Physical Test Methods Sub-Group

Technical Report

8th Round Robin Test for Multi-Capillary Ventilation Calibration Standards (2019-2022)

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1.1 Introduction and Background

The CORESTA Physical Test Methods (PTM) Sub-Group organizes regular round robin tests to establish the capability to calibrate standards used in physical test instrumentation. It is open to member organisations that have a calibration laboratory. This report covers the results of the 8th round robin test on filter ventilation (FV) calibration standards conducted between June 2019 and September 2022. This testing provides a baseline of ventilation instrument performance across the industry since this standard type is used in the pressure drop and ventilation instrumentation of each supplier. Each laboratory is also able to use the results in internal and external audit assessments.

As a difference to the 1st to 7th round robin test this round robin test also included a set of slim filter ventilation calibration standards in order to check if there is any effect on the precision of the measurement of filter ventilation for cigarettes with slim format. The results of this part of the study are presented and discussed in the Annex of this document.

The four participating laboratories in the 8th round robin test on filter ventilation calibration standards are listed in Table 1.

Table 1: Participating Laboratories

Participating laboratories	Function	Accreditation
Körber Technologies Instruments GmbH Hamburg, Germany	Calibration lab & instrumentation supplier	ISO 9001 & 17025
Cerulean Milton Keynes, United Kingdom	Calibration lab & instrumentation supplier	ISO 9001 & 17025
Körber Technologies Instruments SAS Saint Jean de Braye, France	Calibration lab & instrumentation supplier	ISO 9001 & 17025
Zhengzhou Tobacco Research Inst. Zhengzhou, China	Calibration laboratory	

The laboratory identities are coded in the results presented below. The coding is the same as used in previous reports on the round robin tests for filter ventilation calibration standards.

The standards that were circulated between the four laboratories were a set of three ventilation standards at nominally

- 20 % ventilation,
- 50 % ventilation,
- 80 % ventilation.

The three instrumentation suppliers use the same physical test piece design and test pieces that are all supplied from a single source, thus only a single set of standards is circulated.

The relevant international standard at the time of this study was ISO 9512:2002 “Cigarettes — Determination of ventilation — Definitions and measurement principles”. A revised version of this standard has been issued as ISO 9512:2019 during the study, based on the work done by the PTM Sub-Group in updating CORESTA Recommended Method (CRM No. 6).

The ventilation standards are glass rods of 120 mm length by approximately 8 mm diameter that contain 10 parallel capillaries along their length. Additional holes are drilled perpendicular to the long axis of the rod at 12 mm from one end to admit the ventilation flow into one or more of the capillaries. These mimic the ventilation holes in the filter section of a ventilated cigarette. The (nominal) 20 % ventilation standard has one ventilation inlet hole, the 50 % standard has three and the 80 % standard has eight. The standards are calibrated under measured conditions of outlet flow rate, usually close to 17,5 ml/s, pressure, temperature and humidity. During calibration the ventilation flow is measured at the *inlet* side of the standard. This is corrected using the measured pressure drop across the standard to give the corresponding flow at the *outlet* side. The reported ventilation is the percentage of the outlet flow that has passed along the ventilation pathway.

Unlike for pressure drop standards, there is no compensation model for the effects of flow rate, temperature, ambient pressure or ambient humidity on the ventilation percentage, so it is reported as found. All participating laboratories operate under conditions that lie within the limits for measurements specified in ISO 3402:1999. During this test all the measurements were made within ranges of:

- temperature (21,8 – 23,0) °C,
- humidity (58 % – 62 %) RH,
- pressure (99,1 – 102,1) kPa.

1.2 Experimental Protocol

The protocol involved:

- acclimatisation of the standards to laboratory conditions
- testing to the method originally described in ISO 9512:2002 and updated in the latest version of CRM No. 6 (September 2016)
- making three ventilation determinations under repeatability conditions for each standard on two separate days
- re-checking by the originator laboratory after circulation to ensure that there was no change to the original values.

1.3 Results of the 8th Round Robin Test

1.3.1 Overall Results

The overall results of the participants are presented below in Table 2 and as a scatterplot of global coefficient of variation (CoV) of the laboratory means against the global mean ventilation of each test piece in Figure 1.

