CORESTA RECOMMENDED METHOD N° 6

DETERMINATION OF VENTILATION – DEFINITIONS AND MEASUREMENT PRINCIPLES

(2015 Revision – September 2016)

1. SCOPE

This CORESTA Recommended Method specifies a method for the determination of ventilation applicable to cigarettes.

2. NORMATIVE REFERENCES

All CORESTA Recommended Methods and related ISO standards are subject to revision and parties to agreements based on these Recommended Methods are encouraged to investigate the possibility of applying the most recent editions of the methods indicated below.

ISO 3402
Tobacco and tobacco products – Atmosphere for conditioning and testing.

ISO 3308
Tobacco and tobacco products – Routine analytical cigarette-smoking machine – definitions, standard conditions and auxiliary equipment.

ISO 4387
Cigarettes – Determination of total and nicotine-free dry particulate matter using a routine analytical cigarette-smoking machine.

ISO 6565
Tobacco and tobacco products – Draw resistance of cigarettes and pressure drop of filter rods – Definitions, standard conditions and general aspects.

ISO 9512
Cigarettes – Determination of ventilation – Definitions and measurement principles

3. DEFINITIONS

3.1. Ventilation

Aspiration of atmospheric air into an unlit cigarette other than through its front area.

NOTE: dilution: Effect of ventilation on the smoke yield.

3.2. Front area

That end of a cigarette which is intended to be lit.
3.3. **Total airflow \( Q \)**

100% of the volumetric airflow leaving the mouth end of an unlit cigarette which is encapsulated in a measurement device having an insertion depth as defined in ISO 3308.

Under standard test conditions, this total air flow, \( Q \), is 17.5 ml·s\(^{-1}\).

3.4. **Generator for total airflow**

A device to maintain a constant total volumetric airflow at the exit of the mouth end of the cigarette when encapsulated in a measurement head having an insertion depth as defined in ISO 3308.

3.5. **Ventilation airflow**

The flow of air entering an unlit cigarette other than through the front area of the cigarette.

The volumetric rate of ventilation airflow is normalised to the negative pressure at the mouth end of the unlit cigarette, created by the draw resistance of the cigarette when encapsulated in a measurement device having an insertion depth as defined in ISO 3308.

**NOTE 1:** In this document a measured volumetric flow rate is referred to as \( Q \), or \( Q_{\text{SUFFIX}} \) where a component of the ventilation flow is denoted (see 3.7 and figure 1). Ventilation flows are measured on the inlet side to the cigarette and are denoted with a prime (e.g. \( Q'_{\text{SUFFIX}} \)) after conversion to the corresponding volumetric flow rate at the outlet to the cigarette.

**NOTE 2:** The total airflow rate is defined and measured at the outlet to the cigarette and is therefore denoted as \( Q \).

3.6. **Total ventilation**

The total volumetric flow rate of air that has entered the cigarette other than through the front area of the cigarette normalised as defined in 3.5, when the unlit cigarette is encapsulated in a measurement device having an insertion depth as defined in ISO 3308.

3.7. **Degree of ventilation \( V \)**

The ratio, expressed as a percentage, of the ventilation airflow to the total airflow [see figures 1b), 1c) and 1d)]. The degree of total ventilation comprises the airflow as defined in 3.6.

The total ventilation can be divided into the following components of ventilation airflow, with the degree of each being expressed as a percentage of the total airflow:

3.7.1 **Filter ventilation \( Q'_{F} \)**

That air entering the cigarette through the filter joining paper (tipping paper) between the covered part of the mouth end and the beginning of the tobacco rod [see Figure 1b)].

**NOTE:** In practical instrumentation the filter ventilation airflow rate is expected to be approximately equal to the tipping-paper ventilation airflow rate provided that any ventilation holes are not occluded.
3.7.2 Paper ventilation $Q'_p$

That air entering the cigarette through the envelope covering the whole length of the tobacco rod [see Figure 1b]].

