INTERNATIONAL STANDARD

ISO 6565

Fifth edition
2015-12-15

Tobacco and tobacco products — Draw resistance of cigarettes and pressure drop of filter rods — Standard conditions and measurement

Tabac et produits du tabac — Résistance au tirage des cigarettes et perte de charge des bâtonnets-filtres — Conditions normalisées et mesurage

Reference number
ISO 6565:2015(E)

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Foreword

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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).

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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 126, *Tobacco and tobacco products*, Subcommittee SC 1, *Physical and dimensional tests*.

This fifth edition cancels and replaces the fourth edition (ISO 6565:2011), which has been technically revised.

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Introduction

The draw resistance of cigarettes or the pressure drop of filter rods is a widespread and important concept both for product quality specifications and for analytical determinations by mechanical smoking.

Different procedures and apparatus are currently available for this determination. It has so far not been possible to standardize the complete description of the equipment to be used and the detailed procedure. Nevertheless, it has been possible to obtain broad consensus on the definitions to be adopted and the conditions that allow comparable determinations of this characteristic to be made. In order to achieve this, one of the main requirements is the use of transfer standards for the calibration of instruments (see Annex A).

In this International Standard, the results are given in pascals (Pa). For information, they are also given in millimetres water gauge (mmWG).

The values given previously in mmWG are converted into Pa using the following correction factor:

— 1 mmWG = 9,806 7 Pa

For practical use, the values have been rounded.

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Tobacco and tobacco products — Draw resistance of cigarettes and pressure drop of filter rods — Standard conditions and measurement

1 Scope

This International Standard describes a method for the measurement of the draw resistance of cigarettes and pressure drop of filter rods, and specifies the standard conditions applicable to such measurements.

It is applicable to cigarettes, filter rods, and, by extension, to cylindrical tobacco products similar to cigarettes.

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 3402, *Tobacco and tobacco products — Atmosphere for conditioning and testing*

3 Terms and definitions

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

3.1
pressure drop
Δp
static pressure difference between the two ends of

— a test piece completely encapsulated in a measuring device such that no air can pass through the outer membrane (or wrapping),

— a pneumatic circuit, or

— a *pressure drop transfer standard* (3.6)

when it is traversed by an air flow under steady conditions in which the measured volumetric flow, under standard conditions, at the *output end* (3.4) is 17,5 ml/s, as defined in ISO 3402

Note 1 to entry: This is expressed in pascals (Pa) (or in mmWG).

3.2
draw resistance
Δp_D
negative pressure which has to be applied to the *output end* (3.4), under test conditions (see ISO 3402), in order to sustain a volumetric flow of 17,5 ml/s, exiting at the output end, when the cigarette is encapsulated in a measurement device to a depth of approximately 9 mm, as defined in ISO 3308

Note 1 to entry: Any ventilation zones and the tobacco rod are exposed to the atmosphere.

Note 2 to entry: The concept of draw resistance can also be subjectively judged when a cigarette is smoked by a consumer/taste panel. Under such circumstances, draw resistance is not measured objectively because the conditions of the formal definition are not met.

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3.3
input end
<cigarettes> end of the test piece intended to be lit

3.4
output end
end opposite from the *input end* (3.3)

3.5
standard direction of flow
direction from the *input end* (3.3) to the *output end* (3.4)

Note 1 to entry: In the case of a filter rod, the *input end* (3.3) and the *output end* (3.4) are defined by the direction of flow.

3.6
pressure drop transfer standard
transfer standard for *pressure drop* (3.1) measurement systems which is calibrated under standard ambient conditions and used under local ambient conditions

Note 1 to entry: The form and properties of suitable transfer standards are given in Annex A.

3.7
dummy standard
device with the same shape and similar form to a *pressure drop transfer standard* (3.6), for use in leak testing of calibration apparatus

Note 1 to entry: A suitable dummy standard consists of a pressure drop transfer standard or a smooth metal tube of similar dimensions.

3.8
reference standard
pressure drop transfer standard (3.6) against which other pressure drop transfer standards are compared

Note 1 to entry: Such a reference standard is generally reserved for this purpose and is not used for the routine calibration of pressure drop measuring instruments.

3.9
monitor reference standard
reference standard (3.8) used to confirm the correctness of calibration of an instrument or measurement system

Note 1 to entry: See A.4.2.3.4.

4 Test conditions

4.1 Test conditions common to cigarettes and filter rods

4.1.1 General

The test conditions shall be constant and in agreement with the conditions under which the calibration was performed (see Clause 5).

NOTE The use of transfer standards for calibration enables measurements to be made under test conditions outside those described by ISO 3402.

4.1.2 Air flow

The air flow shall be from the input end in the standard direction of flow (see 3.5).

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4.1.3 Position

The position of the test piece may be either horizontal or vertical, but products with cavities containing loose-fill material shall be positioned vertically.

4.2 Conditions particular to cigarettes — Insertion of the test piece

The output end of the test piece shall be inserted into a measurement device encapsulated to a depth of approximately 9 mm.

NOTE The intention is to achieve a good seal while not occluding any ventilation holes.

4.3 Conditions particular to filter rods — Encapsulation

The test piece shall be completely encapsulated in a measuring device so that no air can pass through the filter rod wrapping.

5 Instrument calibration

The instrument shall be calibrated before normal testing using transfer standards. This shall be done at least once per day. The calibration shall be carried out in accordance with the instrument manufacturer's instructions.

The instrument shall be recalibrated if the atmospheric conditions change by more than 2 °C for temperature, or by more than 5 % for relative humidity.

Each calibration of the instrument shall be recorded for later reference.

