Physical Test Methods Sub-Group

Technical Report

11th Collaborative Study (2018) on Physical Parameters of Cigarettes and Filters

December 2018

Sub-Group Co-ordinator:

Bernhard Eitzinger, delfort AG, Austria

Study Co-ordination:

CORESTA PTM Proficiency Test Coordination Group
(B. Eitzinger, J. Fiebiger, Ph. Le Men, P. Müller)

Table of Contents

1. INTRODUCTION

1.1 Purpose and Scope

The Physical Test Methods (PTM) Sub-Group of CORESTA carries out a normally annual inter-laboratory study on physical parameters of cigarettes and filters. This collaborative study allows to monitor the repeatability and reproducibility of the test methods used and further allows the laboratories to assess their performance when measuring certain physical parameters of cigarettes and filters, such as weight, diameter, pressure drop, draw resistance and ventilation. This collaborative study contributes to the objectives of the PTM Sub-Group, which require to organise, conduct and report on routine inter-laboratory studies in order to maintain CORESTA Recommended Methods, to assess inter-laboratory consistency and to enable continual improvement of participating laboratories.

In addition to monitoring the performance of the test methods, the results from this study allow each laboratory to evaluate its proficiency in comparison to other laboratories, to derive actions for improvement and to fulfil accreditation requirements.

All results will be presented in anonymized form.

1.2 Study Protocol

The test protocol used for this collaborative study is given in Appendix A and will be briefly summarized below.

The protocol contained information on the products to be tested, the preparation of samples, set-up and calibration of instruments and the procedure for carrying out the measurements. The study participants were required to provide data to identify their laboratory, data on the instruments and calibration methods used and all measurement results obtained. The data were collected in an Excel-sheet and sent to the Test Coordination Group for further processing and evaluation.

Once received, the data set was inspected for obvious inconsistencies, e.g. wrong units of measurement, such as reporting weight in g instead of mg, or reporting circumference instead of diameter. In cooperation with the respective laboratory such inconsistencies were corrected as far as possible and the data sets of all laboratories were anonymized, compiled to a single large data set and then used for statistical analysis.

The distribution of sample materials, the protocol and the data collection sheet started in June 2018 and laboratories were asked to report the results until end of August 2018.

Compared to previous inter-laboratory studies on physical parameters carried out until 2016 the protocol was modified in several aspects for the 10th Collaborative Study on Physical Parameters in 2017. This modified protocol also applied to the present collaborative study.

- The use of ISO standards was made mandatory, which changed the character of the study from a proficiency test to a collaborative study.
- A replicate measurement was defined as the average of 10 individual measurements and all evaluations are based on the reported replicates only.
- Five replicate measurements are to be made instead of three in past studies.
- A repeat measurement on the same filter sample set was deleted from the protocol.
- The sample conditioning was changed from exactly 48 hours to a minimum of 48 hours.

On the one hand these changes in the protocol formalized certain practices that were already used in the past studies (ISO standards, number of individual measurements) and on the other hand improved the reliability of the statistical results and simplified the protocol. It is intended that the protocol of this collaborative study is used for further studies during the next years.

1.3 Products and Measurements

For the collaborative study cigarettes and filters with the main properties according to Table 1 were used. The values in Table 1 do not necessarily represent actual measured values but just serve as an indication of the general characteristics of the product. In Table 1 the pressure drop (PD) is given as the fully encapsulated pressure drop for filters and the open draw resistance of cigarettes.

The cigarettes were manufactured by the owner of the respective brand and the filters were manufactured by Solvay Acetow GmbH. The products were not pre-selected with respect to any parameter such as weight or pressure drop and are therefore subject to typical product variability.

With the exception of the 10th Collaborative Study (2017), where only three cigarette samples and five filter samples were available, this study was carried out with the normally used set of five cigarette samples and five filter samples. Even though the cigarettes and filters change every two to three years it is attempted that they have similar properties than the samples used in past studies.

Table 1 – Characteristics of the tested products

3	ID	Product Description	Length	Diameter	PD	Ventilation
			mm	mm	mmWG	%
Filters	F1	Cellulose Acetate Filter	126	7,2	440	
	F2	Cellulose Acetate Filter	126	5,4	500	
	F3	Cellulose Acetate Filter	126	7,8	290	
	F4	Cellulose Acetate Filter	126	7,8	510	
	F5	Cellulose Acetate Filter	126	7,8	730	
Cigarettes	C1	Pianissimo Precia	98	5,4	86	88
	C2	Virginia Slims	98	7,4	110	56
	C3	Benson & Hedges	98	7,7	120	33
	C4	hi-lite	83	7,8	86	31
	C5	Mevius Premium Menthol	83	7,8	87	55

For each product a single batch was produced and one randomly selected sample set was prepared for each laboratory and each replicate measurement. Each sample set consisted of 10 filters or cigarettes and as there were five replicate measurements each laboratory received at least 5×10 test pieces per product.

The laboratories were asked to determine the following physical parameters.

Filters

- Weight (mg)
- Diameter (mm)
- Fully Encapsulated Pressure Drop (PD) (mmWG)

Cigarettes

- Weight (mg)
- Diameter (mm)
- Open Draw Resistance (mmWG)
- Closed Draw Resistance (mmWG)
- Degree of Filter Ventilation (FV) (%)

A replicate measurement, consisting of the average of 10 individual measurements, had to be carried out for all products and all physical parameters on each of five different days of testing, using a new sample set on each day of measurement.

Thus, a laboratory completing the full set of measurements had to conduct 5 (filters) × 5 (days) × 3 (parameters) × 10 (individual measurements) = 750 measurements on filters and 5 (cigarettes) × 5 (days) × 5 (parameters) × 10 (individual measurements) = 1250 measurements on cigarettes, i.e. in total 2000 individual measurements.

For the measurements the laboratories had to follow the respective ISO standards, such as ISO 6565 for the determination of pressure drop, open and closed draw resistance, ISO 9512 for the determination of the degree of filter ventilation and ISO 2971 for diameter. For weight no ISO standards or CORESTA Recommended Methods exist, but CORESTA Guide No. 6 had to be considered.

1.4 Study Participants

In total 15 laboratories participated with the entire list of participants in alphabetical order given in Table 2. A code was assigned to each laboratory by a member of the Test Coordination Group, thus the order of laboratories in Table 2 does not agree with the order of the laboratories in other tables. Not all laboratories were able to measure all types of products, for example, some measured only cigarettes or were not able to measure filters with small diameters. One laboratory received two sample sets as indicated in Table 2.

Table 2 – List of Participants

Participant Name	Country
Altria Client Services	USA
ASL Analytic Service Laboratory GmbH	Germany
Beijing Omerica Technology Co. Ltd.	China
British American Tobacco	Germany
Essentra Scientific Services	United Kingdom
Imperial Tobacco Polska S.A.	Poland
ITC Life Sciences & Technology Center	India
Japan Tobacco Inc.	Japan
Molins PLC	United Kingdom
Papierfabrik Wattens GmbH	Austria
Reemtsma Cigarettenfabriken (2 sample sets)	Germany
Sampoerna Scientific Technical Services	Indonesia
Solvay Acetow GmbH	Germany
Tabacalera del Este S.A. (2 sample sets)	Paraguay
Zhengzhou Tobacco Research Institute	China

2. STATISTICAL EVALUATION

2.1 Raw Data Treatment

In total 17 data sets were received and after an initial screening for inconsistencies and any corrections, if needed, the data were prepared for statistical analysis. Mean values (MV) over all laboratories and replicates, the average within-laboratory standard deviation (SDw), that is, the standard deviation of a single replicate averaged over all laboratories and the between-laboratory standard deviation (SDb), that is the standard deviation of the mean values obtained by all laboratories, are provided for filters in Table 3 and for cigarettes in Table 4. The number (N) of data sets is also given.

Table 3 – Summary data for filters over all labs and days, outliers included

	Weight				Diameter				Pressure Drop			
ID	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	SDw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
F1	747,50	2,62	2,55	15	7,15	0,006	0,006	15	442,91	11,79	4,74	13
F2	440,98	2,22	3,87	15	5,35	0,005	0,005	15	496,64	15,17	5,92	13
F3	828,49	2,44	2,49	16	7,81	0,007	0,005	16	290,98	6,50	2,12	14
F4	857,94	2,23	2,29	16	7,80	0,006	0,004	16	513,19	14,59	3,60	14
F5	863,42	2,19	2,14	16	7,80	0,006	0,005	16	722,77	28,74	5,44	14

Table 4 – Summary data for cigarettes over all labs and days, outliers included

	Weight				Diameter				Open Draw Resistance			
ID	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	Sdw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
C1	536,73	4,25	4,16	16	5,43	0,009	0,007	16	86,32	1,39	1,32	16
C2	924,56	8,20	5,00	16	7,37	0,009	0,009	16	111,20	1,47	1,57	16
C3	988,42	10,56	5,52	16	7,69	0,014	0,006	16	118,52	1,35	2,23	16
C4	803,35	5,72	5,56	16	7,81	0,015	0,006	16	85,40	1,04	1,06	16
C5	813,95	6,32	4,86	16	7,82	0,014	0,006	16	87,19	1,59	1,26	16

	Closed Draw Resistance				Filter Ventilation			
	MV	SDb	SDw	N	MV	SDb	SDw	N
	mmWG	mmWG	mmWG		%	%	%	
C1	349,31	9,51	8,48	16	87,44	0,54	0,58	16
C2	196,82	4,36	3,71	16	57,36	1,58	0,55	16
C3	161,42	3,01	2,62	16	34,17	1,54	1,20	16
C4	116,75	2,27	2,25	16	31,59	1,60	0,44	16
C5	152,78	3,18	2,69	16	55,93	1,40	0,53	16

2.2 Outlier Analysis and Removal

Repeatability and reproducibility data were determined following ISO 5725-2, whereby outlier testing according to Cochran's test and Grubb's test was used. First for each laboratory the maximum and the minimum of the five replicates was checked for being an outlier according to Grubb's test ("within-laboratory Grubb's test"). Any outliers that were detected were removed from the data set, but the other replicates remained for further calculations.

Second the standard deviations of each laboratory's results were compared to the total standard deviation by Cochran's test to detect any laboratories that had an unusually high standard deviation. If an outlier was detected this data set was removed from further analysis.

In a third step Grubb's test ("between-laboratory Grubb's test") was used to check if the mean value of a laboratory was exceptionally high or low compared to the other laboratories. All outliers were removed. These two outlier tests were repeated as often as was necessary until no further outliers appeared. Generally the number of outliers was low so that there was no danger of removing too many data sets.

After elimination of outliers global statistics, in particular mean values and standard deviations, were calculated and the repeatability and reproducibility statistics were determined.

In order to evaluate laboratory proficiency in the form of z-scores, as described in ISO 13528:2015, a 'true' value and standard deviation need to be assigned to each product and each physical parameter, which form the basis for the calculation of z-scores. In contrast to other studies, where the 'true' value is known or can be easily assigned, such values are not available in this study. Consequently, the 'true' mean value and standard deviation were determined as the global average and standard deviation obtained by the above outlier

elimination procedure used for the determination of repeatability and reproducibility. The z-scores were then calculated for all laboratories, which reported data, based on their originally reported data set irrespective of whether their results were excluded in the calculation of the global mean value and standard deviation.

The laboratories which were excluded are listed for each product and parameter for the filters and cigarettes in Table 5. The outliers are coded in the following manner. LxxC means that laboratory xx was excluded by Cochran's test (C). Likewise LxxGWL means that the lowest value of laboratory xx qualified as outlier by the within-laboratory Grubb's test (GW), and analogously LxxGWH for the highest values. In a similar manner the outliers detected by the between-laboratory Grubb's (GB) test are coded as LxxGBL and LxxGBH, respectively.

