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Standard Guide for Selection of Permanent and Durable Offset and Book Papers[1]

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1. Scope

1.1 This guide covers offset and book papers, both coated and uncoated, used in the preparation of permanent records. Permanent records usually are expected to last several hundred years in a records repository, with little change in properties that affect readibility or handling, although some records are expected to have shorter lifetimes.

1.2 Acidic materials incorporated in paper during manufacture (for example, rosin-alum sizing) contribute to deterioration. It has been shown **(1, 2, 3, 4, 5)**[2] that the life expectancy of uncoated papers is an approximate function of the pH of an aqueous extract of the paper.

1.3 The following would be expected to contribute significantly to the life expectancy of books and documents: the use of papers with controlled acidity or of papers manufactured under neutral or alkaline conditions, especially papers with a calcium carbonate filler that absorbs acidic gases from the atmosphere or can neutralize acidic materials formed in the aging of paper.

1.4 Three pH levels reflecting three levels of life expectancy are outlined in this guide. As one cannot rely on pH alone as an indicator of stability, minimum retentions of properties after accelerated aging at 90°C and 50 % relative humidity are suggested for the three levels of life expectancy.

1.5 In selecting papers for permanent records, papers with acceptable durability are evaluated for life expectancy through accelerated aging.

1.6 This guide should be used in the purchase of paper for permanent records.

1.7 This guide is based on the use of fiber sources used in the production of paper that contains no more than 1 % lignin for papers used in archives, libraries, and other permanent records. However, under proper conditions (see X1.8) paper containing more than 1 % lignin may be employed for many other end uses in paper for records that are required to have a substantial life expectancy.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Product[3]
D 589 Test Method for Opacity of Paper[3]
D 644 Test Method for Moisture Content of Paper and Paperboard by Oven Drying[3]
D 645/D 645M Test Method for Thickness of Paper and Paperboard[3]
D 646 Test Method for Grammage of Paper and Paperboard (Weight per Unit Area)[3]
D 689 Test Method for Internal Tearing Resistance of Paper[3]
D 774/D 774M Test Method for Bursting Strength of Paper[3]
D 828 Test Method for Tensile Breaking Strength of Paper and Paperboard[3]
D 1030 Test Method for Fiber Analysis of Paper and Paperboard[3]
D 1968 Terminology Relating to Paper and Paper Products[3]
D 2176 Test Method for Folding Endurance of Paper by the M.I.T. Tester[3]
D 3424 Test Method for Evaluating the Lightfastness and Weatherability of Printed Matter (Procedures 3 and 7)[4]
D 4714 Test Method for Determination of Effect of Moist Heat on Properties of Paper and Paperboard[3]
D 4988 Test Method for Determination of Alkalinity of Paper as Calcium Carbonate (Alkaline Reserve of Paper)[3]
D 5625 Test Method for Measuring Length, Width and Squareness of Sheeted Paper and Paper Products[3]

2.2 *TAPPI Standards:*

T 236 Kappa number of pulp[5]
T 400 Sampling and accepting a single lot of paper, paperboard, fiberboard, or related product[5]

[1] This guide is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.20 on Permanent Records Papers.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

[5] Available from Technical Association of the Pulp and Paper Industry, Technology Park, Atlanta, PO Box 105113, Atlanta, GA 30348.

T 401 Fiber analysis of paper and paperboard[5]
T 403 Bursting strength of paper[5]
T 410 Grammage of paper and paperboard (weight per unit area)[5]
T 411 Thickness (caliper) of paper and paperboard[5]
T 412 Moisture in paper and paperboard[5]
T 414 Internal tearing resistance of paper[5]
T 425 Opacity of paper (15°/diffuse illuminant A, 89 % reflectance backing and paper backing)[5]
T 452 Brightness of pulp, paper, and paperboard (directional reflectance at 456 nm)[5]
T 459 Surface strength of paper (wax pick test)[5]
T 479 Smoothness of paper (Bekk method)[5]
T 480 Specular gloss of paper and paperboard at 75 degrees[5]
T 494 Tensile breaking properties of paper and paperboard[5]
T 509 Hydrogen ion concentration (pH) of paper extracts (cold extraction method)[5]
T 511 Folding endurance of paper (M.I.T. tester)[5]
T 538 Smoothness of paper and board (Sheffield method)[5]

2.3 *ISO Standard:*

ISO 5630/1 Laboratory Aging of Paper—Aging in a Dry Oven at 105°C[6]
ISO 5630/3 Laboratory Aging of Paper—Aging in a Moist Oven at 80°C, 65 % Relative Humidity[6]
ISO 9706 Paper for Documents, Specifications for Permanence, Normative Annex—Special instructions for determining kappa number[6]

3. Terminology

3.1 *Definitions:*[7]

3.1.1 *acid-sized paper*, *n*—paper that has been manufactured using a procedure or process at pH values below 7 (usually 4.0 to 6.5) that results in a paper that has resistance to aqueous-liquid penetration.

