WI 060808.02

T 460

DRAFT NO. 2

DATE June 14, 2006

TAPPI

WORKING GROUP CHAIRMAN JW Walkinshaw

SUBJECT CATEGORY Physical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Air resistance of paper (Gurley method)

(Revision of T 460 om-02)

(Underlines in text indicate changes/revisions since last draft)

1. Scope

1.1 This method is used to measure the air resistance of approximately 6.45 sq. cm. (l sq. in.) circular area of paper using a pressure differential of 1.22 kPa. The recommended range of the liquid column instrument is from 5 to 1800 seconds per 100 mL cylinder displacement. For more impermeable papers the time requirements become so excessive that other techniques are preferable.

1.2 This method measures the volume of air that passes through the test specimen, along with any possible leakage of air across the surface; therefore it is unsuitable for rough-surface papers which cannot be securely clamped so as to avoid significant surface and edge leakage.

1.3 For a similar method of measuring air resistance that tests paper at a higher pressure (approx. 3 kPa), and has higher resolution in measuring smaller air volumes, refer to TAPPI T 536. For a method of measuring air permeance at pressures up to 9.85 kPa, using both smaller and larger test areas, refer to TAPPI T 547.

2. Summary

This method measures the amount of time required for a certain volume of air to pass through a test specimen. The air pressure is generated by a gravity-loaded cylinder that captures an air volume within a chamber using a liquid seal. This pressurized volume of air is directed to the clamping gasket ring, which holds the test specimen. Air that passes through the paper specimen escapes to atmosphere through holes in the downstream clamping plate.

3. Significance

The air resistance of paper may be used as an indirect indicator of Z-directional fluid permeance, as well as other variables such as: degree of refining, absorbency (penetration of oil, water, etc.), apparent specific gravity, and filtering efficiency for liquids or gases. Air resistance is influenced by the internal structure and also the surface finish of the paper. Internal structure is controlled largely by the type and length of fibers, degree of hydration, orientation, and compaction of the fibers; as well as the type and amount of fillers and sizing. The measurement of air resistance is a useful control test for machine production; but due to the number and complexity of factors outlined above; careful judgment should be used in the specification limits for air resistance.

4. Definition

Air resistance is the resistance to the passage of air, offered by the paper structure, when a pressure difference exists across the boundaries of the specimen. It is quantified by obtaining the time for a given volume of air to flow through a specimen of given dimensions under a specified pressure, pressure difference, temperature, and relative humidity.

5. Apparatus[1]

5.1 *Oil sealed instruments*

5.1.1 Air resistance apparatus, consisting of a vertically positioned outer cylinder which is partly filled with a sealing fluid, and an inner cylinder that can slide freely in the outer cylinder. Air pressure, generated by the weight of the inner cylinder, is applied to the specimen which is held between clamping plates.

[1] Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list in the set of TAPPI Test Methods, or may be available from the TAPPI Quality and Standards Department.

5.1.2 The clamping plates are located at the bottom of the apparatus, and a center feed tube directs the pressurized air to the clamping plates. The top of the floating inner cylinder is closed.

NOTE I: On some earlier instruments, the clamping plates are mounted on top of the floating inner cylinder. Refer to Appendix A.l for additional details.

Some versions of this apparatus utilize a hand-tightened capstan (jackscrew) arrangement to tighten the clamping plates together, while other versions are equipped with a dead weight (typically 0.907 kg) loading a lever arm. The recommended clamping force is 180 ± 30 newtons. This mechanism provides a technique to give uniform loading, and thus minimize the operator influence on the test. Controlled clamping force is the preferred method of clamping the specimen.

5.1.3 An elastomeric gasket is attached to the clamping plate on the side exposed to air pressure to minimize the leakage of air between the surface of the paper specimen and the clamping plate. The gasket is 28.58 ± 0.13 mm inside diameter and 34.93 ± 0.13 mm outside diameter. A satisfactory material is Thiokol, grade ST, polished plate molded, 0.8 ± 0.1 mm thick, 50-60 IRHD (International Rubber Hardness Degrees – ISO 48). Other materials may be recommended by the instrument manufacturer. Since the hardness of the elastomer will change with age, this gasket must be replaced on a periodic basis to ensure optimum sealing characteristics. For alignment and protection, the gasket is cemented in a groove machined in the clamping plate. The groove is concentric with the aperture in the opposing plate. The groove is 28.45 +0.000 /-0.08 mm inside diameter and about 35.18 +0.08 /-0.000 mm outside diameter to fit the outside diameter of the basket, at a depth of 0.50 ± 0.03 mm.

