INTERNATIONAL STANDARD

ISO 8791-4

Second edition
2007-11-15

Paper and board — Determination of roughness/smoothness (air leak methods) —

Part 4:
Print-surf method

Papier et carton — Détermination de la rugosité/du lissé (méthodes du débit d'air) —

Partie 4: Méthode Print-surf

Reference number
ISO 8791-4:2007(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 8791-4 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

This second edition cancels and replaces the first edition (ISO 8791-4:1992), which has been technically revised.

This version of ISO 8791-4 differs from the previous (1992) version as follows:

— a definition of Print-surf compressibility has been added;

— a description of a modified backing holder for testing high-stiffness papers and board has been added;

— Annex D describing the calibration of Print-surf instruments has been revised and expanded;

— some minor editorial changes have been made.

ISO 8791 consists of the following parts, under the general title *Paper and board — Determination of roughness/smoothness (air leak methods)*:

— *Part 1: General method*

— *Part 2: Bendtsen method*

— *Part 3: Sheffield method*

— *Part 4: Print-surf method*

Paper and board — Determination of roughness/smoothness (air leak methods) —

Part 4:
Print-surf method

1 Scope

This part of ISO 8791 specifies a method for determining the roughness of paper and board using an apparatus which complies with the Print-surf method, as defined in this part of ISO 8791. It is applicable to all printing papers and boards with which it is possible to form a substantially airtight seal against the guard lands of the measuring head.

2 Normative references

The following referenced documents are indispensable for the application of this document. 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*

ISO 4094, *Paper, board and pulps — International calibration of testing apparatus — Nomination and acceptance of standardizing and authorized laboratories*

3 Terms and definitions

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

3.1
Print-surf roughness
mean gap between a sheet of paper or board and a flat circular land pressed against it under specified conditions

NOTE The mean gap is expressed as the cube root mean cube gap calculated as specified in Annex A. The Print-surf roughness is expressed directly as the average value of roughness, in micrometres.

3.2
Print-surf compressibility
K
percentage decrease in surface roughness when measurements are made consecutively at the two standard clamping pressures specified in this part of ISO 8791

4 Principle

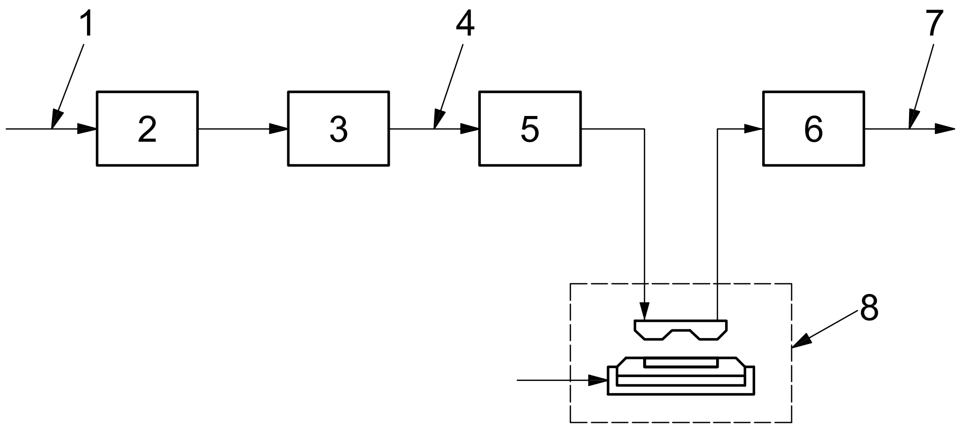
The test piece is placed between a circular flat metal sensing surface and a resilient backing, and inner and outer circular lands form a seal with the test piece. Under the influence of a pressure difference, air flows across the measuring land between the measuring land and the test piece. The rate of air flow is measured on a variable-area flowmeter, or the pressure difference across the measuring land is compared to the pressure difference across a known impedance. In both cases, the result is expressed as the air gap, in micrometres.

5 Apparatus

5.1 Print-surf tester (two types)

5.1.1 Print-surf tester, which operates according to one of the following principles.

5.1.1.1 Variable-area flowmeter type, in which a standard pressure difference is created across the measuring land and the air-flow rate is measured on a variable-area flowmeter. The air-flow rate varies with roughness and the flow rate is converted to roughness, in micrometres. The flow diagram for this type of instrument is shown in Figure 1.

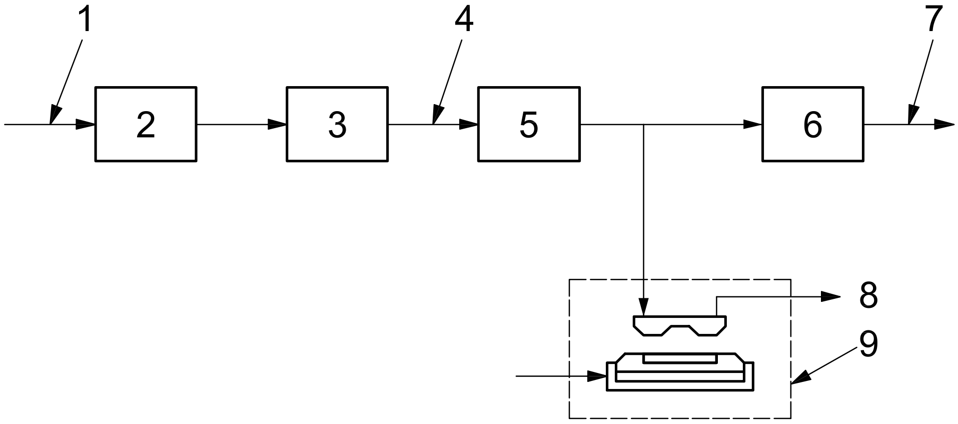


Key

1 incoming air 300 kPa to 600 kPa
2 filter
3 pressure-regulator valve
4 6,2 kPa or 19,6 kPa
5 on/off valve
6 flow indicator tubes
7 to atmosphere
8 sensing head and clamping device