3.1.2 *alkaline-filled paper*, *n*—a paper containing an alkaline filler such as calcium carbonate; having a pH value in excess of 7 (extract pH usually in the range from 7.5 to 10.0), and containing a reserve buffering capacity that can neutralize acidic materials formed in the paper, or acidic gases sorbed from the atmosphere.

3.1.3 *alkaline-sized paper*, *n*—paper that has been manufactured using a procedure or process at a pH value above 7 (usually 7.5 to 10.0) that results in paper that has resistance to aqueous liquid penetration.

3.1.4 *book paper*, *n*—a general term for a group of uncoated or coated papers (exclusive of newsprint) suitable for the graphic arts.

3.1.4.1 *Discussion*—Grammage of book papers is usually in the range from 44 to 148 g/sq m (basis weight 30 to 100 lb, 25 × 38 in.—500 sheets). They are characterized by a wide variety of surface finishes (for example, antique, eggshell, machine, English, dull, matte, supercalendered, glossy, etc.), with good formation, printability and cleanliness.

3.1.5 *coating*, *n—of paper*, the layer of pigment and adhesive applied to the surface of paper or paperboard to create a new surface.

3.1.5.1 *Discussion*—Paper is coated to improve smoothness and the efficiency of printing. Although the kind and amount of coating are important, the purchaser is concerned with performance, that is, smoothness, resistance to pick, printability, etc.

3.1.6 *neutral-sized paper*, *n*—paper that has been manufactured using a procedure or process at a pH value of 7 (with a normal range of 6.5 to 7.5) that results in a paper that has resistance to aqueous-liquid penetration.

3.1.7 *offset paper*, *n*—an uncoated or coated paper designed for use in offset lithography.

3.1.7.1 *Discussion*—The kind, type and combinations of pulps used in the manufacture of offset papers depend on the sheet qualities desired. Important qualities are good internal bonding, high surface strength, good dimensional stability, lack of curl, and freedom from fuzz and foreign surface material.

3.2 *Definitions of Terms Specific to Standards for Paper for Permanent Records:*

3.2.1 *durability*, *n—of paper*, the capacity of paper or paperboard to resist the effects of wear in performance situations.

3.2.1.1 *Discussion*—*Durability* should not be used interchangeably with *permanence*. For example, paper currency should be durable, but maximum permanence is not essential.

3.2.2 *life expectancy*, LE[8], *n—for paper*, length of time a product can be expected to maintain its functional (that is, physical, chemical, appearance, and so forth) characteristics when stored under prescribed conditions.

3.2.3 *life expectancy designation*, *n—for paper records*, a rating in years for the life expectancy of paper, when stored under prescribed conditions.

3.2.3.1 *maximum life expectancy, LE-1000, n—for paper*, a paper is expected to be usable for 1000 years when stored under prescribed conditions.

3.2.3.2 *high life expectancy, LE-100, n—for paper*, a paper is expected to be usable for 100 years when stored under prescribed conditions.

3.2.3.3 *medium life expectancy, LE-50, n—for paper*, a paper is expected to be usable for 50 years when stored under prescribed conditions.

3.2.4 *paper with a minimum pH value*, *n*—as the stability of paper is an approximate function of pH, one approach to describing a stable paper is to specify a minimum pH value, for example, 5.5. This value can be achieved with a rosin-alum sizing system.

3.2.5 *permanence*, *n—of paper*, the tendency to resist changes in any or all of its properties with the passage of time.

3.2.5.1 *Discussion*—It is expected that the terms maximum, high, and medium permanence eventually will be replaced with maximum, high, and medium life expectancy, or with the LE designations LE-1000, LE-100, and LE-50.

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[6] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

[7] See also the *Dictionary of Paper*, Tappi Press.

[8] Adapted from American National Standards Institute Committee IT9.1; approved December 1991.

4. Significance and Use

4.1 The only completely valid way to check the life expectancy of paper is to store it under the relevant conditions for the expected lifetime of the document, perhaps several hundred years. As this is not feasible, one must rely on observations made on historical documents and on our current knowledge of factors, in terms of paper properties and paper composition, that increase life expectancy, and on the retention of selected properties after accelerated aging.

