

CORESTA RECOMMENDED METHOD N° 6

DETERMINATION OF VENTILATION – DEFINITIONS AND MEASUREMENT PRINCIPLES

(*March 2000*)

1. SCOPE

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

2. NORMATIVE REFERENCES

All CORESTA Recommended Methods 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.

CORESTA Recommended Method N° 21

Atmosphere for conditioning and testing tobacco products.

CORESTA Recommended Method N° 22

Routine analytical cigarette-smoking machine: specifications, definitions and standard conditions.

CORESTA Recommended Method N° 23

Determination of total and nicotine-free dry particulate matter using a routine analytical cigarette-smoking machine - Determination of total particulate matter and preparation for water and nicotine measurements

CORESTA Recommended Method N° 41

Determination of the draw resistance of cigarettes and filter rods.

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 filter rods – Definitions, standard conditions and general aspects.

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

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 RM N° 22.

Under standard test conditions, the total air flow, Q , is 17,5 ml/s

3.4. Generator for total airflow

A device to maintain a constant total airflow at the exit of the mouth end of the cigarette when encapsulated in a measurement head having an insertion depth as defined in RM N° 22.

3.5. Ventilation airflow

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

The ventilation flow is normalised to the negative pressure at the mouth end of the cigarette, created by the draw resistance of the cigarette when encapsulated in a measurement device having an insertion depth as defined in RM N° 22.

3.6. Total ventilation

The total amount of lateral air entering the cigarette, other than through its front area, when encapsulated in a measurement device having an insertion depth as defined in RM N° 22.

3.7. Degree of ventilation

The ratio, expressed as a percentage, of the ventilation air flow to the total airflow.

[See figures 1b), 1c) & 1d).]

3.8. Components of total ventilation

That air entering through the cigarette paper, and through the materials comprising and attaching the filter to the tobacco rod, contributing to total ventilation.

[See figures 1 b), 1 c) and 1 d).]

3.9. Filter ventilation

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 1 b).]

3.10. Paper ventilation

That air entering the cigarette through the envelope covering the whole length of the tobacco rod.

[See figure 1 b).]

3.11. Butt ventilation

That air entering the cigarette between the covered part of the mouth end of the cigarette and the position defined by the butt length appropriate to the cigarette.

[See figure 1 c).]

3.12. Burnable tobacco rod ventilation

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 1 c).]

3.13. Tipping-paper ventilation

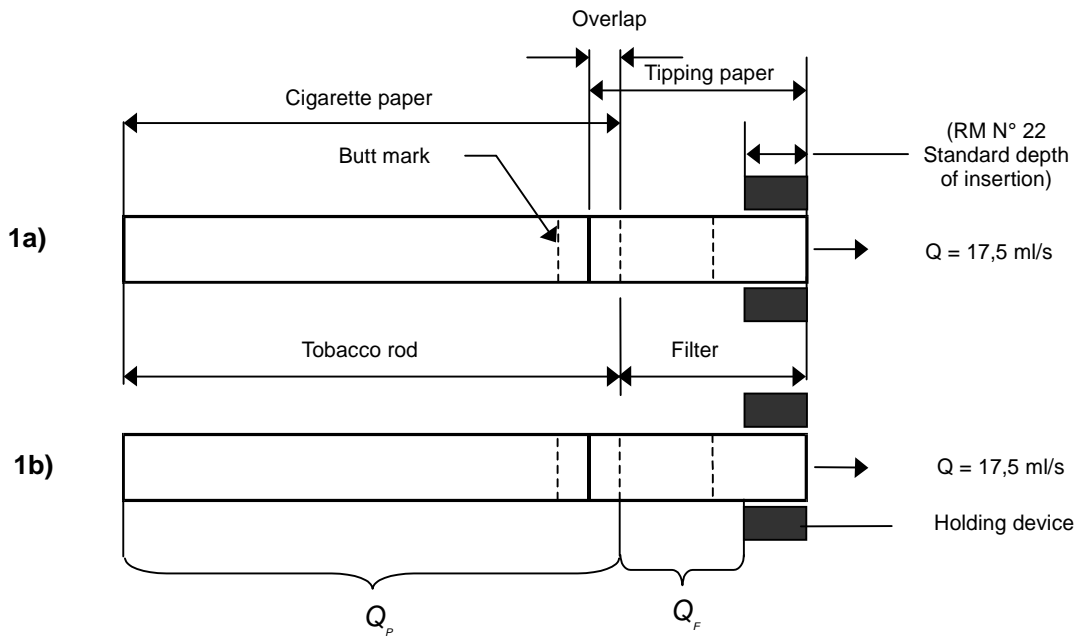
That air entering the cigarette through the filter joining paper (tipping paper) between the covered part of the mouth end and the tobacco rod end of the tipping paper.

