International Standard ISO 5636/3

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Paper and board — Determination of air permeance (medium range) — Part 3 : Bendtsen method

Papier et carton — Détermination de la perméabilité à l'air (valeur moyenne) — Partie 3 : Méthode Bendtsen

First edition — 1984-07-15

UDC 676.3/.7 : 620.165.29 **Ref. No. ISO 5636/3-1984 (E)**

Descriptors : paper, paperboards, tests, determination, air permeability, test equipment.

Price based on 7 pages

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5636/3 was developed by Technical Committee ISO/TC 6, *Paper, board and pulps*, and was circulated to the member bodies in March 1983.

It has been approved by the member bodies of the following countries :

Australia	India	Sweden
Austria	Italy	Switzerland
Belgium	Kenya	Tanzania
Brazil	Korea, Rep. of	Turkey
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No member body expressed disapproval of the document.

Printed in Switzerland

Paper and board — Determination of air permeance (medium range) — Part 3 : Bendtsen method

0 Introduction

This International Standard specifies methods of measuring the rate of flow of air through unit area of a sheet of paper or board, under unit pressure difference. The measurements may be made with any apparatus which complies with the specifications given in this International Standard.

ISO 5636/1 specifies basic requirements for the apparatus and general operating procedures. Other parts specify detailed requirements and operating procedures applicable to specific types of apparatus.

1 Scope

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

2 Field of application

The method is applicable to papers and boards having air permeances between 0,35 and 15 µm/(Pa·s). The method is unsuitable for rough surfaced papers and boards, such as creped and corrugated papers, which cannot be securely clamped to avoid leakage.

3 References

ISO 186, *Paper and board — Sampling for testing.*

ISO 187, *Paper and board — Conditioning of samples.*

ISO 5636/1, *Paper and board — Determination of air permeance (medium range) — Part 1 : General method.*

4 Definition

For the purpose of this International Standard, the following definition applies.

air permeance : The mean flow of air through unit area under unit pressure difference in unit time, under specified conditions.

It is expressed in micrometres per pascal second [1 ml/(m^2·Pa·s) = 1 µm/(Pa·s)].

5 Principle

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

6 Apparatus

The apparatus consists of a compressor and pressure stabilizing reservoir to supply air, a flow meter with a pressure controlling device and a measuring head (see figure 1).

Annex A gives details of the care and maintenance of Bendtsen testers.

6.1 Compressor

The compressor shall generate 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.

6.2 Pressure stabilizing reservoir

The pressure stabilizing reservoir shall have a volume of about 10 litres and shall be installed between the compressor and the flow meter.

6.3 Manostat

The air pressure shall be controlled by a manostat at the inlet of the flow meter. Most Bendtsen instruments are provided with three interchangeable manostat weights which control the air pressure at 0,74 ± 0,01 kPa, 1,47 ± 0,02 kPa and 2,20 ± 0,03 kPa. The nominal air pressure should be marked on each weight. However, the standard pressure is 1,47 kPa and this manostat weight shall be used when testing in accordance with this part of ISO 5636.

6.4 Flow meter

The flow meter shall be fitted with variable area flow meters which offer optional flow rate measurements in the ranges 5 to 150, 50 to 500 and, on some instruments, 300 to 3 000 ml/min. These three variable area flow meters shall be capable of being read to within 2, 5 and 20 ml/min respectively.

Three capillary tubes shall be provided for calibration of the flow meter, one for each variable area flow meter. The capillary tubes shall themselves be accurately calibrated against a reliable standard (for example a soap film meter) under the same pressure difference as that in the measuring head. (Annex B gives details of calibration of the flow meter and variable area flow meter tubes.)

NOTE — Other methods of measuring flow rate are permitted provided they can be shown to meet the accuracy requirements of this part of ISO 5636. If such a method is used, it should be described in the test report.

6.5 Measuring head

The measuring head consists of a device in which the test piece is clamped between an annular flat surface and a circular rubber gasket. Both 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 10,0 ± 0,2 cm^2. The tubing used to connect the head to the flow meter shall be made of rubber or plastics material, 7 mm in internal diameter and 9 mm in external diameter.

7 Sampling

Sampling shall be carried out in accordance with ISO 186.

8 Conditioning

Conditioning shall be carried out in accordance with ISO 187.

