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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Paper and board — Determination of thickness and apparent bulk density or apparent sheet density

Papier et carton — Détermination de l'épaisseur et de la masse volumique des feuilles uniques ou des feuilles en liasses

Reference number
ISO 534 : 1988 (E)

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.

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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 534 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*.

This second edition combines and cancels the first editions of ISO 438 : 1980 and ISO 534 : 1980 and introduces the concepts of apparent bulk density and apparent sheet density.

Annex A forms an integral part of this International Standard.

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Paper and board — Determination of thickness and apparent bulk density or apparent sheet density

1 Scope

This International Standard specifies two methods of measuring the thicknes of paper and board and of calculating the apparent bulk density or the apparent sheet density from the thickness determinations. The methods are

a) measurement of single sheets of paper or board (single sheet thickness);

b) measurement of a pack of sheets of paper of grammage up to 224 g/m^2 (bulking thickness).

These methods are not applicable to corrugated fibreboard and, in the case of method b), not to certain soft papers such as tissues which are creped and/or embossed, due to the slow or excessive compression which takes place when measurements are made on such materials.

It should be noted that two alternative pressures are permitted (see table 1); the pressure of 100 kPa ± 10 kPa is preferred.

NOTE — It should be noted that the two methods generally lead to different results.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 186 : 1985, *Paper and board — Sampling to determine average quality.*

ISO 187 : 1977, *Paper and board — Conditioning of samples.*

ISO 536 : 1976, *Paper and board — Determination of grammage.*

ISO 5725 : 1986, *Precision of test methods — Determination of repeatability and reproducibility for a standard test method by inter-laboratory tests.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 single sheet thickness: Distance between one surface of a paper or board and the other, determined under an applied static load, using the standard method of test.

3.2 bulking thickness: Thickness of a single sheet of paper, calculated from the thickness of several superimposed sheets (termed a pack), measured under an applied static load, using the standard method of test.

3.3 apparent bulk density: Mass per unit volume of paper or board, expressed in grams per cubic centimetre and calculated from the bulking thickness. This term is normally applicable to paper.

3.4 apparent sheet density: Mass per unit volume of paper or board, expressed in grams per cubic centimetre and calculated from the single sheet thickness. This term is normally applicable to paper or board.

4 Principle

4.1 Measurement of the thickness of a single sheet or a pack of sheets under a specific static load by means of a high-precision micrometer. Expression of the results in terms of the thickness of a single sheet or bulking thickness per sheet according to the test requirements.

4.2 Calculation of the apparent bulk density or apparent sheet density of the paper or board from a knowledge of its grammage and thickness.

5 Apparatus

5.1 Dead-weight micrometer, provided with two plane, parallel, circular pressure faces, between which the paper or board is placed for measurement.

The pressure exerted between the pressure faces during the thickness measurement shall be as given in table 1.

Table 1 — Pressure between pressure faces

Pressure kPa	Status of value
100 ± 10	Preferred
50 ± 5	Alternative

NOTE — It is the long-term objective of this International Standard to allow only 100 kPa, but because of the long working life of micrometers it is not possible, at this time, to set a target date for the elimination of the alternative pressure.

The two pressure faces shall form an integral part of the micrometer, such that one face is fixed (the anvil) and the other is movable in a direction perpendicular to the plane of the fixed face.

One face shall be 16,0 mm ± 0,5 mm in diameter and the second face shall be of such a size that it is in contact with the whole area of the other face when the micrometer reads zero. Thus, a circular region of a test piece, nominally 200 mm^2 in area, is subjected during the thickness measurement to the pressure exerted between the faces.

The performance requirements of the micrometer shall be such that, when calibrated according to the method given in annex A, the micrometer complies with the requirements given in tables 1 and 2 (see also 9.1).

Table 2 — Micrometer performance requirements

Micrometer characteristic	Maximum permitted value
Indication error	± 2,5 µm or ± 0,5 %
Error of parallelism between pressure faces	5 µm or 1 %
Repeatability of measurement (as standard deviation)	2,5 µm or 0,5 %

NOTES

1 The maximum permitted value of a micrometer characteristic is the greater of the two values quoted for it in the table.