5.1.4 The outer cylinder is 254 mm high with an internal diameter of 82.6 mm. It has four vertical bars, each 245.5 mm long, 2.4 mm wide and 2.4 mm thick, mounted equidistantly on the inner surface of the outer cylinder to serve as guides for the inner cylinder. It has a fluid level indicator to assist in adding the proper amount of sealing fluid.

5.1.5 The inner cylinder is 254 mm high with an outside diameter of 76.2 mm, an inside diameter of 74.1 mm, and has a total mass of 567 ± 0.5 g, so as to produce a nominal pressure of 1.22 kPa. It is made of an aluminum alloy and has graduation marks on the outside diameter which represent the volume circumscribed within the cylinder. These marks are used to indicate a certain volume of air that passes through the clamping area that holds the paper specimen. The cylinder is graduated in units of 50 mL with a total range of 350 mL.

NOTE 2: Some inner cylinders are also graduated in units of 25 mL for the first 100 mL, and have a graduation at the 400 mL interval.

5.1.6 A stopwatch or electric timer, capable of recording time to the nearest 0.1 second, is required. Some instruments are available with automatic timing devices.

5.2 *Electronic instruments*

5.2.1 There is another technique in use (1) that utilizes an electronic mass airflow meter to measure the outflow of air from a paper specimen that is subjected to a pressure differential of 1.22 kPa. By measuring the outflow (discharge of air) from the specimen, surface leakage does not bias the measurement. The test results are virtually identical to those obtained from the liquid column instrument when there is no surface leakage at the clamping rings of the liquid column instrument.

6. Materials

Sealing fluid: The outer cylinder is filled to the liquid level indicating mark with a lubricating oil having a kinematic viscosity of 10 to 13 mm /s (60-70 s Saybolt Universal) at 38°C and a flash point of at least 135°C. The specific gravity at 23°C must be between 0.86 and 0.89.

NOTE 3: A light spindle oil is suitable for this purpose. Oil must be used instead of water because it does not affect the moisture content of the specimen. Also, the higher specific gravity of water will affect the volume of air that passes through the specimen, as there is a "manometer effect" that causes a different amount of air to pass through the specimen than indicated by the graduations on the inner cylinder.

7. Calibration

7.1 The instrument can be tested for air leakage by clamping a thin piece of smooth impervious metal foil or cellophane between the clamping plates. A maximum leakage of 50 mL in 5 h is allowable. This test does not ensure a similar low surface leakage for a paper specimen under test.

7.2 Electronic timing devices should be checked in accordance with the manufacturer's instructions. Calibration flow restrictor plates will facilitate this test. Perform the calibration checks in accordance with the manufacturer's instructions.

8. Sampling

Obtain a sample of the paper in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product."

9. Test specimens

Prepare 10 test specimens of sufficient size from each test unit of the sample. A 50 mm square, or larger size, is generally adequate.

NOTE 4: The test results for some grades of paperboard may be affected by specimen cut size when there is inadequate stick-out from the clamping rings. This is due to transverse air flow through the edge of the specimen, rather than all of the air flowing through the sheet in the Z direction.

10. Conditioning

Condition and test the specimens in an atmosphere in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products."

11. Procedure

11.1 Oil sealed instruments

11.1.1 Place the instrument on a level surface, free of vibrations, so that the outer cylinder is vertical. Fill the outer cylinder with sealing fluid to a depth of about 125 mm, as indicated by a ring on the inner surface of the cylinder or to a depth specified by the instrument manufacturer.

11.1.22 Raise the inner cylinder before inserting the specimen in the test clamp until its rim is supported by the catch. Clamp the specimen between the clamping plates. Some versions use a hand-tightened capstan (jackscrew), while other versions are equipped with an eccentric cam lifting mechanism. Since the capstan version has no measurement or control of the clamping force, tighten with care in order to ensure proper specimen sealing. Over tightening, as well as under tightening, can cause erroneous results. Excessive clamping force may overstress the structural parts of the instrument and affect the parallel alignment of the upper and lower gasket surfaces. The eccentric cam lifting mechanism is actuated by turning one of the two knobs to the left or to the right of the lifting assembly. This self-locking design decreases the potential of using excessive clamping force. After the specimen is properly clamped, gently lower the inner cylinder until it floats.