Outliers were found for laboratories 3, 4, 5, 11, 12, 13 and 14.

Table 5 – Laboratories which were excluded as outliers by Cochran's test (C) or Grubb's test based on within-laboratory data (GW) and between-laboratory data (GB)

ID	Weight	Diameter	Pressure Drop	Open Draw Resistance	Closed Draw Resistance	Filter Ventilation
F1						
F2	L05GWL		L05GBL	not	not	not
F3		none	L05GBL	applicable	applicable	applicable
F4			L05GBL			
F5			L05GBL, L14GBL			
C1					L13GBL	L05C
C2			not	L03GWL	L11GBL, L11C	L05GBH
C3	L12GBH	L04GBH	applicable		L03GWL, L11GBL	L05GBH
C4	L12GBH			L13GWH		L05GBH
C5	L12GBH					L05GBH

The remaining data sets were then used to calculate a global mean and standard deviation.

2.3 Robust Mean Values and Standard Deviations

After the removal of outliers robust mean values and between-laboratory standard deviations were calculated using ISO 5725-2. The results for the filters are given in Table 6 and for cigarettes in Table 7. In all tables the number of laboratories is denoted by N.

Table 6 – Robust mean values (MV), between-laboratory standard deviations (SDb) and within-laboratory standard deviation (SDw) for filters

	Weight				Diameter				Pressure Drop			
ID	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	SDw	N
	mg	mg	mg		mm	mm	Mm		mmWG	mmWG	mmWG	
F1	747,50	2,62	2,55	15	7,15	0,006	0,006	15	442,91	11,79	4,74	13
F2	441,34	1,50	2,36	15	5,35	0,005	0,005	15	500,66	2,86	5,07	12
F3	828,49	2,44	2,49	16	7,81	0,007	0,005	16	292,58	2,44	2,12	13
F4	857,94	2,23	2,29	16	7,80	0,006	0,004	16	516,97	3,74	3,68	13
F5	863,42	2,19	2,14	16	7,80	0,006	0,005	16	722,77	28,74	5,44	14

Table 7 – Robust mean values (MV), between-laboratory standard deviations (SDb) and within-laboratory standard deviation (SDw) for cigarettes

	Weight				Diameter				Open Draw Resistance			
ID	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	Sdw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
C1	536,73	4,25	4,16	16	5,43	0,009	0,007	16	86,32	1,39	1,32	16
C2	924,56	8,20	5,00	16	7,37	0,009	0,009	16	111,28	1,65	1,40	16
C3	986,29	6,46	5,56	15	7,69	0,007	0,006	15	118,52	1,35	2,23	16
C4	802,03	2,31	5,31	15	7,81	0,015	0,006	16	85,33	1,07	0,88	16
C5	812,72	4,08	4,86	15	7,82	0,014	0,006	16	87,19	1,59	1,26	16

	Closed Draw Resistance				Filter Ventilation			
	MV	SDb	SDw	N	MV	SDb	SDw	N
	mmWG	mmWG	mmWG		%	%	%	
C1	351,40	4,62	8,71	15	87,47	0,54	0,35	15
C2	197,56	3,34	3,17	15	57,01	0,75	0,50	15
C3	162,05	2,16	2,33	15	33,82	0,60	1,21	15
C4	116,75	2,27	2,25	16	31,22	0,64	0,44	15
C5	152,78	3,18	2,69	16	55,63	0,78	0,52	15

2.4 Evaluation of Repeatability and Reproducibility

Based on the robust mean value and the between-laboratory and within-laboratory standard deviations repeatability and reproducibility statistics were calculated according to ISO 5725-2. The results are given first for filters in Tables 8a-b and then for cigarettes in Tables 9a-c. The Tables show the standard deviation (SD), the limit and the coefficient of variation (CoV) relative to the global mean value for repeatability and reproducibility.

Table 8a – Repeatability and reproducibility statistics for filter weight and diameter

	Weight						Diameter					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mg	mg	%	mg	mg	%	mm	mm	%	mm	mm	%
F1	2,55	7,21	0,34	3,47	9,81	0,46	0,006	0,017	0,085	0,008	0,023	0,113
F2	2,36	6,66	0,53	2,59	7,31	0,59	0,006	0,016	0,103	0,007	0,019	0,125
F3	2,49	7,05	0,30	3,30	9,34	0,40	0,005	0,014	0,062	0,008	0,023	0,103
F4	2,29	6,48	0,27	3,03	8,57	0,35	0,004	0,012	0,055	0,007	0,020	0,090
F5	2,14	6,06	0,25	2,91	8,24	0,34	0,005	0,013	0,058	0,007	0,021	0,093

Table 8b – Repeatability and reproducibility statistics for filter pressure drop

	Pressure Drop					
	Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV
	mmWG	mmWG	%	mmWG	mmWG	%
F1	4,74	13,42	1,07	12,53	35,44	2,83
F2	5,07	14,35	1,01	5,37	15,18	1,07
F3	2,12	6,01	0,73	3,09	8,74	1,06
F4	3,68	10,42	0,71	4,99	14,10	0,96
F5	4,45	12,58	0,61	7,27	20,56	0,99

Table 9a – Repeatability and reproducibility statistics for cigarette weight and diameter

	Weight						Diameter					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mg	mg	%	mg	mg	%	mm	mm	%	mm	mm	%
C1	4,16	11,78	0,78	5,65	15,98	1,05	0,007	0,019	0,126	0,011	0,030	0,198
C2	5,00	14,15	0,54	9,34	26,43	1,01	0,009	0,026	0,124	0,012	0,034	0,163
C3	5,56	15,73	0,56	8,15	23,06	0,83	0,006	0,016	0,074	0,009	0,025	0,114
C4	5,31	15,02	0,66	5,28	14,94	0,66	0,006	0,018	0,082	0,016	0,045	0,206
C5	4,86	13,74	0,60	5,96	16,86	0,73	0,006	0,018	0,081	0,015	0,043	0,194

Table 9b – Repeatability and reproducibility statistics for cigarette draw resistance

	Open Draw Resistance						Closed Draw Resistance					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mmWG		%	mmWG		%	mmWG		%	mmWG		%
C1	1,32	3,73	1,53	1,82	5,15	2,11	8,71	24,62	2,48	9,06	25,61	2,58
C2	1,40	3,97	1,26	2,07	5,87	1,86	3,17	8,98	1,61	4,38	12,40	2,22
C3	2,23	6,29	1,88	2,40	6,80	2,03	2,33	6,59	1,44	3,00	8,50	1,85
C4	0,88	2,48	1,03	1,33	3,75	1,55	2,25	6,35	1,92	3,03	8,57	2,60
C5	1,26	3,57	1,45	1,59	4,49	1,82	2,69	7,62	1,76	3,99	11,29	2,61

Table 9c – Repeatability and reproducibility statistics for cigarette filter ventilation

	Degree of Filter Ventilation					
	Repeatability			Reproducibility		
ID	SD	Limit	CoV	SD	Limit	CoV
	%	%	%	%	%	%
C1	0,35	0,99	0,40	0,63	1,78	0,72
C2	0,50	1,41	0,87	0,87	2,50	1,53
C3	1,21	3,42	3,58	1,24	3,50	3,66
C4	0,44	1,24	1,40	0,75	2,12	2,40
C5	0,52	1,48	0,94	0,90	2,55	1,62

2.5 Evaluation of Laboratory Performance (z-Scores)

Based on the robust mean value and the between-laboratory standard deviation the z-scores were calculated as described in ISO 13528:2015. The results are given first for filters and then for cigarettes. In the tables fields marked in orange are z-scores with $2<|z|<3$ and red fields are those with $3\leq|z|$.

Table 10 – Z-Scores for all laboratories on the measurement of weight, diameter and pressure drop of filters

	Weight					Diameter					Pressure Drop				
ID	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1	-0,06	-0,66	-0,47	-0,45	0,12	0,56	-0,41	0,02	0,25	0,59	0,57	-0,07	1,66	1,21	1,56
2	1,63	0,72	0,65	1,22	1,18	1,22	1,01	0,32	0,50	0,57	0,64	1,52	1,54	1,44	1,10
3	0,40	1,52	0,28	0,49	0,44	-0,38	0,56	-0,40	-1,12	-1,14					
4	0,73	1,46	1,70	1,48	2,09	-1,64	-2,09	-1,66	-1,23	-1,67	0,15	1,96	0,93	0,93	1,15
5	-0,24	-4,25	-0,53	-0,15	-0,38	0,58	1,05	-0,20	0,33	-0,09	-2,43	-18,78	-9,30	-14,13	-16,85
6	0,07	0,91	-0,13	-0,02	0,07	0,40	1,46	1,39	0,31	1,05	0,73	-0,03	-0,95	-0,48	-0,92
7															
8	-0,84	-0,27	0,08	-0,69	0,04	0,66	0,36	0,53	0,57	0,77	0,49	-0,29	0,82	0,79	0,24
9	-0,08	-0,20	-1,23	-0,15	-0,31	0,49	0,19	1,41	1,14	1,22	-0,23	0,52	-1,53	-0,95	-1,07
10	-0,77	-0,73	-1,08	-1,36	-1,48	-0,50	-0,21	-0,67	-0,93	-0,93	-0,74	-0,84	-0,94	-1,48	-1,18
11	-2,00	-1,27	-1,46	-1,41	-1,18	-1,23	-1,04	-0,75	-1,12	-0,92	-0,27	-0,49	-0,22	0,26	0,43
12	1,94	1,20	2,14	2,40	1,67	1,66	1,35	1,68	2,31	1,80	-1,01	-1,08	-0,32	-0,89	-1,46
13	0,25	0,32	-1,04	-0,49	-0,82	-0,26	-0,81	-0,72	-0,86	-0,91	1,65	0,09	-0,02	0,70	-0,04
14			0,39	-0,28	-0,59			0,82	0,87	0,77			-1,03	-1,52	-5,59
15	-1,06	-1,54	0,69	-0,62	0,48	-1,71	-0,41	-1,63	-1,01	-0,55	0,34	-1,21	0,17	0,01	0,43
16	-0,36	-1,04	0,10	-0,14	-1,05	-0,51	-0,02	0,07	-0,24	-0,01					
17	0,39	0,25	-0,08	0,17	-0,29	0,65	-0,98	-0,22	0,21	-0,56	0,12	0,44	0,01	-0,01	-0,24

Table 11 – Z-Scores for all laboratories on the measurement of weight, diameter, open draw resistance, closed draw resistance and degree of filter ventilation for cigarettes

