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

**Part 5:
Gurley method**

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

Partie 5: Méthode Gurley

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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 5636-5:2003), 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.

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

Part 5: Gurley method

1 Scope

This part of ISO 5636 specifies the Gurley method for determining the air permeance of paper and board using an air resistance tester, the Gurley apparatus.

It is applicable to papers and boards which have air permeances between $0,1 \mu\text{m}/(\text{Pa}\cdot\text{s})$ and $100 \mu\text{m}/(\text{Pa}\cdot\text{s})$ when tested with the Gurley apparatus.

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

This part of ISO 5636 may also be used to determine the air resistance of paper and board.

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 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

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*

ISO 385, *Laboratory glassware — Burettes*

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

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 [$1 \text{ ml}/(\text{m}^2\cdot\text{Pa}\cdot\text{s}) = 1 \mu\text{m}/(\text{Pa}\cdot\text{s})$].

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.

3.2

air resistance

time required for a specific volume of air under unit pressure to pass through unit area

Note 1 to entry: Air resistance is expressed in seconds per 100 millilitres [s/(100 ml)].

4 Principle

The air is compressed by the weight of a vertical cylinder floating in a liquid. A test piece is in contact with the compressed air and the cylinder falls steadily as air passes through the test piece. The time for a given volume of air to pass through the test piece, i.e. the air resistance is measured and from this the air permeance is calculated.

5 Apparatus and materials

5.1 Gurley apparatus, see [Figure 1](#), that consists of an outer cylinder (see [5.1.3](#)) partly filled with sealing fluid (see [5.2](#)) and an inner cylinder (see [5.1.4](#)) having an open top, sliding freely in the outer cylinder. Air pressure, provided by the weight of the inner cylinder, is applied to the test piece held between clamping plates (see [5.1.1](#)) in a circular orifice.

5.1.1 Clamping plates are at the base of the apparatus, and a central feed tube directs the pressurized air to the clamping plates. Some versions of this apparatus use a hand-tightened capstan (jackscrew) arrangement to tighten the clamping plates together, others are equipped with a dead weight of 901 g loading a lever arm and others use a pneumatic system. The recommended clamping force is (180 ± 30) N. 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 test piece.

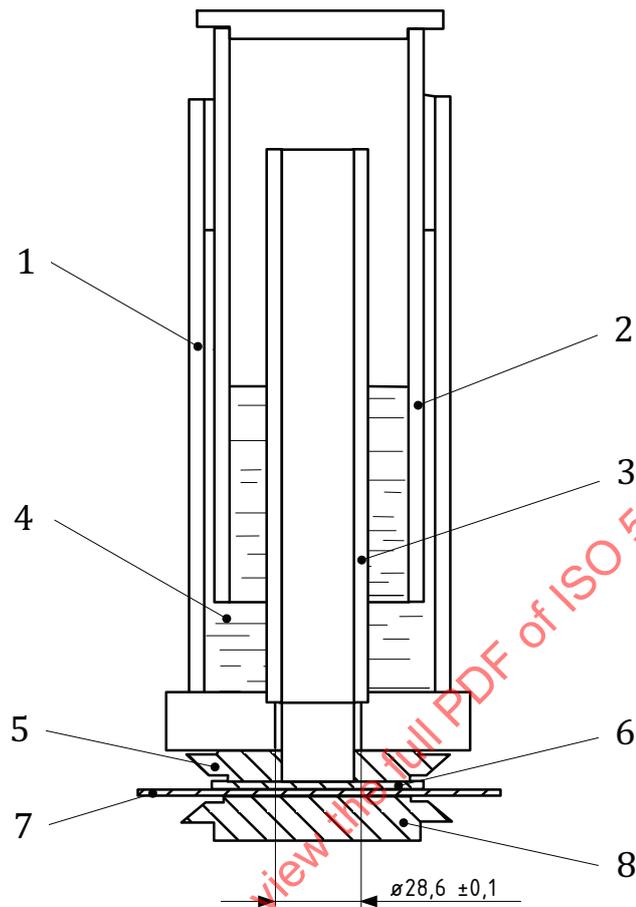
5.1.2 Rubber gasket attached to the clamping plate on the side exposed to the air pressure prevents leakage of air between the surface of the paper and the clamping plate. The gasket consists of a thin, elastic, oil-resistant, non-oxidizing material, having a smooth surface, a thickness of 0,7 mm to 1,0 mm and a hardness of 50 IRHD (International Rubber Hardness Degrees) in accordance with ISO 48. The inside diameter of the gasket is about 28,6 mm and the outside diameter is about 34,9 mm. The aperture of the gasket is concentrically aligned with the aperture in the clamping plates. To align and protect the gasket in use, it is cemented to a groove machined in the upper clamping plate. The groove is concentric with the aperture in the opposing plate, has an internal diameter of $(28,50 \pm 0,15)$ mm and a depth of $(0,45 \pm 0,05)$ mm. Its outside diameter is $(35,2 \pm 0,1)$ mm for convenience in inserting and attaching the gasket. The gasket, when mounted inside the concentric groove, defines the measurement area and shall have an inside diameter of $(28,6 \pm 0,1)$ mm (642 mm² area). The gasket should be changed at regular intervals.