2 Where a tolerance is expressed in the form of a percentage, it is based upon the thickness of the test piece under test. Thus, it is possible for a given micrometer to comply with the requirements of the table for some materials, but not for others.

3 For measurements on very thin papers, an instrument with better performance than that specified in this table may be required.

5.2 Thickness gauges, corresponding to approximately 10 %, 30 %, 50 % 70 % and 90 % of the full scale reading of the micrometer. Each gauge shall be accurate to 1 µm.

6 Sampling

Sample in accordance with ISO 186.

7 Conditioning

Condition the sample in accordance with ISO 187.

8 Preparations of test pieces

Prepare the test pieces in the same standard atmospheric conditions used to condition the sample. Avoid areas with folds, creases, cracks or other defects which could influence the results.

8.1 Bulking thickness

Cut a sheet, from each specimen taken at random from those selected in accordance with clause 6, of dimensions preferably 200 mm × 250 mm, the 200 mm dimension being in the machine direction (see figure 1). If this is not possible, prepare smaller sheets of at least 150 mm × 150 mm.

Make up a pack of ten sheets to form the test piece, ensuring that there are the same number of sheets in each test piece and that all the sheets are oriented in the same way. Each sheet shall be independent of the rest; for example, one sheet folded and inserted into the test piece to form two or more sheets shall not be permitted.

Prepare at least four test pieces.

NOTE — In special circumstances, such as for thick or very thin sheets or when agreed between the manufacturer and user, a smaller or larger number of sheets or a smaller or larger size of sheet may be used. The number of sheets used and their size should be reported.

8.2 Single sheet thickness

Cut not more than two test pieces from each specimen taken at random from those selected in accordance with clause 6, of minimum dimensions 60 mm × 60 mm. Ensure, however, that the test piece dimensions are not so large that the micrometer reading is affected by the test piece mass that overhangs the lower pressure face while a measurement is being made. Therefore, do not permit test pieces of board to exceed 100 mm × 100 mm. These test piece dimensions are usually satisfactory for making measurements on paper.

Prepare at least 20 test pieces.

9 Procedure

9.1 Verification and calibration of micrometer

At appropriate time intervals, calibrate the micrometer and verify its performance using the method given in annex A.

For micrometers in frequent use, determine the indication error and repeatability of measurement daily. Determine the pressure exerted between the pressure faces and their error of parallelism at monthly intervals.

When measurements are to be made on very thin papers, it is necessary to verify the performance of the micrometer at the temperature at which it is to be used.

9.2 Determinations

Carry out the test in the standard atmospheric conditions at which the samples were conditioned.

9.2.1 Determination of thickness

Place the micrometer on a horizontal vibration-free surface and interpose the test piece between the open pressure faces of the micrometer. Permit the test piece to be held by the pressure faces, by very carefully allowing the movable pressure face to move steadily and slowly, at a velocity less than 3 mm/s, towards the anvil so that any punching effect is avoided.

Record the micrometer reading, as soon as its value becomes steady, normally within 2 s to 5 s, but before any "bedding down" of the paper can occur. Avoid imposing any manual stress on the test piece or micrometer while a reading is being made.

For bulking thickness, make one measurement at each of the five positions on the test piece that are indicated in the figure, that is, situated between 40 mm and 80 mm from the edges of the test piece and distributed along the two edges which are in the cross direction of the paper.