NOTE 1 To obtain the best accuracy, calibrate the instrument as close as possible to its full-scale deflection or at the maximum point of the range of values of the products to be tested.

To check for air leaks that might have occurred during the calibration and to check the linearity of the measuring system, at least one intermediate value pressure drop standard should be used in order to obtain a mid-scale value.

NOTE 2 In addition to the mid-scale value, a calibration check can be made with a pressure drop standard that has a nominal pressure drop value close to the draw resistance or pressure drop of the test pieces to be measured.

6 Procedure

6.1 Conditions common to vacuum and pressure instruments

Record details of the instrument type and configuration, including measurement settling time, if this can be determined (see 6.2 and 6.3).

Insert the test piece (either manually or automatically) into the measuring device of the instrument. Read the value of the draw resistance or pressure drop and record it.

6.2 Conditions particular to vacuum instruments

Before reading the draw resistance or pressure drop, leave the test piece in the measuring device until the reading is steady.

NOTE Practice has shown that a settling time of 4 s to 6 s is normally sufficient.

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6.3 Conditions particular to pressure instruments (for filter rods only)

Determine the required settling time depending on the draw resistance of the test piece and the type of instrument. The reading for pressure drop shall be recorded at a constant time after the insertion of the test piece.

For the particular conditions described in 6.2 and 6.3, practice has shown that for low draw resistance or pressure drop, i.e. below 2 000 Pa (or about 200 mmWG), a settling time of 2 s to 3 s is sufficient, while for higher draw resistances or pressure drop, i.e. above 4 000 Pa (or about 400 mmWG), a settling time of 4 s to 6 s is required.

7 Expression of results

The expression of the laboratory results depends on the purpose for which the data are required and the level of laboratory precision.

Express the results as follows:

— individual draw resistance or pressure drop of a test piece, rounded to the nearest 10 Pa (or to the nearest 1 mmWG);

— average and standard deviation of the draw resistance or pressure drop of a sample, rounded to the nearest 1 Pa (or to the nearest 0,1 mmWG).

8 Precision

8.1 Interlaboratory test

Details of an interlaboratory test on the precision of the method are summarized in Annex B. The values derived from this interlaboratory test might not be applicable to values and matrices other than those given.

8.2 Repeatability

The absolute difference between two independent single results, obtained using the same method on identical test material in the same laboratory by the same operator using the same equipment within a short interval of time will, in not more than 5 % of cases, be greater than the values given in Table 1 for cigarettes and Table 2 for filter rods.

Table 1 — Cigarettes

Repeatability limit, r	
Pa	mmWG
$r = 23$	$r = 2{,}3$

Table 2 — Filter rods

Repeatability limit, r	
Pa	mmWG
$r = 0{,}007 \times m\Delta p$	$r = 0{,}007 \times m\Delta p$
NOTE $m\Delta p$ is the mean value of the pressure drop Δp, expressed in pascals (Pa) (or in mmWG).	

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8.3 Reproducibility

The absolute difference between two single test results, obtained using the same method on identical test material in different laboratories with different operators using different equipment will, in not more than 5 % of cases, be greater than the values given in Table 3 for cigarettes and Table 4 for filter rods.

Table 3 — Cigarettes

Reproducibility limit, R	
Pa	mmWG
R = 57	R = 5,8

Table 4 — Filter rods

Reproducibility limit, R	
Pa	mmWG
$R = 0{,}023 \times m\Delta p$	$R = 0{,}023 \times m\Delta p$
NOTE $m\Delta p$ is the mean value of the pressure drop Δp, expressed in pascals (Pa) (or in mmWG).	

9 Test report

The test report shall show the method, instrument, and instrument configuration used.

It shall also mention any operating conditions not specified in this International Standard or regarded as optional, as well as any circumstances that might have influenced the results.

The test report shall include all details required for the complete identification of the sample and the results obtained.

It shall mention, in particular, the following information:

a) the product name or identification;

b) the date of sampling;

c) the date of test;

d) the type of instrument used, instrument configuration, or settling time;

e) the results;

f) the total number of test pieces tested;

g) the room temperature in degrees Celsius (°C) during testing;

h) the relative humidity in percentage (RH %) during testing;

i) the atmospheric pressure.

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Annex A
(normative)

Calibration of pressure drop transfer standards

A.1 Essential properties of calibration standards

NOTE All uncertainty values quoted in this Annex are given at 95 % confidence level.

Pressure drop transfer standards have defined pressure drop values, which can be used to calibrate measuring instruments for the determination of the draw resistance of cigarettes and pressure drop of cigarette filter rods.

The certified value of the pressure drop standard is the calibrated value adjusted by means of a compensation formula that normalizes the calibrated value to standard ambient conditions in accordance with ISO 3402 (given as 22 °C, 60 % RH, and 86 kPa to 106 kPa).

The derivation of this compensation formula is given in A.4.6.

A.2 Essential properties of pressure drop transfer standards

Although different types of pressure drop standards are available, this Annex refers specifically to standards with 10 capillaries and made from glass. In particular, the application of the compensation formulae given in A.4.6 and the values of repeatability and reproducibility quoted are specific to glass multicapillary standards. Other values of repeatability and reproducibility and other compensations might be appropriate for standards of different construction.

Pressure drop transfer standards shall exhibit the following properties.

— They shall be made of a chemically inert material which is unaffected by use or ageing.

— They shall closely resemble the physical size and shape of a filter rod or cigarette.

— They shall have defined and repeatable values within stated confidence limits.

— The airflow through the pressure drop standard shall be laminar and shall have repeatable measurement characteristics.

