruments TI 59 programmable calculator which determined the straight line of best fit through the points.

Figure 2 on page 123

Coefficients of correlation between the mean folding endurance values and days of artificial aging obtained by the use of the Texas Instruments TI 59 programmable calculator are shown in Table 5.

Table 5. Correlation Coefficients between Mean Folding Endurance Values and Artificial Aging Times

Paper	Coefficient of Correlation
Burnie Bank	0.957
Canary Bank	0.975
Dry Process Copying Paper	0.942
Permalife Bond	0.950
Plus Fabric Bond	0.840
Archive Text	0.989

We make three observations on the folding endurance test results:

(i) the high coefficients of correlation in Table 5 between mean folding endurance values and artificial aging times might, perhaps, justify the extrapolation of the data to estimate fold values for longer aging periods.

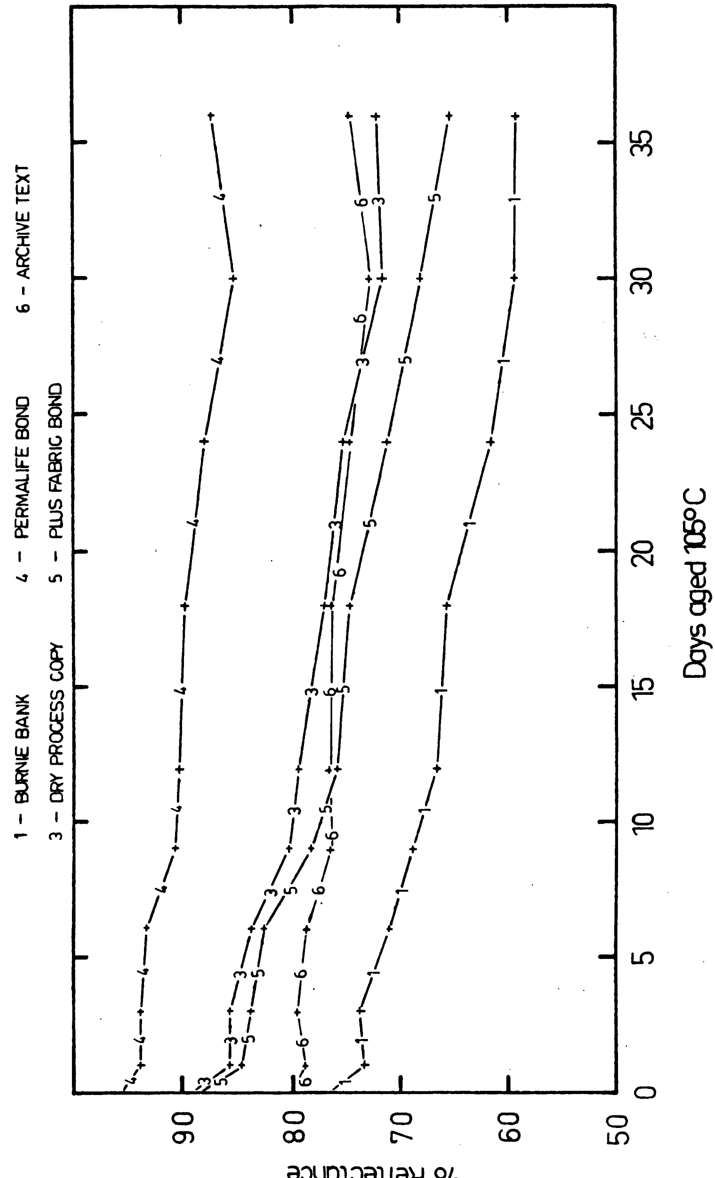
(ii) basis weight is not the sole determinant, nor even a reliable indicator, of folding endurance.

(iii) the initial ranking of the six papers for unaged folding endurance did not change materially during accelerated aging.

3.3 Brightness

Percentage reflectance values are given in Appendix B and are displayed in Figure 3.