Figure 1 — Flow diagram for variable-area flowmeter type

5.1.1.2 Impedance type, in which the air from the controlled pressure source passes first through a fluidic impedance and then through the sensing head, after which it discharges to atmosphere. The pressure differences across the fluidic impedance and across the land are each measured by a transducer. These pressure differences vary with roughness and the signals are converted to roughness, in micrometres. The flow diagram for this type of instrument is shown in Figure 2.



Key

1 incoming air 300 kPa to 600 kPa
2 filter
3 pressure-regulator valve
4 19,6 kPa
5 fluidic impedance
6 pressure transducer
7 analog signal
8 to atmosphere
9 sensing head and clamping device

Figure 2 — Flow diagram for impedance instrument type

5.1.2 Procedures for maintaining these testers in good working order are given in Annex B.

5.2 Principal components of the system

5.2.1 Air supply, supplying clean air, free of oil and water droplets, at a steady pressure within the range 300 kPa to 600 kPa.

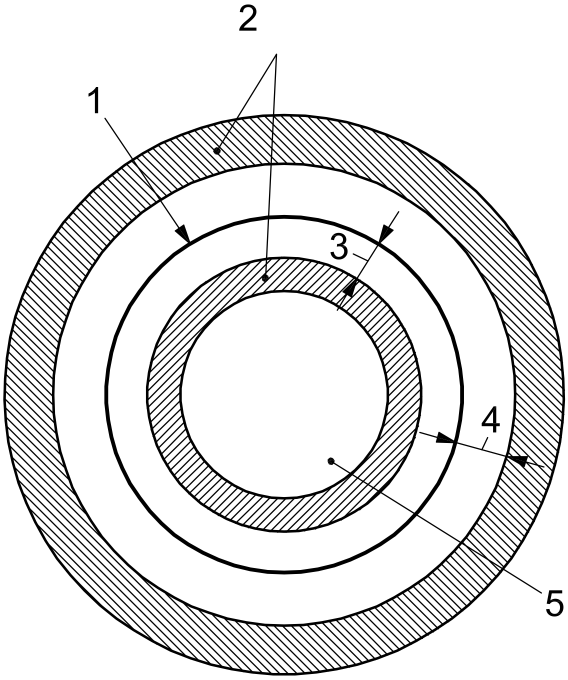
5.2.2 Sensing-head pressure regulator, allowing setting of the sensing-head differential pressure to 19,6 kPa ± 0,1 kPa or, on variable-area flowmeter instruments only, to either 6,2 kPa ± 0,1 kPa or 19,6 kPa ± 0,1 kPa.

5.2.3 Sensing head, (see Figures 3 and 4), consisting of three concentric, annular lands composed of suitable material which have coplanar, polished surfaces. The centre or measuring land shall be 51,0 µm ± 1,5 µm wide and have an effective length of 98,0 mm ± 0,5 mm. The two guard lands shall each be at least 1 000 µm wide at any point, and the radial distance between them at any point shall be 152 µm ± 10 µm. The measuring land shall be centred between them to within ± 10 µm.

The lands shall be mounted in an airtight mounting, constructed so that air can be passed into the gap between one guard land and the measuring land, and exhausted from the gap between the measuring land and the other guard land. The back of the mounting shall be flat and form a ground mating surface with the flat surface of a manifold fitted with air inlet and outlet ports.

A spring-loaded protective collar may be fitted outside the guard lands. If such a protective collar is fitted, the force exerted by the loading spring shall be taken into account when setting the clamping pressure.

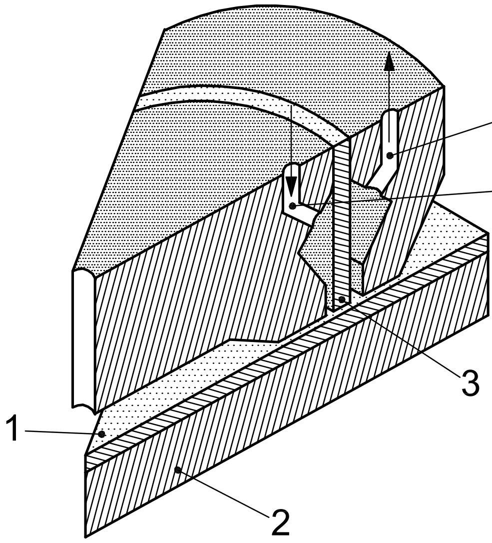
NOTE In many instruments fitted with the protective collar, the force exerted by the loading spring is 9,8 N.