Since ventilation is expressed as a percentage, where ventilation values are *compared* in percentage terms this is specifically indicated as ‘relative % or ‘% of mean’ in the case of coefficient of variation (CoV).

Table 2: Overall Results

Standard	Global Mean (% ventilation)	Std Dev of Lab Means (% ventilation)	CoV of Lab Means (%)	Range (% ventilation)	Range of value (relative %)
Nom 20 %	18,7	0,18	0,98	0,4	2,09
Nom 50 %	50,9	0,07	0,15	0,2	0,34
Nom 80 %	78,0	0,20	0,26	0,5	0,60

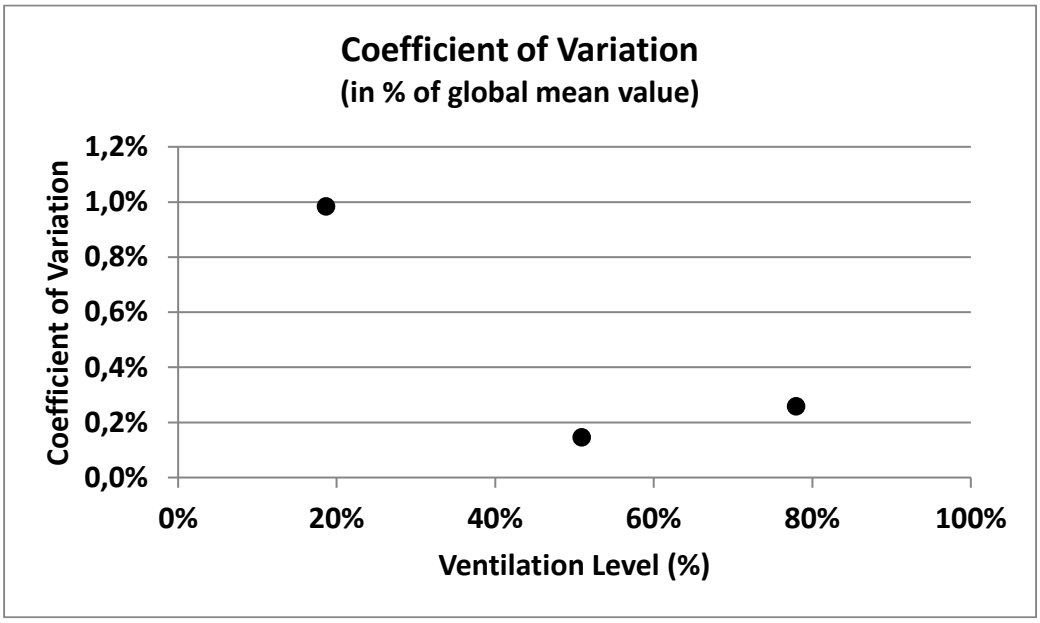

Figure 1: Coefficient of Variation of the Global Mean vs. Ventilation Level

1.3.2 Individual Laboratory Results

The individual mean values obtained by each laboratory for each FV calibration standard are shown in Table 3. The relative deviation of each laboratory from the global mean value was calculated and is shown in Table 4. The standard deviation and the coefficient of variation are shown by laboratory and by calibration standard in Tables 5 and 6, respectively.

The relative deviation from the global mean is also presented by laboratory in Figure 2 and by calibration standard in Figure 3.

Table 3: Laboratory Mean by Sample (% Ventilation)

	Laboratory Code			
Sample	**A**	**B**	**C**	**D**
Nom 20 %	18,79 %	18,46 %	18,57 %	18,85 %
Nom 50 %	50,94 %	50,94 %	50,81 %	50,99 %
Nom 80 %	78,15 %	78,01 %	78,04 %	77,68 %

Table 4: Deviation from Sample Mean (Relative %)

	Laboratory Code			
Sample	**A**	**B**	**C**	**D**
Nom 20 %	0,67 %	-1,12 %	-0,51 %	0,97 %
Nom 50 %	0,04 %	0,04 %	-0,21 %	0,13 %
Nom 80 %	0,23 %	0,05 %	0,09 %	-0,37 %

Table 5: Laboratory Standard Deviation by Sample (% Ventilation)