NOTE 5: To avoid spilling the oil, raise the inner cylinder with no test specimen in the clamp area. Raise the cylinder slowly.

11.1.3 As the inner cylinder moves steadily downward, measure the number of seconds, to the nearest 0.1 s, required for the inner cylinder to descend from the 150 mL mark to the 250 mL mark, referenced to the rim of the outer cylinder.

NOTE 6: The interval between the 150 to 250 mL marks is specified as cylinder buoyancy effects limit the generation of 1.22 kPa average pressure to that specific interval. See Appendix A.2.

NOTE 7: If the results of the first two tests are less than five seconds or greater than 1800 seconds, stop testing and report that the air resistance is outside the range of this test method.

NOTE 8: One manufacturer of this equipment recommends a working range from a minimum of 10 seconds, with no upper limit. They advise caution in using the instrument for measurements below 10 seconds because the inner cylinder does not have adequate time to achieve a stable velocity of descent.

11.1.4 Refer to Table 1 and Table 2 for the appropriate correction factors if displacement intervals other than the 150 to 250 mL marks are used. Multiply the measured time by the correction factors from the appropriate table to obtain a corrected result for the alternate interval. It may be expedient to use shorter intervals for relatively impervious papers, and longer intervals for more porous papers. Also, instruments that use electronic timing devices may be adjusted to use different intervals. If the correction factors are not used, the percentage error related to the measurement interval can be determined from the data in the tables.

11.2 *Electronic instruments*

11.2.1 Refer to manufacturer's instructions for calibration and measurement procedures.

Table 1: Correction factors for timing 100 mL indicated displacement

Scale Markers Used	Correction factor (multiplier)
0 to 100 mL	1.017
50 to 150 mL	1.011
100 to 200 mL	1.006
150 to 250 mL	1.000
200 to 300 mL	0.994
250 to 350 mL	0.988

Table 2: Correction factors for timing 50 mL indicated displacement

Scale Markers Used	Correction factor (multiplier)
0 to 50 mL	2.040
50 to 100 mL	2.029
100 to 150 mL	2.017
150 to 200 mL	2.006
200 to 250 mL	1.994
250 to 300 mL	1.982
300 to 350 mL	1.970

11.3 Test five specimens with the top side up, and test five specimens with the top side down.

12. Report

12.1 For each test unit, report the air resistance as the mean of the ten tests in seconds required for 100 mL indicated cylinder displacement. Report to the nearest 0.1 s if less than 15 s and to the nearest second if it is 15 s or more. Also record the highest and lowest observed values, plus any values rejected in accordance with TAPPI T 1205 "Dealing with Suspect (Outlying) Test Determinations." If desired, report the standard deviation.

12.2 If the tests were performed without the controlled loading of clamping plates, indicate that information in the report.

12.3 Report any deviation in the test procedure, such as testing specimens at different clamping areas or using cylinders of different weights that generate different pressures. Also, there may be a reason to test one side only of specimens that exhibit "two-sidedness" properties.

13. Precision

13.1 The following estimates of repeatability and reproducibility are based on data from selected samples of the CTS-TAPPI Interlaboratory Program from 1997 through 2001. Samples on which this data is based were uncoated printing grades. Participants were asked to follow TAPPI Official Test Method T 460 om-96 to conduct this testing. Testing is based on 10 determinations per test result and 1 test result per lab, per material.

Repeatability = 8%

Reproducibility = 16%

The chart below shows representative data on which the figures above are based.

Air Resistance Measurements

(data in seconds)

Grade	Grand Mean	Stnd Dev Btwn Lab Results	Repeatability r and %r		Reproducibility R and %R		Labs Included
Printing	29.3	1.9	3.0	10.2%	5.2	17.7%	85
Printing	21.7	1.1	1.3	6.2%	3.1	14.1%	90
Printing	18.1	1.4	2.2	11.8%	3.9	21.7%	85
Printing	17.4	0.8	1.2	7.0%	2.3	13.4%	79
Printing	16.4	1.0	1.5	9.0%	2.8	17.0%	84
Printing	11.5	0.6	0.6	5.1%	1.7	14.7%	81

Repeatability and reproducibility are estimates of the maximum difference (at 95%) which should be expected when comparing test results for materials similar to those described above under similar test conditions. These estimates may not be valid for different materials or testing conditions.