**NOTE:** In practical instrumentation the paper ventilation airflow rate is expected to be approximately equal to the cigarette-paper ventilation airflow rate provided that any ventilation holes are not occluded.

3.7.3 Butt ventilation $Q'_b$

That air entering the cigarette between the covered part of the mouth end of the cigarette and the position defined by the butt length (as defined in ISO 3308) appropriate to the cigarette [see Figure 1c]].

3.7.4 Burnable tobacco rod ventilation $Q'_r$

That air entering the cigarette through its paper between the position defined by the butt length appropriate to the cigarette and the end of the cigarette which would be lit [see Figure 1c]].

3.7.5 Tipping-paper ventilation $Q'_m$

That air entering the cigarette through the filter joining paper (tipping paper) between the covered part of the mouth end and the tobacco rod end of the tipping paper [see figure 1d)].

3.7.6 Cigarette-paper ventilation (also envelope ventilation) $Q'_c$

Air entering the cigarette through the cigarette paper between the end of cigarette which would be lit and the frontal end of the tipping paper [see Figure 1d]].

\[
\text{Degree of filter ventilation: } V_F = \left( \frac{Q'_F}{Q} \right) \times 100\%
\]

\[
\text{Degree of paper ventilation: } V_P = \left( \frac{Q'_P}{Q} \right) \times 100\%
\]

\[
\text{Degree of total ventilation: } V = V_F + V_P = \left[ \left( \frac{Q'_F + Q'_P}{Q} \right) \right] \times 100\%
\]
Degree of burnable tobacco rod ventilation: \( V_R = \left( \frac{Q'_R}{Q} \right) \times 100\% \)

Degree of butt ventilation: \( V_B = \left( \frac{Q'_B}{Q} \right) \times 100\% \)

Degree of cigarette paper ventilation: \( V_C = \left( \frac{Q'_C}{Q} \right) \times 100\% \)

Degree of tipping paper ventilation: \( V_M = \left( \frac{Q'_M}{Q} \right) \times 100\% \)

Figure 1 – Different degrees of ventilation. See 3.5 for the significance of the prime (') designator.

4. PRINCIPLE

Air is drawn by vacuum, at a constant flow, in the standard smoking direction through an unlit cigarette. The individual components of ventilation resulting from the total airflow leaving the mouth end of the cigarette are measured separately. The degree of ventilation is calculated.

5. STANDARD CONDITIONS

5.1. Prior to measurement cigarettes shall be conditioned in an atmosphere as specified in ISO 3402.

5.2. Ventilation measurements shall be made on unlit cigarettes in accordance with the test atmosphere as specified in ISO 3402.

5.3. The direction of airflow in the cigarette shall be that which would occur when the cigarette is smoked.

6. APPARATUS

6.1. The apparatus used shall allow separate assessment of the ventilation components shown in Figure 1.

6.2. The cigarettes shall be held in the measurement head, by a holding device, with an insertion depth as defined by ISO 3308.
6.3. Seals used to hold the cigarette and partition ventilation measurement regions shall be sized and positioned appropriately to the dimensions of the product under test to minimise any systematic influence on measured parameters [see figure 2].

6.4. When the total air flow is applied, the pressure of air surrounding the cigarette within the ventilation chamber region shall be not more than 20 Pa (approximately 2 mmWG) lower than the pressure of air at the inlet to the non-ventilation airflow path at the front of the standard.

NOTE: Experiments conducted during the development of this method show that the measured ventilation flows reduce proportionally to increased pressure drop of the apparatus’ ventilation measurement path.

6.5. A generator for total airflow is used to establish the measurement conditions.

The total air flow shall be stable. The fluctuations in total airflow shall not exceed ±0,10 ml·s⁻¹.

NOTE: A critical flow orifice (CFO) is normally used to establish a constant total airflow for vacuum based measurement systems.