— The level of uncertainty of the certified value of pressure drop transfer standards shall not exceed 1 % of its absolute value.

A.3 Calibration apparatus

A.3.1 Holder for standard under test

To determine the pressure drop of a glass multicapillary transfer standard, it shall be placed in a holder, the mechanical arrangement of which shall not modify the characteristics of the standard, nor create any systematic influences upon the calibrated value. The essential qualities of a typical arrangement are illustrated in Figure A.1.

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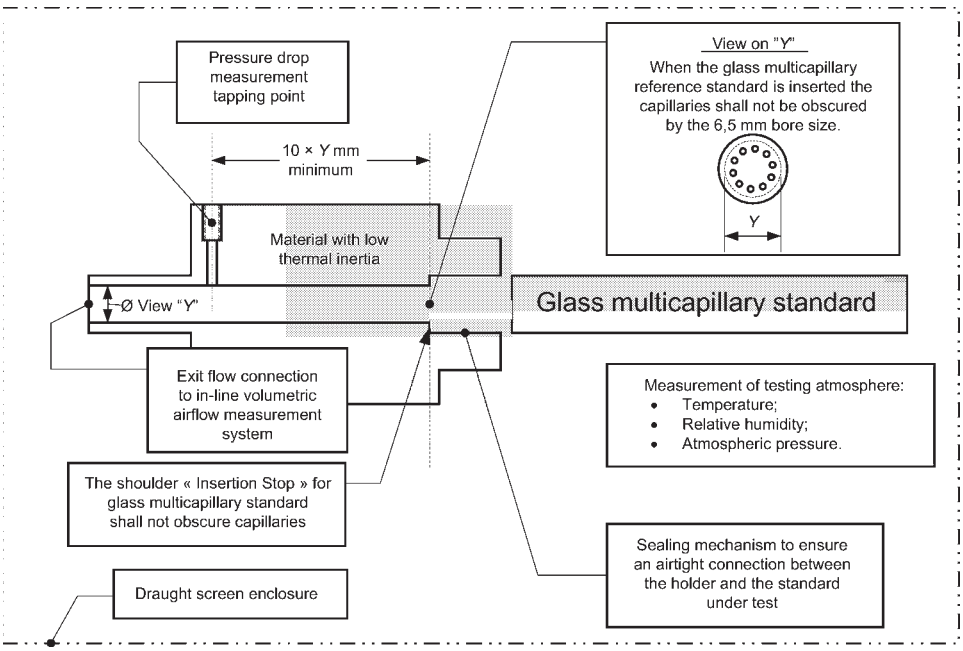

Figure A.1 — Essential qualities of calibration device

A.3.2 Determination of volumetric flow

A.3.2.1 General

A volumetric flow measurement device (VFMD) that does not generate any systematic influence on the flow measurement is used to determine the time taken for a volume displacement of air to be drawn through the standard under test.

The VFMD shall have a maximum uncertainty of 0,3 % of indicated volume.

NOTE Refer to ISO 5725-1 for information on specified limits of uncertainty.

Two examples of volumetric flow measurement devices are described in A.3.2.2 and A.3.2.3.

A.3.2.2 Piston driven

This device takes the form of a precision bore cylinder, inside which a piston is moved at a constant speed by a precision motor to draw a constant volumetric flow through the standard under test from atmosphere.

A.3.2.3 Vacuum driven

This device takes the form of a precision bore cylinder with a free moving piston which is moved vertically upward by the application of a separate suction source applied to the outflow of the cylinder. This apparatus has sensors that monitor the movement of the piston to allow a precise measurement of the time to displace a known volume of air, which has been drawn through the standard under test from atmosphere and which collects under the piston.

A.3.2.4 Measurement of air temperature, relative humidity, and atmospheric pressure

The temperature and relative humidity of the measurement air shall be measured at a point in close proximity to the air entering the standard, within the confines of the draught screen enclosing the standard under test.

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The atmospheric pressure measurement shall be made within the testing environment and recorded at the same time as the temperature and relative humidity measurements.

The temperature measurement shall have a maximum uncertainty of 0,3 °C.

The relative humidity measurement shall have a maximum uncertainty of 5 %.

The atmospheric pressure measurement shall have a maximum uncertainty of 100 Pa.

NOTE See ISO 5725-1 for further information on limits of uncertainty.

A.3.2.5 Pressure measurement system

A differential pressure measurement system shall be connected to the tapping point of the holder to measure the pressure difference between the exit end of the standard and the atmosphere, while the standard is traversed by the controlled airflow under steady conditions.

This pressure difference shall be measured and recorded.

The pressure measurement system shall have a maximum uncertainty of 0,2 % of the measured value.

A.3.2.6 Suction source

A suction source, as described in 3.2, capable of drawing a constant volumetric airflow, shall be placed in line with a VFMD which is, in turn, connected to the exit flow connection of the holder.

A typical arrangement of the calibration apparatus is illustrated in Figure A.2.