The user of this data is advised that it is based on actual mill and laboratory testing. There is no knowledge of the exact degree to which the referenced test method was employed. The precision quoted provides an estimate of typical variation in test results which may be encountered when t his method is routinely used.

14. Keywords

Air permeance, Air permeability, Air resistance, Density, Densitometer, Porosity

15. Additional information

15.1 Effective date of issue: to be assigned.

15.2 The results of this test, when reported as seconds per 100 mL cylinder displacement, per 6.45 sq. cm. (1 sq. in.), are commonly referred to as Gurley seconds. When the indicated cylinder displacement is 100 mL, the actual volume of air that passes through the paper is 106 mL at 1.22 kPa, or 107 mL at atmospheric pressure.

15.3 The relationship to air permeance (*P*), in micrometers per pascal second, referenced to the density at 1.22 kPa is:

$$p = \frac{135.5}{t}$$

where t = seconds per 100 mL cylinder displacement

Prior to this issue, the air permeance formula that appeared in other published test methods was:

$$p = \frac{127}{t}$$

The revised constant can be calculated by 127 (107 ml/100 ml) which corrects for the volume change discussed in 15.2. This was calculated on the basis that the air flow through the test specimen was equal to the 100 mL cylinder displacement, however, this was proven to be an erroneous assumption.

15.4 Related methods: ASTM D 726, Method A; Australian, APPITA AS 1301.420; British, B.S. 5926; Canadian, PAPTAC D.14; International Organization for Standardization, ISO/DIS 5636-5; Scandinavian, SCAN P 19.

15.5 In ASTM D 726, Methods B and C describe techniques for measuring relatively impervious papers, and the values reported are not the same order of magnitude as with the described method.

15.6 In addition to the volume flow calculations, there are other substantive revisions in the 1996 issue of the method. They include:

- The relationship between cylinder displacement and test specimen differential pressure.
- The recommended measurement interval (starting and stopping points).

- The gasket and gasket retaining groove dimensions are toleranced to accommodate various manufacturers designs of this apparatus.

15.7 The 2002 revision includes a revised precision statement.

Appendix A

A.l In earlier versions, the clamping plates are located at the top of the floating inner cylinder, the bottom of the apparatus is closed; and no center feed tube exists. The specimen is clamped in place by using hand-tightened threaded fasteners. For instruments having the clamp in the top of the inner cylinder, raise the inner cylinder with one hand and clamp the specimen with the other. The proper procedure is to tighten the knurled nuts alternately so that the clamping pressure will be equal on both sides. If only one nut at a time is tightened, the clamp will not evenly compress the gasket against the specimen, and air leakage will probably occur. Specimen dimensions of 50 mm by 125 mm may be optimum for this version.

A.2 The test pressure in kPa, P, expressed as a function of cylinder position (2) referenced by the volume graduations on the inner cylinder, V (expressed in mL), can be determined by the following equation:

$$P = 1.247 - 1.418 \times 10^{-4} V$$

The correction factors in Tables 1 and 2 compensate for this decay in pressure as the buoyancy force increases as the inner cylinder descends into the oil.

References

1. Hagerty, G.A. and Walkinshaw, J.W., “Design of a Modern Air Permeability Instrument Comparable to Gurley-type Instruments,” *Tappi Journal* **76** (Feb.): 97 (1993)
2. Walkinshaw, J.W. and Hagerty, G.A., “Analysis of Gurley-type Air Permeability Measurement and the Use of Electronic Flow Sensors,” *Tappi Journal* **75** (March): 181 (1992).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Director of Quality and Standards. ■

WI 060808.02

T 460

DRAFT NO. 1

DATE March 1, 2006

TAPPI

WORKING GROUP
CHAIRMAN to be assigned

SUBJECT
CATEGORY Physical Properties

RELATED
METHODS See "Additional Information"

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Air resistance of paper (Gurley method)

(Five-year review of T 460 om-02)

1. Scope

1.1 This method is used to measure the air resistance of approximately 6.45 sq. cm. (l sq. in.) circular area of paper using a pressure differential of 1.22 kPa. The recommended range of the liquid column instrument is from 5 to 1800 seconds per 100 mL cylinder displacement. For more impermeable papers the time requirements become so excessive that other techniques are preferable.