	Laboratory Code			
Sample	**A**	**B**	**C**	**D**
Nom 20 %	0,03 %	0,05 %	0,06 %	0,06 %
Nom 50 %	0,10 %	0,07 %	0,07 %	0,06 %
Nom 80 %	0,05 %	0,02 %	0,10 %	0,24 %

Table 6: Laboratory Coefficient of Variation by Sample (Relative %)

	Laboratory Code			
Sample	**A**	**B**	**C**	**D**
Nom 20 %	0,17 %	0,26 %	0,31 %	0,32 %
Nom 50 %	0,19 %	0,15 %	0,14 %	0,11 %
Nom 80 %	0,07 %	0,03 %	0,13 %	0,30 %

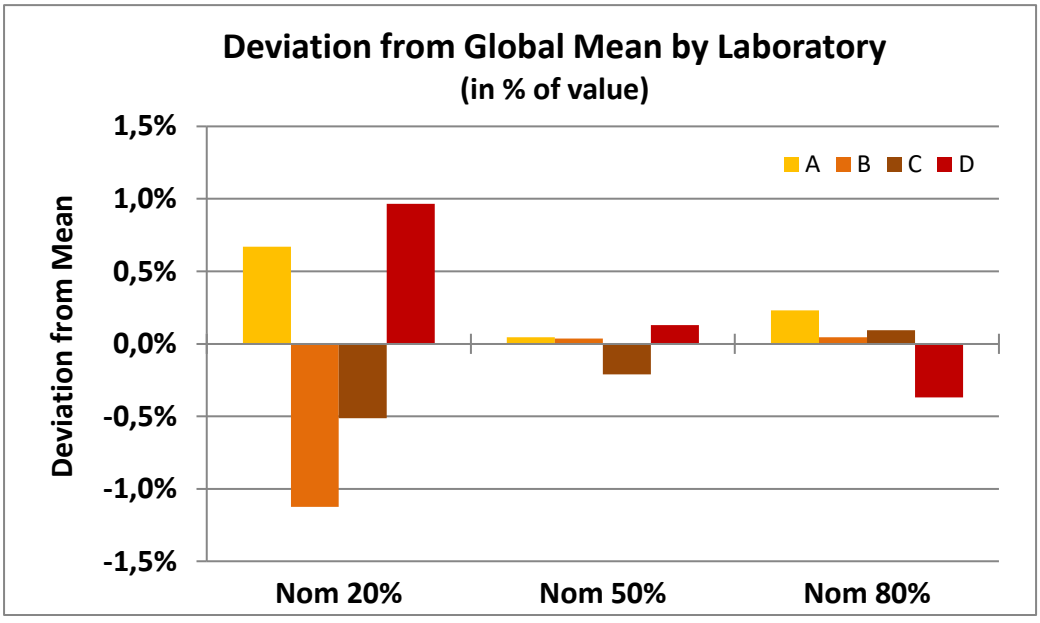

Figure 2: Deviation from Global Mean by Laboratory for Each Sample (Relative %)

