BS ISO 5636-3:2013

BSI Standards Publication

Paper and board — Determination of air permeance (medium range)

Part 3: Bendtsen method

National foreword

This British Standard is the UK implementation of ISO 5636-3:2013. It supersedes BS 6538-2:1992 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PAI/11, Methods of test for paper, board and pulps.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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INTERNATIONAL STANDARD

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Third edition
2013-11-01

Paper and board — Determination of air permeance (medium range) —

Part 3: Bendtsen method

Papier et carton — Détermination de la perméabilité à l'air (plage de valeurs moyennes) —

Partie 3: Méthode Bendtsen

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

This third edition cancels and replaces the second edition (ISO 5636-3:1992), which has been technically revised. In this third edition mainly editorial changes have been made and also precision data has been added as informative Annex C.

ISO 5636 consists of the following parts, under the general title *Paper and board — Determination of air permeance (medium range)*:

— *Part 3: Bendtsen method*

— *Part 4: Sheffield method*

— *Part 5: Gurley method*

— *Part 6: Oken method*

NOTE 1 *Part 1: General method* will be withdrawn after the third editions of Parts 3, 4 and 5 have been published, as it was considered redundant.

NOTE 2 *Part 2: Schopper method* was withdrawn in 2006 as it was considered obsolete.

NOTE 3 *Part 6: Oken method* is being prepared.

INTERNATIONAL STANDARD **ISO 5636-3:2013(E)**

Paper and board — Determination of air permeance (medium range) —

Part 3: Bendtsen method

1 Scope

This part of ISO 5636 specifies the Bendtsen method for determining the air permeance of paper and board using the Bendtsen apparatus.

It is applicable to papers and boards which have air permeances between 0,35 µm/(Pa·s) and 15 µm/(Pa·s) when tested with the Bendtsen apparatus.

It is unsuitable for rough-surfaced materials which cannot be securely clamped to avoid leakage.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 186, *Paper and board — Sampling to determine average quality*

ISO 187, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
air permeance
mean air flow rate through unit area under unit pressure difference in unit time, under specified conditions

Note 1 to entry: Air permeance is expressed in micrometres per pascal second [1 ml/(m^2·Pa·s) = 1 µm/(Pa·s)].

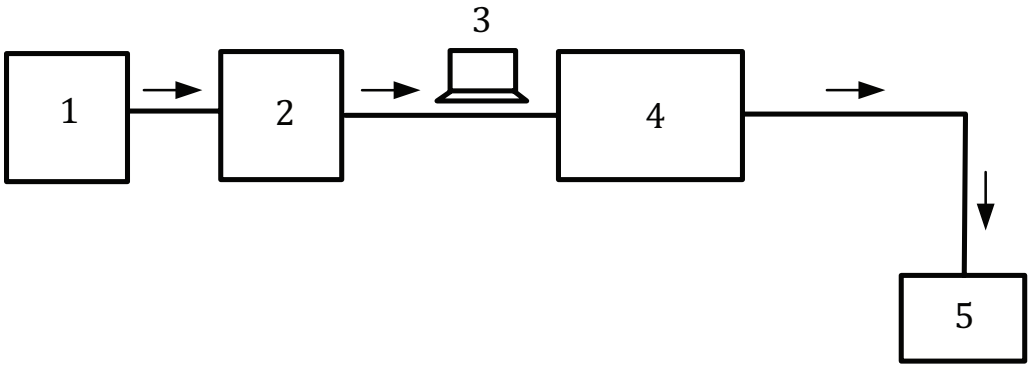
Note 2 to entry: This property is called air permeance, and not air permeability, because it is reported as a sheet property and is not standardized with respect to thickness to give a material property per unit thickness.

4 Principle

A test piece is clamped between a circular gasket and an annular flat surface of known dimensions. The absolute air pressure on one side of the test area of the test piece is equivalent to atmospheric pressure and the difference in pressure between the two sides of the test piece is maintained at a small, substantially constant, value during the test. Determination of the flow of air through the test area in a specified time.

5 Apparatus

Bendtsen apparatus, see Figure 1, consisting of a compressor (see 5.1) and a pressure stabilizing reservoir (see 5.2) to supply air, a flowmeter (see 5.4) with a pressure controlling device (see 5.3) and a measuring head (see 5.5).