9 Preparation of test pieces

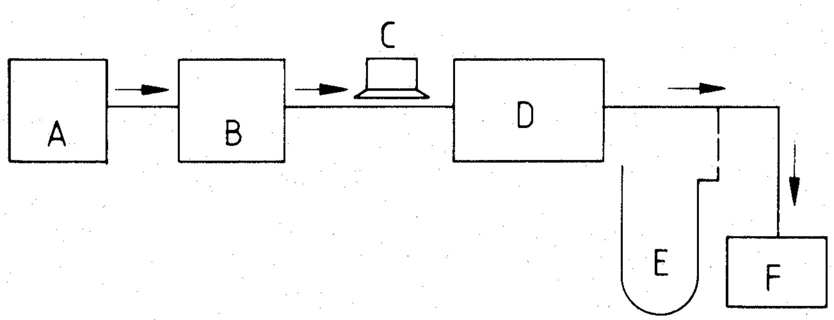
The part of the test piece which will become the test area shall not be handled during preparation and testing.

Not less than ten test pieces shall be cut and their two surfaces identified, for example top side and wire side. The minimum size of the test piece shall be 50 mm × 50 mm. The test area shall be free from folds, wrinkles, holes, watermarks, or defects normally not inherent in the paper or board.

10 Procedure

10.1 Test atmosphere

Testing shall be carried out under the same atmospheric conditions used to condition the test pieces (see clause 8).



A : Compressor
B : Pressure stabilizing reservoir
C : Manostat
D : Central unit
E : Manometer
F : Sample clamping device

Figure 1 — Circuit diagram of test apparatus

10.2 Determination

10.2.1 Place the instrument on a rigid level bench.

Level the instrument by means of the two front feet.

Start the compressor and ensure that no vibration can cause erroneous readings.

10.2.2 Decide which variable area flow meter will be used for the test, selecting, when possible, the variable area flow meter which will give a reading less than 80 % of the scale with the 1,47 kPa manostat weight. Air flows less than 30 ml/min are not recommended. Do not use air flows above 1 200 ml/min, because at high air flows the pressure drop between the flow meter and the measuring head can be sufficient to render the calibration of the variable area flow meter invalid.

Set the valves at the bottom of the variable area flow meters to deliver through the selected variable area flow meter. When the air flow has started, gently place the 1,47 kPa manostat weight on the shaft and start it spinning. It should continue to spin slowly and smoothly.

NOTE — The manostat weight should not be placed on the shaft until after the air flow has started and should be removed before the air flow is stopped.

10.2.3 Set the valve at the outlet of the flow meter to deliver through the larger (upper) outlet and connect the measuring head to this outlet using not more than 700 mm of tubing. (A longer length of tubing results in a significant pressure drop between the flow meter and the head.)

10.2.4 Verify the calibration of the variable area flow meter by temporarily replacing the measuring head with the appropriate capillary tube. The air flow reading should agree with the correct reading for that capillary to within ± 5 %.

10.2.5 With the head again connected to the flow meter, clamp a smooth non metallic rigid plate against the gasket and check that the rotor of the variable area flow meter comes to rest at the bottom of the variable area flow meter. If not, check the measuring head for leaks as described in annex A, clause A.1.

10.2.6 Clamp the test piece between the plate and the gasket. Record the variable area flow meter reading at least 5 s after clamping, with the reading accuracy indicated in 6.4.

NOTE — If a high pressure is used, the gasket may be deformed.

10.2.7 Test the remaining test pieces by the same method, ensuring that in half the tests the upper side of the test piece faces the gasket and in the other half the lower side of the test piece faces the gasket.

10.2.8 After completing the tests, remove the manostat weight and then switch off the compressor.

11 Expression of results

11.1 Calculation of air permeance (P)

Convert to give the air permeance (P) of each test piece, in micrometres per pascal second, by means of the formula

$$0{,}0113\,q$$

where q is the rate of flow of air, expressed in millilitres, per minute, passing through the test area.

11.2 Arithmetic mean

Calculate the arithmetic mean of the air permeance, in micrometres per pascal second, to two significant figures. If there is evidence of a significant difference between the results for each direction of air flow through the test piece, a separate mean for each shall be calculated.

11.3 Standard deviation

Calculate the standard deviation or coefficient of variation of the air permeance for all replicate test results to two significant figures.

12 Test report

The test report shall include the following information :

a) a reference to this part of ISO 5636;

b) the date and place of testing;

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

d) the type of instrument used;

e) the temperature and relative humidity during the test;

f) the number of test pieces tested;

g) the manostat weight used if different from 1,47 kPa;

h) the flow meter range used;

j) the arithmetic mean or means (see 11.2);

k) the standard deviation or coefficient of variation (see 11.3);

m) any deviation from the procedure specified.

Annex A

Care and maintenance of Bendtsen testers

(This annex forms part of the Standard.)

A.1 Checking for air leaks

Check for air leaks in the head by clamping a smooth rigid plate against the gasket as described in clause 10, using the 5 to 150 ml/min variable area flow meter. If the rotor does not remain at rest at the bottom of the variable area flow meter, inspect the plate for damage or imperfections, making sure the rubber gasket is protruding sufficiently to contact the plate firmly and ensuring that it is in good condition. Check air lines and fittings for leaks.