6.6. Ventilation flow measurement device

The device used for measurement of ventilation airflows shall have no intrinsic effect on the volumetric airflow measurement [see figure 2].

Figure 2 – Schematic for ventilation flow measurement
7. SAMPLING

A sample shall be taken which is representative, on a statistical basis, of the population to be characterised.
Samples shall be free of visible defects and creases, which may impair measurement performance.

8. CALIBRATION OF APPARATUS

The measurement device shall be calibrated in accordance with its manufacturer’s recommendations, ensuring the device is leak free prior to implementing or checking calibration. The principles of this calibration are presented in Appendix B.

NOTE: Any calibration needs to span the range of testing required on the products to be measured.

9. PROCEDURE

9.1. Conditioning of test cigarettes
Condition the cigarette sample selected for the test as specified in 5.1.

9.2. Calibration
Calibrate the measurement device as specified in 8.

9.3. Measurement
Ensure that the measurement apparatus has been adjusted to suit the dimensions of the cigarette to be measured.
Insert the cigarette samples to be tested into the measurement head and operate the apparatus in accordance with the manufacturer’s instructions.
Record the required ventilation measurement parameters.

10. EXPRESSION OF RESULTS

The reported value of any ventilation measurements shall be the mean value of individual measurements, expressed as a percentage.

The results shall be expressed as follows:
a) Individual values shall be expressed to the nearest whole integer.
b) Mean values shall be expressed to the first decimal place.
c) The standard deviation shall be expressed to the second decimal place.
11. PRECISION

11.1. Inter-laboratory Test 1994

The precision of this method has been estimated by selecting 5 cigarette product types having the following nominal filter ventilation values which spanned the normal range of measurement:

<table>
<thead>
<tr>
<th>Level</th>
<th>Nominal Filter Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 %</td>
</tr>
<tr>
<td>2</td>
<td>22 %</td>
</tr>
<tr>
<td>3</td>
<td>41 %</td>
</tr>
<tr>
<td>4</td>
<td>58 %</td>
</tr>
<tr>
<td>5</td>
<td>81 %</td>
</tr>
</tbody>
</table>

Data sets from 17 laboratories that complied with the Collaborative Study testing protocol were used in the determination of r & R for this method.

For each of the above 5 product types, individual sample sets comprising 20 samples were tested daily for a period of 5 days.

Outlier analysis was performed in accordance with ISO 5725 and those outlying measurements have been removed for the determination of r & R.

Table 1: Ranges for mean (M), repeatability variance ($s_r^2$), repeatability limit (r), reproducibility variance ($s_R^2$) and reproducibility limit (R) for tipping ventilation, paper ventilation and draw resistance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>M See Note</th>
<th>$s_r^2$ [%^2, \text{mmWG}^2]</th>
<th>r [%^2, \text{mmWG}^2]</th>
<th>$s_R^2$ [%^2, \text{mmWG}^2]</th>
<th>R [%^2, \text{mmWG}^2]</th>
<th>R/r [%^2, \text{mmWG}^2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tipping Ventilation %</td>
<td>[22, 2-80, 6]</td>
<td>[0,10-0,47]</td>
<td>[0,86-1,91]</td>
<td>[0,45-1,07]</td>
<td>[1,88-2,89]</td>
<td>[1,42-2,21]</td>
</tr>
<tr>
<td>Paper Ventilation %</td>
<td>[3,2-11,7]</td>
<td>[0,03-0,11]</td>
<td>[0,50-0,91]</td>
<td>[0,09-0,28]</td>
<td>[0,84-1,47]</td>
<td>[1,19-2,28]</td>
</tr>
<tr>
<td>Draw Resistance mmWG</td>
<td>[70,3-128,1]</td>
<td>[0,44-2,39]</td>
<td>[1,86-4,33]</td>
<td>[2,03-8,85]</td>
<td>[3,99-8,33]</td>
<td>[1,19-2,15]</td>
</tr>
</tbody>
</table>

NOTE: In calculating the conditions for r & R, the products having a ventilation value below 1,5% are not included due to the fact that normal confidence limits do not apply in these circumstances.