4.2 In this guide the suggested requirements are given in terms of the following:

4.2.1 Physical tests to identify potential durability in service,

4.2.2 A minimum percentage retention of selected properties after accelerated aging for 12 days at 90°C and 50 % relative humidity, and

4.2.3 Tests related to composition of the paper that are indicative of stability:

4.2.3.1 A pH test, for screening only.

4.2.3.2 For maximum life expectancy, the presence of an alkaline filler such as calcium carbonate, to serve as a buffering agent against attack by acidic contaminants from the atmosphere, and from the paper during aging.

4.2.3.3 Fiber analysis or a certificate from the supplier concerning fiber composition.

4.3 Although data from tests that may be performed in the laboratory do not correlate perfectly with use situations, several tests are available that should be useful to estimate the durability of paper. Examples of such tests, in approximate order of usefulness, are tearing force, tensile properties (tensile strength, elongation and tensile energy absorption), burst, and folding endurance. If possible, all of these tests should be used.

4.4 Papers buffered with a calcium carbonate filler, and with fiber composition in accordance with 7.1.2, are considered to have maximum life expectancy **(1, 4, 6)**.

4.4.1 It has been reported **(7)** that some coated papers lose folding endurance rapidly during accelerated aging, much more rapidly than the uncoated base paper.

4.4.2 Coated papers do not retain physical properties and brightness as well after accelerated aging as uncoated papers (see Table X1.3). The average for the retentions of tensile, TEA, tear, and burst after accelerated aging of 19 uncoated papers with pH values >7.0 is 91 %. The same average for 13 coated papers is 85 %.

4.4.3 More study is needed on the effect of coatings on the stability of paper, which is another reason why an accelerated aging procedure should be used in the evaluation of most papers for permanent records, especially coated papers.

4.5 Papers with a neutral or alkaline pH without a calcium carbonate filler may or may not have the expected life expectancy. An acid paper may have been treated with a surface size containing enough calcium carbonate to give an alkaline extract pH. Also, an acid paper may have been coated with a formulation containing calcium carbonate pigment. Therefore, an accelerated aging procedure is necessary to ensure the exclusion of such papers. If a paper is not coated with a calcium carbonate formulation, or if it is not surface sized with a sizing agent that contains calcium carbonate, the pH test should be valid.

4.6 In order to estimate the relative life expectancy of paper, it is necessary to develop a data base on the accelerated aging of several papers covering a spectrum of life expectancies. This information is available on the aging of 48 papers (see Note 1), and the aging of a collection of 13 papers (see Note 2). Retentions of selected physical properties after accelerated aging are used as indicators of probable longevity. Examples of tests that are useful for the purpose of estimating probable longevity include tearing force, tensile strength, elongation, tensile energy absorption (TEA), burst, and brightness.

NOTE 1—The 48 papers were supplied by manufacturers of book and offset papers, and are representative of papers that are available in the marketplace. See Table X1.1 and Table X1.2.

NOTE 2—The set of 13 papers was tested by the Institute for Paper Science and Technology (IPST) for the National Information Standards Organization (NISO), Subcommittee II, who made the data available to ASTM Committee D06. See Table X1.4.

4.7 Although arbitrary limits are suggested for various properties, these suggested limits are for guidance only. There are no limits to properties that can be measured in the laboratory above which a paper is acceptably durable or permanent, or both, and below which it is not acceptable. No paper has been tested that quite met all criteria in this guide for maximum stability. Selections must be made on the basis of the potential value of the records to be generated, resources, cost, and what is available in the marketplace.

4.8 Comparisons have been made between dry-oven aging at 100°C and natural aging for 36 years **(4)**. Correlations between dry-oven aging and natural aging are not perfect, but the data show that this approach is useful.

4.8.1 Comparisons have been made between dry-oven aging for 18 h at 105°C, and moist aging for 18 h at 65°C and 85 % relative humidity, of pulp samples with natural aging for 17 to 29 years **(8)**. Correlations of dry-oven aging and of moist aging with natural aging were good.

4.8.2 The parameters known to promote instability in paper also cause degradation in moist accelerated aging. Moist aging is a useful technique for comparing the relative stability of several papers. Paper usually degrades much faster during moist aging than during dry aging.

4.9 Coated papers present a special problem with respect to stability. Formulations for binders in coatings may be developed from a large number of polymeric materials. These formulations are proprietary and little is known about their stability.

5. Classification—Types

5.1 Three types of offset and book papers are described, according to life expectancy. These life expectancy levels are differentiated by pH and type of filler. One cannot rely on pH alone as an indicator of stability, but must also use accelerated aging in accordance with 8.3.