Dimensions in millimetres

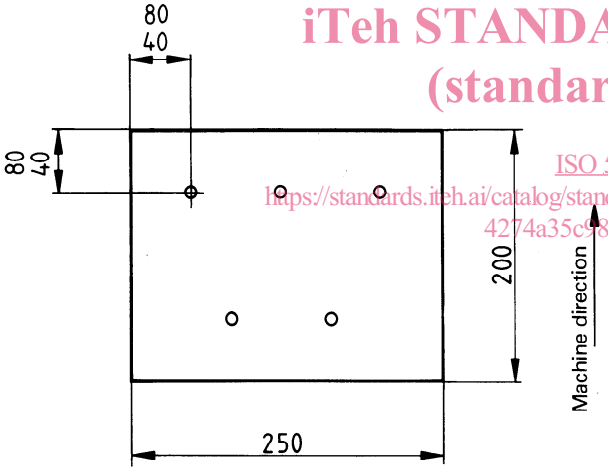

Figure 1 — Positions of measurement on test piece

Carry out the measurements on at least four test pieces.

For single sheet thickness make one measurement on each test piece, the measurement being made at a position at least 20 mm from any side of the test piece.

9.2.2 Determination of apparent density

If the apparent density of the paper or board is to be calculated, determine the grammage of the sample by the method specified in ISO 536.

10 Expression of results

10.1 Bulking thickness

10.1.1 Calculate the mean value of the readings (not less than 20). Divide it by the number of sheets comprising each test piece to obtain the bulking thickness of a single sheet of paper and express the result, in micrometres, to three significant figures.

10.1.2 Record the maximum and minimum values of the bulking thickness.

10.1.3 Calculate the standard deviation of the bulking thickness.

10.1.4 Calculate the precision of the mean at the 95 % confidence level.

10.2 Single sheet thickness

10.2.1 Calculate the mean value of the readings (not less than 20) to obtain the average thickness of a single sheet of paper or board. Express the result, in micrometres, to three significant figures.

10.2.2 Record the maximum and minimum values of single sheet thickness.

10.2.3 Calculate the standard deviation of the single sheet thickness.

10.2.4 Calculate the precision of the mean at the 95 % confidence level.

10.3 Apparent density

10.3.1 Apparent bulk density

Calculate the apparent bulk density, in grams per cubic centimetre, from the formula

$$\frac{g}{\delta_1}$$

where

g is the grammage of the paper, in grams per square metre;

δ_1 is the mean thickness of the paper , in micrometres.

Report the result to two decimal places.

10.3.2 Apparent sheet density

Calculate the apparent sheet density, in grams per cubic centimetre, from the formula

$$\frac{g}{\delta_2}$$

where

g is the grammage of the paper or board, in grams per square metre;

δ_2 is the mean single sheet thickness of the paper or board, in micrometres.

Report the result to two decimal places.

NOTE — It is stressed that the apparent density of paper, calculated from the bulking thickness, is not necessarily the same as the apparent density of the same paper calculated from the single sheet thickness detemined using the same apparatus.

11 Precision

11.1 Repeatability

11.1.1 Bulking thickness

Under routine laboratory conditions, repeatability varies from 0,1 µm to 0,5 µm with a mean value of 0,31 µm, or from 0,1 % to 0,9 % with a mean value of 0,5 %.

The difference between two single test values found on identical test material, by one operator using the same micrometer within a short time interval, will exceed the repeatability on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 0,3 % calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises from the inherent variability of paper.

11.1.2 Single sheet thickness

Under routine laboratory conditions, repeatability varies from 0,8 µm to 2,2 µm, with a mean value of 1,3 µm, or from 1,1 % to 2,6 % with a mean value of 2,0 %.

The difference between two single test values found on identical test material, by one operator using the same micrometer within a short time interval, will exceed the repeatability on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 1,5 µm calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises from the inherent variability of paper.

11.2 Reproducibility

11.2.1 Bulking thickness

Under routine laboratory conditions, reproducibility varies from 1,7 µm to 3,4 µm with a mean value of 2,7 µm, or from 2,4 % to 6,2 % with a mean value of 3,7 %.

The difference between two single and independent results found by two operators, working in different laboratories on identical test material, will exceed the reproducibility on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 0,65 % calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises not only form the inherent variability of paper but also from environmental and operator differences.

11.2.2 Single sheet thickness

Under routine laboratory conditions, reproducibility varies from 4,2 µm to 8,6 µm with a mean value of 5,9 µm, or from 4,7 % to 10,9 % with a mean value of 7,9 %.