FIG.3 : PAPERS 1,3,4,5&6-% REFLECTANCE vs AGING



Canary Bank is a yellow paper and so no comparison with the results for the white papers is useful. Its data are included in Apendix B merely for completeness. The other papers exhibited generally decreasing percentage reflectance values as oven aging periods increased. Aging for only one day at 105±2°C was sufficient to cause pronounced brightness reversion in all papers except Archive Text. Behaviour between the intervals of 30 and 36 days of oven aging varied. Burnie Bank (paper 1) and Dry Process Copying Paper (paper 3) showed little change; Permalife Bond (4) and Archive Text (6) inexplicably increased their percentage reflectance values slightly; and Plus Fabric Bond (5) continued to lose reflectance as it, alone of all the papers, had done throughout the entire aging series.

The brightness results accord with Spinner's statement[8] that increased reversion due to the presence of lignin and rosin has been demonstrated.

Table 6. Increased Brightness Reversion related to the presence of Lignin and Rosin

Paper	Reflectance Percentage (mean of 20) Control %	After 36 days oven aging %	Loss of Brightness as percentage of control value %	Reaction to Tests for: Lignin	Alum/Rosin
Burnie Bank	76.9	59.1	23.1	pos.	pos.
Dry Process Copy. Paper	89.3	72.3	19.0	pos.	pos.
Plus Fabric Bond	88.7	65.8	25.8	pos.	pos.
Permalife Bond	95.7	87.3	8.8	neg.	neg.
Archive Text	80.4	74.6	7.2	neg.	neg.

('pos.' = positive; 'neg.' = negative)

Flourescent whitening agents (or 'optical whiteners') in the form of dyes are often incorporated into paper. Their ability to absorb invisible ultra-violet radiation and re-emit the energy as a visible flourescence gives a greater uniformity of reflectance throughout the sheet.

Samples of the six test papers were examined for the presence of flourescent substances using as an ultra-violet source a Phillips black-light tube mounted in a rectangular luminaire at a distance of 30cm. Wavelengths were above 320nm with a maximum intensity of 350nm.

Results were as follows:

Fluorescence observed	Fluorescence absent
Burnie Bank	Canary Bank
Dry Process Copy. Paper	Permalife Bond
Plus Fabric Bond	Archive Text

Plus Fabric Bond emitted by far the strongest fluorescence. Though Permalife Bond did not flouresce, it exhibited a pale lilac glow which may be due to the presence of titanium dioxide as a filler or coating.

3.4 pH Cold Extraction Values

Table 7 presents pH cold extraction values.

Table 7. pH Cold Extraction Values before and after Artificial Aging (mean of 20)

	Days of Artificial Aging									
	0		1		12		24		36	
Paper No	pH	error	pH	error	pH	error	pH	error	pH	error
1	5.1	0.01	5.1	0.01	5.0	0.02	5.2	0.01	5.1	0.03
2	5.1	0.02	5.0	0.03	4.9	0.03	5.1	0.02	5.1	0.03
3	5.6	0.04	5.6	0.03	5.5	0.03	5.5	0.02	5.4	0.03
4	8.3	0.14	8.3	0.22	7.6	0.08	7.3	0.12	7.3	0.15
5	5.0	0.03	5.0	0.04	5.0	0.04	5.1	0.04	5.1	0.02
6	7.1	0.08	7.0	0.05	7.1	0.10	6.9	0.03	7.1	0.08

Except for paper 4 (Permalife Bond), there was little change in pH levels from the unaged state to the end of the artificial aging series. The data display some ostensible increases in the course of oven aging. These were due to minor fluctuations in the pH level of the distilled water supply (which were monitored by the concurrent chromatography paper cold extractions — see 2.6.6).

Given the comparative aspect of this study, it was of interest to note there was no change in the ranking of the pH levels of the six papers between the unchanged control state and after 36 days of accelerated aging. It would seem therefore that, in so far as pH levels can be taken as indicators of potential permanence, the initial pH level is as useful as any subsequent artificially aged value.