5.1.3 Outer cylinder with a height of 254 mm and an internal diameter of 82,6 mm. The inner surface has three or four bars, not less than 190 mm and not greater than 245,5 mm in length and 2,4 mm square or 2,4 mm diameter, spaced equidistantly to serve as guides for the inner cylinder.

5.1.4 Inner cylinder, graduated in units of 50 ml and with a full-scale reading of at least 300 ml. It may have 25 ml graduations between the 0 ml and 100 ml markings. The scale markings represent true volumes enclosed within the inner cylinder and shall be accurate to within 3%. The exact volume of the inner cylinder may be checked by means of the procedure given in Annex A. The cylinder has a height of $(254,0 \pm 0,5)$ mm, an external diameter of $(76,2 \pm 0,5)$ mm and an internal diameter about 74 mm such that the mass of the cylinder assembly is $(567,0 \pm 0,5)$ g.

5.1.5 Volumes referred to are nominal volumes and should, in principle be increased by the volume of fluid displaced by the walls of the inner cylinder during the test. In practice, since this error is common to all instruments of this type, it is ignored.

Dimension in millimetres

**Key**

- 1 outer cylinder
- 2 inner cylinder mass 567 g
- 3 central feed tube
- 4 sealing fluid
- 5 upper clamping plate
- 6 rubber gasket
- 7 test piece
- 8 lower clamping plate

Figure 1 — Diagrammatic sketch of air resistance (Gurley) apparatus

5.2 Sealing fluid, oil having a density of $(860 \pm 30) \text{ kg/m}^3$ [$(0,86 \pm 0,03) \text{ g/cm}^3$], a viscosity of 16 cP to 19 cP at 20 °C in accordance with ISO 3104, and a flash point of at least 135 °C.

NOTE The change in specification of the oil viscosity from that of a kinematic viscosity of 10 mm²/s to 13 mm²/s at 38 °C is based on the typical physical properties of lightweight paraffin oils.

5.3 Ancillary equipment, stopwatch, or electric timer, accurate to within 0,5% at all levels and capable of being read to the nearest 0,1 s.

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

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

Calibrate the apparatus according to the instructions of the manufacturer or according to Annex A.

10 Procedure

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

It is essential to avoid vibration of the apparatus, as this increases the rate of air displacement.

Check that the air flow reading obtained with the non-porous plate (see 5.4) clamped in the clamping plates is zero.

For those papers where surface air leakage or leakage through the sheet may be a problem, the clamping force shall be controlled to ensure repeatability. The clamping force shall be repeatable and set at a force of (180 ± 30) N.

Place a test piece between the clamping plates and measure the time required, in seconds, for the first two consecutive 50 ml scale markings to pass the rim of the outer cylinder. The time shall be measured to the nearest 0,1 s. Repeat for the remaining test pieces.

For relatively impermeable papers and boards, the reading may be taken at the end of the first 50 ml interval. With very open or porous papers, a larger volume of air may be timed. If a steady movement of the inner cylinder is not attained before the zero mark is reached, timing may be started at the 50 ml mark.

If a volume other than 100 ml is used, calculate the time-based on 100 ml.

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):

$$P = \frac{135,3}{t} \quad (1)$$

where t is the mean time, in seconds, for the passage of 100 ml of air (as measured on the volume marks on the cylinder).