Key

1 measuring land
2 guard lands
3 passage connected to air supply
4 passage leading to flowmeters or atmosphere
5 recess vented to atmosphere

Figure 3 — Plan of the measuring and guard lands of the sensing head



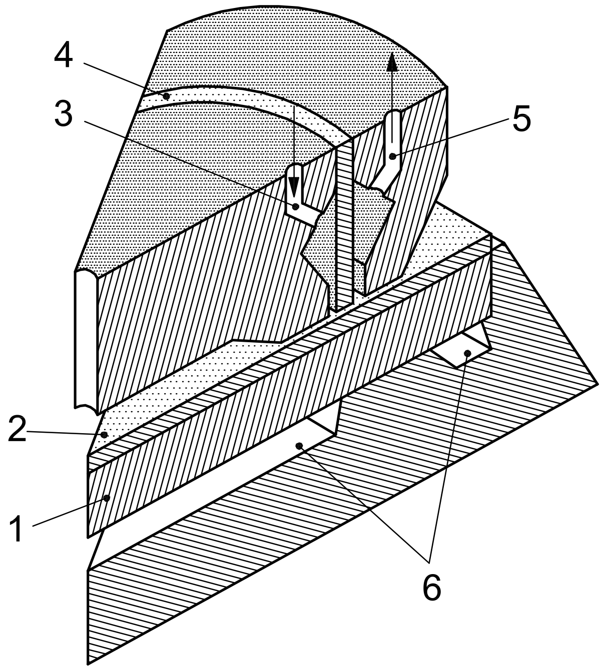
Key

1 paper
2 resilient backing
3 measuring land
4 regulated low-pressure air
5 to flowmeters or atmosphere

Figure 4 — The sensing head sectioned on two radii

5.2.4 Backing holders, consisting of rigid metal discs of known mass, each recessed to accommodate a resilient backing at least 10 mm greater in diameter than the outside diameter of the outer guard land. The mass of both the resilient backing and the holder shall be allowed for in the initial adjustment of the clamping pressure.

It has been observed that high-stiffness papers and boards can interact negatively with the flat metal backing holder and cause erroneously high roughness results. This problem can be solved by using a modified backing holder which relieves those areas of the backing holder not directly below the measuring land, as shown in Figure 5.



Key

1 resilient backing
2 paper
3 regulated low-pressure air
4 measuring land
5 to flowmeters or atmosphere
6 new modified clamp platen showing machined cut-away

Figure 5 — The sensing head sectioned on two radii showing cut-away platen

5.2.5 Two resilient backings, of different types, which can be held in the recessed holders by means of double-sided adhesive tape.

5.2.5.1 Soft backing, resilient, consisting of an offset printing blanket composed of a layer of synthetic rubber, at least 600 µm thick, bonded to a fabric backing giving an overall thickness of 2 000 µm ± 200 µm. The apparent hardness of the complete backing shall be 83 IRHD ± 6 IRHD (International Rubber Hardness Degrees).

5.2.5.2 Hard backing, resilient, usually made from a polyester film bonded at its periphery to cork, offset blanket or similar material. A small exhaust hole shall be provided to prevent air being trapped between the film and the backing. The apparent hardness of the assembly shall be 95 IRHD ± 2 IRHD.

5.2.6 Clamping mechanism, allowing clamping of the resilient backing at pressures of either 980 kPa ± 30 kPa or 1 960 kPa ± 30 kPa, the pressure being calculated from the total area of the measuring and guard lands.

NOTE 1 On some earlier instruments, these values may be displayed on the gauge as 10 kgf/cm^2 and 20 kgf/cm^2.

Note that the spring loading in the protective collar (5.2.3) and the weight of the backing and its holder need to be taken into account. The rate of clamping shall be such that the pressure reaches 90 % of its final value in about 0,4 s, and 99 % of its final value in about 0,8 s.

NOTE 2 A third pressure of 490 kPa (5 kgf/cm^2) is available on most instruments, but is not acceptable for use with this part of ISO 8791 because of a tendency for air to leak under the guard lands.

Variable-area flowmeter measurement systems shall have a pressure gauge fitted to the instrument to indicate the clamping pressure, which shall be adjustable. Impedance measurement systems shall have integrated pneumatic and electronic circuitry which automatically controls the clamping pressure. In each case, the actual pressure achieved shall be verified as specified in B.3.

5.3 Measuring system

5.3.1 The air-flow rate shall be measured with either a set of variable-area flowmeters or by measuring the pressure drop across an impedance.

5.3.2 Variable-area flowmeter instruments shall be fitted with flowmeters which are graduated to show the “cube root mean cube gap” between the paper and the measuring land surface, in micrometres (see Annex A). The flowmeters shall be calibrated by the procedures outlined in either Annex C or D.

5.3.3 Impedance instruments measure air leakage by means of fluidic impedance, a pressure transducer and a function generator. They display or print the roughness, in micrometres to the nearest 0,1 µm, based on automatic measurement of pressure difference, over the range 0,6 µm to 6,0 µm. The value displayed shall be the value calculated after 3 s to 5 s. This device shall be calibrated by the procedure described in Annex D.

6 Sampling

If the tests are being made to evaluate a lot, the sample should be selected 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

The sample shall be conditioned 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 at least 10 test pieces for each side to be tested. The minimum size of each test piece shall be 100 mm × 100 mm, and their surfaces shall be identified in some convenient way (for example, side one or side two).

The test area shall be free of all folds, wrinkles, holes or other defects, and should not include watermarks. Do not handle that part of the test piece which will become part of the test area.