A.2 Manostat weights

Care shall be taken when handling manostat weights to avoid damage to the rims. In particular, they 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. Using a junction piece, connect a water manometer and a suitable capillary to the outlet of the flow meter and check that the pressure at this point is within 5 % of the desired manometer reading when the air flow is as follows.

a) **5 to 150 ml/min variable area flow meter**

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

b) **50 to 500 ml/min variable area flow meter**

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

c) **300 to 3 000 ml/min variable area flow meter**

Desired manometer reading (mm) : 150 ± 10 at all flow rates, up to 1 200 ml/min.

To ensure that the pressure drop between this point and the test piece is not significant, the connecting tube to the head shall be at least 7 mm in internal diameter and not more than 700 mm long.

The manostat weights shall not be lubricated.

A.3 Movement

Check that the floats spin freely in the variable area flow meter tubes. A float which does not spin well may give stable readings. However, a spinning float has a self-cleaning action and is less likely to give errors by sticking to the walls of the variable area flow meter tubes. Check the conditions of the flutes as this mainly determines whether it will spin properly, especially at low flow rates. Other factors important for good spinning are mechanical symmetry and the condition of the top rim.

Should a float become wedged in the spring at the bottom or the top of a variable area flow meter 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 variable area flow meter tubes with a special spanner, take off the metal block at the top of the variable area flow meter and remove the variable area flow meter tube. A recurrence of sticking can be prevented by adjusting the shape. The bottom spring should terminate in a horizontal loop centred in the variable area flow meter. The top spring should terminate in a vertical loop centred in the variable area flow meter.

A.4 Cleaning the variable area flow meter

If the variable area flow meter tube or float is dirty, giving high readings, remove the float from the tubes, clean both with carbon tetrachloride, then dry in an air stream.

A liquid detergent may be used as an alternative to carbon tetrachloride. If so, add to the tube, flush with water, reversing the flow several times, and use diluted aqueous solution [about 10 % (V/V)] to clean the float. Finally, rinse both with distilled water, and dry in a stream of air.

Replace faulty tubes.

A.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.

A.6 Gaskets

Gaskets should be regularly inspected for signs of deterioration and replaced if necessary.

NOTE — There are indications that the dimensions of the gaskets change with time. It is therefore necessary to ensure that replacement gaskets of the correct dimensions are used.

Annex B

Calibration of flow meters and variable area flow meters

(This annex forms part of the Standard.)

B.1 Checking flow meters with capillary tubes

Flow meter floats 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 flow meter against the capillary tube normally used for an adjacent variable area flow meter.

b) If both readings are high, check the flow meter 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.

d) If the two readings do not agree, or if the faults found in b) or c) cannot be identified, arrange for the flow meter operating at 1,47 kPa to be checked against a soap film meter or a soap bubble meter or other suitable flow measuring device.

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

B.2 Checking calibration of variable area flow meter and capillary tubes

Variable area flow meter and capillary tubes may be calibrated by checking against a soap film meter of which there are several designs. Figure 2 is a diagramatic representation of a suitable meter.

B.2.1 Soap bubble meter

B.2.1.1 Apparatus and material

B.2.1.2 Soap bubble meter (see figure 2) consisting of :

— tube squeezer (pinch clamp);

— glass flask, of capacity 1 litre;

— water manometer, graduated in millimetres;

— thermometer;

— volumeter (the volume between the two marks is carefully calibrated) with marks indicating 100 ml, 250 ml and 1 500 ml. The different ranges may be achieved with replaceable volumeters;

— needle valve;

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

B.2.1.3 Stop-watch.

B.2.1.4 Soap solution, 3 to 5 % liquid detergent in distilled water.

B.2.2 Procedure

To calibrate the flowmeter tubes, disconnect the measuring head from the downstream end of the rubber or plastic tubing and connect in its place the soap bubble meter at C. Start air flow, place the 1,47 kPa manostat weight on the shaft and start it spinning. Set the valves to deliver through the flowmeter to be calibrated to the soap bubble meter. Adjust the tube squeezer and needle valve to give a conveniently measurable air flow and ensure that the flow rate and manometer reading remain 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 time measurements are in excess of 30 s. Repeat the procedure at about six air flows distributed over the upper 80 % of the flowmeter range. Note also the temperature, atmospheric pressure and the manometer reading at each air flow.

To calibrate a capillary tube, connect the tube between the Bendtsen instrument and the soap bubble meter (at C). Remove the needle valve and also any connecting tubing at the top of the volumeter so that the pressure in volumeter system is as close as possible to atmospheric. In this procedure it is essential for the pressures at the inlet and outlet ends of the capillary to be substantially the same as those existing when the capillary is used as in 10.2.4.