5.2 *Type I, Maximum Life Expectancy*, LE-1000—Neutral- or alkaline-sized paper made with an alkaline filler, such as calcium carbonate, which will give an extract pH which usually is in the range from 7.5 to 10.0.

5.3 *Type II, High Life Expectancy*, LE-100—Neutral- or alkaline-sized paper with an extract pH usually in the range from 6.5 to 7.5.

5.4 *Type III, Medium Life Expectancy*, LE-50—Paper with a minimum extract pH of 5.5.

6. Evaluation of Papers for Potential Durability

6.1 Tearing force, tensile at break, elongation at break, tensile energy absorption, folding endurance, and burst are tests usually associated with durablity. Suggested values for data from these tests, except for fold, that might be used in selecting book papers for various levels of durability are given in Table 1. These suggested values are for guidance only and are based on a sampling of what is available in the marketplace.

7. Evaluation of Papers for Life Expectancy

7.1 *Composition Variables*:

7.1.1 *pH Requirements and Accelerated Aging Recommendations*—See Table 2.

7.1.2 *Fiber Composition (Test Method D 1030)*—The paper shall be made from cotton, linen, or fully bleached chemical fiber. Virgin or recycled fiber may be used in any proportion, as agreed upon between the buyer and the seller at time of purchase, as long as the paper meets the requirements of the test method. The kappa number (from ISO 9706) shall not exceed 5.

7.1.3 *Buffer Capacity (Alkaline Reserve) (Test Method D 4988)*—Type I paper, LE-1000, shall contain an alkaline filler, such as calcium carbonate. The minimum shall be 2 % calculated to calcium carbonate, based on the oven-dry weight of the finished paper.

7.2 *Accelerated Aging*—Accelerated aging shall be carried out in accordance with Test Method D 4714 at 90°C, at 50 % relative humidity. Fifty percent relative humidity is suggested for the following reasons: (*1*) A large amount of data using these conditions has been developed by several organizations, so 90-50 is" standard by practice." (*2*) Humid ovens can be used to control relative humidity to 50 %.

7.3 *Useful Tests After Accelerated Aging*:

7.3.1 Tearing force, tensile strength at break, elongation at break, tensile energy absorption, burst, brightness, and folding endurance are useful tests for the evaluation of permanence. For papers that do not have maximum stability, aging at 90°C and 50 % relative humidity causes substantial change in most of these tests. Tensile strength shows little change with accelerated aging unless the paper is very unstable. Tearing force is a simple and useful test. Tensile energy absorption is a measure of the capacity of a paper to resist the wear and tear of a library environment. Burst is a simple and useful test, and has the advantage of being fairly insensitive to the moisture content of the paper in the range from 25 to 50 % relative humidity. Brightness is a rough measure of appearance. Change in brightness with accelerated aging is an important consideration for coated papers, as the coating contains one or more polymeric materials whose stability bears no relation to the stability of the paper. Folding endurance has been used for years as a sensitive indicator of changes in paper. Its variability and lack of precision have led to the use of other tests that may be more meaningful. Elongation is sensitive to accelerated aging, and to approximately the same magnitude as tensile energy absorption.

7.3.2 Suggested limiting values for data from these tests that might be useful in selecting papers for various levels of permanence are given in Table 3. These suggested limits are for guidance only. They are based on data obtained from accelerated aging at 90°C and 50 % relative humidity for 12 days of a collection of 48 papers, and a collection of 13 papers.

7.4 *Aging Patterns*—Different papers frequently do not retain physical properties and brightness uniformly after aging. One paper may pass all suggested guidelines for LE-1000 except burst, and another paper may have high burst and limited tear. For 19 uncoated papers with pH values >7.0, the

TABLE 1 Guidelines for Selection of Durable Book Papers[A]

Test	Test Values Related to Durability[B]			
	Medium Durability		Substantial Durability	
	MD	CD	MD	CD
Tensile strength, kN/m	4.8	2.4	5.5	3.0
Tensile energy absorption, J/m^2	55	75	65	85
Tear, mN[C]	500		600	
Burst, kPa		200		225

[A] See 4.6. These guidelines are for coated and uncoated papers. It would be reasonable to relax the guidelines for coated papers and for light-weight papers, depending on the use requirements.

[B] These tests have been found to be empirically related to durability, but they do not tell the complete story.

[C] The values for the tear of coated papers may be reduced from 600 to 500 for substantial durability, and from 500 to 400 for medium durability.