9 Procedure

9.1 Carry out the test in the same atmospheric conditions as those used to condition the sample (see Clause 7).

9.2 Ensure that the instrument is on a rigid horizontal surface free from vibration and that it is level. Before use on any particular day, check the system for leakage as specified in B.1.

9.3 Select and fit the backing disc appropriate for the material being tested. In general, the hard backing should be used for papers that are to be printed by letterpress presses fitted with paper backings. Papers to be printed by other processes, and boards however printed, should be tested with the soft backing.

9.4 Select and adjust the clamping pressure, using the following as a guide:

— Hard backing letterpress 1 960 kPa ± 30 kPa

— Soft backing letterpress 1 960 kPa ± 30 kPa

— Soft backing offset 980 kPa ± 30 kPa

9.5 For a tester of the variable-area flowmeter type, select the lowest-range flowmeter which will give a reading greater than 20 % of the scale range.

Always start with the highest-range flowmeter and turn the flow range selector switch successively to a flowmeter of lower range, in order to avoid subjecting the low-range flowmeters to a high air flow.

9.6 Test the first test piece by the following procedure.

9.6.1 Variable-area flowmeter type

Set the sensing-head differential pressure to 6,2 kPa ± 0,1 kPa by adjusting the pressure from the low side.

NOTE 1 If the pressure gauge indicates differential pressure in metres of water gauge, 0,63 m is equivalent to 6,18 kPa.

NOTE 2 The pressure gauge on some instruments has been found to be sensitive to jolts and, if the adjustment is made downwards from a higher pressure, the resulting pressure for a given scale reading will be higher than if the adjustment is made upwards from a lower pressure.

Clamp the first test piece under the sensing head, with the side to be tested uppermost. This operation can cause the reading on the sensing-head pressure gauge to change, but such a change may be ignored. Record the reading on the flowmeter to the nearest 0,05 µm, 3 s to 5 s after application of clamping pressure. Readings shall be taken level with the top of the flowmeter float. Select the lowest-range flowmeter which gives results greater than 20 % of the scale range.

If the reading obtained is less than 20 % of the range of the lowest-range flowmeter, increase the sensing-head pressure to 19,6 kPa ± 0,5 kPa (2,0 m water gauge). All readings taken at this pressure shall be multiplied by 0,667 [(for the background of this factor, see Annex A, Equation (A.1)] to give the roughness, in micrometres, unless the flowmeters are calibrated for this pressure.

9.6.2 Impedance type

Place a test piece under the head with the side to be tested uppermost. Clamp the test piece either automatically or manually. Record the reading, 3 s to 5 s after application of clamping pressure.

9.7 Repeat step 9.6 for the other test pieces and calculate the arithmetic mean and standard deviation or coefficient of variation for the side tested. For variable-area flowmeter-type instruments, do not repeat the procedure for selection of the appropriate flowmeter and sensing-head pressure.

9.8 If a result is required for the roughness of the other side, take a second set of test pieces and repeat steps 9.6 and 9.7.

9.9 If Print-surf compressibility is to be determined, the lower of the two clamping pressures shall be selected and adjusted first. Follow step 9.6 and record the result and, without unclamping the test piece, next select and adjust the higher clamping pressure and again record the result. Repeat this sequence for the other test pieces. Calculate Print-surf compressibility using the equation in Clause 10.

10 Calculation

The Print-surf compressibility, K, can be defined mathematically by the equation:

$$K = \frac{100(G_1 - G_2)}{G_1}$$

where

G_1 is the surface roughness value obtained at a nominal clamping pressure of 1 MPa;

G_2 is the surface roughness value obtained at a nominal clamping pressure of 2 MPa.

11 Precision

The following estimates of repeatability and reproducibility, calculated according to TAPPI Test Method T 1200 and published in TAPPI Test Method T 555, are based on data taken from the CTS-TAPPI Interlaboratory Program for Paper and Paperboard and are reprinted and used by permission of TAPPI. Testing is based on 10 determinations per test result and 1 result per laboratory, per material. The estimates were determined prior to the availability and use of standard reference materials. The reproducibility is expected to improve with the introduction of a reference standard system.

Table 1 — Roughness measurements in μm

Material description	Grand mean	Range	Repeatability r and %r		Reproducibility R and %R		Number of laboratories
Coated cover, gloss	0,824	1,192 – 0,590	0,026	3,2 %	0,368	44,7 %	67
Coated face stock	1,125	1,390 – 0,887	0,030	2,6 %	0,320	28,4 %	71
Coated offset	1,193	1,420 – 0,984	0,043	3,6 %	0,291	24,4 %	67
Coated offset	1,255	1,500 – 1,049	0,045	3,6 %	0,281	22,4 %	67
Speciality paper	2,701	3,031 – 2,358	0,106	3,6 %	0,410	15,2 %	71
Laser bond, uncoated	3,511	3,965 – 3,031	0,172	4,9 %	0,580	16,5 %	33
Offset	4,602	5,141 – 4,000	0,145	3,2 %	0,772	16,8 %	30
Offset	5,415	6,117 – 4,680	0,167	3,1 %	1,049	19,4 %	30

12 Test report

The test report shall include the following information:

a) a reference to this part of ISO 8791;

b) date and place of testing;

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

d) the type of instrument used;

e) the backing and type of backing holder used;

f) the number of test pieces tested;

g) the sensing-head differential pressure, in kilopascals;

h) the clamping pressure, in kilopascals;

i) the mean of the test results for each side tested;

j) the standard deviation or coefficient of variation for each side tested;

k) any deviation from this procedure which may have affected the results.