The difference between two single and independant results found by two operators, working in different laboratories on identical test material, will exceed the reproducibility on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 3,2 µm calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises not only form the inherent variability of paper but also from environmental and operator differences.

12 Test report

The test report shall include the following information:

a) reference to this International Standard;

b) precise identification of the sample;

c) date and place of testing;

d) the conditioning atmosphere used;

e) the pressure exerted between the micrometer pressure faces;

f) if measured, the mean bulking thickness in micrometres to three significant figures, the maximum and minimum values, the standard deviation and the precision of the mean at the 95 % confidence level;

g) if measured, the mean single sheet thickness in micrometres to three significant figures, the maximum and minimum values, the standard deviation and the precision of the mean at the 95 % confidence level;

h) if required, the apparent bulk density or the apparent sheet density to two decimal places;

i) the number of test pieces used for the test;

j) in the case of bulking thickness, the number of sheets used for each test piece;

k) the number of readings taken;

l) the grammage of the sample, if determined;

m) any departure from the procedure specified in this International Standard, together with any circumstances or influences that may have affected the results.

Annex A
(normative)

Verification of micrometer performance and calibration

A.1 General

Verify the performance of the micrometer, using the following tests in the order given.

If the micrometer performance is not within the tolerance appropriate to a particular test (see 5.1), make the necessary correction and recommence the series of tests.

A.2 Pressure exerted between pressure faces

Any suitable means of verifying the accuracy and uniformity of the pressure exerted between the pressure faces may be used.

A.3 Indication error and repeatability of measurement

A.3.1 With the pressure faces in contact with one another, set the micrometer reading to zero. Do not reset the zero reading during the following procedure.

A.3.2 Open the gap between the pressure faces, allow it to close again (see 9.2) so that the pressure faces make contact with one another, and note the micrometer reading. Repeat this procedure at least five times.

A.3.3 Take one of the thickness gauges specified in 5.2, open the gap between the pressure faces, interpose the gauge, allow the faces to close upon the gauge (see 9.2) and note the micrometer reading. Take care not to handle the measuring surfaces of the thickness gauge. Repeat this procedure at least five times.

A.3.4 Repeat the procedure described in A.3.3, using, in turn, each of the remaining thickness gauges.

NOTE — The thickness gauges are used singly, not in combination.

A.3.5 Repeat the procedure described in A.3.2.

A.3.6 For each gauge thickness at which micrometer readings are taken, calculate

a) the repeatability of measurement, that is, the standard deviation of the five (or more) readings taken;

b) the indication error, that is, the difference between the mean of the five (or more) readings taken and the gauge thickness.

A.4 Parallelism of pressure faces

A.4.1 Take one of the thickness gauges specified in 5.2, open the gap between the pressure faces and interpose the gauge, as near as possible to one edge of the faces. Allow the pressure faces to close upon the gauge (see 9.2) and note the micrometer reading.

A.4.2 Open the gap between the pressure faces and interpose the thickness gauge, as near as possible to the edge of the faces and diametrically opposite the edge used in A.4.1. Allow the pressure faces to close upon the gauge (see 9.2) and again note the micrometer reading.

A.4.3 Repeat the procedure described in A.4.1 and A.4.2, using positions as near as possible to the edge of the pressure faces and on a diameter perpendicular to that passing through the points referred to in A.4.1 and A.4.2.

A.4.4 Repeat the procedure described in A.4.1, A.4.2 and A.4.3, using, in turn, each of the remaining thickness gauges.

NOTE — The thickness gauges are used singly, not in combination.

A.4.5 For each gauge thickness at which micrometer readings are taken, calculate the error of parallelism from the formula

$$0{,}5\sqrt{d_1^2 + d_2^2}$$

where

d_1 is the difference between the readings corresponding to opposite ends of a diameter of the pressure faces;

d_2 is the difference between the readings corresponding to opposite ends of a diameter of the pressure faces perpendicular to that used to obtain d_1.

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