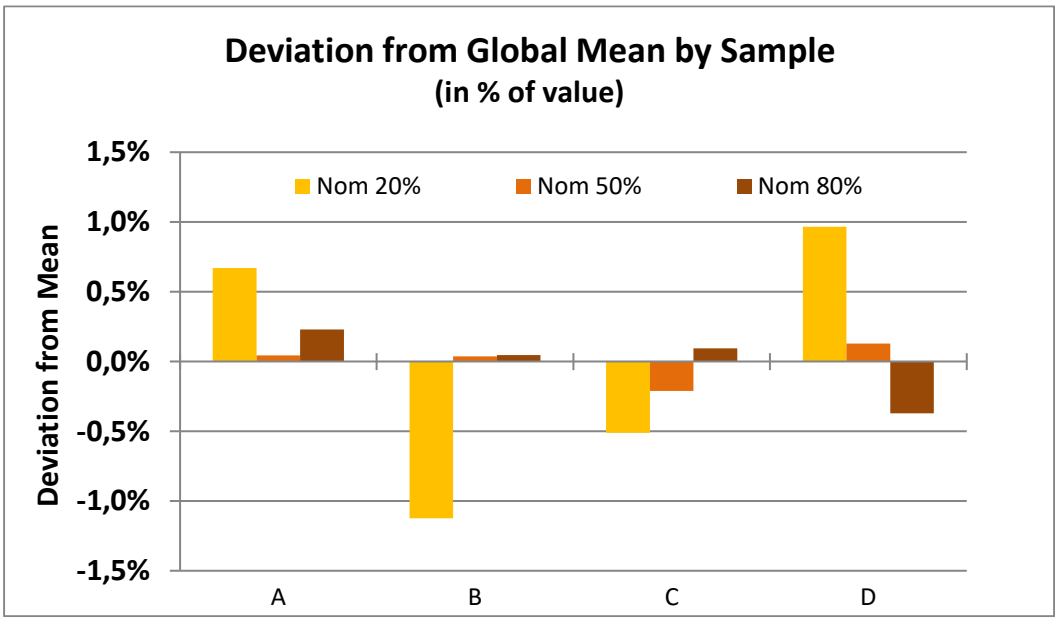

Figure 3: Deviation from Global Mean by Sample for Each Lab (Relative %)

1.4 Re-check of Standards

The ventilation values of the standards were re-checked by the originating laboratory after the circulation was complete. The overall difference was a change in ventilation of -0,09 % absolute with individual differences all less than ±0,20 % absolute ventilation. Thus, it is concluded that there was no systematic change to the value of the standards during circulation that has affected the validity of the results of the study.

1.5 Repeatability and Reproducibility Estimations

Repeatability and reproducibility (r and R) estimations were calculated according to the principles of ISO 5725:1994. The data were screened for outliers, but no outliers were detected. With the participation of just four laboratories only r and R standard deviations are presented.

Table 7 presents the summary data and repeatability and reproducibility estimations as % ventilation and the repeatability and reproducibility coefficient of variation as relative %.

Table 7: Repeatability and Reproducibility Estimates in % Ventilation (Means and Standard Deviations) and % Relative (Coefficients of Variation)

	Standard		
	Nom 20 %	**Nom 50 %**	**Nom 80 %**
Grand Mean for All Laboratories	18,67 %	50,92 %	77,97 %
Standard Deviation of Lab Means	0,18 %	0,10 %	0,20 %
Repeatability Standard Deviation	0,05 %	0,05 %	0,13 %
Reproducibility Standard Deviation	0,19 %	0,10 %	0,24 %
Repeatability Coefficient of Variation	0,27 %	0,09 %	0,17 %
Reproducibility Coefficient of Variation	1,02 %	0,20 %	0,30 %

1.6 Comparison with Results from Previous Round Robin Tests

A direct comparison between the results of all the round robin tests conducted to date is presented in Figure 4 in terms of the global coefficient of variation vs. ventilation level for each standard.