Annex A
(normative)

Calculation of roughness in micrometres

For the purposes of this part of ISO 8791, the cube root mean cube gap, G_3, in metres, in the direction of the air flow between the measuring land and the test piece is calculated from the equation:

$$G_3 = \left(\frac{12 \times \eta \times b \times q_v}{l \times \Delta p} \right)^{\frac{1}{3}} \tag{A.1}$$

where

η is the viscosity, in pascal seconds, of air at room temperature;

b is the width, in metres, of the measuring land;

q_v is the volume of air flowing in unit time, in cubic metres per second;

l is the median length, in metres, of the measuring land;

Δp is the pressure difference, in pascals, across the measuring land.

The roughness, in micrometres, is then equal to $G_3 \times 10^6$.

If the differential pressure exceeds 1 % of the absolute pressure then Δp should be calculated as in Equation (A.2) to correct for the compressibility of air:

$$\Delta p = \frac{p_u^2 - p_d^2}{2 p_m} \tag{A.2}$$

where

p_u is the absolute upstream pressure;

p_d is the absolute downstream pressure;

p_m is the pressure at which the flow q_v is measured.

Equation (A.2) is derived on the assumption that the gap between the measuring land and the test piece is uniform across the width of the land, but that it varies along its length.

Equation (A.1) is subject to the assumptions that the flow is laminar, that the temperature is constant throughout, and that the kinetic energy changes per unit volume of air are negligible compared with Δp. The flow conditions are normally well within the laminar range, but the kinetic energy can be important when rough papers are measured, unless the differential pressure is restricted. To estimate the extent of the error, the full equation for flow over the measuring land may be used:

$$\Delta p = \frac{12 \times \eta \times b \times q_v}{l \times G_3^3} + \frac{C \times \rho \times q_v^2}{2 \times l^2 \times G_3^2} \tag{A.3}$$

where

ρ is the density of air measured at pressure p_m;

C is a coefficient found by experiment for a number of papers, and is approximately equal to 2,5.

Additional information about the background of Equations (A.1), (A.2) and (A.3) may be found in a paper published in Paper Technology[2].

Annex B
(normative)

Maintenance of Print-surf roughness testers

B.1 Leakage

The apparatus shall be maintained free of leakage, visible surface irregularities of the backings and pressure gauge error, as detailed in B.1.1, B.1.2 and B.3. Check for leakage at the lowest clamping pressure available and a sensing-head differential pressure of 19,6 kPa.

B.1.1 Leakage between the back of the sensing head and its supporting manifold is indicated by a measurable air flow when the soft backing is clamped directly against the head. Such leakage can be corrected by a thin smear of petroleum jelly on the mating surfaces.

B.1.2 Damage to the sensing head is detected as follows:

a) Carefully wipe the face of the sensing head with a lint- and oil-free, soft clean material.

b) Clamp a smooth scratch-free piece of 125 µm thick film, such as cellulose acetate, between the sensing head and the hard backing. Measure the air flow.

This test is very sensitive to dust, due to static charges and even to fingerprints. If a measurable flow is found, carefully wipe the surface of the film and repeat the test.

It is recommended that a suitable film be obtained from the instrument manufacturer/supplier.

c) If it is impossible to obtain a zero reading on the lowest range flowmeter, confirm damage by inspecting the measuring surface at a magnification of about $\times$ 50 with a stereoscopic microscope. On impedance instruments, a reading greater than 0,8 µm indicates the possibility of damage.

d) If pits or scratches are apparent, replace the sensing head.

B.2 Sensing head

At frequent intervals, inspect the head, preferably with a stereoscopic microscope, to ensure that the gaps between the measuring land and guard lands are free from debris. If necessary, clean as advised by the instrument manufacturer.

B.3 Pressure gauges

Whenever the instrument is used, check that both gauges register zero when the air supply is disconnected.

At least once a year, check the accuracy of pressure gauges and transducers by connecting in parallel a manometer or transducer, the latter having been calibrated against dead weights. Operate the instrument normally and record the actual static pressures achieved.

Convert the clamping pressure reading to force per unit area of guard plus measuring land surface. Correct for the weight of the resilient backing plus holder and for the force exerted by the spring-loaded protective collar. Compare the corrected clamping pressure and the measured head pressure to the gauge readings and pressure settings specified in 5.2.2 and 5.2.6.

Replace defective gauges or repair faulty control systems.

B.4 Resilient backing

Inspect the clamping surfaces daily and, as soon as any visible damage occurs, replace the backing using the procedure in the instrument manual. It is advisable to replace the backing on a regular basis and also if a zero reading cannot be obtained.

B.5 Evenness of clamping

Place a sheet of high-quality white paper on the hard backing, cover it with a piece of carbon paper, place the "sandwich" in the measuring gap and apply the clamping pressure. An uneven print indicates uneven clamping which shall be corrected by referring to the manufacturer.

Annex C
(normative)

Calibration of variable-area flowmeters

C.1 General

The variable-area flowmeters may be calibrated individually using a soap-bubble meter such as that shown in Figure C.1 or they may be calibrated against ISO reference standards by the procedure described in Annex D.