There is doubt about the relationship of acidity to potential for permanence (Dixon and Nelson[9], Browning[10], Gray[11]). Stuhrke[12] has reported however that permanency specifications for paper exist which call for a pH of 6.5 or higher; that other specifications say the value should not be lower than pH5.5; but that there is no disagreement about the poor permanency of paper which has a value below pH5.5.

Taking these dicta as a whole, the six test papers in this study fall readily (except, marginally, in the case of Dry Process Copying Paper) into two groups:

those with potential for permanence
(4) Permalife Bond
(6) Archive Text

others
(1) Burnie Bank
(2) Canary Bank
(3) Dry Process Copying Paper
(5) Plus Fabric Bond

4. COMPARISONS

To explore those initial broad groupings further and to test consistency of characteristics within each group, we now compare in Table 8 two papers which seem unlikely to have a potential for permanence; in Table 9 two papers which appear to have archival qualities; and in Table 10 a paper (Plus Fabric Bond) which purports to have permanent/durable characteristics against a standard grade paper (Burnie Bank).

Table 8. Comparison of Burnie Bank and Canary Bank

	Burnie Bank	Canary Bank
Basis weight (g/m² — as measured)	43.8	44.7
Thickness (mm)	0.07	0.07
Lignin	present	inconclusive
Alum sizing	present	present
Initial pH level	5.1	5.1
Optical whiteners	present	absent
Brightness loss after 36 days oven aging	23.1%	no comparable data
Initial fold value	96	108
Fold value after oven aging for:		
4 hours	66	69
8 hours	41	40
16 hours	22	18
1 day	2	2

Both are thin, lightweight, acidic papers with less handling and storage potential. That is not said in denigration, but to emphasise that their use should be fitted to their characteristics — Burnie Bank and Canary Bank appear from the above tests to be suitable for short term records only.

Dry Process Copying Paper is thicker than Burnie Bank and Canary Bank (0.11mm versus 0.07mm) and is heavier (78.9g/m² versus 43.8 and 44.7g/m²). It had markedly better fold values of 100 in the control state, 50 after 1 day of oven aging and 37 after 3 days. Indeed, it managed a reading of 6 folds (mean of 50) after 24 days of oven aging. Nonetheless, Dry Process Copying Paper is an alum-sized paper which lost reflectance to the extent of 19.1% after 36 days oven aging and with much less fold retention than the better 'permanent/durable' papers. It does not appear to be suitable for archival purposes.

Table 9. Comparison of the Reputed 'permanent/durable' Papers

	Permalife Bond	Archive Text	Plus Fabric Bond
Basis weight (g/m² — as measured)	72.7	82.9	69.4
Thickness (mm)	0.12	0.12	0.11
Lignin	absent	absent	slight
Alum sizing	absent	absent	present
Initial pH level	8.3	7.1	5.0
Optical whiteners	absent	absent	present
Brightness loss after 36 days oven aging %	8.8	7.2	25.8
Initial fold value	152	269	83
Fold value after oven aging for:			
1 day	131	254	3
6 days	87	154	—
18 days	48	106	—
30 days	23	40	—
36 days	19	24	—

Permalife Bond and Archive Text are broadly of a class. Both are alkaline papers free from alum-sizing; brightness loss after 36 days oven aging was markedly less than those of the other test papers; they did not appear (according to the test used) to contain optical whiteners; both are relatively thick; and both retained significant folding endurance values throughout the entire oven aging series. Archive Text, however, had superior fold numbers at all stages.

In our view Permalife Bond and Archive Text can properly be considered for use as archival materials.

Table A indicates that Plus Fabric Bond does not exhibit the characteristics expected of a 'permanent/durable' paper. It is an acidic, alum-sized paper with relatively poor folding endurance; its brightness loss after 36 days of oven aging was 25.8% compared with 8.8% for Permalife Bond and 7.2% for Archive Text. The characteristics of Plus Fabric Bond are more akin to those of a standard grade paper such as Burnie Bank, as Table 10 shows.