	Weight					Diameter					Open Draw Resistance				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	0,58	0,36	0,96	-0,61	0,47	-0,45	-1,20	0,11	0,62	0,53	-0,98	0,85	-0,37	1,60	0,73
2	0,41	0,55	1,62	0,44	0,74	2,01	0,69	1,97	-0,73	-0,94	0,66	0,41	0,53	0,53	0,12
3	0,17	0,28	0,80	0,34	-1,12	-0,47	-1,07	-0,94	-0,24	-0,61	0,88	1,59	0,15	-0,96	0,30
4	0,36	0,44	0,18	1,14	1,71	1,33	2,34	6,76	-1,95	-2,09	0,59	-0,15	1,63	1,06	1,68
5	-0,14	0,15	-0,56	-0,56	0,10	0,58	0,32	-0,32	-0,44	-0,07	1,35	0,57	-0,46	0,72	1,03
6	0,09	0,17	0,94	0,84	0,01	0,53	0,20	0,37	-0,04	-0,10	-0,73	-0,19	0,56	-0,40	-0,24
7	-0,11	0,52	0,20	-0,72	1,00	-0,75	-0,63	-0,76	-0,29	0,20	0,26	-1,31	1,08	-0,03	0,42
8	0,17	0,44	0,19	0,68	0,78	-0,69	-0,03	0,26	1,00	1,30	1,69	0,79	-0,48	-0,62	0,67
9	0,29	-0,52	-0,41	0,67	-0,47	0,38	0,25	0,07	0,24	0,16	0,03	-0,38	0,89	0,87	-0,79
10	-2,10	-2,01	-1,28	-1,15	-1,56	-1,51	-1,09	-1,25	-0,14	0,12	0,03	-1,88	-1,15	-0,96	-0,76
11	-1,07	-0,93	-2,31	-2,30	-1,94	-1,76	-1,10	-1,90	0,35	0,21	-1,25	-0,71	-1,59	-0,98	-1,51
12	2,76	2,70	5,28	9,11	4,83	0,56	1,60	1,41	2,45	2,10	0,67	0,51	1,84	1,45	1,00
13	-0,81	-0,67	-0,50	-0,35	-0,39	0,23	0,20	-0,24	-0,90	-0,94	-2,12	-0,19	-0,71	0,10	-0,94
14	-0,29	-0,78	-0,78	-0,65	-0,47	-0,82	-0,40	0,02	-0,28	-0,28	-0,72	-0,51	-0,48	-1,75	-2,06
15															
16	-0,50	-0,33	0,61	1,08	0,47	0,09	0,53	1,04	1,12	1,17	0,09	0,65	-1,00	-0,23	0,44
17	0,18	-0,37	0,34	1,13	0,65	0,74	-0,62	0,17	-0,78	-0,74	-0,43	-0,82	-0,45	0,61	-0,09

	Closed Draw Resistance					Filter Ventilation				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	-0,18	0,35	-0,10	1,07	0,33	-1,93	-1,39	0,11	-0,20	-0,66
2	2,27	0,53	0,45	0,56	0,08	-1,02	-0,44	0,36	0,05	-0,76
3	0,52	1,37	-1,77	-0,91	-0,24	-0,36	-0,53	-1,13	-1,28	-1,28
4	0,58	0,29	1,68	1,51	2,05	0,16	-0,24	0,26	0,36	0,51
5	0,50	-0,11	-0,76	-0,09	-0,11	-0,75	7,51	9,47	9,24	6,09
6	-1,08	-1,60	-0,15	-0,39	-0,30	1,22	0,55	-0,37	-0,04	0,26
7	-0,72	-0,77	0,07	-0,23	0,16	0,22	0,58	-1,55	-0,93	-0,45
8	0,61	0,69	-0,37	-0,40	0,63	0,61	0,61	0,47	0,24	0,44
9	-0,55	0,02	0,35	0,80	-0,25	1,52	1,77	0,28	0,43	0,92
10	0,24	-2,15	-1,73	-0,93	-0,89	-0,11	-0,93	-1,76	-1,76	-1,77
11	-1,77	-3,52	-3,72	-2,08	-2,55	-0,49	-1,61	-0,91	-1,11	-0,98
12	1,01	1,65	2,18	1,54	1,24	0,14	1,04	1,22	1,13	0,76
13	-7,26	0,14	0,08	0,75	0,33	0,53	0,50	1,56	2,28	1,97
14	-0,61	-0,59	-0,53	-1,13	-0,99	-1,67	-0,73	-0,17	0,14	-0,24
15										
16	-0,98	0,44	-0,98	-0,08	0,31	1,23	1,34	1,30	0,32	1,05
17	0,15	-0,25	0,65	0,03	0,20	-0,05	-0,52	0,33	0,37	0,23

3. DATA INTERPRETATION

3.1 Repeatability and Reproducibility

The results for repeatability and reproducibility, Tables 8a-b and Tables 9a-c, do not show any exceptional values and are in line with the values reported in the respective ISO standards. It has to be taken into account that the testing of physical parameters as carried out in this study is considered as "destructive" so that each individual measurement has to be performed on a different filter or cigarette. Consequently, repeatability and reproducibility data also include the product variability.

Nevertheless the coefficients of variation of repeatability and reproducibility for the measurement of diameter and weight are generally below 1 %, which is satisfactory for practical purposes.

As expected the weight variability of cigarettes is higher than of filter rods, therefore the repeatability coefficient of variation is higher by a factor of about 2 for cigarettes compared to filters. The reproducibility of the measurement of flow parameters like pressure drop, draw resistances and filter ventilation is also higher for cigarettes by a factor of 2 compared to filters, which can partially be attributed to higher product variability.

The reproducibility coefficient of variation for flow parameters is in the low percent range, which is acceptable for routine measurements.

The coefficients of variation for repeatability and reproducibility are rather stable over the entire product range tested in this study, which indicates that the repeatability standard deviation increases approximately proportional to the mean value of the respective parameter.

In summary, the results are within expectations and do not immediately suggest the need for a revision of the concerned methods.

3.2 Laboratory Performance

As described in ISO 13528:2015, in normal circumstances about 95 % of all z-scores will be in the range between -2 and 2. Occasionally, absolute z-scores equal to or greater than 2 may be expected at a rate of about 5 %, while absolute z-scores equal to or greater than 3 will occur only at a rate of about 0,3 %.

Thus for absolute z-scores between 2 and 3 it is up to the laboratory to decide if these exceptional values are of importance and require any corrective action or review of the laboratory procedures. For absolute z-scores of 3 or higher it is strongly recommended that the laboratory investigates the reasons for the deviation and derives appropriate actions from these investigations.

In the present study, for filters 13 of 240 determinations, i.e. 5,4 %, resulted in absolute z-scores of 2 or higher and 6 of 240 determinations, i.e. 2,5 %, in absolute z-scores of 3 or higher. For the cigarettes 31 of 400 determinations (7,8 %) provided absolute z-scores of 2 or higher and 11 determinations (2,8 %) had absolute z-scores of 3 or higher.

Comparing these rates of occurrence of absolute z-scores between 2 and 3 with the expected rates it can be concluded that the present study did not deliver any unusual results. However, the rates of absolute z-scores above 3 are higher than expected. These high z-scores are concentrated in a few laboratories, for which a review of their procedures is recommended.

It can be seen in Tables 10 and 11 that particularly laboratory 5 obtained a series of z-scores below -3 for the pressure drop of filters and a series of z-scores above 3 for the filter

ventilation of cigarettes. In total this laboratory accounts for almost 25 % of all z-scores having absolute values above 2. It is therefore recommended that laboratory 5 checks its procedures for the measurement of these parameters.

Further it can be seen that laboratory 12 generally measures high cigarette weights and also the filter weights, although not always statistically significant, were generally higher than the 'true' value.

It is also noteworthy that laboratory 11 obtained negative z-scores in filter weight, filter diameter, cigarette weight, cigarette open and closed draw resistance and filter ventilation, which indicates a tendency that the measured values are generally lower than the 'true' values. In total 7 of 40 measured parameters were statistically significantly lower than the global average.

Higher z-scores of other laboratories are irregularly dispersed over products and parameters and do not show any pattern that might lead to immediate recommendations for review of the procedures.

In total 9 of the 17 participating laboratories did not obtain any z-scores with an absolute value above 2, thus their results fit rather well to each other and to the 'true' value for all physical parameters tested in this study. These laboratories are 1, 3, 6, 7, 8, 9, 15, 16 and 17.

3.3 Comparison with Historical Data

One of the purposes of this study is to assess laboratory performance so that over time a steady improvement can be achieved. The following historical assessment by comparing data from the 7th Proficiency Test on Physical Parameters (2014), the 8th Proficiency Test on Physical Parameters (2015), the 9th Proficiency Test on Physical Parameters (2016) and the 10th Collaborative Study on Physical Parameters (2017) with the current test results are an attempt to investigate, if such an improvement can be observed.
The results of this analysis have to be interpreted very cautiously as different laboratories have taken part in the five inter-laboratory studies and as the tested products differed in the studies. Also as the data are anonymized the performance of individual laboratories cannot be assessed. Instead an average robust coefficient of variation is calculated over all products in a category by the ratio of the robust standard deviation and the robust global mean value and expressed as a percentage. As the robust standard deviation is calculated from the between-laboratory standard deviations it may be expected that the robust coefficient of variation decreases over time as the laboratories improve and the differences between the laboratories become smaller.
The results of this analysis are provided for information only and are not based on any specific statistical test or analysis.

Table 12 – Historical development of a robust coefficient of variation for parameters measured on filters

	Robust Coefficient of Variation				
Parameter	%				
	2014	**2015**	**2016**	**2017**	**2018**
Weight	0,239	0,392	0,421	0,332	0,300
Diameter	0,070	0,063	0,089	0,080	0,084
Pressure Drop	2,710	1,715	1,357	1,105	1,124

Table 13 – Historical development of a robust coefficient of variation for parameters measured on cigarettes

Parameter	Robust Coefficient of Variation %				
	2014	2015	2016	2017	2018
Weight	0,528	0,852	0,817	0,721	0,625
Diameter	0,126	0,104	0,103	0,172	0,150
Open Draw Resistance	2,104	1,476	1,370	1,632	1,354
Closed Draw Resistance	2,403	2,732	2,305	1,984	1,673
Degree of Filter Ventilation	2,785	2,211	2,524	1,347	1,432

First it has to be noted that the measurement of weight, diameter, pressure drop, draw resistance and the degree of filter ventilation is based on mature measurement methods so that no substantial change from year to year can be expected. The variability of the measurement of filters is generally lower than for cigarettes, which is likely to be due to the higher homogeneity of filters and their higher resistance to mechanical damage during transport and handling.

The observed variation for pressure drop, draw resistance and filter ventilation is in good agreement with the variability reported in ISO 6565 and ISO 9512, respectively. Thus the laboratories seem to properly apply these standards. As the methods have not changed from 2014 to 2018 most of the observed changes may be attributable to the change in the test pieces and to the differences in the laboratories that have taken part in the tests.

Since 2017 this inter-laboratory study has been carried out as a collaborative study by making the test methods mandatory. Therefore it is possible to also compare an average coefficient of variation for repeatability and reproducibility between 2017 and 2018. Tables 14a and 14b show these parameters for the filters and Tables 15a and 15b for the cigarettes.

Table 14a – Historical development of repeatability coefficient of variation for parameters measured on filters

Parameter	Repeatability Coefficient of Variation %	
	2017	2018
Weight	0,292	0,338
Diameter	0,071	0,073
Pressure Drop	0,820	0,826

Table 14b – Historical development of reproducibility coefficient of variation for parameters measured on filters

	Reproducibility Coefficient of Variation	
Parameter	**%**	
	2017	**2018**
Weight	0,422	0,428
Diameter	0,102	0,105
Pressure Drop	1,336	1,382

Table 15a – Historical development of repeatability coefficient of variation for parameters measured on cigarettes

	Repeatability Coefficient of Variation	
Parameter	**%**	
	2017	**2018**
Weight	0,733	0,628
Diameter	0,088	0,097
Open Draw Resistance	1,477	1,430
Closed Draw Resistance	2,087	1,842
Degree of Filter Ventilation	1,037	1,438

Table 15b – Historical development of reproducibility coefficient of variation for parameters measured on cigarettes

	Reproducibility Coefficient of Variation	
Parameter	%	
	2017	2018
Weight	0,973	0,856
Diameter	0,190	0,175
Open Draw Resistance	2,100	1,874
Closed Draw Resistance	2,767	2,372
Degree of Filter Ventilation	1,640	1,986

For the filters and for the cigarettes no substantial changes in these parameters could be observed between 2017 and 2018.