Key

1 compressor
2 pressure stabilizing reservoir
3 pressure controlling device
4 flowmeter
5 sample clamping device and measuring head

Figure 1 — Flow diagram of the Bendtsen apparatus

5.1 Compressor, generating air at a pressure of about 127 kPa. If necessary, filters shall be provided to ensure that the air is clean and free of oil.

5.2 Pressure stabilizing reservoir, having a vessel volume of about 10 litres and installed between the compressor and the pressure controlling device, or some other means of providing a stable air flow.

NOTE The pressure stabilizing reservoir is not normally supplied with the apparatus. Its provision, or some other means of providing a stable air flow, is the responsibility of the user.

5.3 Pressure controlling device, to control the air pressure at the inlet of the flowmeter. This shall comprise a manostat weight, a pressure regulator or some other means of creating a steady nominal air pressure of (1,47 ± 0,02) kPa measured at the manostat.

NOTE Most Bendtsen apparatus are provided with three interchangeable manostat weights but only the 1,47 kPa manostat meets the requirement of this part of ISO 5636.

5.4 Variable-area flowmeters, to measure the flow rate in the following ranges: 5 ml/min to 150 ml/min, 50 ml/min to 500 ml/min and 300 ml/min to 3 000 ml/min. The resolution of these variable-area flowmeters shall be 2 ml/min, 5 ml/min and 20 ml/min respectively. The variable-area flowmeter may be replaced by an electronic air flowmeter having a measuring range suitable for the material measured that allows the air flow to be determined with an error of less than ± 5 ml/min or ± 5 % whichever is greater.

On some apparatus the available measuring ranges are 0 to 300 ml/min and 300 ml/min to 3 000 ml/min. The resolution of these variable area flowmeters shall be 1 % of the maximum reading scale.

5.5 Measuring head, consisting of a device in which the test piece is clamped between an annular flat surface and a circular rubber gasket. The annular ring and the gasket shall be of such dimensions that the

test area of the test piece enclosed by either of them is (1 000 ± 20) mm^2. The tubing used to connect the head to the flowmeter shall be made of rubber or plastics material, (7,0 ± 0,5) mm in internal diameter and (690 ± 10) mm long.

NOTE 1 A longer length of tubing results in a significant pressure drop between the flowmeter and the measuring head.

NOTE 2 On most commercial instruments the valve at the outlet of the flowmeter has two outlets. For air permeance measurement the tubing is connected to the larger diameter outlet.

5.6 Flat non-porous plate, of approximate dimensions 100 mm x 100 mm, which can be clamped between the rubber orifice plates to check the zero reading.

5.7 Calibration plate device, to enable the test assembly to be connected to an external calibration system (see Clause 9 and Annex A).

6 Sampling

If the mean quality of a lot is to be determined, sampling shall be in accordance with ISO 186. If the tests are made on another type of sample, make sure that the test pieces taken are representative of the sample received.

7 Conditioning

Condition the sample in accordance with ISO 187.

8 Preparation of test pieces

Prepare the test pieces in the same atmospheric conditions as those used to condition the sample.

Cut not less than 10 test pieces and identify their two sides, for example side 1 and side 2. The test area shall be free from folds, wrinkles, holes, watermarks or defects not inherent to the sample. Do not handle the part of the test piece which will become part of the test area. An adequate test piece size is 100 mm x 100 mm.

If the air permeances measured on the two sides are significantly different and if this difference is required to be shown in the test report, 10 tests are required for each side.

9 Calibration

9.1 Variable-area flow-measuring device

Calibrate the variable-area flowmeter by temporarily replacing the measuring head with the appropriate calibrated capillary tube.

Calibrate the instrument sufficiently frequent to ensure that the reading does not deviate at any time by more than ± 5 % from the true value.

9.2 Electronic flow-measuring device

Calibrate the instrument according to the instructions of the manufacturer.

10 Procedure

Carry out the test in the same atmospheric conditions used for the conditioning and preparation of test pieces.

Tests shall be performed according to the instructions of the manufacturer.

Test a minimum of 10 test pieces, five with side 1 up and five with side 1 down.

If applicable, choose a variable-area flowmeter which gives readings greater than 20 % of the scale range with 1,47 kPa. Air flows above 1 200 ml/min shall not be used because at high air flows the pressure drop between the flowmeter and the measuring head significantly reduces the pressure in the measuring head.