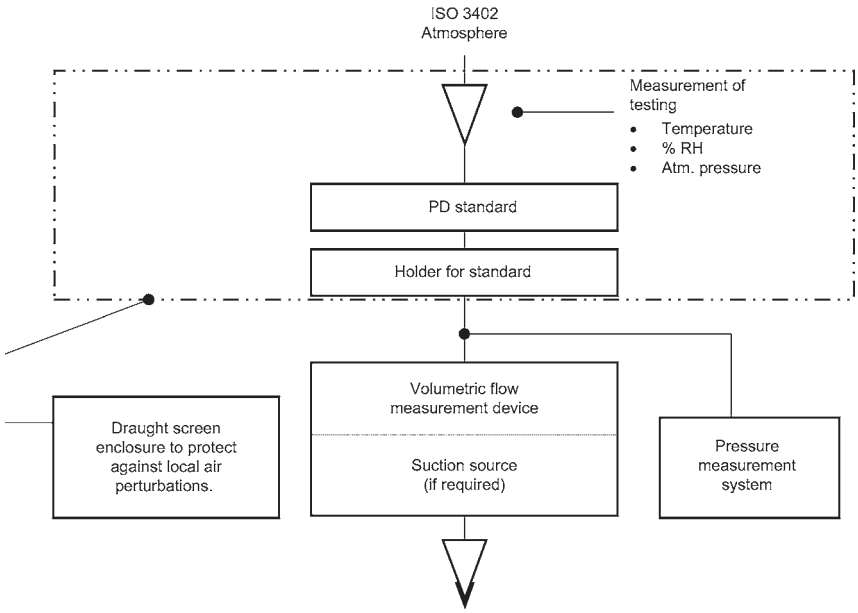

Figure A.2 — Typical arrangement of calibration apparatus

Soap bubble flow meters shall not be used for the calibration of pressure drop transfer standards. These devices increase the moisture content of the measurement air, causing increased volumetric flow and decreased velocity.

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A.4 Calibration procedure

A.4.1 Cleaning of standards

A.4.1.1 General

A.4.1.1.1 Before calibration, all standards shall be cleaned by immersion in an ultrasonic bath containing a solution of distilled water and 5 % non-ionic surfactant solvent.

NOTE Two examples of non-ionic surfactant solvents are Igepal CO 630® (Nonylphenol Ethoxylate) and Branson GP® concentrated cleaning formula[1)].

A.4.1.1.2 The standards shall be submerged in the cleaning vessel in the cleaning solution for a minimum time of 10 min with their longitudinal axis between 10° and 20° from vertical. This ensures that any contact with the floor of the cleaning vessel will be on the edge of the standard, thereby avoiding any possible contamination of the capillaries.

A.4.1.1.3 Following the cleaning process, the standards shall be submerged and rinsed in an ultrasonic bath containing pure distilled or deionised water (free from dissolved salts and other compounds) for a minimum time of 5 min.

A.4.1.1.4 The standards shall then be dried, ensuring that no residual water deposits remain in the capillaries and the possibility of the ingress of contamination is minimised.

A.4.2 Pre-calibration procedures

A.4.2.1 General

Measurements shall be conducted in a testing atmosphere in accordance with ISO 3402 and the calibration apparatus shall be configured in accordance with the arrangement illustrated in Figure A.1.

A.4.2.2 Equilibration of standards

The calibration apparatus and pressure drop transfer standards awaiting tests shall be left open to the testing atmosphere for a minimum of 12 h to ensure equilibrium with the testing atmosphere has been reached before any measurements are undertaken.

A.4.2.3 Apparatus leakage test and measurement integrity check

A.4.2.3.1 General

A dummy standard shall be installed in the holder and a leakage test shall be performed to test the integrity of the measurement system, according to A.4.2.3.2 for vacuum driven systems or A.4.2.3.3 for piston driven systems.

The leakage test shall precede any calibration or series of calibrations and shall be performed once on each day that calibration takes place.

1) Igepal CO 630® (Nonylphenol Ethoxylate) and Branson GP® are examples of suitable products available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

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A.4.2.3.2 Procedure for vacuum driven systems

Perform the following procedure for vacuum driven systems.

a) A dummy standard shall be installed in the calibration holder with its downstream exit end connected to the VFMD and its upstream end free to atmosphere.

b) The system shall be operated by application of a vacuum to the outlet port of the VFMD to create a negative pressure underneath the piston and at the exit end of the standard.

c) When the piston reaches the middle of the VFMD, the dummy standard shall have its atmospheric end capped and the outlet port of the VFMD shall be vented to atmosphere.

d) After allowing sufficient time for the VFMD piston to become stationary (minimum 30 s), any leakage will be observed by monitoring the position and stability of the piston for a period of time to detect any leaks greater than 1,5 ml/min.

e) The monitoring time (t_M) for 1 mm movement of the piston required can be calculated using Formula (A.1)

$$t_M = \frac{A_p \times l_p}{q_{V,l}} \quad \text{(A.1)}$$

where

A_p is the cross-section, expressed in square centimetres (cm^2), of the piston;

l_p is the distance of displacement of the piston, i.e. 0,1 cm;

$q_{V,I}$ is the volume flow rate, expressed in millilitres per minute, of the minimum acceptable leak, i.e. 1,5 ml/min.

For example, for a VFMD with a nominal cylinder diameter of 44,5 mm, a minimum monitoring time of 1 min is required, during which time any movement of the piston level shall be less than 1 mm. For a VFMD with a nominal cylinder diameter of 76,2 mm, the equivalent leakage detection time for a 1 mm displacement would be 3 min.

A.4.2.3.3 Procedure for piston driven systems

Perform the following procedure for piston driven systems.

a) A dummy standard shall be installed in the calibration holder with its downstream exit end connected to the VFMD and its upstream end sealed from atmosphere.

b) The VFMD system shall be set to a dead volume of 1 000 ml ± 100 ml. A negative pressure in the range of 2,8 kPa to 3,2 kPa shall be applied.

c) After allowing sufficient time for the pressure to reach a stable value, the leakage volume shall be measured and shall not exceed 1,5 ml/min.