1.2 This method measures the volume of air that passes through the test specimen, along with any possible leakage of air across the surface; therefore it is unsuitable for rough-surface papers which cannot be securely clamped so as to avoid significant surface and edge leakage.

1.3 For a similar method of measuring air resistance that tests paper at a higher pressure (approx. 3 kPa), and has higher resolution in measuring smaller air volumes, refer to TAPPI T 536. For a method of measuring air permeance at pressures up to 9.85 kPa, using both smaller and larger test areas, refer to TAPPI T 547.

2. Summary

This method measures the amount of time required for a certain volume of air to pass through a test specimen. The air pressure is generated by a gravity-loaded cylinder that captures an air volume within a chamber using a liquid seal. This pressurized volume of air is directed to the clamping gasket ring, which holds the test specimen. Air that passes through the paper specimen escapes to atmosphere through holes in the downstream clamping plate.

3. Significance

The air resistance of paper may be used as an indirect indicator of Z-directional fluid permeance, as well as other variables such as: degree of beatingrefining, absorbency (penetration of oil, water, etc.), apparent specific gravity, and filtering efficiency for liquids or gases. Air resistance is influenced by the internal structure and also the surface finish of the paper. Internal structure is controlled largely by the type and length of fibers, degree of hydration, orientation, and compaction of the fibers; as well as the type and amount of fillers and sizing. The measurement of air resistance is a useful control test for machine production; but due to the number and complexity of factors outlined above,above; careful judgment should be used in the specification limits for air resistance.

4. Definition

Air resistance is the resistance to the passage of air, offered by the paper structure, when a pressure difference exists across the boundaries of the specimen. It is quantified by obtaining the time for a given volume of air to flow through a specimen of given dimensions under a specified pressure, pressure difference, temperature, and relative humidity.

5. Apparatus[1]

5.1 Air resistance apparatus, consisting of a vertically positioned outer cylinder which is partly filled with a sealing fluid, and an inner cylinder that can slide freely in the outer cylinder. Air pressure, generated by the weight of the inner cylinder, is applied to the specimen which is held between clamping plates.

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[1] Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list in the set of TAPPI Test Methods, or may be available from the TAPPI Quality and Standards Department.

5.2 The clamping plates are located at the bottom of the apparatus, and a center feed tube directs the pressurized air to the clamping plates. The top of the floating inner cylinder is closed.

NOTE I: On some earlier instruments, the clamping plates are mounted on top of the floating inner cylinder. Refer to Appendix A.l for additional details.

Some versions of this apparatus utilize a hand-tightened capstan (jackscrew) arrangement to tighten the clamping plates together, while other versions are equipped with a dead weight (typically 0.907 kg) loading a lever arm. The recommended clamping force is 180 ± 30 newtons. This mechanism provides a technique to give uniform loading, and thus minimize the operator influence on the test. Controlled clamping force is the preferred method of clamping the specimen.

5.3 An elastomeric gasket is attached to the clamping plate on the side exposed to air pressure to minimize the leakage of air between the surface of the paper specimen and the clamping plate. The gasket is 28.58 ± 0.13 mm inside diameter and 34.93 ± 0.13 mm outside diameter. A satisfactory material is Thiokol, grade ST, polished plate molded, 0.8 ± 0.1 mm thick, 50-60 IRHD (International Rubber Hardness Degrees – ISO 48). Other materials may be recommended by the instrument manufacturer. Since the hardness of the elastomer will change with age, this gasket must be replaced on a periodic basis to ensure optimum sealing characteristics. For alignment and protection, the gasket is cemented in a groove machined in the clamping plate. The groove is concentric with the aperture in the opposing plate. The groove is 28.45 +0.000 /-0.08 mm inside diameter and about 35.18 +0.08 /-0.000 mm outside diameter to fit the outside diameter of the basket, at a depth of 0.50 ± 0.03 mm.