Equation (1) is based on a mean pressure difference of 1,22 kPa and a test area of 642 mm² and a volume of 100 ml of air passing through the test piece measured at room pressure.

NOTE Due to the testing principle of this method, the actual pressure in the instrument decreases as the cylinder descends into the oil and the actual volumes passing through the test piece are slightly greater than the scale volumes. In practice, since these errors are consistent and common to all instruments of this type, they are ignored.

If the air resistance is required, this shall be reported as "Air resistance (Gurley)" in seconds and is the mean time, t . Report air resistance with two significant figures.

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 air permeance with three significant figures.

If the air permeances measured on the two sides differ significantly (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 using the Gurley apparatus, first calculate the air permeances for the individual test pieces and from it the standard deviation or coefficient of variation.

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 complete identification of the sample;
- d) the conditioning atmosphere used;
- e) the number of test pieces tested, as specified in 10 and [11.1](#);
- f) the measured volume, if different from 100 ml;
- g) the mean air permeance or permeances as specified in [11.2](#);

- h) if required, the air resistance or air resistances, as specified in [11.1](#);
- 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.

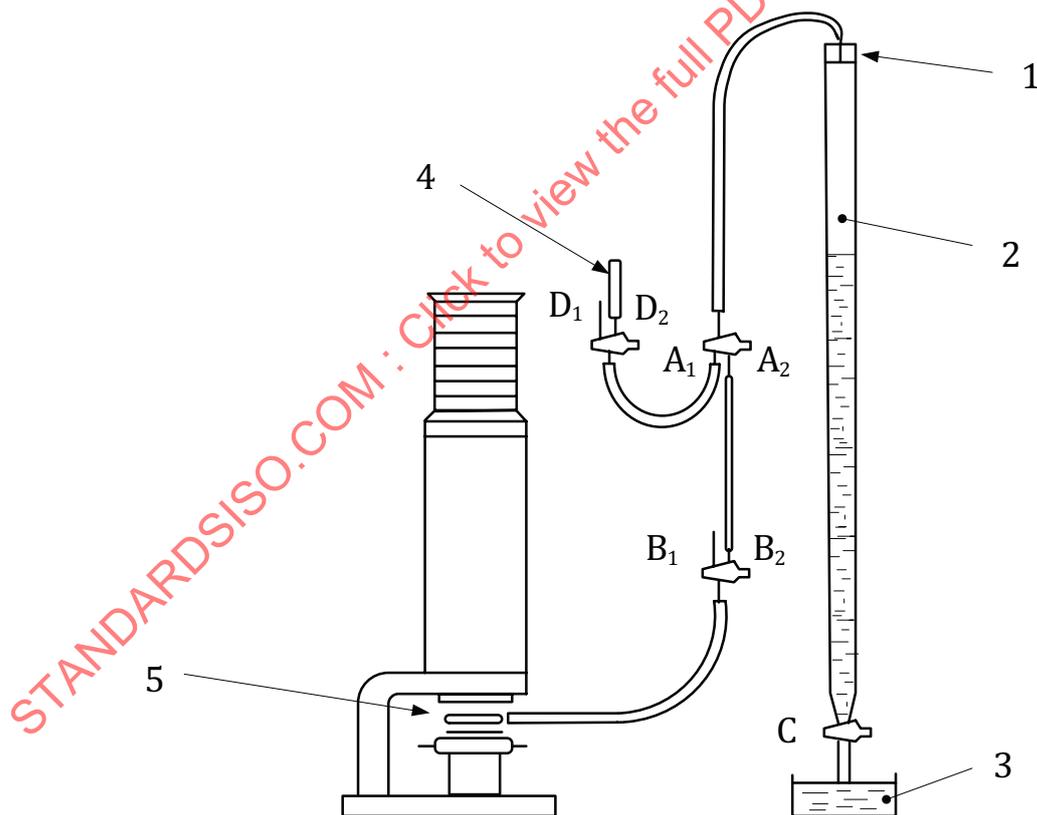
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Annex A (normative)

Volume check — Gurley apparatus

Check the apparatus for air leakage by clamping a thin sheet of smooth, rigid, impermeable metal or plastic between the orifice plates. Using the procedure in [Clause 10](#), the leakage shall not exceed 50 ml in 5 h. If there is a leak exceeding 50 ml in 5 h, repeat the check with a sheet of soft rubber in place of the hard-surfaced material. No air will then escape at the clamping plates and leaks elsewhere can be detected. Seal any leaks with neoprene or another suitable adhesive.