11.2. Inter-laboratory Test 2015

In a further inter-laboratory test carried out in 2015 with 21 participating laboratories five cigarette samples having the following approximate degrees of filter ventilation were used.

<table>
<thead>
<tr>
<th>Cigarette</th>
<th>Nominal Filter Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29 %</td>
</tr>
<tr>
<td>2</td>
<td>36 %</td>
</tr>
<tr>
<td>3</td>
<td>46 %</td>
</tr>
<tr>
<td>4</td>
<td>53 %</td>
</tr>
<tr>
<td>5</td>
<td>88 %</td>
</tr>
</tbody>
</table>
For each of the above cigarettes three sample sets of 10 cigarettes were prepared and the degree of filter ventilation was measured on three consecutive days using a new sample of 10 cigarettes on each day. Each mean value obtained from a set of 10 cigarettes is considered as a single determination of the degree of filter ventilation, so that three replicate determinations were made. Outlier analysis was performed in accordance with ISO 5725 and any outlying measurements have been removed before the calculation of repeatability and reproducibility parameters. As a new set of cigarettes was used for each determination of the degree of filter ventilation, repeatability and reproducibility data include product variability. This product variability may constitute a substantial portion of repeatability and reproducibility, as the ratio of reproducibility to repeatability is rather close to 1.

The results are shown in Table 2.

**Table 2**: Ranges for mean value, repeatability variance ($s_r^2$), repeatability limit (r), reproducibility variance ($s_R^2$) and reproducibility limit (R), as well as the ratio between reproducibility limit and repeatability limit (R/r).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean %</th>
<th>$s_r^2$</th>
<th>r %</th>
<th>$s_R^2$</th>
<th>R %</th>
<th>R/r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tipping Ventilation</td>
<td>[27.2-91.3]</td>
<td>[1.59-4.58]</td>
<td>[3.57-6.04]</td>
<td>[3.10-6.10]</td>
<td>[4.69-6.98]</td>
<td>[1.00-1.39]</td>
</tr>
</tbody>
</table>

12. **TEST REPORT**

The test report shall include the number of cigarette samples and all necessary information for complete identification of the samples.

The test report shall specify the method used and the result(s) obtained. It shall also mention any operating details not specified in this Recommended Method or regarded as optional, together with details of any deviations from the Recommended Method.
ANNEX A
(normative)

CALIBRATION OF VENTILATION STANDARDS

A.1. Calibration of Ventilation Standards

Ventilation Standards are used to calibrate measuring instruments for the determination of the components of total ventilation of cigarettes.

Ventilation standards have defined ventilation values that are used to calibrate mid-range ventilation measurements.

Ventilation standards have defined pressure drop values, which can be used to calibrate measuring instruments for the determination of draw resistance of cigarettes within the expected target range of measurement.

A.2. Essential properties of ventilation standards

a) Ventilation standards should be made of an inert material which is unaffected by use or ageing.

b) Standards should closely resemble the physical size and shape of a cigarette.

c) The standard shall have a ventilation zone in the tipping paper / filter region that allows calibration of the instrument’s ventilation chamber (see Figure 3). This ventilation zone shall have defined and repeatable values for:
   - degree of ventilation
   - pressure drop ventilation zone open (PDo)
   - pressure drop ventilation zone closed (PDc)

when a suction source, having a total airflow of 17,5 ml·s⁻¹, is applied to the outlet of the standard.

The standard may also include a second ventilation zone suitable to calibrate the degree of ventilation of a second ventilation chamber in the cigarette paper / envelope region; also to enable measurement of the pressure drop with both zones closed (PDe).

d) The airflow through the ventilation standard shall be laminar. The ventilation standard shall have repeatable measurement characteristics and shall be largely unaffected by changing atmospheric conditions.

e) Ventilation standards shall be inscribed, or have affixed, a unique ID having a certificate of calibration giving a traceable value of tipping ventilation. Additional parameters may be included.