NOTE Readings on variable-area flowmeters are unreliable at the low end of the scale range.

Check that the air flow reading obtained with the non-porous plate (see 5.6) clamped in the measurement gap is zero.

Place a test piece in the measuring gap and record the variable-area flowmeter reading at least 5 s after clamping, in ml/min, with the reading accuracy indicated in 5.4. Repeat for the remaining test pieces.

All papers are hygrosensitive to some degree, and readings should be taken at the initial stabilization point to avoid any possible effect of incoming air adding moisture to, or extracting moisture from, the test piece.

11 Calculation and expression of results

11.1 Calculation of air permeance

Calculate the air permeance, P, in micrometres per pascal second, to three significant figures, from Equation (1):

$$P = 0{,}011\ 3 \times q \tag{1}$$

where q is the mean air flow rate, in millilitres per minute, passing through the test area of 1 000 mm^2 at a related pressure of 1,47 kPa in the measuring head.

If required, calculate the mean air permeance for each side separately. If the means for the two sides are significantly different (more than 10 %), 10 tests are required for each side.

11.2 Reporting the results

Report the results with three significant figures.

If the air permeances measured on the two sides are significantly different (more than 10 %) and if this difference is required to be shown in the test report, report the means for the two sides separately. Otherwise, calculate the mean value of the measurements for the two sides.

11.3 Standard deviation and coefficient of variation

If the standard deviation or coefficient of variation is required, calculate it from the replicate rate of flow of air measurements and correct to micrometres per pascal second using Equation (1).

If the results for the two sides are reported separately, calculate the standard deviations or coefficients of variation for the two sides separately.

12 Test report

The test report shall include the following information:

a) a reference to this part of ISO 5636;

b) date and place of testing;

c) all the information necessary for the complete identification of the sample;

d) the conditioning atmosphere used;

e) the number of test pieces tested, as specified in Clause 10 and 11.1;

f) the nominal air pressure used;

g) if applicable, the flowmeter range used;

h) the mean air permeance or permeances, as specified in 11.2;

i) if required, the standard deviation or coefficient of variation or the values for each side, as specified in 11.3;

j) any deviations from this part of ISO 5636 that may have affected the results.

Annex A
(normative)

Calibration of capillary tubes and variable-area flowmeters

A.1 Checking variable-area flowmeters with capillary tubes

Flowmeter floats and tubes appear to be susceptible to wear. If a scale reading with the capillary tube connected differs by more than 5 % from the indicated value, the following procedure should be adopted:

a) Check the variable-area flowmeter against the capillary tube normally used for an adjacent variable-area flowmeter;

b) If both readings are high, check the variable-area flowmeter tube and float for cleanness and clean if necessary;

c) If both readings are low, check for constrictions or leaks in the system, for example kinks or leaks in the plastics or rubber tube. Replace tubing if kinks or leaks occur;

d) If the two readings do not agree, or if the faults found in b) or c) cannot be identified, calibrate the variable-area flowmeter according to A.2;

e) From the results of d) determine whether the variable-area flowmeter or capillary tube is at fault and replace if necessary.