TABLE 2 pH and Accelerated Aging

Paper Sizing	pH	Calcium Carbonate Filler, %	Longevity Type	Accelerated Aging
Uncoated:				
Alkaline	7.5 to 10.0[A]	2	LE-1000	recommended
Neutral	6.5 to 7.5[A]	...	LE-100	optional
Acid	>5.5	...	LE-50	optional
Coated:				
Alkaline	7.5 to 10.0[A]	2	LE-1000	recommended
Neutral	6.5 to 7.5[A]	...	LE-100	recommended
Acid	>5.5	...	LE-50	recommended recommended[B]

[A] Approximate range.

[B] Papers with coatings containing calcium carbonate and papers with an alkaline surface size. Use spot pH test in accordance with 10.2.1.

TABLE 3 Guidelines for the Selection of Permanent Book Papers[A]

Test	Retention Values Related to Permanence, %[B]		
	Medium Life Expectancy, LE-50	High Life Expectancy, LE-100	Maximum Life Expectancy, LE-1000
Tensile	85	90	95
Tensile energy absorption	70	80	90
Tear	75	85	90
Burst	80	90	95
Brightness[C]	90	92	95

[A] See 4.6. These guidelines are for coated and uncoated papers. It would be reasonable to relax the guidelines for coated papers and for light-weight papers, depending on the use requirements.

[B] These suggeested retention values (or change in brightness) are based on aging of the papers, mentioned in Table 1, for 12 days at 90°C and 50 % relative humidity. These suggested values are subjective and for guidance only.

[C] Coated papers on the average change more in brightness than uncoated papers. See 4.8 and Table X1.1, Table X1.2, and Table X1.3.

suggested guidelines were selected so that at least one third of the papers passed each test. However, no paper has been tested that passed all of the suggested guidelines for maximum stability.

8. Selection of Paper for Permanent and Durable Records

8.1 *Durability*—From the group of papers that are available for selection, test for properties related to durability as in Section 6 and Table 1. Using the data from these tests, select a number of papers depending on need for evaluation by accelerated aging.

8.2 *Composition Variables*—Evaluate these papers on the basis of composition as in Section 7.

8.3 *Stability Toward Accelerated Aging*—Age the papers from this selection procedure at 90°C and 50 % relative humidity for 12 days. Test the unaged and aged specimens at the same time, preferably for tensile properties, tear, burst, and brightness. Calculate the percent retention of the property.

8.3.1 Compare the percent retention for each property with the suggested retentions in Table 3 for various levels of permanence. No paper is likely to meet all of the guidelines for maximum stability. Selection of specific papers becomes a matter of judgment, based on availability, technical requirements, price, and available funds.

8.3.2 In recognition of what is available in the marketplace, the guidelines probably will need to be relaxed for coated papers.

9. Considerations Other than Permanence and Durability

9.1 *Physical Properties*:

9.1.1 *Grammage (weight per unit area)*—It is customary to request that the variation of test unit averages within a shipment (or lot) be not more than 5 % above or below the specified value.

9.1.2 *Thickness*—It is customary to request that the caliper or thickness of a shipment (or lot) of paper should be not more than 6 % above or below the specified value.

9.1.3 *Smoothness*—This is a measure of surface levelness, which is a very important printing property with the smoothness range being dictated by the specific printing process.

9.1.4 *Pick*—This test is a measure of the strength of a paper in the "Z" direction, that is, perpendicular to the plane of the sheet. Data from the pick test have been correlated with performance in printing presses. The Dennison wax test (TAPPI T459) is commonly used for uncoated papers, and the IGT Pick Test (now Useful Method 591) for coated papers.

9.2 *Optical Properties*:

9.2.1 *Opacity*—The property of a sheet of paper that obstructs the passage of light and prevents see-through of printing on the other side of the sheet. This property is especially important for printing papers.

9.2.2 *Specular Gloss*—This is the ratio of the intensity of light reflected from the specimen to that similarly reflected from an arbitrary standard for specified and equal angles of incidence and reflection. An important measure of gloss or glare of paper; it is usually evaluated for incident and reflected rays of light making a small angle with the surface of the paper.

9.2.3 *Color*—The paper may be white or colored. The hue, if defined, should be specified at time of purchase.

9.2.4 *Fluorescence*—This is the fluorescent component of directional reflectance of white papers. If fluorescence is objectionable to the end use of the paper, the limits and measurement are a matter of discussion between the buyer and the seller.

9.3 *Other Considerations*:

9.3.1 *Finish*—Many "finishes" are available (see 4.1.5). This is a matter of personal or institutional choice.