5.4 The outer cylinder is 254 mm high with an internal diameter of 82.6 mm. It has four vertical bars, each 245.5 mm long, 2.4 mm wide and 2.4 mm thick, mounted equidistantly on the inner surface of the outer cylinder to serve as guides for the inner cylinder. It has a fluid level indicator to assist in adding the proper amount of sealing fluid.

5.5 The inner cylinder is 254 mm high with an outside diameter of 76.2 mm, an inside diameter of 74.1 mm, and has a total mass of 567 ± 0.5 g, so as to produce a nominal pressure of 1.22 kPa. It is made of an aluminum alloy and has graduation marks on the outside diameter which represent the volume circumscribed within the cylinder. These marks are used to indicate a certain volume of air that passes through the clamping area that holds the paper specimen. The cylinder is graduated in units of 50 mL with a total range of 350 mL.

NOTE 2: Some inner cylinders are also graduated in units of 25 mL for the first 100 mL, and have a graduation at the 400 mL interval.

5.6 A stopwatch or electric timer, capable of recording time to the nearest 0.1 second, is required. Some instruments are available with automatic timing devices.

6. Materials

Sealing fluid: The outer cylinder is filled to the liquid level indicating mark with a lubricating oil having a kinematic viscosity of 10 to 13 mm /s (60-70 s Saybolt Universal) at 38° C and a flash point of at least 135°C. The specific gravity at 23°C must be between 0.86 and 0.89.

NOTE 3: A light spindle oil is suitable for this purpose. Oil must be used instead of water because it does not affect the moisture content of the specimen. Also, the higher specific gravity of water will affect the volume of air that passes through the specimen, as there is a "manometer effect" that causes a different amount of air to pass through the specimen than indicated by the graduations on the inner cylinder.

7. Calibration

7.1 The instrument can be tested for air leakage by clamping a thin piece of smooth impervious metal foil or cellophane between the clamping plates. A maximum leakage of 50 mL in 5 h is allowable. This test does not ensure a similar low surface leakage for a paper specimen under test.

7.2 Electronic timing devices should be checked in accordance with the manufacturer's instructions. Calibration flow restrictor plates will facilitate this test. Perform the calibration checks in accordance with the manufacturer's instructions.

8. Sampling

Obtain a sample of the paper in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product."

9. Test specimens

Prepare 10 test specimens of sufficient size from each test unit of the sample. A 50 mm square, or larger size, is generally adequate.

NOTE 4: The test results for some grades of paperboard may be affected by specimen cut size when there is inadequate stick-out from the clamping rings. This is due to transverse air flowairflow through the edge of the specimen, rather than all of the air flowing through the sheet in the Z direction.

10. Conditioning

Condition and test the specimens in an atmosphere in accordance with TAPPI T 402 "Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products."

11. Procedure

11.1 Oil sealed instruments

11.1.1 Place the instrument on a level surface, free of vibrations, so that the outer cylinder is vertical. Fill the outer cylinder with sealing fluid to a depth of about 125 mm, as indicated by a ring on the inner surface of the cylinder or to a depth specified by the instrument manufacturer.

11.1.22 Raise the inner cylinder before inserting the specimen in the test clamp until its rim is supported by the catch. Clamp the specimen between the clamping plates. Some versions use a hand-tightened capstan (jackscrew), while other versions are equipped with an eccentric cam lifting mechanism. Since the capstan version has no measurement or control of the clamping force, tighten with care in order to ensure proper specimen sealing. Over tightening, as well as under tightening, can cause erroneous results. Excessive clamping force may overstress the structural parts of the instrument and affect the parallel alignment of the upper and lower gasket surfaces. The eccentric cam lifting mechanism is actuated by turning one of the two knobs to the left or to the right of the lifting assembly. This self-locking design decreases the potential of using excessive clamping force. After the specimen is properly clamped, gently lower the inner cylinder until it floats.

NOTE 5: To avoid spilling the oil, raise the inner cylinder with no test specimen in the clamp area. Raise the cylinder slowly.

11.1.3 As the inner cylinder moves steadily downward, measure the number of seconds, to the nearest 0.1 s, required for the inner cylinder to descend from the 150 mL mark to the 250 mL mark, referenced to the rim of the outer cylinder.

NOTE 6: The interval between the 150 to 250 mL marks is specified as cylinder buoyancy effects limit the generation of 1.22 kPa average pressure to that specific interval. See Appendix A.2.