[See figure 1 d).]

3.14. Cigarette-paper ventilation

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.

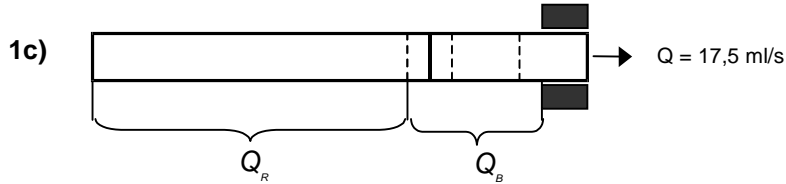
[See figure 1 d).]



Degree of filter ventilation: $V_F = (Q_F / Q) \times 100\%$

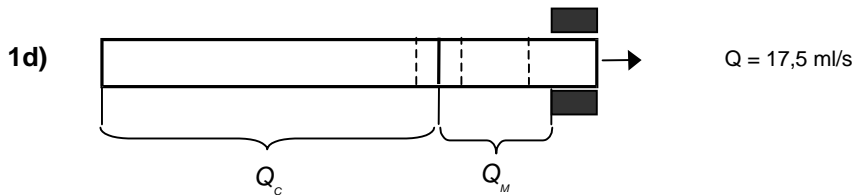
Degree of paper ventilation: $V_P = (Q_P / Q) \times 100\%$

Degree of total ventilation: $V = V_F + V_P = [(Q_F + Q_P) / Q] \times 100\%$



Degree of burnable tobacco rod ventilation: $V_R = (Q_R / Q) \times 100\%$

Degree of butt ventilation: $V_B = (Q_B / Q) \times 100\%$



Degree of cigarette paper ventilation: $V_C = (Q_C / Q) \times 100\%$

Degree of tipping paper ventilation: $V_M = (Q_M / Q) \times 100\%$

Figure 1 – Different degrees of ventilation

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 RM N° 21.
- 5.2. Ventilation measurements shall be made on unlit cigarettes in accordance with the test atmosphere as specified in RM N° 21.
- 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 RM N° 22.
- 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. The measuring pressure surrounding the cigarette contained in the measurement head, other than at the front end and the mouth end enclosed in the holding seal, shall not be lower than 20 Pa of the testing atmosphere when the total airflow is applied.

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.

Deviations from the total airflow shall not exceed $\pm 0,10$ ml/s.

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.]