Table 10. Comparison of Burnie Bank and Plus Fabric Bond

	Burnie Bank	Plus Fabric Bond
Basis weight (g/m² — as measured)	43.8	69.4
Thickness (mm)	0.07	0.11
Lignin	present	slight presence
Alum sizing	present	present
Initial pH level	5.1	5.0
Optical whiteners	present	present
Brightness loss after 36 Days oven aging (%)	23.1	25.8
Initial fold value	96	83
Fold value after oven aging for:		
4 hours	66	37
8 hours	41	24
16 hours	22	40
1 day	2	3

5. DISCUSSION

The conclusions drawn from this study which follow must be treated with some reserve, for the scope of the tests undertaken was necessarily limited. Moreover, the literature recognises that a battery of investigations which can forecast permanence with certainty has not yet been devised. Wilson and Parks[13] have recently remarked that prediction of the permanence of paper is not an exact science, though progress is being made toward that goal. In their comparison of accelerated aging of book papers with natural aging they found, for example, that correlation of retention of folding endurance after natural and accelerated aging were fair only; and although fold is useful as an evaluation method after accelerated aging, it should not be relied upon completely. They remark too that pH is a reasonably good criterion of stability, put possibly for complex reasons.

In his 1976 report for TAPPI on the evaluation of paper permanence and durability Roberson[14] said

> There is a real need for long-term natural aging data which includes both chemical and physical tests run on a variety of papers at regular intervals over many years. These data would increase our knowledge of the aging phenomenon and facilitate selection of the most meaningful accelerated aging method.

As a contribution to that purpose the Australian Archives Conservation Laboratory has dispersed the remaining stocks of test papers to repositories throughout Australia where they will be stored in standard boxes in both air-conditioned and ambient environments.

The papers will experience coastal climatic conditions ranging through some thirty degrees of latitude (from Darwin, 12° S to Hobart, 43° S) as well as the inland, relatively dry climate of Canberra (35° S, elev. 600m).

Samples of the papers will be tested for deterioration each five years for, say, twenty five years. In addition to enabling the Australian Archives Conservation Laboratory to study the behaviour of the papers over a substantial period whilst being held in a variety of atmospheres, there will be an opportunity to compare the consequences of natural aging with those induced by the artificially accelerated aging methods of the 1980 tests.

Pending these and other intensive investigations of papers available in Australia there is a need for some ready method of enabling Government departments and agencies to go some way towards fulfilling their archival responsibilities by designating the types of paper to be used for specific record purposes, the papers to be selected by recourse to a relatively simple established set of criteria.

The authors have noted that the W.J. Barrow Research Laboratory postulated in 1969 [15] that a paper which is free of groundwood, alum and alum-rosin size and has a pH of 6.5+ might be expected to possess sufficient ability to qualify it for library and archival use. They suggest that the Barrow criteria be augmented by data on thickness, basis weight, folding endurance in the unaged state and response to ultra-violet scanning for optical whiteners. Much of the information could be assembled with a relatively limited input of equipment, time and skills; yet it might bring together a sufficient battery of information for papers to be categorized adequately for end use purposes. The proposition would require correlation by prior experimental and statistical investigation.

6. CONCLUSIONS

Two propositions are put forward:

(i) the physical characteristics of the six types of paper and their behaviour under the tests applied suggest that:

(a) Burnie Bank, Canary Bank, Dry Process Copying Paper and Plus Fabric Bond should be used for short-term records only.

(b) Permalife Bond and Archive Text are appropriate papers for archival use.

(ii) Pending more intensive investigation of writing papers available in Australia, it would be valuable if materials were ranked for short-term or archival uses against a set of criteria which could be established without accelerated aging or extended physical and chemical tests. The criteria might include:

basis weight
thickness
presence of lignin
presence of alum sizing
initial pH level
presence of optical whiteners
initial fold score

The proposition would require correlation by prior experimental and statistical investigation.