A.2 Checking calibration of variable-area flowmeters

A.2.1 General

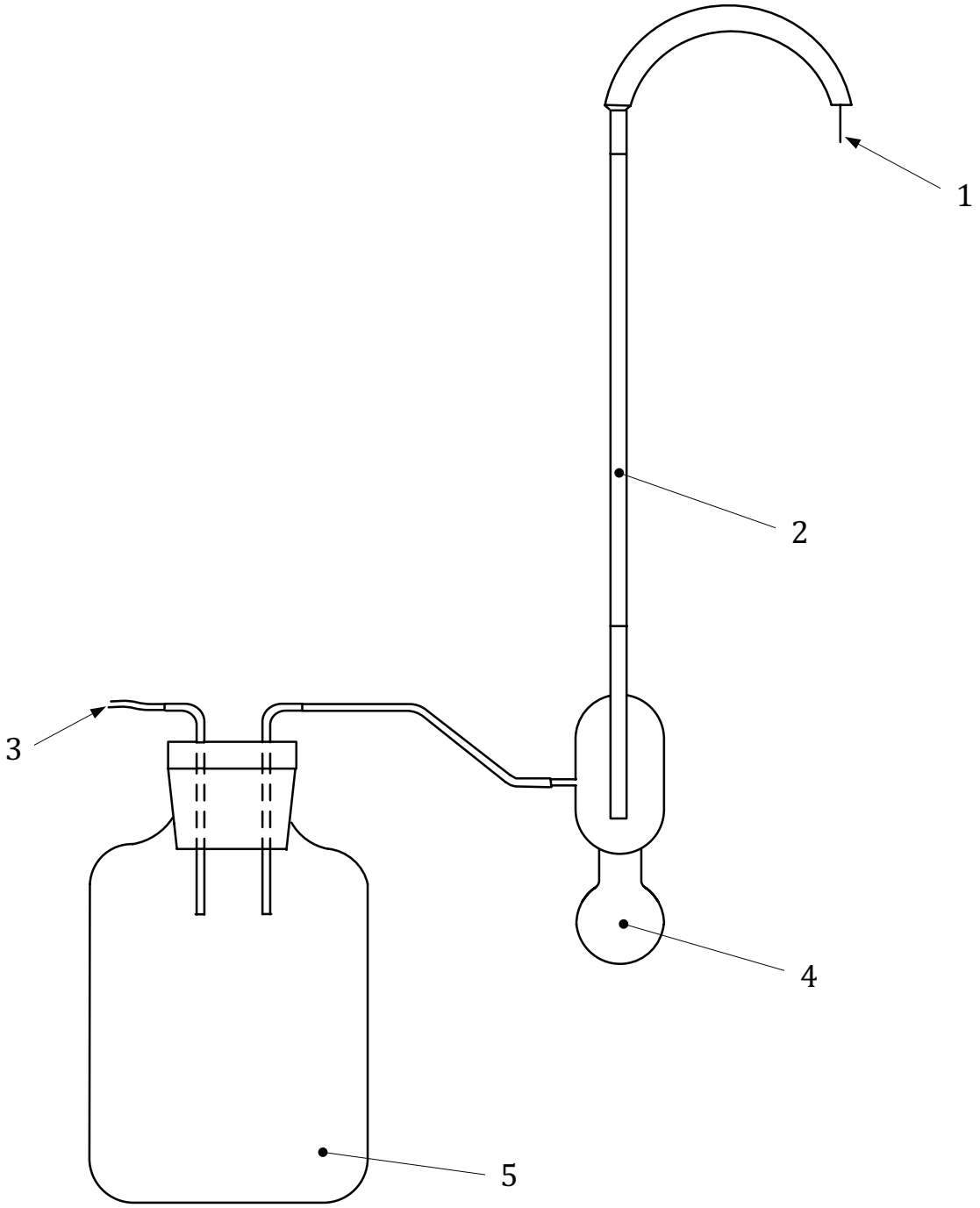
Variable-area flowmeters may be calibrated by checking against a soap film meter of which there are several designs. Figure A.1 shows a diagrammatic representation of a suitable meter.

NOTE Other calibration procedures are permitted provided they are at least as accurate as the procedure described in this Annex.

This procedure describes the calibration of variable-area flowmeters, using a soap-bubble meter (Figure A.1). The method can also be used to calibrate electronic flow-measuring devices, provided a suitable attachment is available.

The principle of the method is that the movement of a soap bubble introduced into an air flow from the flow-measuring device being tested is timed between two marks in a volumeter representing an accurately known volume and the actual air-flow rate is calculated. This is repeated at other air flow rates until the whole flowmeter range of the instrument has been covered.

NOTE This method of calibration gives satisfactory accuracy if the test atmospheric conditions do not deviate appreciably from 101,3 kPa and 23 °C. For this reason, it is desirable, if possible, to choose a day for calibration when the meteorological conditions are favourable.



Key

1 needle valve
2 volumeter
3 connection point
4 rubber bulb
5 glass flask, of capacity 1 litre

Figure A.1 — Soap-bubble meter

A.2.2 Apparatus and materials

A.2.2.1 Soap-bubble meter, consisting of

— glass flask or bottle, of capacity 1 litre,

— volumetric tube, with graduation marks indicating 50 ml, 1 000 ml and 2 000 ml; the different ranges may be achieved with replaceable volumeters (suitable designs are given in Reference [4] in the Bibliography),

— needle valve, and

— glass and rubber tubing of as large an internal diameter as practicable to minimize pressure drop.

A.2.2.2 Stopwatch, capable of being read to 0,1 s.