The level of uncertainty of calibration of ventilation standards shall not exceed 1,5 % absolute.

f) The certificate of calibration shall state the actual atmospheric pressure, temperature and relative humidity of the laboratory-testing atmosphere during calibration.
A.3. Procedure

A.3.1. Apparatus

a) To determine the characteristics of the ventilation standard it shall be held in a calibration apparatus, the mechanical arrangement of which shall not modify the characteristics of the standard nor create any systematic influences upon the measurement. Measurements shall be conducted in a testing atmosphere in accordance with ISO 3402.

b) The calibration apparatus shall facilitate measurement and calibration of pressure drop of the ventilation standard.

c) When the total air flow is applied, the pressure of air surrounding the standard within the ventilation chamber region shall be not more than 20 Pa lower than the pressure of air at the inlet to the non-ventilation airflow path at the front of the standard [see figure 3].

d) The calibration apparatus should have a generator for total airflow to establish the fluid measurement conditions and to maintain a constant total airflow (Q) of 17.5 ml·s⁻¹ ± 0.3% at the outlet end of the ventilation standard.

A.3.2. Ventilation Flow Measurement

a) The laboratory atmosphere should be maintained in accordance with ISO 3402 Section 3.2 during conditioning and testing, as follows:
- temperature (22 ± 2) °C
- relative humidity (60 ± 5) %.

b) The ventilation standard should be checked for signs of damage and submitted for calibration only if in good physical condition.

c) The ventilation standard should be cleaned if necessary.

d) The ventilation standard should be conditioned in the laboratory atmosphere for a minimum of 12 hours before measurement.

e) The measurement apparatus should be checked to ensure that it is leak-tight according to specifications (also see Annex D) and that the seals to the ventilation standard are in good condition before the measurements commence.

f) The performance of the measurement equipment should be validated before use by at least one reference standard with intermediate ventilation. Optionally, two further reference standards may be used to cover the whole measuring range. Alternatively, 0% ventilation and 100% ventilation can be checked. Measurements should not commence if the measured reference ventilation value(s) are outside the expected range.

g) The ventilation standard should be stabilised in the measurement apparatus, with air being drawn through the standard at a flow rate of nominally 17.5 ml·s⁻¹, for a minimum of 5 minutes before measurements commence.

h) If the volumetric flow into the ventilation path is measured using an in-line flow measurement device, this should introduce a series pressure drop of less than 20 Pa. For a higher pressure drop it is necessary to balance the pressure between the inlets to the standard in the ventilation chamber and the front area of the standard to avoid a systematic influence on the ventilation flow.
i) A volumetric flow measurement device, that does not generate any systematic influence on flow measurement, shall be used to check the total airflow that is applied to the outlet of the ventilation standard when inserted into the calibration apparatus.

**NOTE:** It has been customary practice in the past to measure volumetric airflows by means of a soap bubble flow meter. This creates measurement errors in pressure drop calibration due to the saturation of the measurement air by the soap bubble flow meter, which causes the volumetric flow to artificially increase and the viscosity to decrease.

j) A typical calibration procedure might comprise the following steps, although details will vary according to the apparatus used and the operating procedure for the equipment.

![Calibration Procedure Diagram](image)

**A.3.3. Pressure Drop Measurement**

The pressure drop characteristics of the ventilation standard shall be measured in accordance with ISO 6565. For measuring the pressure drop with ventilation zones open the ventilation flow measuring devices may be removed to ensure that the ventilation zones are at atmospheric pressure as defined in ISO 6565.