For cigarettes with the exception of diameter, which has very low variability, the reproducibility coefficient of variation is about 30 % to 45 % higher than the repeatability coefficient of variation for all parameters and this ratio remains stable from 2017 to 2018, so that no specific changes have occurred, which would require further investigation.

Overall there seem to be only small changes and no specific trends in this variation parameters so that the results do not suggest a need for revision of any of the concerned standards. Also the variability is sufficiently low for all practical purposes.

4. REFERENCES

- ISO 3402:1999, Tobacco and tobacco products – Atmosphere for conditioning and testing
- CORESTA Guide 6:2009, A User Guideline for the Use of Balances for Cigarettes and Cigarette Related Products
- ISO 2971:2013, Cigarettes and filter rods -- Determination of nominal diameter -- Method using a non-contact optical measuring apparatus
- ISO 6565:2015, Tobacco and tobacco products -- Draw resistance of cigarettes and pressure drop of filter rods -- Standard conditions and measurement
- ISO 9512:2002, Cigarettes -- Determination of ventilation -- Definitions and measurement principles
- ISO 5725-2:1994, Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method
- ISO/IEC 17043:2010, Conformity assessment – General requirements for proficiency testing.
- ISO 13528:2015, Statistical methods for use in proficiency testing by interlaboratory comparison

5. APPENDICES

APPENDIX A – Protocol

The protocol is reproduced in its original form. Minor typographical errors were corrected and e-mail addresses were removed.

Protocol for the 11th Proficiency Test (2018) on Physical Parameters

1. Preparation of Samples

1.1 All measurements should take place in an environment according to ISO 3402 (Testing atmosphere: (22±2)°C, (60±5) % rH). Give comments in case of deviation.

1.2 Prepare for each product – see data sheet: products - 5 separate samples (#1, #2, #3, #4, #5) of 10 filter rods / cigarettes. Sample 1 is measured on Day 1, sample 2 on Day 2 and sample 3 on Day 3, sample 4 on Day 4 and sample 5 on Day 5.

1.3 Samples should be unpacked and conditioned at least 48h (conditioning time can affect the level / results of physical parameters !) regarding ISO 3402 (conditioning atmosphere: (22±1)°C, (60±3) % rH) prior to the measurement. Give comments in case of deviation.

1.4 To avoid changes in sample-moisture the samples should be transferred from conditioning environment to the instrument in tightly closed plastic boxes.

2. Instrument Setup

2.1 The instrument system should be arranged to make the weight measurement first, followed by diameter or PD and ventilation (the order of these last three is normally provided by the instrument system).

2.2 Before making measurements, the instrument(s) should be set up to accept the sample being measured (e.g. for slim products - hopper adjustment, sleeves, measuring head; for filter rods - length of sleeve-holder to ensure a totally encapsulated PD measurement).

2.3 All specific instrument information should be recorded in the instrument configuration sheet.

3. Calibration of Instruments

3.1 At the beginning of each measuring day (run of all products) all instruments have to be checked for accuracy and, if necessary, recalibrated according to current ISO-standards:

3.2 PD: ISO 6565
Diameter: ISO 2971
FV: ISO 9512
Balance in regards to the instrument suppliers recommendation

Repeat calibration check after every change in the units (e.g. PD/FV unit: necessary changes caused by sample diameter and/or changes from cigarette to filter rod measurements).
If possible do not recalibrate until all products have been measured. If this is impossible, make a note in the comments column.

3.3 PD calibration should be carried out using nominally 800 mmWG multicapillary standards for filter PD measurements and nominally 200 mmWG multicapillary standards for cigarette measurements

Calibration checking should use at least 2 levels of PD standards to ensure an effective linearity and leak check:

400 mmWG and 800 mmWG nominal for filter rods
200 mmWG and 400 mmWG nominal for cigarettes

Standards should be calibrated according the CRM 41 (June 2007).
If the difference between the measured and the defined value of the standard during a calibration check exceeds ± 0,5 % of the defined value, recalibrate the instrument.

3.4 For all parameters (size, weight, PD, ventilation and diameter) the defined values should be noted in the instrument configuration sheet. The defined and the measured / actual values should be noted in the record sheet.

3.5 In case of the use of automatic calibration, no extra calibration according 3.3 is necessary.

4. Making Measurements

4.1 Measure all parameters as defined in data recording sheets.

4.2 Record date and time of each measurement as defined in data recording sheet - see 5.1

4.3 Randomise the order of sample measurement in a practical order to avoid excessive measuring head changes.

4.4 Measurements should be made using the same measurement procedures as used on routine samples (daily business).

4.5 Measure one set of products in one measurement run on one instrument within a single day - see measurement scheme 4.8

4.6 Record individual readings for each sample of 10 cigarettes or filters, as defined in data recording sheet - see 5.1. If the mean value is not based on a sample size of N=10 (e.g. caused by damaging a cigarette/ filter rod during the measurement or a faulty measurement) please note the deviating N in the comments column.

4.7 Measurement Scheme:

	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
	Data recording sheet DAY 1	Data recording sheet DAY 2	Data recording sheet DAY 3	Data recording sheet DAY 4	Data recording sheet DAY 5
Individual measurements per day	5*10 = 50 filters + 5*10 = 50 cigarettes	5*10 = 50 filters + 5*10 = 50 cigarettes	5*10 = 50 filters + 5*10 = 50 cigarettes	5*10 = 50 filters + 5*10 = 50 cigarettes	5*10 = 50 filters + 5*10 = 50 cigarettes
Individual measurements in total	250 filters + 250 cigarettes				

Remark: Day 1 can be different for filters and cigarettes but samples 1, 2, 3, 4 & 5 must be analysed on a different day.

5. Recording of Results

5.1 Record results as defined in data recording sheet:

Please use 1 sheet per day from DAY 1 to DAY 5	
do not use internal terms for Lab ID:	Lab ID=company ID
date measured:	dd/mm/yyyy
time measured:	hh:mm (24 hours clock)
individual weight:	mg
diameter (not circumference!):	mm
PD (fully encapsulated):	mmWG
PD open:	mmWG
PD closed:	mmWG
FV:	%
and decimal-places as given with the print-out of the instrument	

If no relevant information is available, please fill in: n.a. (abbreviation for: not applicable)

Remark: It is not permitted to make any changes on the data recording sheets. Results being reported not in the correct way will be rejected from the trial!
For any additional information or remarks please use the comments column. You could also add an additional spreadsheet.

5.2 E-mail completed spreadsheets (file) to : Ph. Le Men and J. Fiebiger - latest by August 31^{t}

Set e-mail subject line:	Proficiency Test 2018 results - PTM Sub-Group
Rename the completed file:	Add the company ID at the beginning of the existing file name

APPENDIX B – Data Summary (Mean Values)

The mean value represents the average over all five replicate measurements including all outliers.

Appendix B.1: Mean values of weight, diameter and pressure drop for filters over all laboratories (ID)

	Weight					Diameter					Pressure Drop				
	mg					mm					mmWG				
ID	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1	747,34	440,35	827,33	856,95	863,68	7,15	5,35	7,81	7,80	7,80	449,64	500,46	296,62	521,48	742,04
2	751,78	442,42	830,06	860,66	866,00	7,15	5,36	7,81	7,80	7,80	450,44	505,00	296,34	522,36	739,24
3	748,56	443,62	829,18	859,04	864,38	7,14	5,36	7,81	7,79	7,79					
4	749,42	443,52	832,62	861,26	868,00	7,14	5,34	7,80	7,79	7,79	444,66	506,26	294,84	520,44	739,50
5	746,88	434,97	827,20	857,62	862,59	7,15	5,36	7,81	7,80	7,80	414,22	446,94	269,92	464,08	630,02
6	747,68	442,70	828,16	857,90	863,58	7,15	5,36	7,82	7,80	7,81	451,52	500,56	290,26	515,16	726,92
7															
8	745,30	440,94	828,68	856,40	863,50	7,15	5,36	7,81	7,80	7,81	448,63	499,84	294,57	519,91	733,96
9	747,30	441,04	825,48	857,60	862,74	7,15	5,35	7,82	7,80	7,81	440,14	502,14	288,84	513,40	726,00
10	745,50	440,24	825,86	854,90	860,18	7,14	5,35	7,80	7,79	7,80	434,16	498,26	290,30	511,44	725,34
11	742,26	439,44	824,94	854,80	860,84	7,14	5,35	7,80	7,79	7,80	439,72	499,26	292,04	517,94	735,16
12	752,58	443,14	833,70	863,30	867,09	7,15	5,36	7,82	7,81	7,81	431,03	497,57	291,81	513,65	723,62
13	748,16	441,82	825,96	856,84	861,62	7,14	5,35	7,80	7,79	7,80	462,38	500,92	292,54	519,60	732,26
14			829,44	857,32	862,12			7,81	7,80	7,81			290,08	511,26	698,50
15	744,72	439,04	830,16	856,56	864,46	7,14	5,35	7,80	7,79	7,80	446,92	497,20	293,00	517,02	735,12
16	746,56	439,78	828,72	857,64	861,12	7,14	5,35	7,81	7,79	7,80					
17	748,52	441,72	828,30	858,32	862,78	7,15	5,35	7,81	7,80	7,80	444,36	501,92	292,60	516,92	731,06

Appendix B.2: Mean values of weight, diameter, open and closed draw resistance and filter ventilation of cigarettes for all laboratories (ID)

	Weight					Diameter					Open Draw Resistance				
	mg					mm					mmWG				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	539,18	927,50	992,51	800,62	814,63	5,42	7,36	7,69	7,82	7,83	84,96	112,68	118,02	87,04	88,00
2	538,48	929,10	996,72	803,06	815,76	5,44	7,38	7,70	7,80	7,81	87,24	111,96	119,24	85,90	87,32
3	537,44	926,88	991,48	802,82	808,14	5,42	7,37	7,68	7,81	7,81	87,54	113,90	118,72	84,30	87,52
4	538,26	928,20	987,42	804,68	819,72	5,44	7,40	7,74	7,78	7,79	87,14	111,04	120,72	86,46	89,06
5	536,13	925,77	982,64	800,75	813,13	5,43	7,38	7,69	7,81	7,82	88,20	112,22	117,90	86,10	88,34
6	537,12	925,92	992,36	803,98	812,78	5,43	7,38	7,69	7,81	7,82	85,30	110,96	119,28	84,90	86,92
7	536,28	928,84	987,60	800,38	816,80	5,42	7,37	7,68	7,81	7,82	86,68	109,12	119,98	85,30	87,66
8	537,46	928,20	987,54	803,60	815,92	5,42	7,37	7,69	7,83	7,84	88,66	112,58	117,87	84,67	87,94
9	537,96	920,26	983,64	803,58	810,80	5,43	7,38	7,69	7,82	7,82	86,36	110,66	119,72	86,26	86,30
10	527,82	908,08	978,02	799,38	806,36	5,41	7,36	7,68	7,81	7,82	86,36	108,18	116,98	84,30	86,34
11	532,18	916,94	971,36	796,72	804,80	5,41	7,36	7,67	7,82	7,82	84,58	110,10	116,38	84,28	85,50
12	548,44	946,69	1020,37	823,11	832,46	5,43	7,39	7,70	7,85	7,85	87,25	112,13	121,00	86,88	88,30
13	533,28	919,02	983,06	801,22	811,14	5,43	7,38	7,69	7,80	7,81	83,38	110,96	117,56	85,44	86,14
14	535,50	918,12	981,22	800,54	810,82	5,42	7,37	7,69	7,81	7,82	85,32	110,44	117,88	83,46	84,88
15															
16	534,60	921,88	990,24	804,54	814,64	5,43	7,38	7,70	7,83	7,84	86,44	112,36	117,18	85,08	87,68
17	537,50	921,50	988,48	804,64	815,36	5,43	7,37	7,69	7,80	7,81	85,72	109,92	117,92	85,98	87,08