A.2.2.3 Soap solution, 3 % to 5 % liquid detergent in distilled water.

A.2.2.4 Barometer, or other means of ascertaining the actual atmospheric pressure.

NOTE It may be sufficient to contact a local meteorological station to obtain information about the atmospheric pressure.

A.2.3 Procedure

A.2.3.1 Make sure that the instrument is level on a surface free from variations. Make sure that the internal adjustment of the flowmeter has been carried out according to the instructions of the manufacturer.

A.2.3.2 To calibrate a variable-area flow-measuring device, disconnect the test assembly from the downstream end of the rubber or plastic tubing and connect in its place the soap-bubble meter. Set the valves to deliver air through the flowmeter to be calibrated and then through the soap-bubble meter at the connection point (3). Start the airflow, place the manostat weight corresponding to a pressure of 1,47 kPa on the shaft and start it spinning. Set the valves to deliver through the variable-area flowmeter to be calibrated to the soap-bubble meter. Adjust the needle valve to give a conveniently measurable air flow and ensure that the flow rate remains constant. Rapidly squeeze the rubber bulb at the bottom of the volumeter so that a soap bubble enters the volumeter tube. Note the time in seconds for it to move between marks representing a known volume. The volumeter range should be chosen so that the time taken for the bubble to pass from the first to the second graduation is longer than 30 s.

Repeat the procedure at about six different air flow rates distributed over the flowmeter measurement range such that all readings are greater than 20 % of the scale range.

Record the atmospheric pressure.

NOTE At high airflows the pressure drop in the system can cause errors in calibration. To minimize these errors, the length and diameter of the tubing should be the same in calibration as in testing.

A.2.4 Calculation

Calculate the true air flow, in millimetres per minute, from each measured time and volume and check that the flowmeter reading is within 5 % of this flow. If not, check the operation of the flowmeter and if necessary construct a calibration graph.

NOTE If extreme accuracy is required, it can be necessary to correct for temperature, pressure and relative humidity variations, but the precision of the method in other respects does not warrant the application of this correction.

A.3 Checking calibration of capillary tubes

To calibrate a capillary tube, remove needle valve (1 in Figure A.1), and connect the tube in its place. Disconnect the measuring head and connect the instrument to the soap-bubble meter as in A.2.3. Set the valves to deliver through the appropriate variable-area flowmeter. Rapidly squeeze the rubber bulb at the bottom of the volumeter and time the passage of a soap bubble as in A.2.3.

Calculate the air flow as in A.2.4.

Annex B
(normative)

Care and maintenance of variable-area flowmeter-type Bendtsen testers

B.1 Checking for air leaks

Check for air leaks by testing the circular land against the flat plate as described in Clause 10, using the 5 ml/min to 150 ml/min flowmeter. If the rotor does not remain at rest at the bottom of the flowmeter, check the plate and the land surfaces for damage and imperfections, and check the condition of the tubing and the connections.

B.2 Manostat weight

Care shall be taken when handling the manostat weight to avoid damage to the rim. In particular, it shall not be placed on the shaft until the air flow has been started and shall be removed before it has stopped.

Check that the axial hole through the weight is clean.

Disconnect the measuring head and attach to that end of the tube a T-piece with a suitable capillary tube attached in the "straight-though" position and a water manometer attached to the side position. Check that the pressure at this point is within 5 % of the desired manometer reading when the air flow is as follows:

a) 5 ml/min to 150 ml/min variable-area flowmeter

Air flow (ml/min)	10	100	150
Desired manometer reading (mm)	152	150	148

b) 50 ml/min to 500 ml/min variable-area flowmeter

Air flow (ml/min)	50	100	300	500
Desired manometer reading (mm)	152	151	149	146

c) 300 ml/min to 3 000 ml/min variable-area flowmeter

Desired manometer reading (mm): 150 ml/min ± 10 ml/min at all flow rates up to 1 200 ml/min. Do not use air flows above 1 200 ml/min, see Clause 10.

To ensure that the pressure drop between this point and the test piece is not significant, the connecting tube to the head shall be 5 mm in internal diameter and not more than 700 mm long.

The manostat weights shall not be lubricated.

B.3 Movement of floats

Check that the floats spin freely in the variable-area flowmeter tubes. Although a float which does not spin well may give stable readings, a spinning float has a self-cleaning action and is less likely to give erros by sticking to the walls of the tubes. Check the condition of the tubes as this mainly determines

whether it will spin properly, especially at low flow rates. Other factors important for good spinning are mechanical symmetry and condition of the top rim.