A.4.2.3.4 Monitor reference standards

The calibration laboratory shall maintain a set of reference standards to be used as calibration monitors, which shall be measured each day that the calibration laboratory is conducting measurements. The set of reference standards shall consist of a minimum of two standards of different pressure drop levels and which covers the range of pressure drop measurements to be carried out.

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A log shall be maintained of the measured values of monitor reference standards together with the operator identity and all ambient conditions at the time of test.

NOTE ISO 8258 and ISO 7870-1 give graphical methods for monitoring long-term measurement process stability.

If the measurements of the monitor reference standards are within the normal declared limits of uncertainty, then the calibration apparatus shall be deemed fit for use.

If the measurements of the monitor reference standards are outside the normal declared limits of uncertainty, then the apparatus should be checked for leaks or measurement errors, or both.

The monitor reference standards shall be rechecked following any remedial work.

A.4.3 Calibration method — Measurement procedure

A.4.3.1 This method describes a measurement procedure that generates a pressure drop across the standard under test proportional to the nominal 17,5 ml/s flow traversing it.

A.4.3.2 Measurement air, drawn from atmosphere through the standard under test, shall be drawn through the system for a minimum of 5 min prior to measurement to ensure thermal equilibrium.

A.4.3.3 The air temperature and relative humidity of the testing atmosphere within the draught screen enclosure containing the standard under test shall be measured together with atmospheric pressure and shall be recorded for application in the compensation formula.

A.4.3.4 A stabilized volumetric flow of nominally 17,5 ml/s (17,5 ± 0,3) ml/s shall be established through the VFMD and drawn through the standard under test.

A.4.3.5 The static differential pressure between the exit of the standard and atmosphere shall be monitored and recorded throughout the time of the stabilized volumetric flow measurement.

A.4.3.6 One reading of pressure is the average of at least three contiguous repeat measurements of the differential pressure, recorded during the elapsed time of the stabilized volumetric flow.

A.4.3.7 The compensation formula (A.4.6) shall be applied to the pressure reading to normalize the calibrated value of the pressure drop transfer standard to standard ambient conditions of 22 °C, 60 % RH, atmospheric pressure of 1 013 hPa, and a flow rate of 17,5 ml/s.

A.4.3.8 Steps A.4.3.2 to A.4.3.7 shall be repeated a further two times. The compensated pressure drop value of the pressure drop transfer standard shall be recorded as the mean of the three replicate values of normalized pressure drop.

The calibrated value of the standard, rounded to the nearest 1 Pa (0,1 mm WG), shall be recorded on an accompanying calibration certificate and may be inscribed on the pressure drop transfer standard. The pressure drop transfer standard shall be inscribed with a unique reference identification number.

A.4.4 Certification

Each standard shall be supplied with a certificate of calibration, which shall contain the following minimum information:

a) product name and unique reference number;

b) date of test;

c) operator reference;

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d) description of testing apparatus and traceable reference serial numbers of all measurement equipment;

e) temperature of testing atmosphere in degrees Celsius (°C) during testing;

f) relative humidity in percentage (RH %) during testing;

g) atmospheric pressure in hectopascals (hPa) or millibars (mbar) during testing;

h) compensated pressure drop calibration value;

i) limits of uncertainty of measurement;

j) any observation during time of testing.

A.4.5 Precision and accuracy

During the development of this calibration method, an inter-laboratory trial was made between the suppliers of calibration standards. Four sets of pressure drop transfer standards were used in this study, each consisting of four standards, one each of nominal value 200 mm WG, 400 mm WG, 600 mm WG, and 800 mm WG, respectively. Each laboratory measured each set of standards using the method described in this Annex, all measurements on one set of standards being completed in one day. The measurements were then repeated on three other days to give a total of four days' measurements.

This gave the results shown in Table A.1.

Table A.1 — Precision results

Nominal Δp		Reproducibility standard deviation		Repeatability standard deviation	
Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)
1 961	200	4,217	0,43	2,059	0,21
3 922	400	9,414	0,96	3,236	0,33
5 884	600	11,572	1,18	4,315	0,44
7 845	800	17,946	1,83	4,707	0,48

The above interlaboratory trial involved only three laboratories, there being only three competent laboratories known at present. Thus, the reproducibility and repeatability standard deviations are quoted rather than the repeatability and reproducibility figures, since the trial did not meet all of the criteria set out in ISO 5725 for the assessment of measurement methods. This should be taken into account when comparing these figures with those for other methods.

To ensure that the practised methods and procedures do not diverge from the standard, it is recommended that calibration laboratories take part in annual collaborative studies. To this end, the above figures, and those obtained from future studies, may be used to assess laboratory competence.

A.4.6 Description of the compensation process

The compensation process is described in detail in Reference [10]. This compensation has been validated for the most commonly used pressure drop standards composed of 10 parallel capillary tubes, the structure being made of glass. A short description of the compensation process is given below.

Pressure drop (Δp) values are influenced by the ambient conditions during calibration, i.e. by temperature, T, and relative humidity, RH, of air, and atmospheric pressure, p_{atm}. One way of reducing the influence of these ambient factors is to apply compensation. A suitable compensation formula can be derived by considering the effects of ambient conditions on the basic characteristics of the measurement air. When calibrating pressure drop standards, the objective of the compensation formula is the calculation of a pressure drop value, Δp_S, at standard ambient conditions (T_S = 22 °C, RHS = 60 %,

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p_S = 1 013 hPa, outlet airflow q_S = 17,5 ml/s) from Δp measurements, undertaken at different conditions (T, RH, p_{atm}, q).

Δp can be approximated to a sum of two values Δp_1 and Δp_2, Δp_1 being characteristic of the non-linear behaviour of the standard and Δp_2 of the linear behaviour.