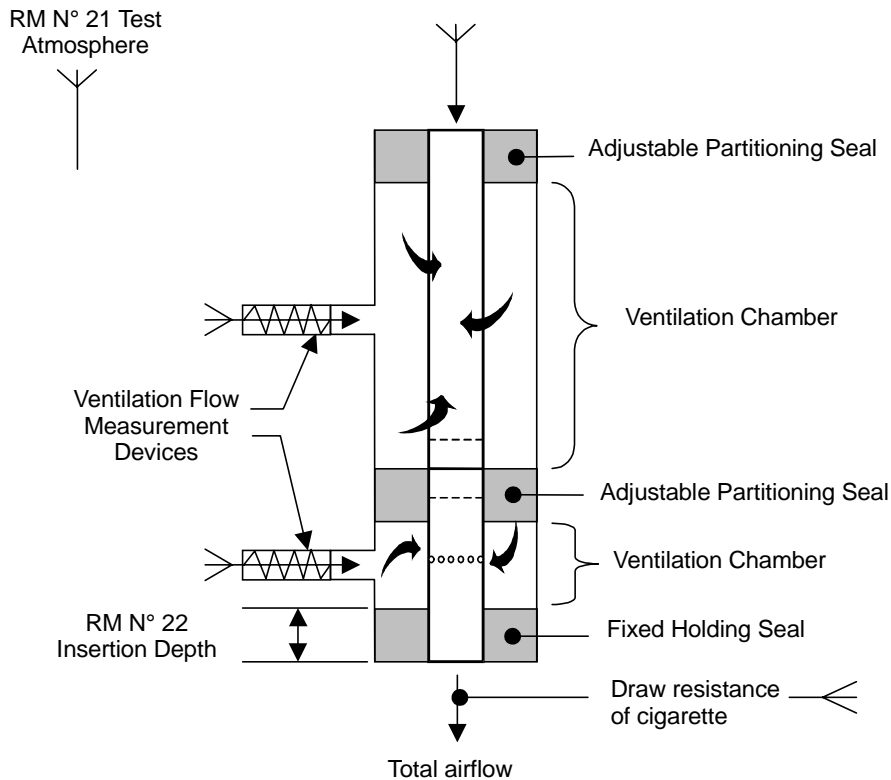


Figure 2 – Schematic for ventilation flow measurement

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 manufacturers recommendations, ensuring the device is leak free prior to implementing or checking calibration.

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 using calibration standards and calibration procedure in accordance with Annex B.

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

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:

Level	Nominal Filter Ventilation
1	0 %
2	22 %
3	41 %
4	58 %
5	81 %

11.1. Interlaboratory test

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.

11.2. Mean Value Ranges for r & R

Table 1: Ranges for mean (m), repeatability (r) and reproducibility (R) for tipping ventilation, paper ventilation and draw resistance.

Parameter	M ^{SEE NOTE}	s_r²	r	s_R²	R	R/r
Tipping Ventilation	[22,2-80,6]	[0,10-0,47]	[0,86-1,91]	[0,45-1,07]	[1,88-2,89]	[1,42-2,21]
Paper Ventilation	[3,2-11,7]	[0,03-0,11]	[0,50-0,91]	[0,09-0,28]	[0,84-1,47]	[1,19-2,28]
Draw Resistance	[70,3-128,1]	[0,44-2,39]	[1,86-4,33]	[2,03-8,85]	[3,99-8,33]	[1,19-2,15]

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 the normal application of confidence limits do not apply in these circumstances.

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 International Standard or regarded as optional, together with details of any deviations from the standard.

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) Ventilation standard shall have defined and repeatable values for:
 - tipping ventilation
 - pressure drop tipping ventilation zones open (PDo)Additional parameters may include:
 - paper ventilation
 - pressure drop tipping ventilation zones closed (PDe)
 - enclosed pressure drop with tipping and paper ventilation zones closed (PDe)when a suction source, having a total airflow of 17,5 ml/s, is applied to the outlet of the standard.
- 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 with a unique ID having a certificate of calibration giving traceable values of tipping ventilation and pressure drop tipping ventilation zones open. 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 RM N° 21.

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

[See figure 3]

- b) 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 \pm 0,3% at the outlet end of the ventilation standard.

NOTE 1: A critical flow orifice (CFO) is normally used to establish a constant total airflow for vacuum based measurement systems.

NOTE 2: An alternative method of calibration may be used to establish flow and pressure drop measurements either side of the 17,5 ml/s calibration point which is subsequently calculated by interpolation.

A.3.2. Volumetric Flow Measurement

- c) 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.
- d) **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.

A.3.3. Pressure Drop Measurement

- e) The pressure drop characteristics of the ventilation standard shall be measured in accordance with RM N° 41.