If a float becomes wedged in the spring at the bottom or top of a variable-area flowmeter tube, tap the instrument lightly while passing air through the tube. If this fails to free the float, loosen the bottom and top bushings around the tubes with a special spanner, take off the metal block at the top of the variable-area flowmeter and remove the tube. A recurrence of sticking can be prevented by adjusting the shape of the springs. The bottom spring should terminate in a horizontal loop centred in the variable-area flowmeter. The top spring should terminate in a vertical loop centred in the variable-area flowmeter.

B.4 Cleaning variable-area flowmeters

If a variable-area flowmeter tube or float is dirty, giving high readings, remove the float from the tube, clean both with liquid detergent or a suitable solvent, then dry in the air stream. If liquid detergent is used, add to the tube, flush with water, reversing the flow several times, and use diluted aqueous solution (a volume fraction of about 10 %) to clean the float. Finally, rinse both with distilled water, and dry in an air stream.

Replace faulty tubes.

B.5 Air tubes

Tubing should be regularly inspected for signs of deterioration and replaced if necessary. All tubing should be replaced at least once a year, whether or not if appears defective.

B.6 Capillary tubes

Capillary tubes can become dirty rather easily and, therefore, should be inspected regularly and carefully with a magnifying glass and, if necessary, cleaned in accordance with the procedure in Clause B.4.

Annex C
(informative)

Precision

The precision data presented in Tables C.1 and C.2 has been obtained from CEPI-CTS, the Comparative Testing Service of the Confederation of European Paper Industries. Estimates of repeatability and reproducibility from the CEPI-CTS program are based on round-robin work in 2011 in which 17 laboratories tested four different sample materials.

The calculations have been made according to ISO/TR 24498[2] and TAPPI T 1200[3].

The repeatability standard deviation reported in Table C.1 is the "pooled" repeatability standard deviation that is, the standard deviation is calculated as the root-mean-square of the standard deviations of the participating laboratories. This differs from the conventional definition of repeatability in ISO 5725-1[1].

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates may not be valid for different materials or different test conditions.

Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77.

NOTE 1 The *repeatability standard deviation* and the *within-laboratory standard deviation* are identical. However, the *reproducibility standard deviation* is NOT the same as *between-laboratories standard deviation*. The reproducibility standard deviation includes both the between-laboratories standard deviation and the standard deviation within a laboratory, viz.:

$$s^2_{\text{repeatability}} = s^2_{\text{within lab}}$$

but

$$s^2_{\text{reproducibility}} = s^2_{\text{within lab}} + s^2_{\text{between lab}}$$

NOTE 2 $2{,}77 = 1{,}96 \times \sqrt{2}$, provided that the test results have a normal distribution and that the standard deviation s is based on a large number of tests.

Table C.1 — Estimation of repeatability of the test method from CEPI-CTS

Sample	Number of laboratories	Mean value ml/min	Repeatability standard deviation s_r ml/min	Coefficient of variation $C_{V,r}$ %	Repeatability limit r ml/min
Level 1	16[a]	14,6	1,13	7,74	3,13
Level 2	17	123	3,07	2,50	8,51
Level 3	16[a]	507	21,1	4,16	58,5
Level 4	15[a]	1 924	72,5	3,77	201

[a] Outliers not included.

Table C.2 — Estimation of the reproducibility of the test method from CEPI-CTS

Sample	Number of laboratories	Mean value ml/min	Reproducibility standard deviation s_R ml/min	Coefficient of variation $C_{V,R}$ %	Reproducibility limit R ml/min
Level 1	16[a]	14,6	2,34	16,0	6,49
Level 2	17	123	7,17	5,83	19,9
Level 3	16[a]	507	40,0	7,89	111
Level 4	15[a]	1 924	234	12,2	649

[a] Outliers not included.

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[1] ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

[2] ISO/TR 24498:2006, *Paper, board and pulps — Estimation of uncertainty for test methods*

[3] TAPPI Test method T 1200 sp-07, *Interlaboratory evaluation of test methods to determine TAPPI repeatability and reproducibility*

[4] GOODERHAM. *J.W.J. Soc. Chem. Ind.* 1944, **63** p. 351

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