C.2 Apparatus and product

C.2.1 Soap-bubble meter, consisting of:

— glass flask or bottle, of at least 1 l capacity;

— volumeter, of 500 ml capacity;

— rubber bulb and soap reservoir;

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

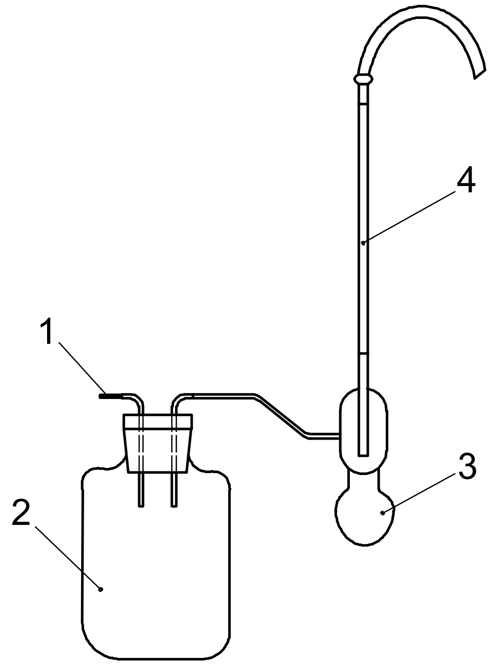
C.2.2 Stopwatch.

C.2.3 Soap solution, for example, a 3 % to 5 % liquid detergent in distilled water.

C.3 Procedure

Connect the inlet of the soap bubble meter to the outlet of the flowmeter. Operate the instrument according to the procedure described in 9.1 to 9.6.1 inclusive, using a test piece of suitable roughness (see note below). 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 the soap bubble to move between marks representing a known volume, such that the time measurements are in excess of 30 s. Note also the corresponding scale reading. Using test pieces of appropriate roughness, repeat the procedure for about six air flows over the range of the flowmeter.

NOTE Some paper test pieces can fail to give stable scale readings during the calibration procedure, due to the effect of moisture change during the test. Do not use material which behaves in this way. Materials other than paper may be used, providing they give readings at appropriate intervals over the range of the flowmeter being calibrated.



Key

1 inlet

2 glass flask

3 rubber bulb

4 volumeter

Figure C.1 — Soap-bubble meter

C.4 Calculation

At each calibration point, calculate the flow rate and using Equation (A.1) convert the flow rate to a roughness, in micrometres. Compare the calculated values with the actual scale readings. For very accurate calibration, it is desirable to allow for the water vapour picked up from the soap solution. If the instrument reading is more than 0,05 µm from the correct value at any point, construct a calibration graph for use in normal testing.

Annex D
(normative)

Calibration of Print-surf instruments against ISO reference standards

D.1 Summary

The essential components of a Print-surf tester are the following: an air-flow measuring system, a sensing head, a resilient backing assembly and a clamping mechanism. The calibration of the air-flow measuring system is described in D.2. It should be noted, however, that this calibration does not include potential variations arising from the sensing head. The use of calibration media as a means of verification of the complete measuring system (including the sensing head) is described in D.3.

D.2 Calibration of air-flow measuring system

D.2.1 Because some impedance-type instruments measure roughness by comparing the impedance presented by the sample against a known impedance within the instrument, rather than by measuring air flow, they cannot be calibrated by the procedure described in Annex C and their calibration according to Annex E is beyond the capability of most paper-testing laboratories.

The calibration of some impedance-type instruments therefore depends on the use of ISO reference standards of level 2, which are devices (dummy heads) with known impedance values expressed in terms of roughness, in micrometres. Such reference standards may be obtained from a laboratory authorized by ISO/TC 6 for this purpose and each device shall be accompanied by a statement of the assigned value in micrometres, determined by a procedure based on the principles enunciated in Annex E. These are available at three levels to cover the full instrument range.

ISO reference standards of level 2 may also be used to calibrate variable-area flowmeter instruments. However, reference standards suitable for calibration of variable-area flowmeters can be unsuitable for use with impedance instruments. Therefore, they shall be used strictly in accordance with the directions of the issuing laboratory.

D.2.2 Insert each level 2 reference standard dummy head in turn into the measuring position, operate the instrument and record the measured value. Compare the value measured in the instrument with the assigned value. If they differ by more than 0,05 µm at any point, construct a calibration chart for use in normal testing.

This procedure assumes that the measuring head is in correct working order and therefore the mechanical condition of the head should be assessed by other means (see B.2 and D.3).

NOTE Impedance-type instruments that use Equations (A.1) and (A.2) can be calibrated with external pressure and flow gauges that are traceable to national and international measurement standards.

D.3 Calibration of measurement system (including sensing head)

D.3.1 The calibration of the measurement system (including the sensing head) depends on the use of ISO reference standards of level 2, which are calibration media with known Print-surf roughness values. Such reference standards may be obtained from a laboratory authorized by ISO/TC 6 for this purpose and each reference standard shall be accompanied by a statement of assigned value in micrometres, determined by a procedure based on the principles enunciated in Annex E. These reference standards are available at three levels to cover the full instrument range.

D.3.2 Insert each level 2 reference standard in turn into the measuring position, operate the instrument and record the reading. In accordance with the directions of the issuing laboratory, obtain the mean and standard deviation of readings. The acceptable tolerance between the value assigned to the reference standards and the value measured in the instrument is ± 2 standard deviations.