9.3.2 *Sizing*—The paper may be internally sized, surface sized, or coated so that it will be suitable for the intended purpose as indicated by the purchaser.

9.3.3 *Printing Properties*—As the paper is to be used in a printing process, a stipulation that the paper shall be suitable for the particular type of printing may be necessary.

9.3.4 *Dimensions and Trim*—The paper shall be furnished in the size, or sizes, specified at time of purchase. Tolerances required for sheet dimensions and squareness should be negotiated with the supplier. Dimensions and trim shall be measured by Test Method D 5625.

9.3.5 *Grain*—The paper shall be supplied grain long or grain short at the option of the seller, unless otherwise specified by the purchaser.

9.3.6 If lightfastness is of concern to the purchaser, use Test Method D 3424, Procedures 3 and 7 as agreed upon between the buyer and the seller.

10. Test Methods

10.1 Applicable ASTM and TAPPI methods are listed in Section 2.

10.2 *Other Procedure*:

10.2.1 *Spot Indicator for pH Screening Test*—Dissolve about 1.0 g of the sodium salt of chlorophenol red in distilled water and dilute to 1 L. Immerse a cotton swab in the indicator solution and squeeze almost dry. A small brush may be used instead of a cotton swab. The object is to wet the fibers of the interior of the paper without contact with any coating or surface size that may be present. Tear the paper to be tested diagonally to expose the inner surface. Touch the applicator to this exposed inner surface of the paper. No color development indicates that the pH is below about 6.5. A purple color indicates that the pH is above about 7.0. This is a very empirical test, and the analyst should first practice with known samples.

11. Certification

11.1 If agreed upon between the buyer and the seller, a manufacturer's certification that the paper was manufactured and tested in accordance with this guide, together with a report of the test results, shall be furnished at the time of shipment.

11.2 If agreed upon between the buyer and the seller, the manufacturer shall certify that the paper was manufactured at a wet end pH of 7, or above, when satisfying the life expectancy requirements of Type I papers.

11.3 If agreed upon in advance between the buyer and the seller, the results obtained by both the seller and the purchaser shall be made available upon request to either party.

12. Keywords

12.1 book paper; life expectancy; maximum life expectancy; offset paper; permanent book paper; permanent offset paper; permanent paper

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL INFORMATION

X1.1 As there are many variables in the manufacture of paper and in the use and storage of records, it is impossible to place definitive values on the number of years that various categories of records will endure.

X1.1.1 It has been established that the rates of both natural and accelerated aging are approximate functions of the pH of paper. However, determination of pH of paper is not a simple task. For an uncoated paper, an extraction pH test is suitable, unless the surface size contains calcium carbonate. There is no way to test the pH of the base paper of a coated sheet if the coating contains calcium carbonate. One can tear the sheet to expose the base paper and perform a spot test, but this is qualitative only. Therefore, one must rely on accelerated aging to evaluate the potential stability of a paper that contains calcium carbonate in the coating or the surface size.

X1.1.2 *Three Types of Papers With a Range of Expected Longevity*:

(*1*) *Type I Papers*, LE-1000—Machine-made papers with an alkaline filler have existed apparently with little change for over 100 years. Hand-made papers containing an alkaline filler have survived for almost 400 years. Alkaline papers perform well in accelerated aging tests.

(*2*) *Type II Papers*, LE-100—The probable longevity of these papers should lie somewhere between Type I and Type III papers.

(*3*) *Type III Papers*, LE-50—The relative condition of paper in old books and documents has been correlated with pH. Barrow **(1)** has shown that the condition of naturally aged paper definitely is a function of pH. Manifold paper in U.S. Government files with pH values as low as 4.2 have survived more than 60 years **(5)**, and the physical properties of these papers are an approximate function of pH. A minimum pH of 5.5 should indicate longevity in excess of 50 years. This is a very conservative estimate.

X1.2 The amount of alkaline filler necessary to ensure stability has never been satisfactorily defined. Arbitrary minimum values of 2 and 3 % have been suggested. Papers containing lignin consume more alkaline reserve during accelerated aging than papers that do not contain lignin **(9)**.

X1.2.1 Paper is weakened by filler in proportion to the amount of filler in the paper **(10)**.

X1.3 Papers containing cotton or linen, or both, are considered by many to be more permanent and durable than wood pulp papers. Cotton and linen fibers generally have not been treated as harshly as wood pulp fibers in the pulping and bleaching process. However, as both cotton and linen, and wood pulp papers, may cover a broad spectrum of life expectancy and durability, generalizations are inappropriate. Cotton linters are not as strong as staple cotton fiber.