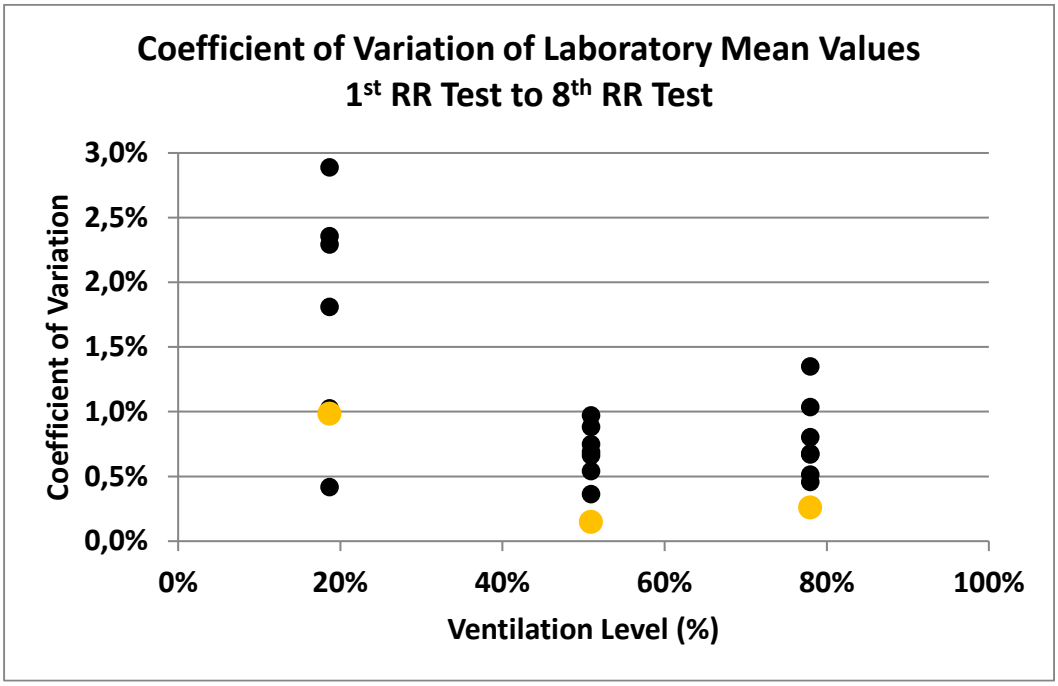

Figure 4: Coefficient of Variation of Laboratory Means vs. Ventilation Level for the 1st to 7th Round Robin Test (Black) and the 8th Round Robin Test (Yellow)

1.7 Comments on the Results

The results of the 8th round robin test on filter ventilation calibration standards are well in line with the historical performance of the method and show lower coefficients of variation with respect to the 50 % and 80 % ventilation standard than previous round robin tests.

The inter-laboratory variation seen here for ventilation calibration is of the order of 1 %, compared to the value of about 0,2 % that is seen for pressure drop standards. This is likely to be accounted for by the additional complexity of ventilation measurement, which:

a. is based on the ratio of two flow measurements, with the ventilation flow measurement also having to be corrected for the pressure drop across the standard,
b. requires careful compensation to minimise the pressure differential between the inlets to the 'main' and ventilation flow paths, and
c. unlike pressure drop calibration, lacks a rigorous procedure to compensate a determination made under the ambient conditions at the time of measurement to the industry standard atmospheric conditions of 22 °C, 101,325 kPa, 60 % RH.

The contribution to instrumental offset deriving from the calibration of ventilation standards in different laboratories is acceptable compared to the reproducibility limit of about 2,5 % to 3,5 % ventilation (approximately 5 % to 10 % of reading) exhibited for filter ventilation measurements in the 14th Collaborative Study on Physical Parameters of Cigarettes and Filters undertaken in 2021.

2. Results on Slim Filter Ventilation Standards

2.1 Introduction and Background

In addition to the filter ventilation calibration standards used for the 1st to 7th round robin tests, which all have a diameter of about 8 mm, the 8th round robin test also included slim filter ventilation calibration standards.

The normal ventilation standards are glass rods of 120 mm length by approximately 8 mm diameter that contain 10 parallel capillaries along their length. The slim versions were approximately 6 mm diameter, but otherwise very similar. Additional holes are drilled perpendicular to the long axis of the rod at 12 mm from one end to admit the ventilation flow into one or more of the capillaries; these mimic the ventilation holes in the filter section of a ventilated cigarette. The nominal 25 % ventilation standard has one ventilation inlet hole, the 60 % standard has three and the 80 % standard has eight. The standards are calibrated under measured conditions of outlet flow rate, usually 17,5 ml/s, pressure, temperature and humidity. During calibration the ventilation flow is measured at the *inlet* side of the standard. This is corrected using the measured pressure drop across the standard to give the corresponding flow at the *outlet* side. The reported ventilation is the percentage of the outlet flow that has passed along the ventilation pathway.

The additional set of five slim-format ventilation standards, with three based on the normal 100 mmWG basis rod and two based on a 200 mmWG basis rod that presented higher pressure drop, had the following properties:

- 25 % ventilation, low pressure drop
- 60 % ventilation, low pressure drop
- 80 % ventilation, low pressure drop
- 25 % ventilation, high pressure drop
- 80 % ventilation, high pressure drop

The four participating laboratories in this test are the same as shown above in Table 1. The laboratory codes are the same as in the tests for the normal-format ventilation standards.

Also the experimental protocol was the same as for the normal-format ventilation standards.

2.2 Overall Results

The overall results of the participants are presented below in Table 8 and as a scatterplot of global coefficient of variation (CoV) of the laboratory means against the global mean ventilation of each test piece in Figure 5.

Since ventilation is expressed as a percentage, where ventilation values are *compared* in percentage terms this is specifically indicated as ‘relative % or ‘% of mean’ in the case of coefficient of variation (CoV). The low and high pressure drop versions are coded L and H respectively.