D.4 Calibration service

In this part of ISO 8791, reference is made to two different forms of reference standards which are required to calibrate the Print-surf instrument:

- dummy heads of known impedance for the calibration of the air-flow measuring system;
- calibration media of known Print-surf roughness values for the calibration of the measurement system (including the sensing head).

To permit working instruments to relate their Print-surf roughness measurements to a standard reference, the following procedure was established.

Certain laboratories having the necessary technical competence and maintaining reference Print-surf instruments having the characteristics specified in this part of ISO 8791 are appointed by ISO/TC 6 as “standardizing laboratories”, in accordance with the provisions of ISO 4094. The standardizing laboratories issue “ISO reference standards of level 2” (IR 2), on demand, to industrial laboratories which use the IR 2 for the purpose of calibrating their Print-surf instruments. The standardizing laboratories shall seek to ensure that their reference instruments are in agreement with one another by the exchange of IR 2 reference standards.

NOTE A list of current standardizing laboratories (including contact information) is maintained on the ISO/TC 6 public website.

Annex E
(normative)

Calibration of an impedance instrument for the purpose of assigning values to ISO reference standards

E.1 Summary

The accuracy of an impedance instrument depends both on the details of the sensing head and clamping system, which are identical to those of other Print-surf instruments, and on the value and linearity of an internal fluidic impedance, the calibration of two pressure transducers, and the accuracy of an inbuilt computer which translates the transducer output signal into a roughness value.

E.2 General

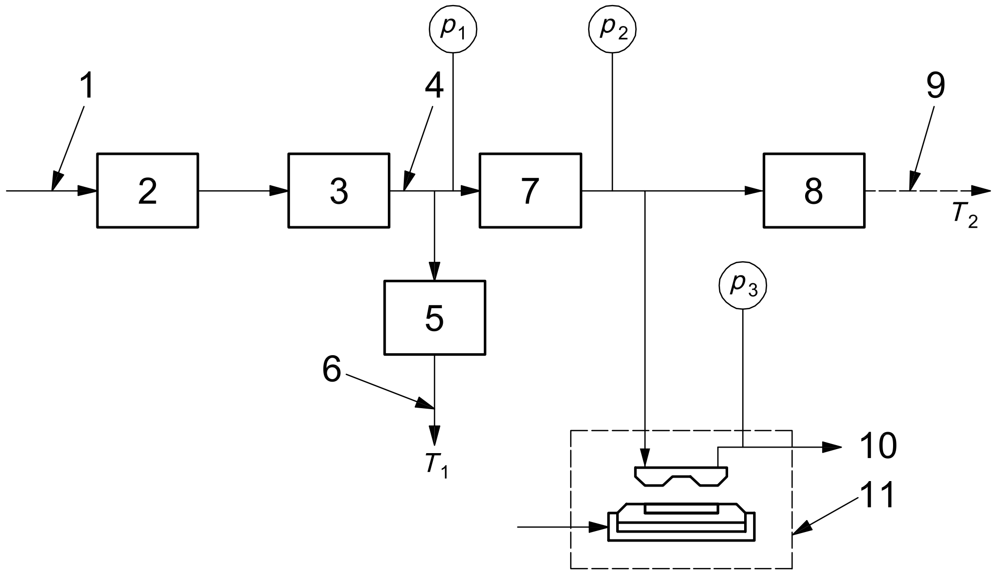
The measuring system of an impedance-type instrument is radically different from the majority of other air leak instruments, in that it is not based on the measurement of the rate of flow of air at a specified differential pressure but on the comparison of the differential pressures across known and unknown fluidic impedance connected in series. This type of measuring system is permissible because the relationship between differential pressure and air flow for the Print-surf sensing head has been shown to be substantially linear, after a minor correction for the compressibility of the air, provided this differential pressure lies below some limiting pressure. The differential pressures can be readily converted to an electrical signal by means of suitable transducers. The roughness of the paper sample can then be calculated from the transducer outputs and the value of the internal fluidic impedance.

This annex provides a review of the points that shall be considered and checked in order to verify that the impedance measuring system is functioning correctly. It does not describe in detail how such checks are to be made.

E.3 Principle

It has been noted in E.1 that all Print-surf instruments use the same type of sensing head. The roughness of a paper sample clamped beneath the head can be calculated from the air flow q_v through the head and the pressure drop Δp across it using Equations (A.1) and (A.2).

Figure E.1 indicates the absolute pressures p_1, p_2 and p_3 at three points in the system. The location of an additional transducer is also given. Note that although p_1 is shown as a gauge pressure of 19,6 kPa, this is not essential.



Key

1 incoming air 300 kPa to 600 kPa
2 filter
3 pressure-regulator valve
4 19,6 kPa
5 pressure transducer 1
6 analog signal
7 fluidic impedance
8 pressure transducer 2
9 analog signal
10 to atmosphere
11 sensing head and clamping device
T_1 output of transducer 1
T_2 output of transducer 2

NOTE p_1, p_2 and p_3 represent absolute pressures.