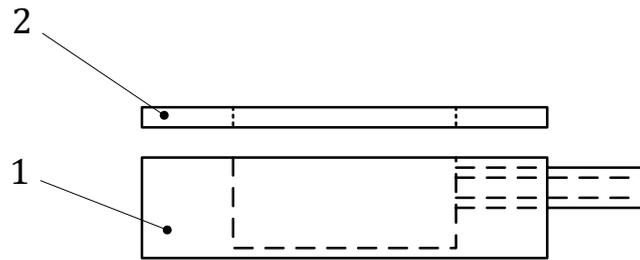
Check the volume of the inner cylinder with the apparatus shown in [Figure A.1](#). By means of a special adaptor plate ([Figure A.2](#)), connect the Gurley apparatus to a 100 ml class A burette, in accordance with ISO 385, graduated in 0,2 ml through two glass stopcocks A and B. Connect another stopcock D to a vacuum line and to stopcock A. For all connections, use rubber pressure tubing.



Key

- 1 rubber stopper 4 connection to vacuum
- 2 100 ml burette 5 adaptor plate
- 3 water collected A to D stopcocks

Figure A.1 — Calibration apparatus



Key

- 1 brass
- 2 rubber

Figure A.2 — Adaptor plate

Fill the burette with water by opening stopcocks A₂, D₂ and C, in that order, until the water level is above the 35 ml mark. Restore atmospheric pressure in the burette by opening D₁. Open B₁, and raise the inner cylinder above the oil level so that its zero mark is about 1,5 mm above a reference point on the outer cylinder. Open A₂ and B₂ and bring the zero mark exactly to the reference point by running water from the burette. Check for air leaks by allowing the apparatus to stand for 15 min. If the cylinder has moved, check all connections for leakage.

Adjust the zero mark exactly to the reference point and read the burette to the nearest 0,1 ml. Run water from the burette until the first 50 ml mark on the inner cylinder coincides with the reference point and read the burette again to the nearest 0,1 ml. The difference between the readings gives the volume of air delivered by the Gurley apparatus for the first 50 ml interval.

Perform three measurements for each 50 ml interval from zero to full scale and calculate the mean of each set of three. If any of the three measurements are not within 1,0 ml of the mean, repeat the measurements. Subtract 5,7% from each mean value to compensate for the volume of fluid displaced by the walls of the inner cylinder, change in oil levels between the cylinders, and the change of pressure within the inner cylinder. If the error is more than 3%, compile a correction table for the graduation of the inner cylinder.

An alternative procedure that does not require the use of a calibrated 100 ml burette is to weigh the volume of water collected to the nearest 0,1 g and determine the volume by calculation using the density of water.

Annex B (informative)

Variations in apparatus

Some of the inner cylinders are also graduated in units of 25 ml for the first 100 ml and may have a graduation at the 400 ml interval. On some cylinders, the engraved graduations are replaced by an adhesive graduation label.

Alternative inner cylinders with a mass of 142 g are available. Air flows obtained with these cylinders are approximately 1/4 of those obtained with the 567 g cylinders.

Alternative clamps to expose an area of 161 mm² (diameter 14,3 mm) or 64 mm² (diameter 9,0 mm) are available and these give air flows about 1/4 and 1/10 of normal.

The use of the alternative cylinders referred to above shall be reported since it is a deviation from the method described in this International Standard. Further observe that the results can be converted only approximately to those which would be obtained with the standard apparatus.

Annex C (informative)

Precision data

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 13 laboratories tested three 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.:

$$s_{\text{repeatability}}^2 = s_{\text{within lab}}^2 \quad \text{but} \quad s_{\text{reproducibility}}^2 = s_{\text{within lab}}^2 + s_{\text{between lab}}^2$$

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 <i>s</i>	Repeatability standard deviation <i>s_r</i> <i>s</i>	Coefficient of variation <i>C_{v,r}</i> %	Repeatability limit <i>r</i> <i>s</i>
Level 1	12 ^a	47,7	2,10	4,40	5,82
Level 2	13	99,8	2,59	2,60	7,18
Level 3	13	505	15,1	2,99	41,9

^a Outlier not included.