	Closed Draw Resistance					Filter Ventilation				
	mg					mm				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	350,58	198,74	161,84	119,18	153,84	86,42	55,97	33,88	31,09	55,12
2	361,92	199,34	163,02	118,02	153,04	86,92	56,68	34,03	31,26	55,04
3	353,80	202,12	158,22	114,68	152,02	87,27	56,62	33,14	30,40	54,64
4	354,10	198,52	165,70	120,18	159,30	87,56	56,84	33,97	31,46	56,03
5	353,70	197,18	160,40	116,54	152,42	87,06	62,62	39,50	37,13	60,38
6	346,42	192,22	161,72	115,86	151,82	88,13	57,43	33,59	31,20	55,84
7	348,08	194,98	162,20	116,22	153,30	87,59	57,45	32,89	30,63	55,29
8	354,25	199,87	161,25	115,85	154,79	87,80	57,47	34,10	31,38	55,98
9	348,84	197,62	162,82	118,56	152,00	88,30	58,33	33,98	31,50	56,35
10	352,52	190,38	158,30	114,64	149,94	87,41	56,32	32,76	30,10	54,25
11	343,20	185,80	154,00	112,02	144,68	87,20	55,81	33,27	30,52	54,87
12	356,08	203,08	166,76	120,24	156,74	87,55	57,79	34,55	31,95	56,23
13	317,84	198,02	162,22	118,46	153,82	87,76	57,39	34,75	32,68	57,17
14	348,58	195,58	160,90	114,18	149,64	86,56	56,47	33,71	31,32	55,45
15										
16	346,88	199,02	159,94	116,58	153,76	88,14	58,02	34,60	31,43	56,45
17	352,12	196,72	163,46	116,82	153,42	87,44	56,63	34,01	31,46	55,81

APPENDIX C – Data Summary (Standard Deviations)

The standard deviation represents the standard deviation of a replicate measurement calculated from the five replicate measurements.

Appendix C.1: Standard deviations of weight, diameter and pressure drop for filters over all laboratories (ID)

	Weight					Diameter					Pressure Drop				
	mg					mm					mmWG				
ID	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1	0,76	1,27	2,62	1,27	2,24	0,004	0,003	0,003	0,003	0,001	4,46	4,54	1,21	4,66	6,20
2	1,99	3,04	3,19	1,21	2,48	0,003	0,009	0,003	0,002	0,005	4,34	6,48	3,71	5,54	4,09
3	1,74	2,26	1,50	1,34	1,94	0,006	0,007	0,003	0,006	0,004					
4	1,44	2,34	4,10	3,12	2,10	0,009	0,003	0,005	0,004	0,004	2,92	6,29	2,89	2,23	1,57
5	2,28	12,27	4,07	2,72	2,56	0,009	0,004	0,006	0,004	0,006	3,27	2,88	2,39	2,21	11,89
6	3,52	0,61	2,12	2,83	1,46	0,007	0,004	0,004	0,003	0,003	5,74	2,84	1,00	3,19	4,61
7															
8	3,94	1,37	2,19	3,27	2,45	0,007	0,004	0,004	0,006	0,005	5,38	4,00	2,13	1,67	5,12
9	3,84	2,57	2,02	2,37	1,29	0,007	0,006	0,005	0,007	0,006	5,75	12,81	3,15	6,68	3,43
10	3,20	1,33	1,29	1,24	2,80	0,003	0,005	0,005	0,003	0,004	2,59	6,35	1,37	4,25	4,69
11	2,40	3,09	2,22	1,51	1,69	0,003	0,004	0,003	0,003	0,006	7,71	6,57	1,57	1,19	4,31
12	1,64	2,11	1,89	3,88	1,81	0,007	0,009	0,005	0,005	0,004	4,03	5,12	1,63	4,23	6,43
13	1,63	3,82	2,63	1,11	2,07	0,005	0,007	0,007	0,003	0,004	4,04	2,86	1,76	0,92	4,12
14			2,21	2,82	2,38			0,006	0,005	0,003			0,62	4,20	5,92
15	3,40	2,41	3,36	2,86	1,62	0,008	0,004	0,006	0,006	0,006	6,01	5,72	2,65	1,87	4,58
16	2,59	2,57	0,47	0,87	3,28	0,006	0,005	0,007	0,001	0,006					
17	0,43	0,66	0,20	0,81	0,67	0,003	0,003	0,002	0,003	0,002	2,18	2,55	0,67	1,42	0,83

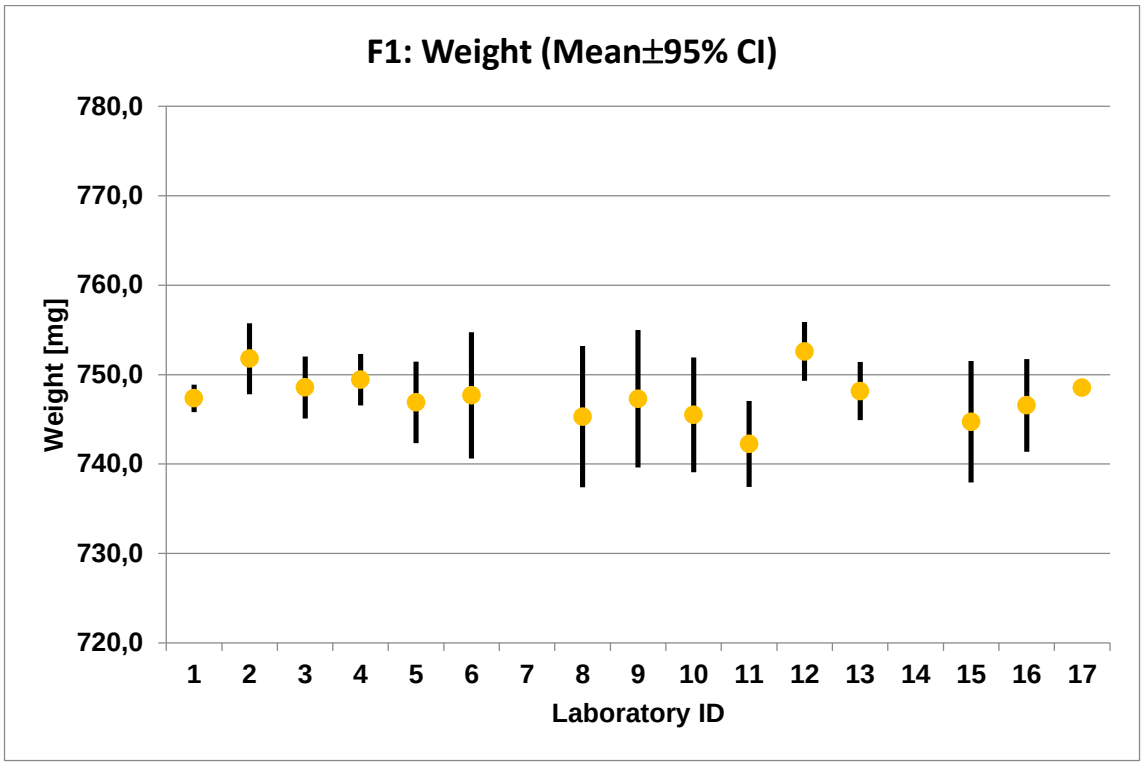
Appendix C.2: Standard deviations of weight, diameter, open and closed draw resistance and filter ventilation of cigarettes for all laboratories (ID)

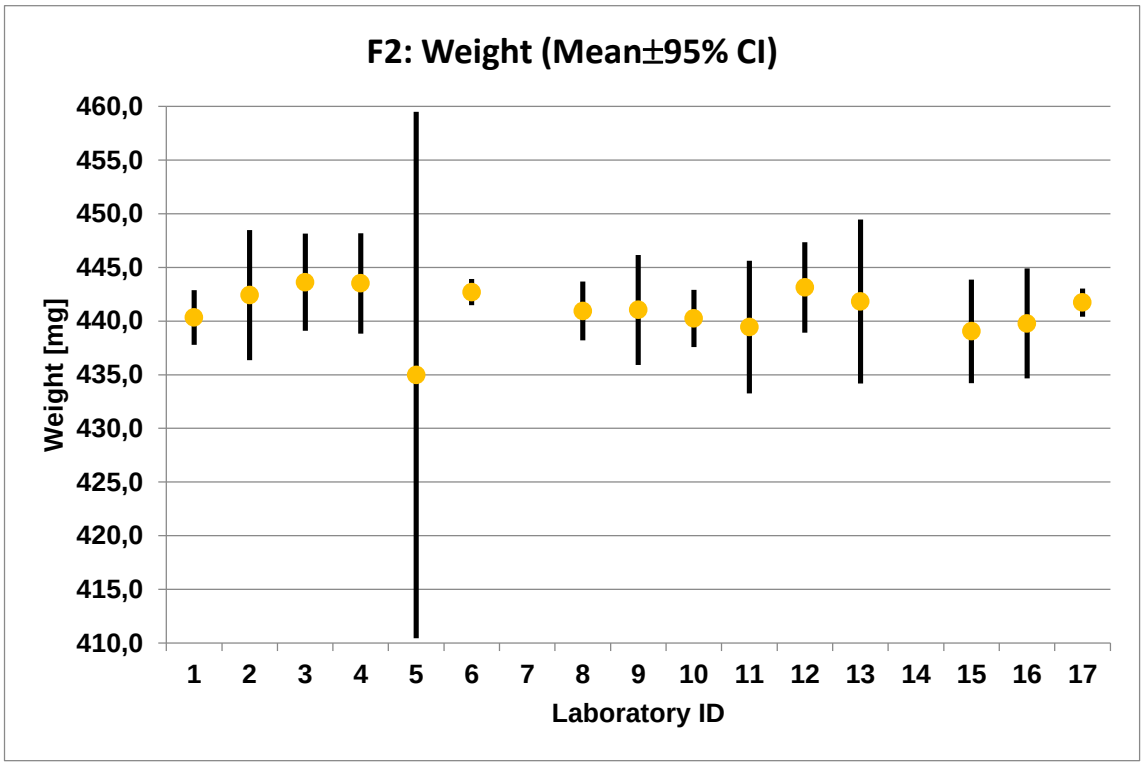
	Weight					Diameter					Open Draw Resistance				
	mg					mm					mmWG				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	2,14	2,45	3,62	5,75	1,64	0,010	0,009	0,010	0,010	0,008	1,51	1,11	1,69	1,51	0,98
2	6,51	7,69	8,44	7,36	4,26	0,007	0,015	0,005	0,006	0,006	1,89	2,36	0,97	0,73	1,57
3	3,76	3,47	3,89	2,15	4,86	0,011	0,007	0,005	0,008	0,008	1,55	2,88	1,07	0,19	0,80
4	2,84	5,64	2,28	6,95	4,74	0,007	0,004	0,006	0,002	0,005	1,35	1,54	3,40	1,33	1,69
5	2,75	5,24	4,13	4,84	4,05	0,003	0,004	0,002	0,006	0,008	0,69	1,77	2,49	0,66	1,93
6	2,62	2,62	7,68	3,65	5,84	0,006	0,009	0,003	0,005	0,005	1,66	0,77	2,59	0,73	0,95
7	7,12	2,91	8,45	8,79	7,10	0,004	0,008	0,005	0,008	0,003	0,36	2,28	1,96	0,80	1,21
8	3,71	5,15	5,70	4,01	5,69	0,005	0,014	0,005	0,006	0,002	0,86	1,23	2,30	0,75	1,78
9	4,81	3,13	4,12	3,51	6,77	0,009	0,005	0,008	0,005	0,010	0,79	0,90	3,58	0,72	0,77
10	5,41	4,50	3,07	3,73	3,83	0,005	0,009	0,003	0,007	0,002	2,51	1,32	2,18	0,83	0,91
11	5,39	4,46	3,69	6,17	4,35	0,005	0,004	0,008	0,004	0,003	0,51	1,37	2,26	1,13	0,97
12	2,44	7,69	4,83	8,46	4,86	0,010	0,016	0,002	0,009	0,011	0,98	1,23	2,90	0,85	0,83
13	2,40	6,46	4,44	2,97	5,93	0,007	0,008	0,005	0,009	0,003	0,91	0,49	1,05	2,51	1,49
14	2,44	7,81	9,14	5,33	2,31	0,007	0,007	0,008	0,004	0,007	0,98	1,13	0,72	1,01	1,58
15															
16	5,35	3,12	5,16	7,03	5,77	0,004	0,005	0,002	0,007	0,007	1,85	1,70	2,70	0,81	1,22
17	1,26	0,88	3,07	1,27	0,56	0,002	0,009	0,006	0,004	0,003	0,47	1,09	0,78	0,32	0,31