A.3.4. Flow Measurement Pressure Drop Compensation

- f) 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.
- g) The measured values for filter and paper ventilation flows shall be modified as follows to provide correct comparison with the 100% total flow value as measured at the exit of the standard:

Paper ventilation flow value: $Q_P = Q_C \times [Atmosphere / (Atmosphere - PD_Z)]$

Filter ventilation flow value: $Q_F = Q_M \times [Atmosphere / (Atmosphere - PD_Z)]$

A.3.5. Calculation of Degree of Ventilation Value

h) The degree of ventilation for the paper ventilation region is expressed as follows:

$$\text{Degree of paper ventilation } V_P = (Q_P / Q) \times 100\%$$

i) The degree of ventilation for the filter ventilation region is expressed as follows:

$$\text{Degree of filter ventilation } V_F = (Q_F / Q) \times 100\%$$

where:

Atmosphere = Actual atmospheric pressure expressed in Pa. If the atmospheric pressure is not measured, it can be approximated to the normal value of 101325 Pascals;

Flow (Q) is the "total air flow" expressed in ml/s;

PD_Z is the ventilation zones open pressure drop of the standard expressed in Pa;

Q_C is the measured paper ventilation flow;

Q_M is the measured filter ventilation flow;

Q_P is the corrected paper ventilation flow;

Q_F is the corrected filter ventilation flow;

V_P is the degree of paper ventilation;

V_F is the degree of filter ventilation;

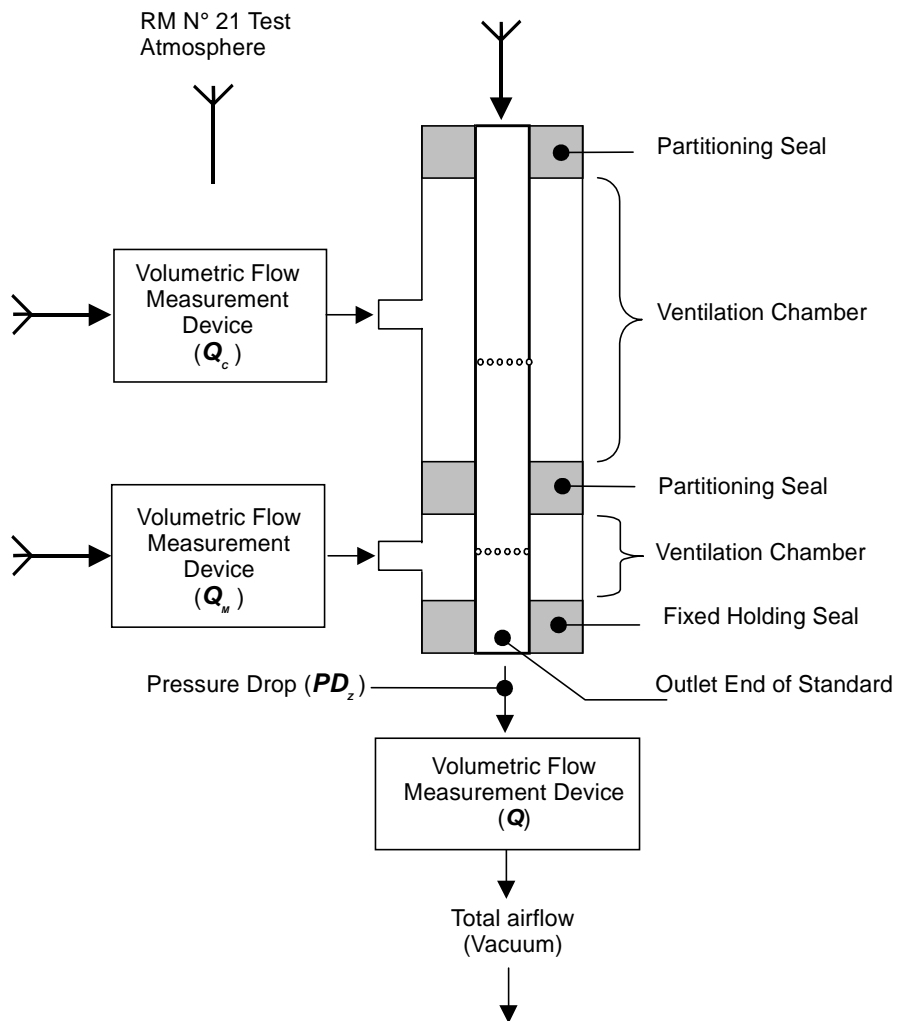


Figure 3 – Calibration apparatus

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 RM N° 41.