Table 8: Overall Results for Slim Ventilation Standards

Standard	Global Mean (% ventilation)	Std Dev of Lab Means (% ventilation)	CoV of Lab Means (%)	Range (% ventilation)	Range of value (relative %)
Nom 25 % L	25,32 %	0,17 %	0,66 %	0,4 %	1,53 %
Nom 60 % L	58,02 %	0,10 %	0,16 %	0,2 %	0,32 %
Nom 80 % L	78,32 %	0,77 %	0,99 %	1,7 %	2,19 %
Nom 25 % H	25,01 %	0,18 %	0,74 %	0,4 %	1,79 %
Nom 80 % H	80,26 %	0,20 %	0,25 %	0,4 %	0,56 %

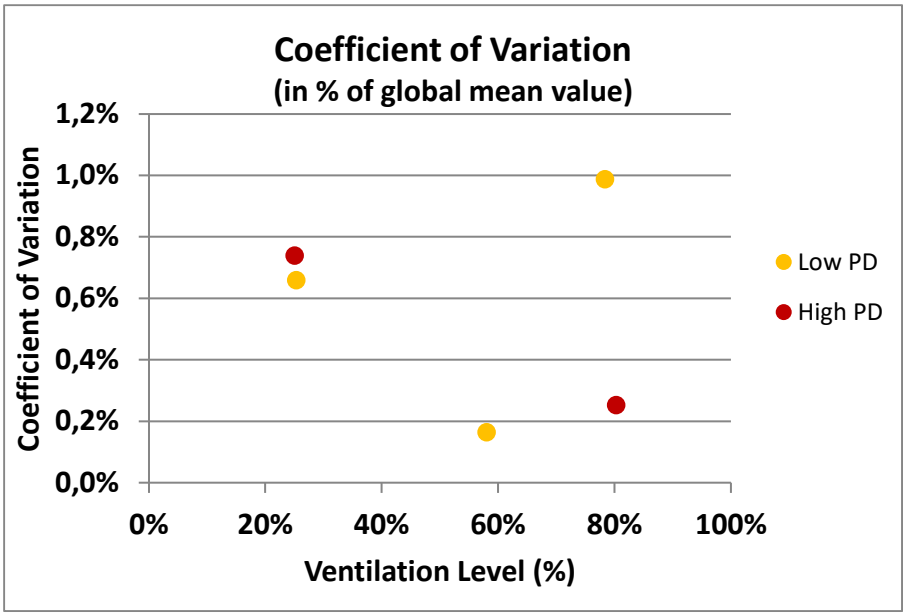

Figure 5: Coefficient of Variation of the Global Mean vs. Ventilation Level for Slim Ventilation Standards

2.3 Individual Laboratory Results

The individual mean values obtained by each laboratory for each FV calibration standard are shown in Table 9. The relative deviation of each laboratory from the global mean value was calculated and is shown in Table 10. The standard deviation and the coefficient of variation are shown by laboratory and by calibration standard in Tables 11 and 12, respectively.

The relative deviation from the global mean is also presented by laboratory in Figure 6 and by calibration standard in Figure 7.

Table 9: Laboratory Mean by Sample (% Ventilation)

	Laboratory Code			
Standard	**A**	**B**	**C**	**D**
Nom 25 % L	25,33 %	25,08 %	25,39 %	25,47 %
Nom 60 % L	57,94 %	58,12 %	58,08 %	57,94 %
Nom 80 % L	79,39 %	77,84 %	77,68 %	78,38 %
Nom 25 % H	25,03 %	24,76 %	25,02 %	25,21 %
Nom 80 % H	80,52 %	80,14 %	80,07 %	80,33 %

Table 10: Deviation from Sample Mean (Relative %)

	Laboratory Code			
Standard	**A**	**B**	**C**	**D**
Nom 25 % L	0,06 %	-0,93 %	0,26 %	0,61 %
Nom 60 % L	-0,14 %	0,18 %	0,10 %	-0,14 %
Nom 80 % L	1,37 %	-0,62 %	-0,82 %	0,07 %
Nom 25 % H	0,10 %	-0,98 %	0,06 %	0,81 %
Nom 80 % H	0,31 %	-0,16 %	-0,25 %	0,09 %