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FOOTNOTES

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13. Wilson and Parks, p. 51.

14. Roberson, p. 65.

15. W.J. Barrow Research Laboratory Inc. p. 9.

APPENDIX A

FOLDING ENDURANCE DATA

Paper	0 HOURS AGING		4 HOURS AGING		8 HOURS AGING		16 HOURS AGING		1 DAYS AGING		3 DAYS AGING	
	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error
1	96	23.2	66	12.3	41	11.8	22	6.9	2	0.5	2	0.00
2	108	20.0	69	17.5	40	10.9	18	7.1	2	0.1	2	0.00
5	83	15.6	37	7.5	24	4.3	40	3.7	3	0.9	2	0.00

Folding endurance (F.E.) and error values of papers
1, 2 and 5 for 0, 4, 8 and 16 hours aging and
1 and 3 days aging.

Paper	0 DAYS AGING		1 DAYS AGING		3 DAYS AGING		6 DAYS AGING		9 DAYS AGING		12 DAYS AGING		18 DAYS AGING		24 DAYS AGING		30 DAYS AGING		36 DAYS AGING	
	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error	F.E.	Error
3	100	14.0	50	5.4	37	4.7	13	2.1	16	1.8	12	1.4	8	0.7	6	0.8	2	0.0		
4	152	11.2	131	15.9	87	13.1	55	9.1	61	4.2	54	4.5	48	3.1	27	2.0	23	1.8	19	1.0
6	269	18.1	254	17.9	207	20.5	154	11.9	131	12.5	108	11.8	106	9.5	60	5.2	40	3.5	24	2.5

Folding Endurance (F.E.) and error values of papers
3, 4 and 6 for 0,1,3,6,9,12,18,24,30 and 36 days aging

APPENDIX B

REFLECTANCE DATA

Paper	0 DAYS AGING		1 DAYS AGING		3 DAYS AGING		6 DAYS AGING		9 DAYS AGING		12 DAYS AGING		18 DAYS AGING		24 DAYS AGING		30 DAYS AGING		36 DAYS AGING	
	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error	% Ref.	Error
1	76.913	1.125	73.114	0.750	73.451	0.967	70.958	1.038	68.707	1.005	66.527	0.876	65.615	0.960	61.660	1.259	59.156	1.207	59.156	1.548
2	40.644	0.357	42.267	0.434	41.976	0.736	42.170	0.433	40.738	0.537	40.928	0.479	39.719	0.407	39.446	0.520	38.994	0.513	40.179	0.529
3	89.331	0.394	85.704	0.378	85.704	0.629	83.753	0.737	80.353	0.707	79.433	0.583	77.090	0.453	75.336	0.773	71.779	0.840	72.277	0.952
4	95.719	0.842	93.756	0.825	93.756	0.688	93.325	0.821	90.573	0.532	90.157	0.793	89.537	0.919	87.902	0.645	85.310	0.376	87.297	0.768
5	88.716	0.781	84.723	0.939	83.753	0.615	82.604	1.328	78.163	1.143	75.858	1.329	74.473	1.305	71.121	1.451	68.077	1.094	65.766	1.343
6	80.353	0.237	79.068	0.233	79.616	0.234	79.068	0.233	76.913	0.226	77.090	0.340	76.560	0.338	74.817	0.658	73.283	0.324	74.645	0.548

Reflectance (Ref.) and error values of six types of test papers oven aged for 0,1,3,6, 9,12,18,24, 30 and 36 days

Paper	4 HOURS AGING		8 HOURS AGING		16 HOURS AGING	
	% Ref.	Error	% Ref.	Error	% Ref.	Error
1	75.336	0.993	74.131	0.976	74.302	0.979
2	40.738	0.831	40.458	0.533	40.644	0.594
5	90.157	2.295	88.308	0.648	88.512	0.997

Reflectance (Ref.) and error values of papers 1, 2 and 5, oven aged for 4, 8 and 16 hours