A degree of nonlinearity, x, can then be defined such as:

$$\begin{aligned} \Delta p_1 &= x \times \Delta p \\ \Delta p_2 &= (1 - x) \times \Delta p \end{aligned} \tag{A.2}$$

The value of x has been experimentally determined over the Δp range from 200 mm WG to 800 mm WG:

$$x = 3,41 \times 10^{-5} \times \Delta p + 3,38 \times 10^{-2} \tag{A.3}$$

It can be shown that the compensated Δp value can be derived from Formulae (A.4) and (A.5) where Δp_{1S} and Δp_{2S} are the unknown parameters:

$$\Delta p_{2S}^2 - (p_S - \Delta p_{1S}) \times \Delta p_{2S} + \frac{\eta_S \times T_S}{\eta \times T} \times (p_{atm} - \Delta p) \times \Delta p_2 = 0 \tag{A.4}$$

$$\Delta p_{1S}^3 - 2 \times p_S \times \Delta p_{1S}^2 + p_S^2 \times \Delta p_{1S} - \frac{\rho_S \times T_S^2}{\rho \times T^2} \times \Delta p_1 \times (p_{atm} - \Delta p_1)^2 = 0 \tag{A.5}$$

where

Δp_{1S} and Δp_{2S} are the compensated values of Δp_1 and Δp_2 in millimetres water gauge (mmWG);

η and ρ are the air viscosity and density respectively during the calibration;

η_s and ρ_s are the air viscosity and density respectively at the standard ambient conditions;

T and T_s is the temperature, expressed in kelvin (K);

p_{atm} and p_s is the atmospheric pressure, expressed in millimetres water gauge (mmWG).

After resolving these equations, the standard Δp_s value with an outlet volumetric airflow of 17,5 ml/s can be then approximated by:

$$\Delta p_{S,17,5} \cong \Delta p_{1S} \times \left[\frac{17,5}{Q(p_S, T_S, \Delta p_S)}\right]^2 + \Delta p_{2S} \times \left[\frac{17,5}{Q(p_S, T_S, \Delta p_S)}\right] \tag{A.6}$$

where

Q is the volumetric flow, expressed in millilitres per second.

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Annex B
(informative)

Results of an interlaboratory trial

B.1 Number of laboratories and test samples

An international collaborative test involving 21 laboratories, which tested six different types (levels) of cigarettes and six different types (levels) of filter rods was carried out in 1994 by CORESTA. The results obtained were subjected to statistical analysis in accordance with ISO 5725 to give the precision data shown in Tables B.3 and B.4.

Procedures used in this study and the results are described below.

B.2 Selection of samples

The cigarette samples used were supplied to the participants by different cigarette manufacturers. Some samples were taken straight from production without any special pre-selection, some were selected for total mass, and one sample was selected for mass and for draw resistance.

The values obtained for repeatability and reproducibility limits in the case of cigarettes therefore will not only reflect the variability in the measuring procedure but also the variability of the product.

The filter rod samples were all carefully selected for pressure drop. Each individual test piece was allowed to differ by a maximum of ±1,5 % from the total mean value for each level. The results for repeatability and reproducibility limits therefore will mainly reflect the variability of the measuring procedure.

B.3 Conditions used for the test

Before measuring, the samples were conditioned for at least 24 h under the following conditions:

— temperature: (22 ± 2) °C;

— relative humidity: (60 ± 5) %.

For each measurement, 30 readings were taken, i.e. 30 randomly selected test pieces were tested. A repetition of the test using 30 different test pieces from the same sample was carried out after a short period of time. In all cases, this was done on the same day.

Although the individual samples could have been tested on different days, most laboratories carried out the tests on the same day.

B.4 Conditioning of the samples

As mentioned above, the laboratories were asked to condition the samples at (22 ± 2) °C and (60 ± 5) % RH for at least 24 h before measurements. This is certainly not production floor practice but it has been found to be necessary to reduce the variation of the samples.

The actual conditions reported by the laboratories ranged from 21 °C to 23,5 °C and from 59 % RH to 66 % RH for cigarettes. Only one laboratory exceeded slightly the maximum value for relative humidity, although not to the extent that the results of this laboratory were affected in any way.

For filter rods, the conditions ranged from 20 °C to 23,5 °C and from 57 % RH to 63 % RH.

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B.5 Conditions during measurements

No specific requirements were made in the test protocol for the ambient conditions during the measurement of the samples.

The actual ambient conditions observed and reported are given in Table B.1.

Table B.1 — Actual conditions observed

	Temperature °C	**Relative humidity** %	**Atmospheric pressure** hPa
Cigarettes	21,5 to 26,5	42 to 64	847 to 1 019
Filter rods	21,5 to 24,5	42,5 to 62	847 to 1 025