Table 11: Laboratory Standard Deviation by Sample (% Ventilation)

	Laboratory Code			
Standard	**A**	**B**	**C**	**D**
Nom 25 % L	0,03 %	0,03 %	0,11 %	0,04 %
Nom 60 % L	0,04 %	0,02 %	0,20 %	0,11 %
Nom 80 % L	0,13 %	0,06 %	0,25 %	0,18 %
Nom 25 % H	0,06 %	0,03 %	0,11 %	0,03 %
Nom 80 % H	0,08 %	0,04 %	0,18 %	0,19 %

Table 12: Laboratory Coefficient of Variation by Sample (Relative %)

	Laboratory Code			
Standard	**A**	**B**	**C**	**D**
Nom 25 % L	0,12 %	0,10 %	0,44 %	0,16 %
Nom 60 % L	0,08 %	0,04 %	0,35 %	0,18 %
Nom 80 % L	0,17 %	0,08 %	0,32 %	0,23 %
Nom 25 % H	0,24 %	0,11 %	0,45 %	0,13 %
Nom 80 % H	0,11 %	0,05 %	0,23 %	0,23 %

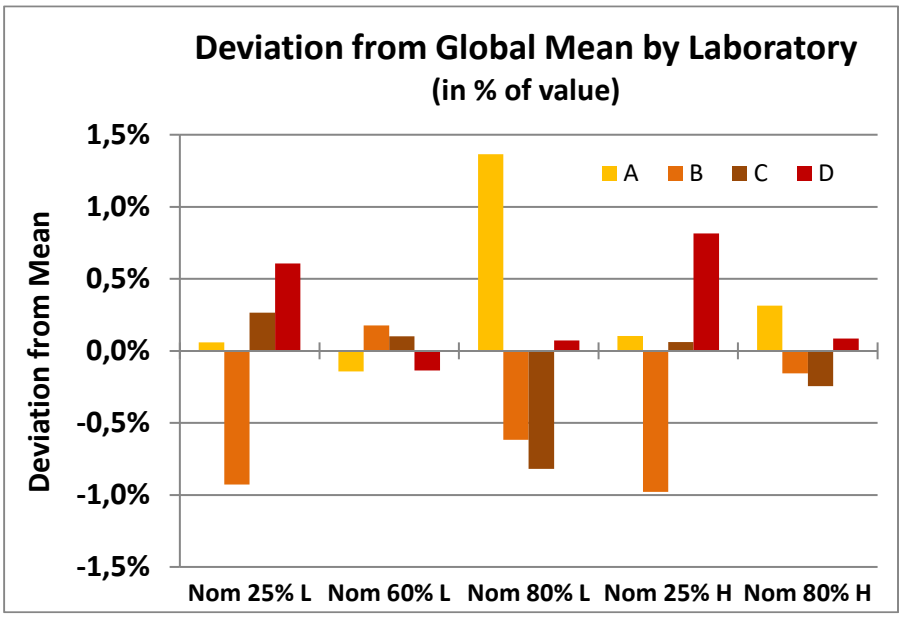

Figure 6: Deviation from Global Mean by Laboratory for Each Sample (Relative %)