X1.4 An accelerated aging test has been used in this guide to assist in the evaluation of the suitability of a paper for use as a permanent record substrate. The following procedures have been adopted as official standards for the accelerated aging of paper:

Organization and Standard No.	Temperature, °C	R H, %
ASTM D776, TAPPI T453, ISO 5630/1	105	low
ASTM D4714, TAPPI T544	90	50[A]
ISO 5630/3	80	65[B]

[A] 90°C and 50 % R H is common practice in many U. S. laboratories.
[B] 80°C and 65 % R H is common practice in Europe.

X1.5 Oven aging at 100 to 105°C has been in existence since 1925 **(11)**. Although not held in high esteem, the procedure is easy to use, and there is a fair correlation between dry-oven aging and natural aging **(3, 4, 8)**. Aging at 80°C and 65 % relative humidity was selected to simulate aging in more humid climates, although data from natural aging for comparison are not available.

X1.6 Considerable data are available from accelerated aging at 90°C and 50 % relative humidity and these conditions are desirable for the evaluation of the permanence of paper.

X1.7 In order to develop a guide for the durability and life expectancy of paper, background data from a sampling of papers that are available in the marketplace has been developed for a collection of 28 uncoated and 20 coated book papers. Data on the uncoated papers are summarized in Table X1.1, and on the coated papers in Table X1.2.

X1.7.1 These papers were aged for 12 days at 90°C and 50 % relative humidity, and the data are summarized in Table X1.3.

X1.7.2 Data on a collection of 13 papers, two uncoated and eleven coated, are summarized in Table X1.4. Accelerated aging data for tearing strength and tensile properties (tensile strength, elongation, and tensile energy absorption) are summarized in Table X1.5.

X1.8 Historically, specifications for paper for permanent records have limited fiber sources to those that would result in no more than 1 % lignin in the papers. The use of alkaline

TABLE X1.1 Summary of Data Related to Durability of 23 Unaged Uncoated Papers[A]

Direction of Test Specimen	MD		CD	
Property:	*Average*	*Range*	*Average*	*Range*
Tear, mN	528	270 to 296	569	255 to 968
Tensile, kN/m	4.83	1.80 to 6.87	2.38	1.40 to 3.98
Elongation, %	1.93	1.6 to 2.3	4.17	2.6 to 6.0
TEA, J/m^2	54.6	32 to 81	75.1	22 to 137
Burst, kPa	162	124 to 290		
Brightness, %	75.0	67.3 to 83.4		
Thickness, 0.061 to 0.170 mm				
Grammage,[B] 51 to 101 g/m^2				

[A] Data generated by ASTM Subcommittee D06.20.
[B] Data from papers of various basis weights are grouped together. The extremes and averages are provided only to give a view of the market place.

TABLE X1.2 Summary of Data Related to Durability of 20 Unaged Coated Book Papers[A]

Direction of Test Specimen	MD		CD	
Property:	*Average*	*Range*	*Average*	*Range:*
Tear, mN	399	235 to 666	453	314 to 666
Tensile, kN/m	5.40	3.91 to 7.31	2.74	1.56 to 4.21
Elongation, %	2.04	1.84 to 2.4	5.09	2.7 to 7.1
TEA, J/m^2	65	46 to 101	104	25 to 208
Burst, kPa	207	145 to 296		
Brightness, %	78.4	68.1 to 85.0		
Thickness, 0.056 to 0.135 mm				
Grammage,[B] 66 to 120 g/m^2				

[A] Data generated by ASTM Subcommittee D06.20.
[B] Data from papers of various basis weights are grouped together. The extremes and averages are provided only to give a view of the market place.

TABLE X1.3 Retention, %, of Properties of 48 Papers after Aging for 12 Days at 90°C and 50 % RH[A]

Uncoated Papers:					
		pH < 7		pH > 7	
		9 Papers		19 Papers	
		Retention, %			
Property	Direction of Test Specimen	MD	CD	MD	CD
Tear	average	60	...	86	...
	range	50 to 73	...	59 to 101	...
Tensile	average	85	89	98	98
	range	76 to 90	85 to 96	89 to 106	90 to 103
Elongation	average	68	65	89	87
	range	56 to 76	49 to 82	73 to 103	66 to 102
TEA	average	54	57	86	85
	range	41 to 66	38 to 79	51 to 109	58 to 105
Burst	average	80		94	
	range	62 to 92		82 to 108	
Brightness	average	89		96	
	range	71 to 97		93 to 98	
Coated Papers:					
		pH < 7		pH > 7	
		7 Papers		13 Papers	
		Retention, %			
		MD	CD	MD	CD
Tear	average	77	...	82	...
	range	70 to 87	...	75 to 98	...
Tensile	average	89	90	94	94
	range	80 to 95	87 to 94	84 to 104	89 to 101
Elongation	average	69	62	79	71
	range	58 to 73	48 to 71	65 to 99	50 to 89
TEA	average	60	56	73	68
	range	44 to 66	40 to 68	52 to 101	45 to 91
Burst	average	82		91	
	range	79 to 88		63 to 102	
Brightness	average	92		95	
	range	87 to 95		92 to 97	