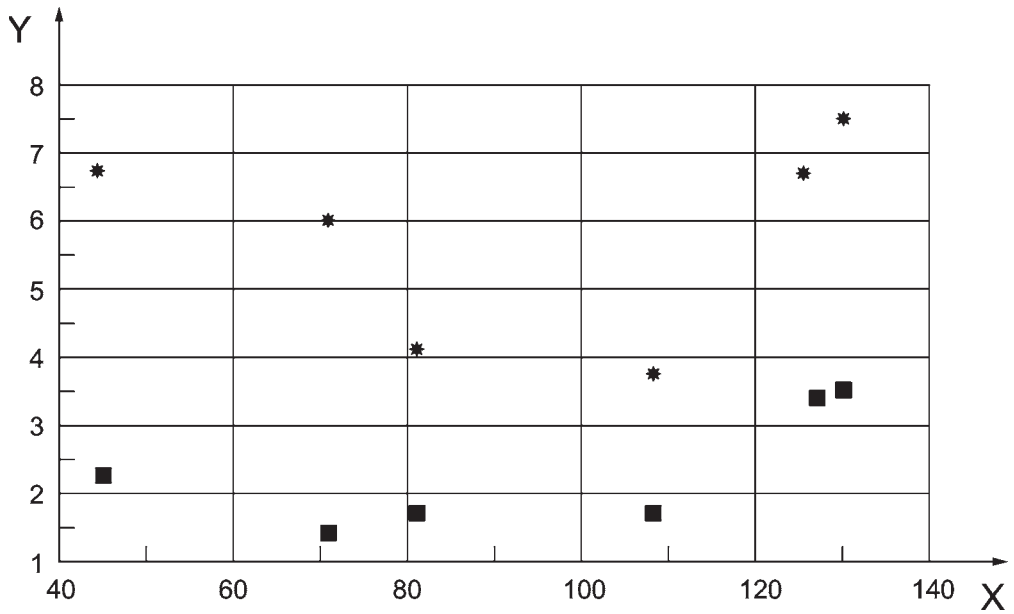
The atmospheric pressures correspond approximately to locations from sea level to 1 800 m above sea level.

B.6 Repeatability and reproducibility limits for the testing of cigarettes

The values for $m\Delta p_D$ (mean draw resistance), r (repeatability limit), and R (reproducibility limit) are given in pascals (Pa) (and in mmWG) in Table B.3.

They were calculated as described in ISO 5725:1986, 14.7.

Figure B.1 shows that there is no evident correlation between the values for r and R and the mean levels $m\Delta p_D$.



Key

X mean draw resistance, $m\Delta p_D$ (mmWG)

Y value of r or R (mmWG)

■ repeatability, r

✸ reproducibility, R

Figure B.1 — Relationship between r or R and $m\Delta p_D$ (for cigarettes)

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Table B.2 — Final values determined for r and R

Final values	
Pa	(mmWG)
r = 23	r = 2,3
R = 57	R = 5,8
NOTE These values are valid for a draw resistance range of 400 Pa (40 mmWG) to 1 300 Pa (130 mmWG).	

Table B.3 — Computed rounded values for mean draw resistance ($m\Delta p_D$), repeatability limit (r), and reproducibility limit (R) for cigarettes

Level	Number of laboratories	$m\Delta p_D$		s^2_r		r		s^2_R		R	
		Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)
1	19	440,81	44,95	6,57	0,67	22,45	2,29	56,89	5,80	66,10	6,74
2	17	696,56	71,03	2,65	0,27	14,21	1,45	43,75	4,46	57,96	5,91
3	17	792,57	80,82	3,64	0,37	16,76	1,71	21,53	2,20	40,70	4,15
4	18	1 059,51	108,04	3,08	0,31	15,39	1,57	17,98	1,83	37,17	3,79
5	19	1 244,66	126,92	13,67	1,39	32,46	3,31	55,16	5,62	65,12	6,64
6	19	1 276,93	130,21	15,69	1,60	34,72	3,54	70,20	7,16	73,45	7,49

B.7 Repeatability and reproducibility limits for the testing of filter rods

The values for $m\Delta p$ (mean pressure drop), r (repeatability limit), and R (reproducibility limit) are given in Table B.4.

They were calculated as described in ISO 5725:1986, 14.7.

From Table B.4 it seems clear that both r and R tend to increase linearly with higher values of $m\Delta p$.

Figure B.2 confirms this linear dependence. The dependence can be expressed by a straight line through the following origin:

$$r = b_r \times m\Delta p$$

$$R = b_R \times m\Delta p$$

where b is the slope.

Table B.4 — Computed rounded values for mean pressure drop ($m\Delta p$), repeatability limit (r), and reproducibility limit (R) for filter rods

Level	Number of laboratories	$m\Delta p$		s^2_r		r		s^2_R		R	
		Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)
1	20	1 965,94	200,47	1,85	0,19	11,96	1,22	26,83	2,74	45,41	4,63
2	20	2 975,15	303,38	5,62	0,57	20,79	2,12	57,40	5,85	66,39	6,77
3	20	4 019,47	409,87	11,24	1,15	29,42	3,00	109,53	11,17	91,79	9,36
4	20	5 105,76	520,64	28,79	2,94	47,07	4,80	188,92	19,27	120,52	12,29
5	20	5 945,80	606,30	26,90	2,74	45,50	4,64	244,08	24,89	137,00	13,97
6	20	7 014,73	715,30	24,17	2,46	43,14	4,40	322,98	32,93	157,59	16,07