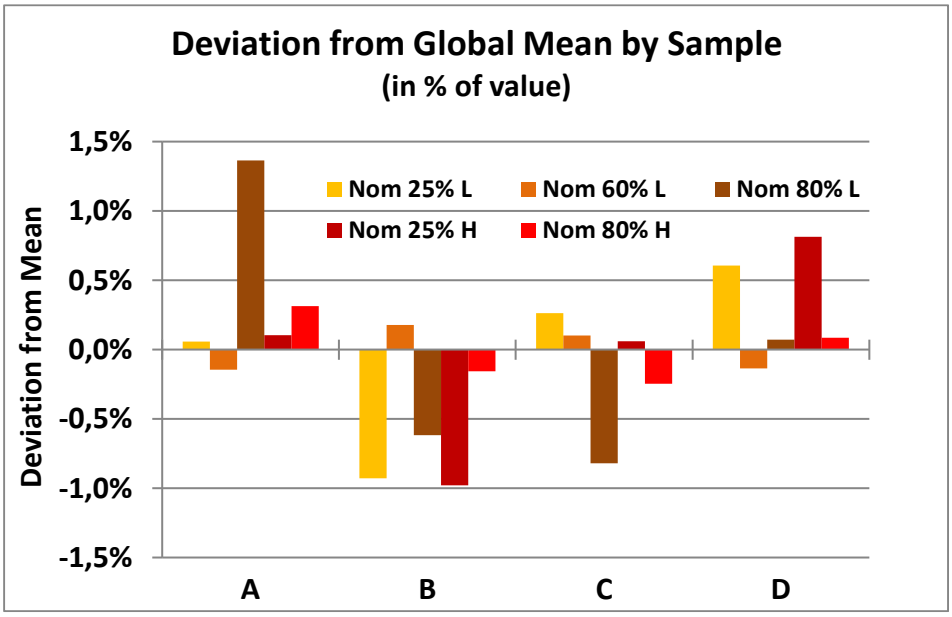

Figure 7: Deviation from Global Mean by Sample for Each Laboratory (Relative %)

2.4 Pressure Drop of Standards

The recorded pressure drop of the standards with the ventilation path open (PDo) is presented in Table 13 and compared to the values the normal-format ventilation standards used above.

Table 13: Pressure Drop Ventilation Standards With the Ventilation Path Open (PDo)

Slim-format Standards		Normal-format Standards	
Standard	**PDo (mmWG)**	**Standard**	**PDo (mmWG)**
Nom 25 % L	84,8	Nom 20 %	83,2
Nom 60 % L	60,1	Nom 50 %	61,9
Nom 80 % L	42,2	Nom 80 %	34,9
Nom 25 % H	171,8		
Nom 80 % H	81,5		

It can be seen that the pressure drop values for the slim- and normal-format standards based on a 100 mmWG basis rod are broadly equivalent.

After conclusion of the circulation, the ventilation standards are normally re-checked to detect any changes that may have happened during circulation. In this case, however, the standards were not available for re-checking.

2.5 Repeatability and Reproducibility Estimations

Repeatability and reproducibility (r and R) estimations were calculated according to the principles of ISO 5725:1994. The data were screened using Mandel's *h* and *k* statistics. There were no outliers although close to an *h* outlier was detected for Lab C and the 80 % low PD standard; it was noted that this standard presented several partially blocked capillaries that might well have contributed to this observation. The protocol excludes the option to clean the standards between measurements. With the participation of just four laboratories only r and R standard deviations are presented.

Tables 8 and 9 respectively present the summary data and r and R estimations as % ventilation and the r and R CoV as relative %.

Table 8: Slim Repeatability and Reproducibility Estimates (% Ventilation)

	Standard				
	Nom 25 % L	**Nom 60 % L**	**Nom 80 % L**	**Nom 25 % H**	**Nom 80 % H**
Grand Mean for All Labs	25,32 %	58,02 %	78,32 %	25,01 %	80,26 %
StD of Lab Means	0,17 %	0,10 %	0,77 %	0,18 %	0,20 %
Repeatability Std Dev (sr)	0,06 %	0,12 %	0,17 %	0,07 %	0,14 %
Reproducibility Std Dev (sR)	0,18 %	0,14 %	0,79 %	0,19 %	0,24 %

Table 9: Repeatability and Reproducibility CoV (Relative %)

	Standard				
	Nom 25 % L	**Nom 60 % L**	**Nom 80 % L**	**Nom 25 % H**	**Nom 80 % H**
Repeatability CoV	0,25 %	0,20 %	0,22 %	0,27 %	0,17 %
Reproducibility CoV	0,70 %	0,25 %	1,01 %	0,78 %	0,30 %

2.6 Comparison between Slim- and Normal-Format Standards

A direct comparison between the results of all eight round robin tests completed to date is presented in Figure 4 in terms of the global coefficient of variation vs ventilation level for each standard. This can be compared directly to Figure 5, where it can be seen that the results from the slim-format ventilation standards fully conform to the historical norm, notwithstanding a possible query on the variation from the 80 % L standard.

2.7 Comments on the Results

The results of the round robin test on slim filter ventilation calibration standards are well in line with the historical performance of the method. Thus, it may be concluded that for the measurement of the filter ventilation of slim cigarettes different similar repeatability and reproducibility properties may be expected than for cigarettes with normal format.