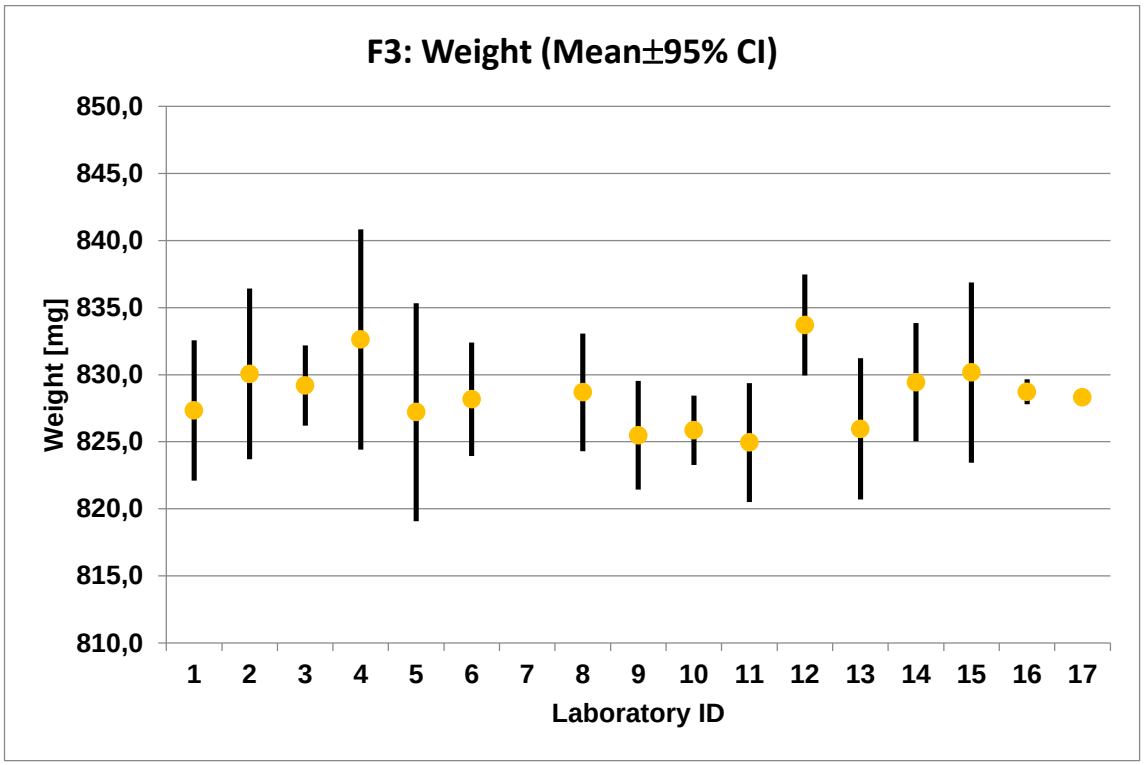
	Closed Draw Resistance					Filter Ventilation				
	mg					mm				
ID	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1	5,70	1,72	1,38	2,77	0,69	0,10	0,65	1,42	0,40	0,48
2	6,98	2,60	1,31	1,57	1,17	0,36	0,82	0,56	0,40	0,59
3	8,95	5,08	4,65	1,41	1,85	0,13	0,35	1,12	0,51	0,46
4	9,14	2,48	2,65	1,79	2,21	0,41	0,77	1,45	0,54	0,28
5	13,80	4,05	3,32	2,90	3,15	1,89	1,07	1,07	0,47	0,56
6	6,18	5,83	2,87	1,02	2,80	0,44	0,20	1,54	0,25	0,70
7	4,90	2,68	3,24	1,07	2,38	0,25	0,70	0,75	0,54	0,21
8	4,94	2,68	1,13	1,61	3,35	0,21	0,22	1,83	0,47	0,37
9	10,98	3,48	2,96	1,32	1,94	0,39	0,84	1,40	0,30	0,53
10	11,72	2,08	2,22	1,44	1,40	0,45	0,34	0,79	0,16	0,55
11	14,45	8,28	2,68	4,47	3,78	0,46	0,09	1,57	0,24	0,44
12	4,09	3,33	3,49	1,37	2,22	0,31	0,27	1,11	0,51	0,59
13	3,54	1,49	1,55	4,06	2,79	0,51	0,37	1,06	0,64	0,63
14	7,76	2,47	1,67	2,70	4,94	0,22	0,32	0,80	0,68	0,65
15										
16	8,19	2,47	2,70	1,42	3,64	0,45	0,29	1,34	0,34	0,79
17	2,08	1,64	0,82	0,78	0,92	0,25	0,32	0,37	0,11	0,17

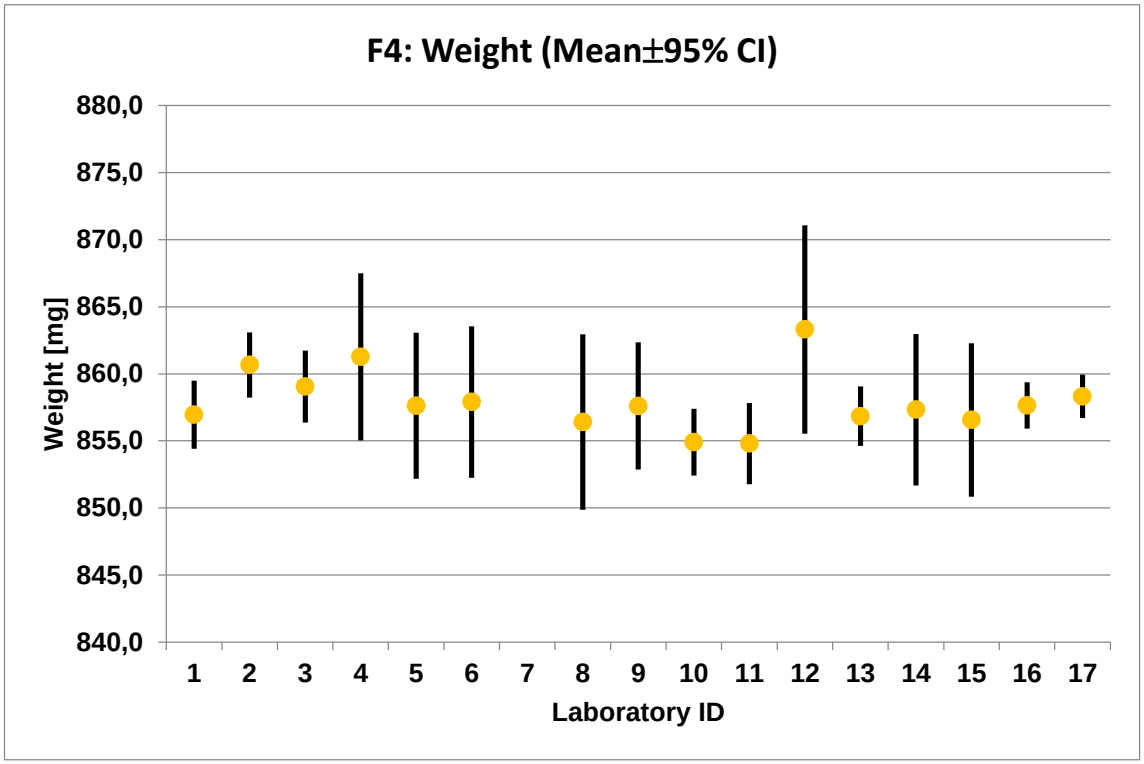
APPENDIX D – Results for Filters (Diagrams)