[A] Data generated by ASTM Subcommittee D06.20.

papermaking technologies, including the use of alkaline sizing and alkaline fillers, may change the situation for some applications. Although some yellowing occurs during light exposure and during dark storage, limited laboratory data show that the physical properties of alkaline papers containing substantial quantities of lignin do not change appreciably during accelerated aging in a moist atmosphere **(12, 13)**.

X1.8.1 Beyond papers for use in archives, libraries, and other permanent records, there are many other end uses where alkaline papers with alkaline size and containing an alkaline filler, and containing substantial quantities of lignin, probably would be suitable for long-term use and, for economic reasons, desirable. The user would decide whether yellowing during light exposure or long-term storage, or both, would be acceptable, and these needs should be agreed upon between the buyer and the seller, and written into standards intended for the purpose.

X1.9 Appearance properties, such as color and reflectance (brightness, whiteness, etc.) that may be affected by light and by dark aging, may be important to the user. The traditional use of bleached chemical wood, or cotton, has been recognized as a way to preserve appearance properties. As fiber sources are less uniform than in the past, it is desirable to measure the effect of light and of dark storage on the appearance properties of paper.

X1.9.1 Test Method D 3424, Procedures 3 and 7, may be used for evaluating fading properties.

TABLE X1.4 Summary of Data on Properties of 13 Papers[A]

Paper	pH	Sample	Tear, mN		Tensile, kN/m		Elongation, %		TEA, J/m^2	
			MD	CD	MD	CD	MD	CD	MD	CD
Coated:[B]										
	<7.5	A	452	531	5.41	2.83	1.54	3.86	55	82
		B	361	437	5.78	2.85	1.51	3.56	57	76
		C	454	537	5.97	2.73	1.60	3.31	63	89
		H	304	399	6.62	2.56	1.84	3.98	82	79
		I	329	435	5.38	2.12	1.58	4.03	56	66
		J	377	489	6.38	2.75	1.81	3.47	77	72
	>7.5	D	392	468	5.34	2.45	1.49	3.74	54	75
		E	428	559	6.50	2.30	1.64	3.51	72	66
		K	417	370	3.99	2.84	1.70	5.26	46	121
		L	427	458	4.90	2.38	1.49	6.33	47	118
		M	401	489	5.36	2.02	1.51	4.56	55	79
Not Coated:	5.7	F	724	822	5.84	2.52	1.40	3.80	55	75
	9.0	G	545	600	4.88	2.55	1.66	3.67	55	74

[A] Data supplied by National Information Standards Organization, Standards Committee II.
[B] The coated papers were torn and spotted with chlorophenol red as described in 10.2.1. The pH of the uncoated papers was determined by extraction.

TABLE X1.5 Retention of Properties of 13 Papers After Aging for 12 Days at 90°C and 50 % Relative Humidity[A]

Paper[B]	pH	Sample	Tear		Tensile		Elongation		TEA	
			MD	CD	MD	CD	MD	CD	MD	CD
Coated:										
	<7.5	A	77	78	106	95	95	78	100	76
		B	95	96	100	97	90	87	89	86
		C	87	90	96	93	89	85	83	62
		H	74	76	86	88	69	55	57	48
		I	90	85	101	98	97	72	100	74
		J	80	80	94	91	81	72	75	67
Average			84	84	97	94	87	75	84	69
	>7.5	D	100	94	96	99	85	103	81	101
		E	100	97	102	94	97	89	97	85
		K	88	108	99	100	89	88	85	83
		L	94	94	98	95	87	84	87	84
		M	96	94	102	101	97	79	98	80
Average			96	97	99	98	91	89	90	87
Not Coated:	5.7	F	50	55	86	86	73	66	58	57
	9.0	G	100	98	100	92	101	108	100	

[A] Calculated from data supplied by National Information Standards Organization, Standards Committee II.
[B] The coated papers were torn and spotted with chlorophenol red as described in 10.2.1. The pH of the uncoated papers was determined by extraction. Paper G is an alkaline filled paper.

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