**A.3.4. Pressure Drop Compensation for Ventilation Flow Measurement**

a) The ventilation flow is normalised to the negative pressure at the outlet of the standard, created by the pressure drop of the standard when contained in a calibration apparatus.

b) The measured values for ventilation flows $Q_i$ of the individual ventilation zones $i=1,2,…$ of the standard shall be modified as follows to provide comparison with the 100% total flow value as measure at the exit of the standard.

$$Q_i' = Q_i \times \left( \frac{p_{\infty}}{p_{\infty} - PD_z} \right)$$
A.3.5. Calculation of Degree of Ventilation Value

The degrees of ventilation of the individual ventilation zones of the standard are expressed as follows.

Degree of ventilation \( V_i = \left( \frac{Q'_i}{Q} \right) \times 100\% \)

with \( i=1,2, \ldots \) where

- \( p_o \) is the actual atmospheric pressure expressed in Pa. If the atmospheric pressure is not measured, it can be approximated to the normal value of 101325 Pa;
- \( Q \) is the "total air flow";
- \( PD_z \) is the ventilation zones open pressure drop of the standard expressed in Pa;
- \( Q_i \) is the measured ventilation flow at ventilation zone \( i \);
- \( Q'_i \) is the corrected ventilation flow at ventilation zone \( i \);
- \( V_i \) is the degree of ventilation of ventilation zone \( i \);

![Figure 3 – Calibration apparatus](image-url)
A.4. Precision

In an inter-laboratory study from October 2014 to July 2015 involving all four relevant laboratories being able to carry out the required procedures calibration standards for filter ventilation and pressure drop have been circulated between the laboratories and each calibration standard was measured three times under repeatability conditions on two separate days. From the data the mean value, standard deviation and the coefficient of variation were calculated.

Table A.1: Mean value, standard deviation and coefficient of variation of the degree of filter ventilation. The mean degree of filter ventilation and the standard deviation are reported in % (dilution), while the coefficient of variation, as usual, is the ratio of the standard deviation and the mean degree of filter ventilation expressed as percentage.

<table>
<thead>
<tr>
<th>Degree of Filter Ventilation</th>
<th>Global Mean</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal 20%</td>
<td>18.64%</td>
<td>0.39%</td>
<td>2.09%</td>
</tr>
<tr>
<td>Nominal 50%</td>
<td>50.95%</td>
<td>0.32%</td>
<td>0.62%</td>
</tr>
<tr>
<td>Nominal 80%</td>
<td>78.12%</td>
<td>0.49%</td>
<td>0.62%</td>
</tr>
</tbody>
</table>

Table A.2: Mean value, standard deviation and coefficient of variation of the pressure drop.

<table>
<thead>
<tr>
<th>Pressure Drop</th>
<th>Global Mean</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal 200 mmWG</td>
<td>199.6 mmWG</td>
<td>0.23 mmWG</td>
<td>0.11%</td>
</tr>
<tr>
<td>Nominal 400 mmWG</td>
<td>391.8 mmWG</td>
<td>0.62 mmWG</td>
<td>0.16%</td>
</tr>
<tr>
<td>Nominal 600 mmWG</td>
<td>647.5 mmWG</td>
<td>0.95 mmWG</td>
<td>0.15%</td>
</tr>
<tr>
<td>Nominal 800 mmWG</td>
<td>837.8 mmWG</td>
<td>1.31 mmWG</td>
<td>0.16%</td>
</tr>
</tbody>
</table>

The results for the degree of filter ventilation and for the pressure drop of calibration standards show that variation is small compared to the typical reproducibility limit found in collaborative studies on the degree of filter ventilation and pressure drop for actual products. Thus, when measuring actual products, instrumental variation deriving from any offset in the calibration standards is negligible as a cause of variation.
ANNEX B
(normative)

CALIBRATION OF VENTILATION MEASURING INSTRUMENTS USING VENTILATION AND PRESSURE DROP STANDARDS

B.1. Calibration of instruments

The calibration and performance testing of instruments for measuring the ventilation of cigarettes shall be conducted in accordance with manufacturer’s instructions.

Principle

For best accuracy of interpolated measurements, calibrate the instrument as close as possible to full scale or at the extreme end of the measurement range of products to be tested.