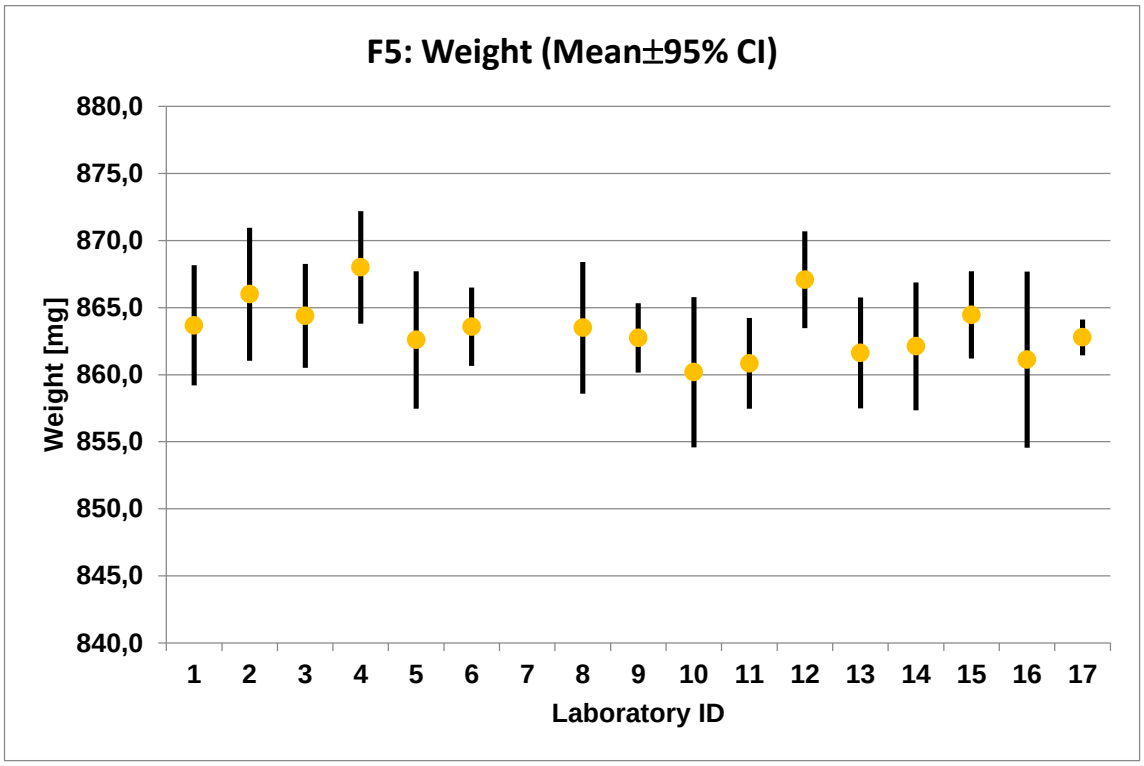
Appendix D.1: Weights of filters F1-F5



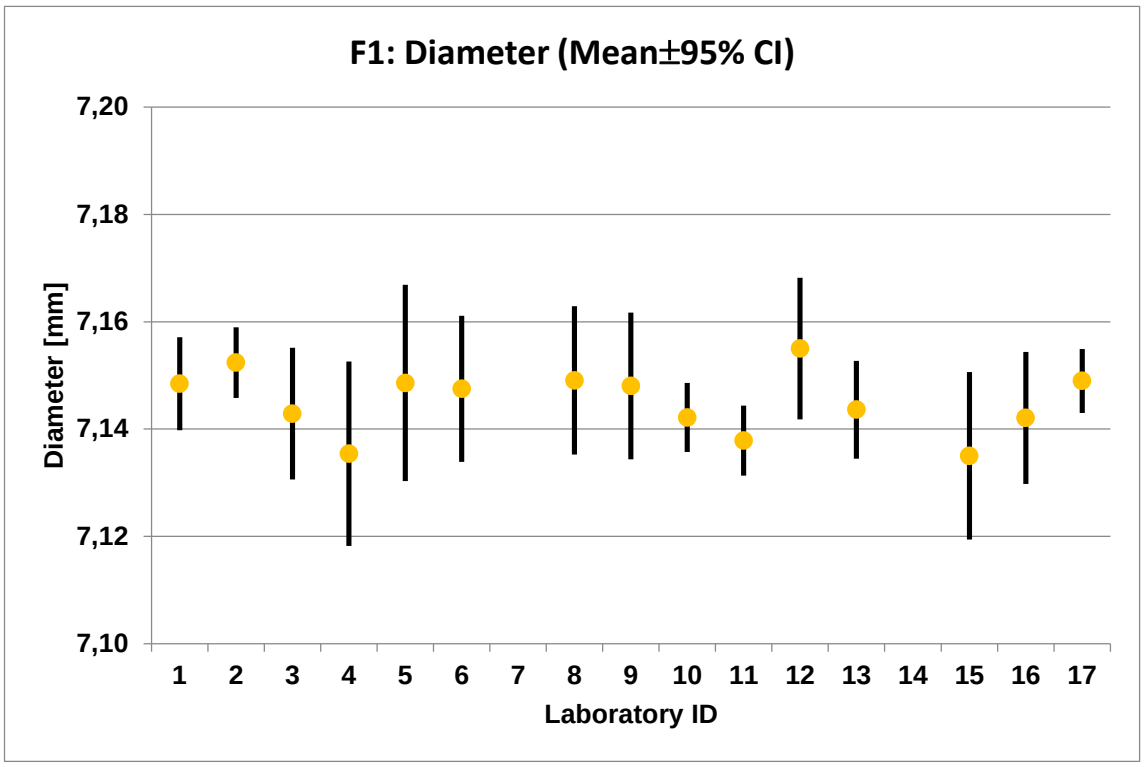


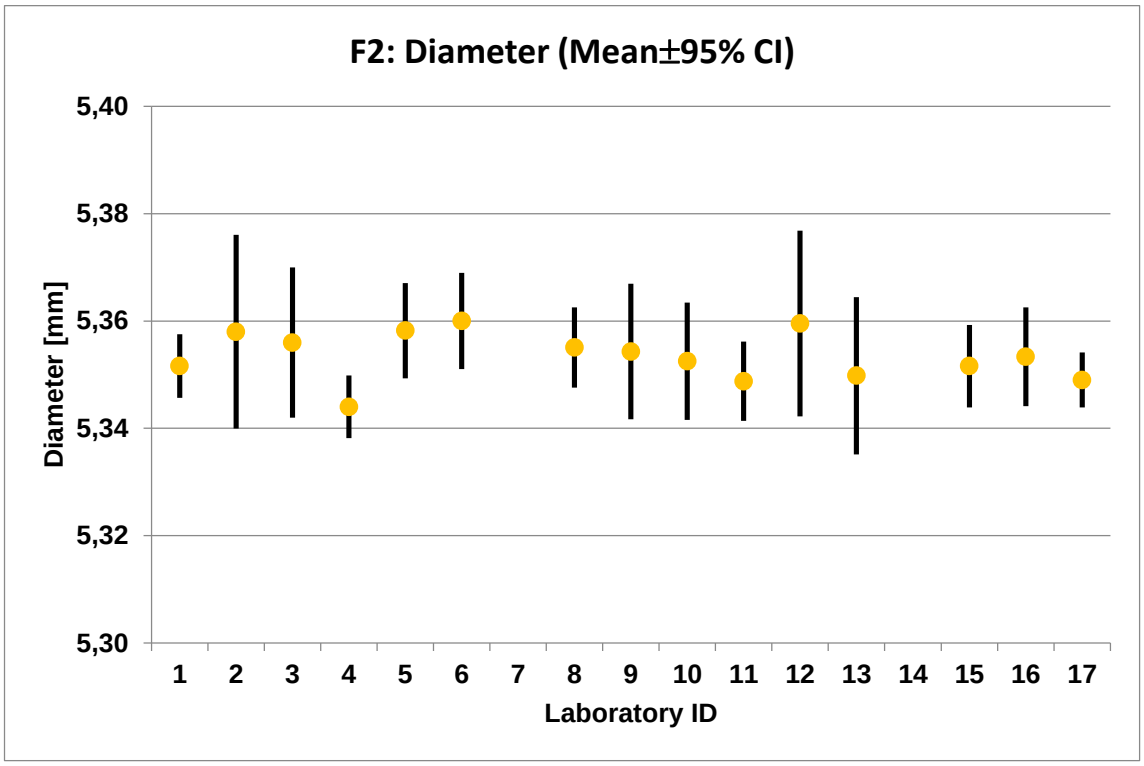

F3: Weight (Mean±95% CI)
Weight [mg]
850,0
845,0
840,0
835,0
830,0
825,0
820,0
815,0
810,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

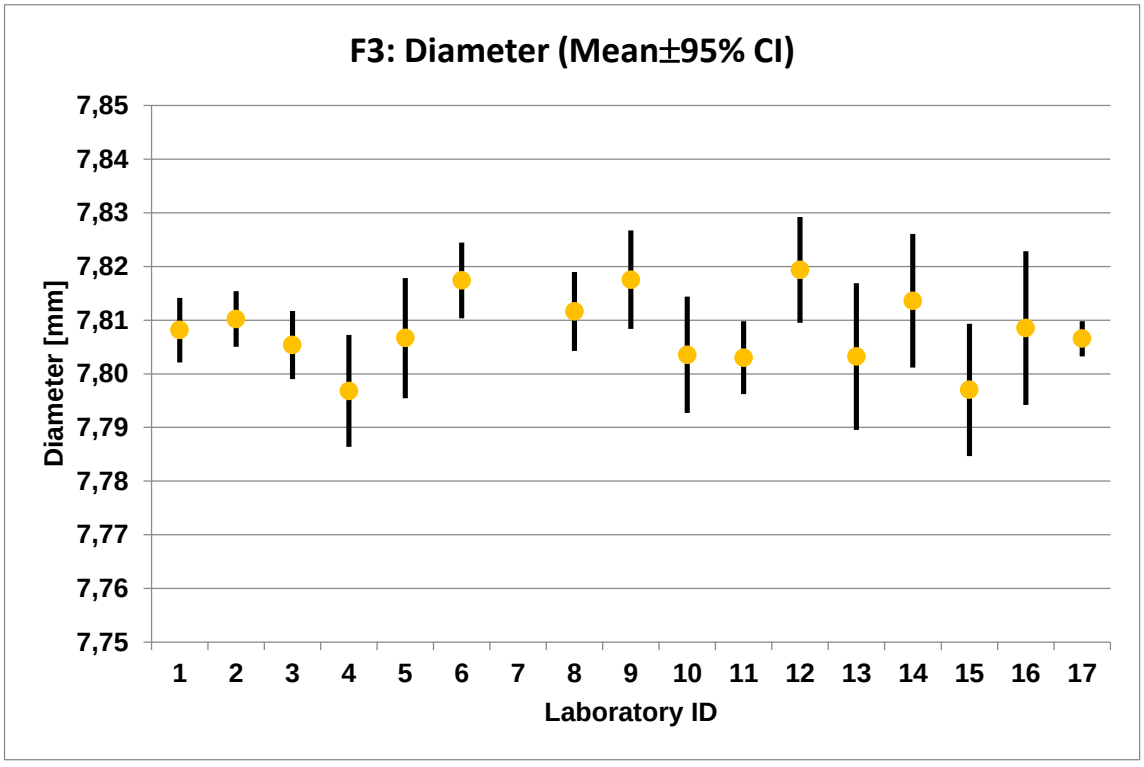

F4: Weight (Mean±95% CI)
Weight [mg]
880,0
875,0
870,0
865,0
860,0
855,0
850,0
845,0
840,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