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 mm WG, the gas density of the outlet flow (Q) would be 100 mmWG below the ventilation flow into the ventilation region of the cigarette.

Having a constant volumetric exit flow (Q) of 17,5 ml/s regardless of 'sample' draw resistance, the respective volumetric flow measurements can be compared if the effect of draw resistance on the ventilation flow is quantified.

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 ml.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):

$$V_1 = (V_2 \times P_2) / P_1 = (17,5 \times 100344) / 101325 = 17,33 \text{ ml.s}^{-1}$$

NOTE: In this method the values given previously in mm WG are converted into pascals (Pa) using the following correction factor: 1 mm WG = 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 from the mouth end.

Measuring cigarettes having a draw resistance in the region of 100 to 250 mm WG 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 be 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 compare within the known repeatability of the measurement system under test.
- If the two measured values do not compare 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.

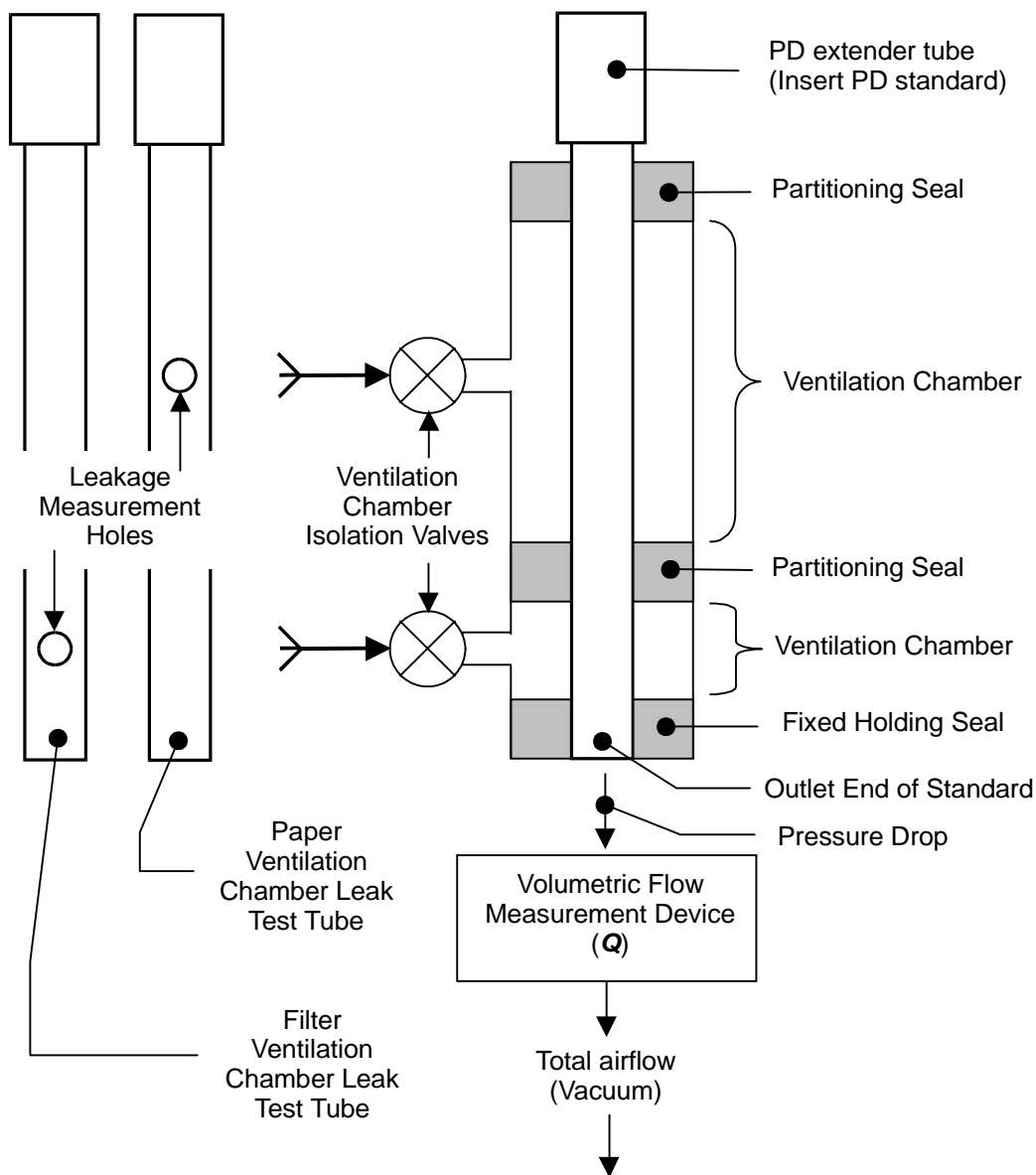


Figure 4 – Ventilation chamber leakage testing apparatus

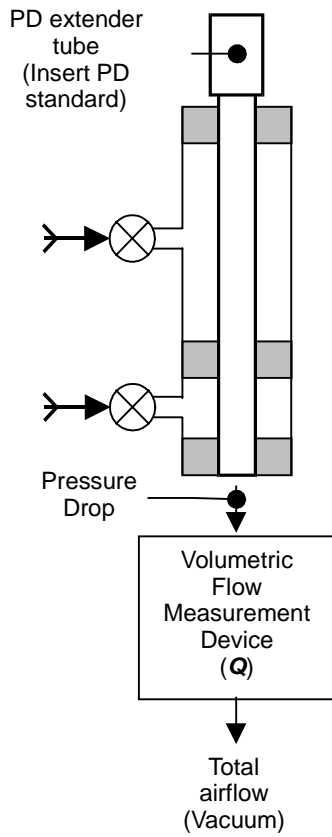


Figure 4.1

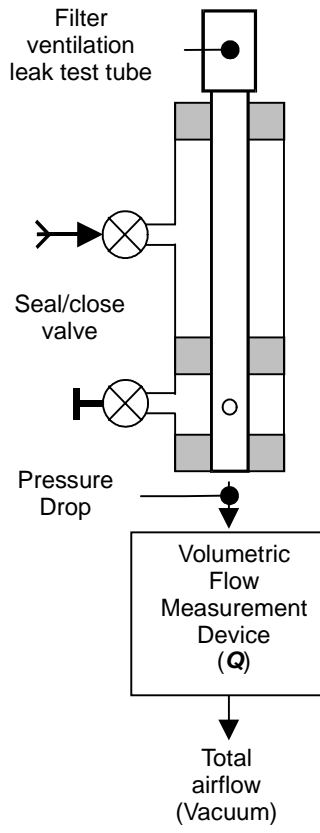


Figure 4.2

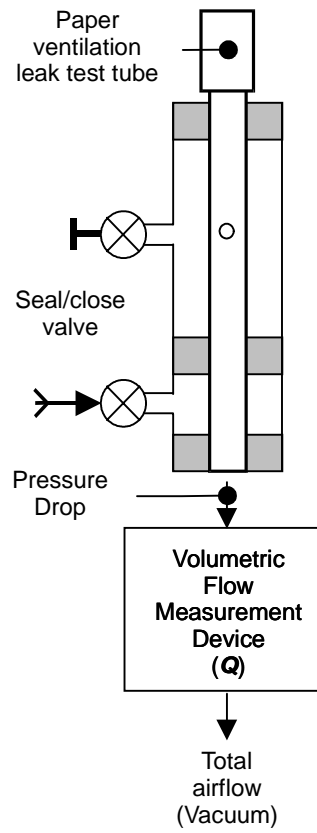


Figure 4.3