NOTE — At air flows above 1 200 ml the pressure drop in the Bendtsen system is substantial and to ensure reproducibility of results it is necessary that the tubing used to connect the flowmeter to the measuring head be carefully controlled at 690 ± 5 mm in length and 7 ± 0,5 mm in internal diameter. For the same reason openings in valves and other fittings on the instrument must not be changed from those provided by the instrument manufacturer.

B.2.3 Calculation

At each calibration point, calculate a flow rate corrected for temperature and pressure from the equation

$$q_0 = \frac{pV \times 296 \times 60}{102{,}8 \times Tt}$$

$$= \frac{172{,}8\, pV}{Tt}$$

where

q_0 is the flow rate, expressed in millilitres per minute, corrected to 102,8 kPa [normal atmospheric pressure (101,3 kPa) plus nominal operating pressure (1,5 kPa)] and 23 °C;

p is the sum, in kilopascals, of actual atmospheric pressure plus pressure differential indicated by the manometer. (A manometer reading of 1 mm = 9,78 Pa at 23 °C);

V is the volume, in millilitres, timed between graduations on the volumeter;

T is the temperature reading, in kelvin. ($T = 273 + \theta$, where θ is the temperature reading in degrees Celsius);

t is the time, in seconds.

B.2.4 Accuracy

This method of calibration gives satisfactory accuracy for test atmospheric conditions which do not deviate appreciably from 101,3 kPa and 23 °C.

In cases where atmospheric conditions differ appreciably from 101,3 kPa and 23 °C, q_0 may be corrected by applying the equation

$$q_0 = \frac{p_1\, T_0\, V}{p_0\, T_1\, t}$$

where

q_0 is the corrected flow rate, expressed in millilitres per minute;

p_0 is the sum of normal atmospheric pressure and nominal measuring pressure [the normal measuring pressure is a 150 mm water column, equal to 1,468 kPa (1 mmH_2O at 23 °C corresponds to a pressure of 9,78 Pa)];

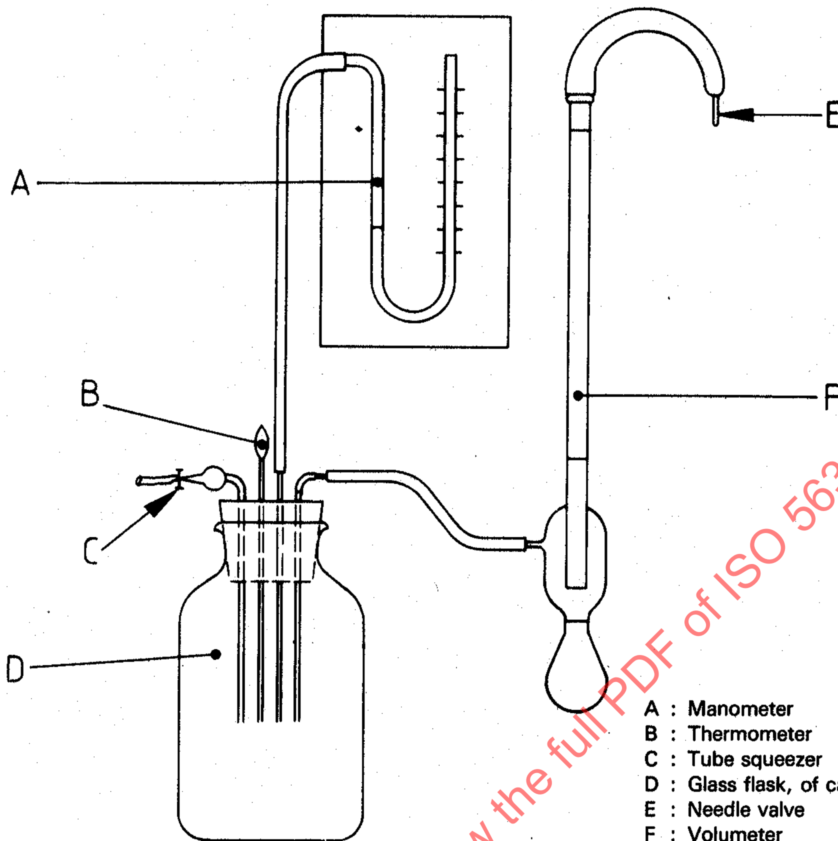
p_1 is the sum of actual atmospheric pressure plus the pressure in the manometer;

T_0 is 296 K;

T_1 is the temperature, in kelvin, in the glass flask. ($T_1 = 273 + \theta$, where θ is the temperature in degrees Celsius);

V is the volume, in millilitres, between graduations on the volumeter;

t is the time, in minutes, for the bubble to travel between marks.



A : Manometer
B : Thermometer
C : Tube squeezer
D : Glass flask, of capacity 1 litre
E : Needle valve
F : Volumeter

Figure 2 — Soap bubble meter