NOTE 7: If the results of the first two tests are less than five seconds or greater than 1800 seconds, stop testing and report that the air resistance is outside the range of this test method.

NOTE 8: One manufacturer of this equipment recommends a working range from a minimum of 10 seconds, with no upper limit. They advise caution in using the instrument for measurements below 10 seconds because the inner cylinder does not have adequate time to achieve a stable velocity of descent.

11.1.4 Refer to Table 1 and Table 2 for the appropriate correction factors if displacement intervals other than the 150 to 250 mL marks are used. Multiply the measured time by the correction factors from the appropriate table to obtain a corrected result for the alternate interval. It may be expedient to use shorter intervals for relatively impervious papers, and longer intervals for more porous papers. Also, instruments that use electronic timing devices may be adjusted to use different intervals. If the correction factors are not used, the percentage error related to the measurement interval can be determined from the data in the tables.

11.2 *Electronic instruments*

11.2.1 Refer to manufacturer's instructions for calibration and measurement procedures.

Table 1: Correction factors for timing 100 mL indicated displacement

Scale Markers Used	Correction factor (multiplier)
0 to 100 mL	1.017
50 to 150 mL	1.011
100 to 200 mL	1.006
150 to 250 mL	1.000
200 to 300 mL	0.994
250 to 350 mL	0.988

Table 2: Correction factors for timing 50 mL indicated displacement

Scale Markers Used	Correction factor (multiplier)
0 to 50 mL	2.040
50 to 100 mL	2.029
100 to 150 mL	2.017
150 to 200 mL	2.006
200 to 250 mL	1.994
250 to 300 mL	1.982
300 to 350 mL	1.970

11.5 3 Test five specimens with the top side up, and test five specimens with the top side down.

12. Report

12.1 For each test unit, report the air resistance as the mean of the ten tests in seconds required for 100 mL indicated cylinder displacement. Report to the nearest 0.1 s if less than 15 s and to the nearest second if it is 15 s or more. Also record the highest and lowest observed values, plus any values rejected in accordance with TAPPI T 1205 “Dealing with Suspect (Outlying) Test Determinations.” If desired, report the standard deviation.

12.2 If the tests were performed without the controlled loading of clamping plates, indicate that information in the report.

12.3 Report any deviation in the test procedure, such as testing specimens at different clamping areas or using cylinders of different weights that generate different pressures. Also, there may be a reason to test one side only of specimens that exhibit “two-sidedness” properties.

13. Precision

13.1 The values of repeatability and reproducibility provided below have been calculated for test results each of which is the average of 10 replicate test determinations. The values are based on data obtained from the CTS Collaborative Reference Program for Paper and Paperboard, Reports 131G through 142G (April 1991 through March 1993) in which the range of test results was 10.6 to 31.82 seconds per 100 mL cylinder displacement. The terms are in accordance with the definitions in TAPPI T 1206 "Precision Statement for Test Methods."

13.2 Repeatability (within a laboratory) = 36.5%.

13.3. Reproducibility (between laboratories) = 39.5%

13.4 Comparability is not known.

13.5 The user of these precision data is advised that it is based on actual mill testing, laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The precision quoted provides an estimate of typical variation in test results which may be encountered when this method is routinely used by two or more parties.

13.1 The following estimates of repeatability and reproducibility are based on data from selected samples of the CTS-TAPPI Interlaboratory Program from 1997 through 2001. Samples on which this data is based were uncoated printing grades. Participants were asked to follow TAPPI Official Test Method T 460 om-96 to conduct this testing. Testing is based on 10 determinations per test result and 1 test result per lab, per material.

Repeatability = 8%

Reproducibility = 16%

The chart below shows representative data on which the figures above are based.

Air Resistance Measurements

(data in seconds)

Grade	Grand Mean	Stnd Dev Btwn Lab Results	Repeatability r and %r		Reproducibility R and %R		Labs Included
Printing	29.3	1.9	3.0	10.2%	5.2	17.7%	85
Printing	21.7	1.1	1.3	6.2%	3.1	14.1%	90
Printing	18.1	1.4	2.2	11.8%	3.9	21.7%	85
Printing	17.4	0.8	1.2	7.0%	2.3	13.4%	79
Printing	16.4	1.0	1.5	9.0%	2.8	17.0%	84
Printing	11.5	0.6	0.6	5.1%	1.7	14.7%	81

Repeatability and reproducibility are estimates of the maximum difference (at 95%) which should be expected when comparing test results for materials similar to those described above under similar test conditions. These estimates may not be valid for different materials or testing conditions.