The instrument’s measurement system should be tested to ensure that a valid zero ventilation measurement can be established. The measurement system should then be checked for leakage and linearity using at least one ventilation standard having an intermediate value.

Method

a) The instrument’s measurement system should be checked for leaks, in accordance with the manufacturer’s instructions, before undertaking calibration. An example of leak testing is given in annex D.

b) The standard should be inserted into the measuring head, in accordance with the manufacturer’s instructions, and allowed to equilibrate to the temperature of the measuring air. When the instrument reading is stable, calibration should be completed.

c) The linearity of the established calibration should be checked. At least one intermediate value ventilation standard should be used to check a mid-range value.

d) Ventilation measurement instruments with the additional capabilities to measure and provide draw resistance of cigarettes and apply draw resistance compensation to the ventilation measurements shall have their pressure drop measurement systems calibrated in line with ISO 6565.

NOTE 1: If only the ventilation value is measured and the equipment does not compensate for pressure drop then this value can be corrected to the compensated value according to informative Annex C containing the method of correction.

NOTE 2: A preferred method of calibrating cigarette ventilation and pressure drop measuring instruments is to use multiple parameter calibration standards that have certificated traceable values for the following parameters:

- tipping ventilation
- paper ventilation
- pressure drop tipping ventilation zones open (PDo)
- pressure drop tipping ventilation zones closed (PDC)
- enclosed pressure drop with tipping and paper ventilation zones closed (PDe)

Use of a single standard reduces the number of calibration pieces required, reduces the risk of operator error and effects due to handling and reduces the time taken to accomplish a calibration sequence.

The three-stage pressure drop calibration and calibration check which can be achieved with measurements PDe, PDC and PDo respectively also provides a valid leakage and linearity check.
ANNEX C
(informative)

MEASUREMENT OF VENTILATION AIRFLOWS IN CIGARETTES

C.1. Theoretical considerations

The degree of ventilation is determined by measuring the volumetric airflow entering defined regions of the cigarette.

These measurements are made on the atmosphere side of the cigarette and then compared with the total flow exiting the cigarette at a reduced pressure i.e., atmospheric pressure less the ‘draw resistance’ value of the cigarette.

The measurement of volumetric flow, in a pneumatic circuit, is dependent upon the air density at the point of measurement, due to pressure drops across any impedance in the flow path(s).

To equate volumetric flows, the measurements have to be normalised to the same atmospheric conditions.

C.2. Generation of measurement errors – The need to compensate for draw resistance

Consider the measurement of ventilation airflow of a cigarette having zero pressure drop between its ventilation holes and outlet end. The measured volumetric flow into the ventilation region would equal the exit flow at the outlet end. This would be due to the artificial situation of the cigarette not having a pressure drop i.e. the volumetric airflows would not be modified by different gas densities.

If the cigarette had a draw resistance of 100 mmWG, the gas density of the outlet flow (Q) would correspond to the gas density at a pressure of 100 mmWG below the pressure at which the ventilation flow enters into the ventilation region of the cigarette.

Boyle’s Law is used to determine the actual ventilation volumetric flow as measured at the input of the tipping region, as follows:

\[ Q_1 \times P_1 = Q_2 \times P_2 \]

where

- \( Q_1 \) = volumetric flow into tipping ventilation region
- \( P_1 \) = atmospheric pressure at input of filter region in Pa
- \( Q_2 \) = total airflow \((17.5 \text{ ml} \cdot \text{s}^{-1})\)
- \( P_2 \) = pressure at outlet end \( P_1 - (100 \text{ mmWG} \times 9,8067) \text{ Pa} \)

Therefore if \( P_1 = 101325 \text{ Pa} \) (normal atmosphere):

\[ Q_1 = (Q_2 \times P_2) / P_1 = (17.5 \times 100344) / 101325 = 17.33 \text{ ml} \cdot \text{s}^{-1} \]

NOTE: In this method the values given previously in mmWG are converted into Pa using the following conversion factor: 1 mmWG = 9,8067 Pa

This shows that the ventilation airflow of a cigarette having a draw resistance of 100 mmWG is reduced and would measure 0.97% low when compared to the constant exit flow of 17.5 ml·s⁻¹ from the mouth end.