Figure E.1 — Flow diagram of an impedance instrument showing additional transducer

The value of a fluidic impedance may be defined as the ratio $\Delta p/q_v$ where Δp is calculated according to Equation (A.2). If the impedance remains constant and provided that Δp lies below some limiting value, the fluidic impedance may be regarded as linear. Given that the impedances of the internal impedance Z_2 and the sensing head Z_2 are both linear, their values can be calculated from the following equations:

$$Z_1 = \frac{(p_1^2 - p_2^2)}{2 \times p_3 \times q_v} \tag{E.1}$$

$$Z_2 = \frac{(p_2^2 - p_3^2)}{2 \times p_3 \times q_v} \tag{E.2}$$

Whence

$$Z_2 = \frac{(p_2^2 - p_3^2) Z_1}{(p_1^2 - p_2^2)} \tag{E.3}$$

From Equation (A.1), it follows that the roughness of the paper beneath the sensing head can then be calculated from:

$$G_3 = \left(\frac{12 \times \eta \times b}{l \times Z_2} \right)^{\frac{1}{3}} \tag{E.4}$$

Pressure p_3 is very close to atmospheric pressure, while p_2 and p_1 can be determined from p_3 and the transducer outputs T_1 and T_2, provided that the transducers have been correctly calibrated to indicate gauge pressure. Thus departures of p_1 from some specified steady value may be allowed for in the calculation of roughness.

E.4 Dynamic aspects of impedance measurements

The dynamics of the measuring system make it impractical to observe the intermediate pressure p_2 by an externally connected manometer when a roughness reading is being taken by the instrument.

A single measurement can be completed in approximately 5 s. At the start of a cycle, air is applied both to the clamping device and to the fluidic impedance. The clamping pressure increases rapidly and after approximately 1 s approaches its final value. The intermediate pressure p_2 begins to rise as soon as the clamping device closes. It approaches its final value at a rate dependent on:

a) the volume of the pipework and dead space between the fluidic impedance and the sensing head; and

b) the values Z_1 and Z_2 of these impedances.

The volume of dead space is so chosen that p_2 closely approaches its final value 3 s after the start of the measuring cycle, even when the value of Z_2 is very high (very smooth paper). At this point, the outputs T_1 and T_2 of the two transducers are read automatically, the clamping mechanism is vented and the air flow to the measuring head is turned off. The roughness value is calculated and displayed digitally.

It follows that, if a water manometer were connected into the pneumatic circuit to measure p_2, the value of p_2 observed during a normal measuring cycle would be in serious error, as would the value of roughness displayed by the instrument.

E.5 Pressure transducers and their calibration

As indicated in E.3, if two pressure transducers are incorporated in the measuring system, corrections can be made automatically for variations in p_1. The transducers shown in Figure E.1 would in fact measure gauge pressures corresponding to $(p_1 - p_3)$ and to $(p_2 - p_3)$, but in practical instruments it might be found preferable to use one of the transducers to measure the pressure difference $(p_1 - p_2)$. This is a detail which is not considered here. The important point is that practical provision should be made to permit the relationship between the pressure seen by the transducers and their outputs to be checked. Each transducer can be assumed to incorporate a conditioning amplifier provided with variable gain and offset. The outputs of the transducers should therefore correspond to a linear relationship of the form:

$$T_1 = A_1(p_1 - p_3) + B_1 \quad \text{(E.5)}$$

$$T_2 = A_2(p_2 - p_3) + B_2 \quad \text{(E.6)}$$

For any particular type of instrument, the constants A_1, A_2, B_1 and B_2 shall be set to correspond to the values used in the instrument to calculate the roughness.

In practice, a permanent tapping point could be provided corresponding to p_1, while p_2 could be accessed by means of a special dummy head to provide a direct connection between the inlet to the sensing head and a tube leading to a manometer, the normal connection to the surface of the paper sample being sealed off. Access to the signals T_1 and T_2 could be provided by way of buffer amplifiers to prevent electrical interference or loading of the measuring circuits. Such facilities would allow the transducers to be calibrated.

E.6 The calculation of roughness

The details of the calculation can vary from instrument to instrument, and will depend on how the pressures p_1 and p_2 are sensed.

The downstream pressure p_3 would normally be assumed to be standard atmospheric pressure. The error in neglecting the effect of normal variations in barometric pressure is slight unless the procedure is carried out at high altitude.

If the transducer outputs T_1 and T_2 can be observed while a measurement is being made, and the value of the fluidic impedance Z_1 is known, then the correctness of the roughness displayed by the instrument can be checked by comparing its roughness readings with the value calculated from Equations (E.3) and (E.4).

E.7 The fluidic impedance

The value and linearity of the fluidic impedance may be checked in a laboratory before installation, measuring the flow q_v by the method described in Annex C.

If p_1 and p_2 can be measured via the transducer outputs T_1 and T_2, then the linearity and value Z_1 of the fluidic impedance can also be checked in place in the instrument. The sensing head could be temporarily replaced by a dummy head designed to allow air from the fluidic impedance to be fed via a needle valve to a suitable apparatus by which flow q_v could be measured.

Finally, it should be noted that suitable linear fluidic impedances compatible with the differential pressures used in the impedance-type instrument cannot readily be made from short glass capillary tubes, unless the required impedance is unusually high, because of problems with non-linearity. They can be made conveniently from suitably designed porous plugs, and are supplied by the instrument manufacturer. A set of three plugs covers the measurement range of the instrument.

Bibliography

[1] ISO 8791-1, *Paper and board — Determination of roughness/smoothness (air leak methods) — Part 1: General method*

[2] PARKER, J.R., An air leak instrument to measure printing roughness of paper and board, *Paper Tech.* **6** (2): T32 (1965)

ICS 85.060

Price based on 22 pages