The user of this data is advised that it is based on actual mill and laboratory testing. There is no knowledge of the exact degree to which the referenced test method was employed. The precision quoted provides an estimate of typical variation in test results which may be encountered when t his method is routinely used.

14. Keywords

Air permeance, Air permeability, Air resistance, Density, Densitometer, Porosity

15. Additional information

15.1 Effective date of issue: to be assigned.

15.2 The results of this test, when reported as seconds per 100 mL cylinder displacement, per 6.45 sq. cm. (1 sq. in.), are commonly referred to as Gurley seconds. When the indicated cylinder displacement is 100 mL, the actual volume of air that passes through the paper is 106 mL at 1.22 kPa, or 107 mL at atmospheric pressure.

15.3 The relationship to air permeance (*P*), in micrometers per pascal second, referenced to the density at 1.22 kPa is:

$$p = \frac{135.5}{t}$$

where t = seconds per 100 mL cylinder displacement

Prior to this issue, the air permeance formula that appeared in other published test methods was:

$$p = \frac{127}{t}$$

The revised constant can be calculated by 127 (107 ml/100 ml) which corrects for the volume change discussed in 15.2. This was calculated on the basis that the air flow through the test specimen was equal to the 100 mL cylinder displacement, however, this was proven to be an erroneous assumption.

15.4 There is another technique in use (1) that utilizes an electronic mass airflow meter to measure the outflow of air from a paper specimen that is subjected to a pressure differential of 1.22 kPa. By measuring the outflow (discharge of air) from the specimen, surface leakage does not bias the measurement. The test results are virtually identical to those obtained from the liquid column instrument when there is no surface leakage at the clamping rings of the liquid column instrument.

15.5 Related methods: ASTM D 726, Method A; Australian, APPITA AS 1301.420; British, B.S. 5926; Canadian, CPPA PAPTAC D.14; International Organization for Standardization, ISO/DIS 5636-5; Scandinavian, SCAN P 19.

15.6 In ASTM D 726, Methods B and C describe techniques for measuring relatively impervious papers, and the values reported are not the same order of magnitude as with the described method.

15.7 In addition to the volume flow calculations, there are other substantive revisions in the 1996 issue of the method. They include:

- The relationship between cylinder displacement and test specimen differential pressure.
- The recommended measurement interval (starting and stopping points).
- The gasket and gasket retaining groove dimensions are toleranced to accommodate various manufacturers designs of this apparatus.

15.8 The 2002 revision includes a revised precision statement.

Appendix A

A.l In earlier versions, the clamping plates are located at the top of the floating inner cylinder, the bottom of the apparatus is closed; and no center feed tube exists. The specimen is clamped in place by using hand-tightened threaded fasteners. For instruments having the clamp in the top of the inner cylinder, raise the inner cylinder with one hand and clamp the specimen with the other. The proper procedure is to tighten the knurled nuts alternately so that the clamping pressure will be equal on both sides. If only one nut at a time is tightened, the clamp will not evenly compress the gasket against the specimen, and air leakage will probably occur. Specimen dimensions of 50 mm by 125 mm may be optimum for this version.

A.2 The test pressure in kPa, P, expressed as a function of cylinder position (2) referenced by the volume graduations on the inner cylinder, V (expressed in mL), can be determined by the following equation:

$$P = 1.247 - 1.418 \times 10^{-4} V$$

The correction factors in Tables 1 and 2 compensate for this decay in pressure as the buoyancy force increases as the inner cylinder descends into the oil.

References

1. Hagerty, G.A. and Walkinshaw, J.W., "Design of a Modern Air Permeability Instrument Comparable to Gurley-type Instruments," *Tappi Journal* **76** (Feb.): 97 (1993)

2. Walkinshaw, J.W. and Hagerty, G.A., "Analysis of Gurley-type Air Permeability Measurement and the Use of Electronic Flow Sensors," *Tappi Journal* **75** (March): 181 (1992).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Director of Quality and Standards. ■