Measuring cigarettes having a draw resistance in the region of 100 to 250 mmWG will result in an error of 1 to 2.5% absolute if the ventilation flow is not compensated for the cigarettes draw resistance value.
ANNEX D
(informative)

DETERMINATION OF LEAKAGE OF VENTILATION MEASUREMENT SYSTEM

D.1. General
This principle of leakage testing can be applied to the range of ventilation measurement instruments used within the industry and is given as an example.
For system specific techniques and recommended test and inspection regimes, reference should be made to the manufactures instructions.

D.2. Principle
a) Leakage testing is undertaken to identify defective adjustable seals and test the sealing integrity of ventilation (measurement) chambers. Common sources of leaks can normally be detected by the use of intermediate ventilation and pressure drop calibration standards to check the accuracy of mid-range measurements following a full-scale calibration.

Normally a 100% standard, made from a non-permeable material, is used to calibrate the full-scale limit of the paper and filter ventilation measurement systems. The measurement system can also be tested for a valid zero % ventilation measurement by initiating a ventilation measurement on a non-ventilated and non-permeable rod shaped test piece.

b) Other leaks can by encountered which may not be evident when testing and/or calibrating with a 100% standard. This is due to the fact that the standard is impervious to airflow leakage with the exception of the purposely manufactured ventilation region(s).

c) Ventilation measurement systems that include the measurements of cigarette draw resistance with filter ventilation zone open (PDo) and closed (PDc) use magnetic valves to isolate the ventilation measurement regions from atmosphere and the ventilation airflow measurement devices. With these systems, it is possible to incur leaks that are not evident when conducting a 100% calibration or checking with an intermediate standard but invalidate measurements performed upon cigarettes. This is the principle, which is discussed in the following sections of this annex.

D.3. Example Method
a) A 100% ventilation standard is used, in the normal manner, to calibrate the full-scale limit of the paper and filter ventilation measurement systems. This ensures that during the time of calibration the total airflow (Q) is directed from atmosphere through the chosen ventilation chamber to exit the outlet end of the standard.

b) Directly following calibration, any ventilation measurement chambers that can be isolated from atmosphere to facilitate pressure drop measurement or any other associated measurement, should be tested for leakage.

c) To perform a leakage test on isolated ventilation measurement chambers the following items are required:
- PD standard having a nominal value of not less than 300 mm WG
- PD extender tube
- Filter ventilation chamber leak test tube
- Paper ventilation chamber leak test tube
d) The pressure drop standard should be installed into an ‘extender tube’ and inserted into the measurement head as illustrated in Figure 4 & Figure 4.1. The measured value of the pressure drop standard should be noted.

e) The pressure drop standard should then be installed into the ‘filter ventilation chamber leak test tube’ and inserted into the measurement head as illustrated in Figure 4.2. A second measurement should be performed on the pressure drop standard and its value should be noted.

The two pressure drop values should differ by less than the known repeatability limit of the measurement system under test.

If the two measured values differ then a leak is present.

f) Repeat steps ‘d’ and ‘e’ using the ‘paper ventilation chamber leak test tube’, as illustrated in Figure 4.3, to test the leakage integrity of the paper ventilation chamber.

Figure 4 – Ventilation chamber leakage testing apparatus
Figure 4.1

Figure 4.2

Figure 4.3

PD extender tube (Insert PD standard)

Filter ventilation leak test tube

Paper ventilation leak test tube

Seal/close valve

Pressure Drop

Volumetric Flow Measurement Device ($Q$)

Total airflow (Vacuum)

Figure 4.1

Figure 4.2

Figure 4.3