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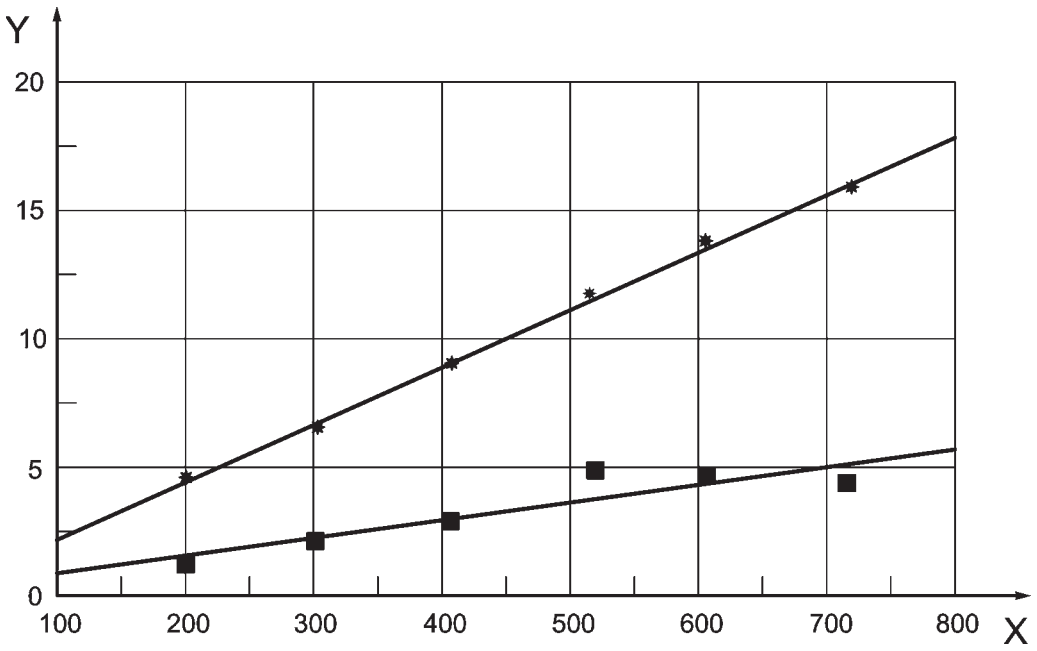

Key

X mean draw resistance, $m\Delta p$ (mmWG)

Y value of r or R (mmWG)

■ repeatability, r

✸ reproducibility, R

Figure B.2 — Relationship between r or R and $m\Delta p$ (for filter rods)

The final values of r and R can be expressed as linear equations.

The slopes of these lines, calculated as described in ISO 5725:1986, 15.6, are given in Table B.5.

Table B.5 — Relationship between r or R and $m\Delta p$ (filter rods)

Final values	
Pa	(mmWG)
$r = 0{,}007 \times m\Delta p$	$r = 0{,}007 \times m\Delta p$
$R = 0{,}023 \times m\Delta p$	$R = 0{,}023 \times m\Delta p$
NOTE 1 $m\Delta p$ is the mean value of pressure drop in pascals (Pa) or in mmWG. NOTE 2 These values are valid for a pressure drop range of 2 000 Pa (200 mmWG) to 7 000 Pa (700 mmWG).	

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Annex C
(informative)

Comparison of draw resistance or pressure drop measurement: Critical flow orifice instruments versus constant mass flow instruments

Due to different interpretations of ISO 6565, there are currently two types of instrument used for the measurement of draw resistance (or pressure drop). The two instruments described below both operate under vacuum.

The first type operates with a critical flow orifice (CFO), which is a constant volumetric flow device. These instruments maintain a constant volume of air at the exit of the test piece regardless of the pressure; the flow rate at the inlet end will fall with the increasing pressure drop of the test piece. Thus, the mass flow rate through the test piece will be lower as the pressure drop of the test piece increases.

The second type operates with a constant mass flow device (CMF) which maintains a constant mass flow rate of air through all test pieces. These instruments maintain a constant mass flow rate of air by automatically compensating for changes in pressure at the exit of the test pieces. As a result, the volumetric air flow rate at the inlet of the test piece remains constant. Since the flow rate through a CMF is always greater than the flow rate through a CFO on the same test piece, the pressure drop readings obtained with a CMF instrument are higher than with a CFO device.

This International Standard requires the use of instruments which maintain a constant volumetric flow at the exit of the test piece, e.g. instruments with a CFO device.

The relationship between the pressure drop readings obtained with a CFO device or with a CMF device can be expressed by the following Formulae (C.1) and (C.2):

$$\Delta p_{\mathrm{M}} = \Delta p_{\mathrm{O}} \times \frac{p_{\mathrm{atm}}}{p_{\mathrm{atm}} - \Delta p_{\mathrm{O}}} \tag{C.1}$$

$$\Delta p_{\mathrm{O}} = \Delta p_{\mathrm{M}} \times \frac{p_{\mathrm{atm}}}{p_{\mathrm{atm}} + \Delta p_{\mathrm{M}}} \tag{C.2}$$

where

Δp_{O} is the pressure drop observed with a CFO device;

Δp_{M} is the pressure drop observed with a CMF device;

p_{atm} is the atmospheric (ambient) pressure.

Table C.1 gives an example.

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Table C.1 — Comparison of the differences between the pressure drop readings obtained with a CFO device or a CMF device (rounded values)

CFO device				CMF device			
Δp_M		Δp_O		Δp_O		Δp_M	
Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)	Pa	(mmWG)
980	100	970	99	980	100	990	101
1 471	150	1 451	148	1 471	150	1 490	152
1 961	200	1 922	196	1 961	200	2 000	204
2 942	300	2 853	291	2 942	300	3 030	309
3 922	400	3 775	385	3 922	400	4 079	416
4 903	500	4 667	476	4 903	500	5 158	526
5 884	600	5 550	566	5 884	600	6 256	638
6 864	700	6 423	655	6 864	700	7 374	752
7 845	800	7 266	741	7 845	800	8 522	869

As can be seen, the readings with a CMF device are higher than with a CFO device and the difference increases with the measured pressure drop. The differences are basically insignificant for pressure drop values below 2 000 Pa (200 mmWG) but become increasingly significant for values above 3 000 Pa (300 mmWG).

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2) ISO 5725:1986 has been withdrawn and replaced by ISO 5725 (all parts).

3) Cancels and replaces ISO 7870:1993.

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