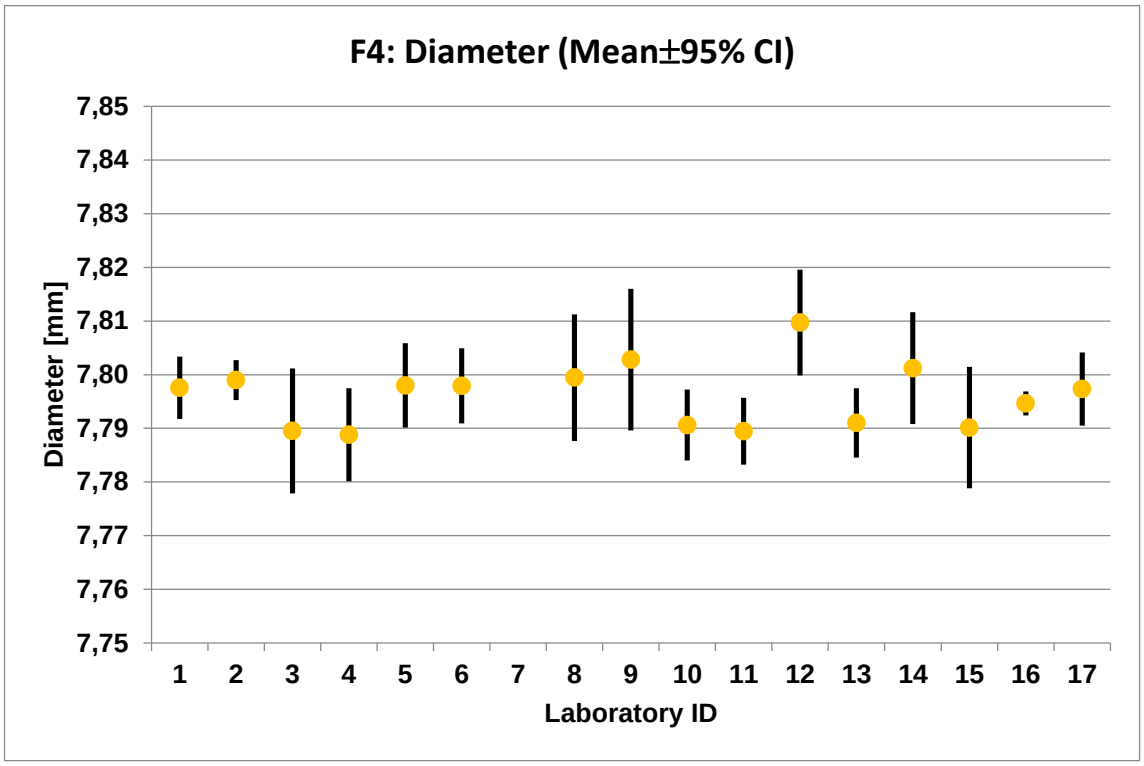


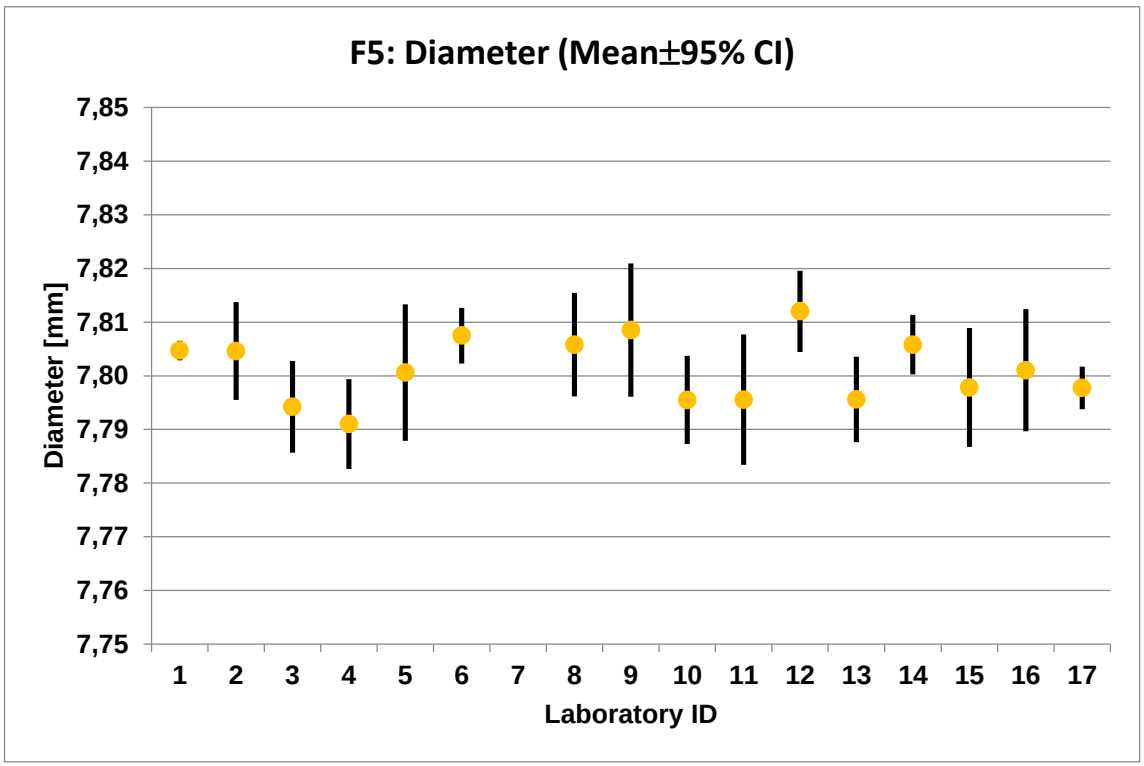
Appendix D.2: Diameters of filters F1-F5



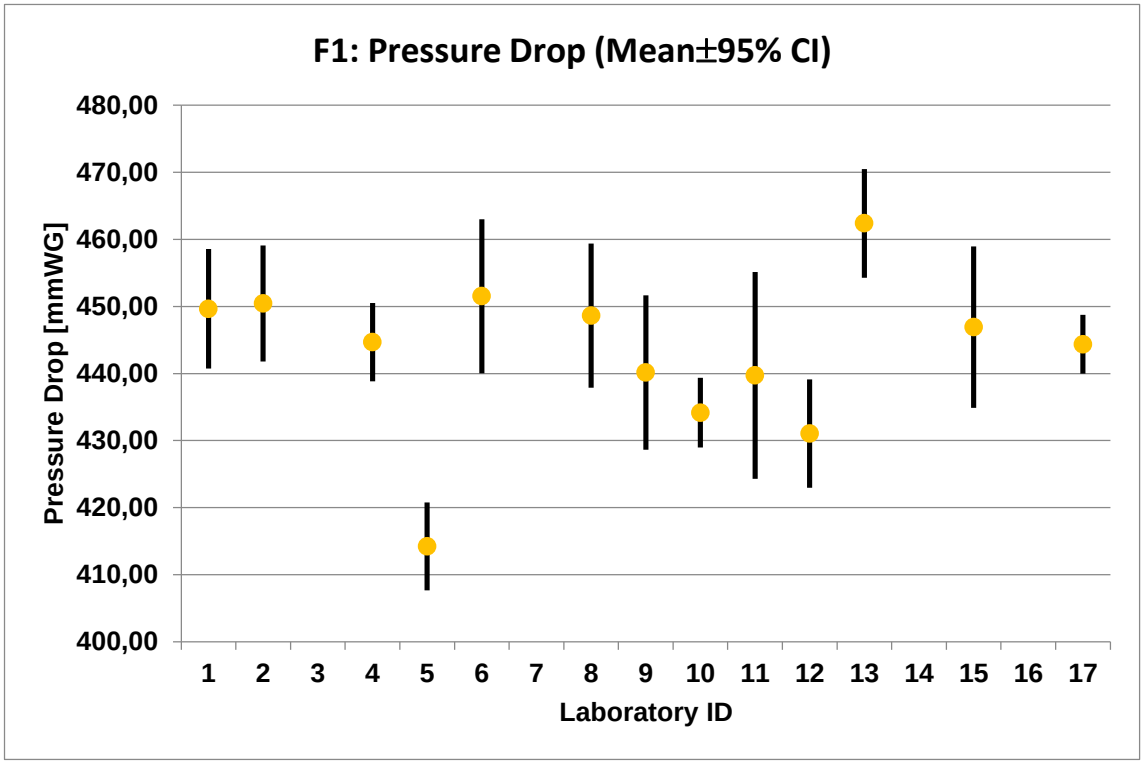

F2: Diameter (Mean±95% CI)
Diameter [mm]
5,40
5,38
5,36
5,34
5,32
5,30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

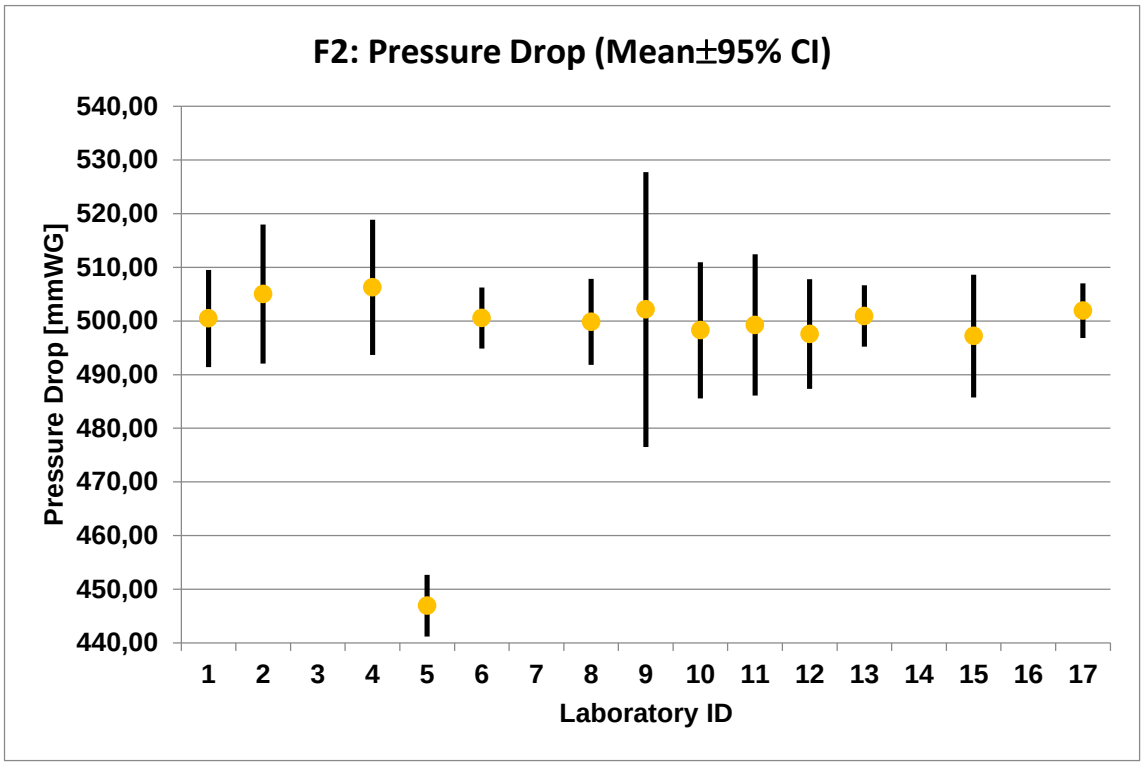

F3: Diameter (Mean±95% CI)
Diameter [mm]
7,85
7,84
7,83
7,82
7,81
7,80
7,79
7,78
7,77
7,76
7,75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

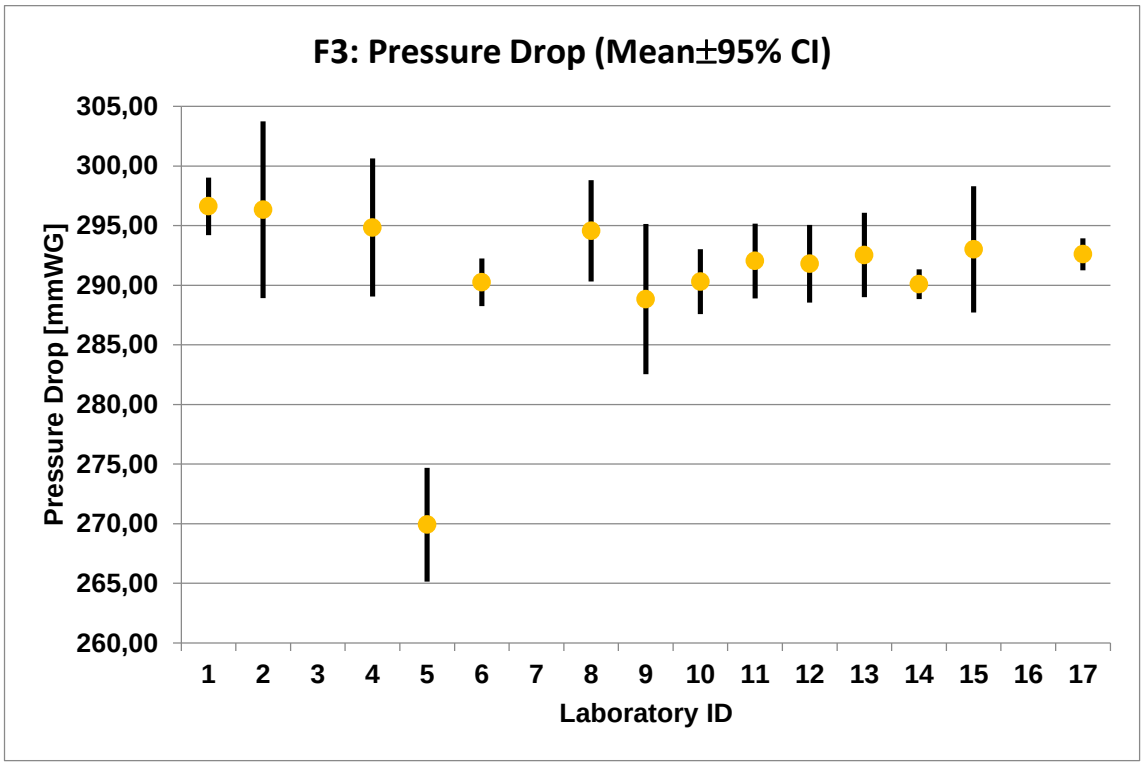

F4: Diameter (Mean±95% CI)
Diameter [mm]
7,85
7,84
7,83
7,82
7,81
7,80
7,79
7,78
7,77
7,76
7,75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

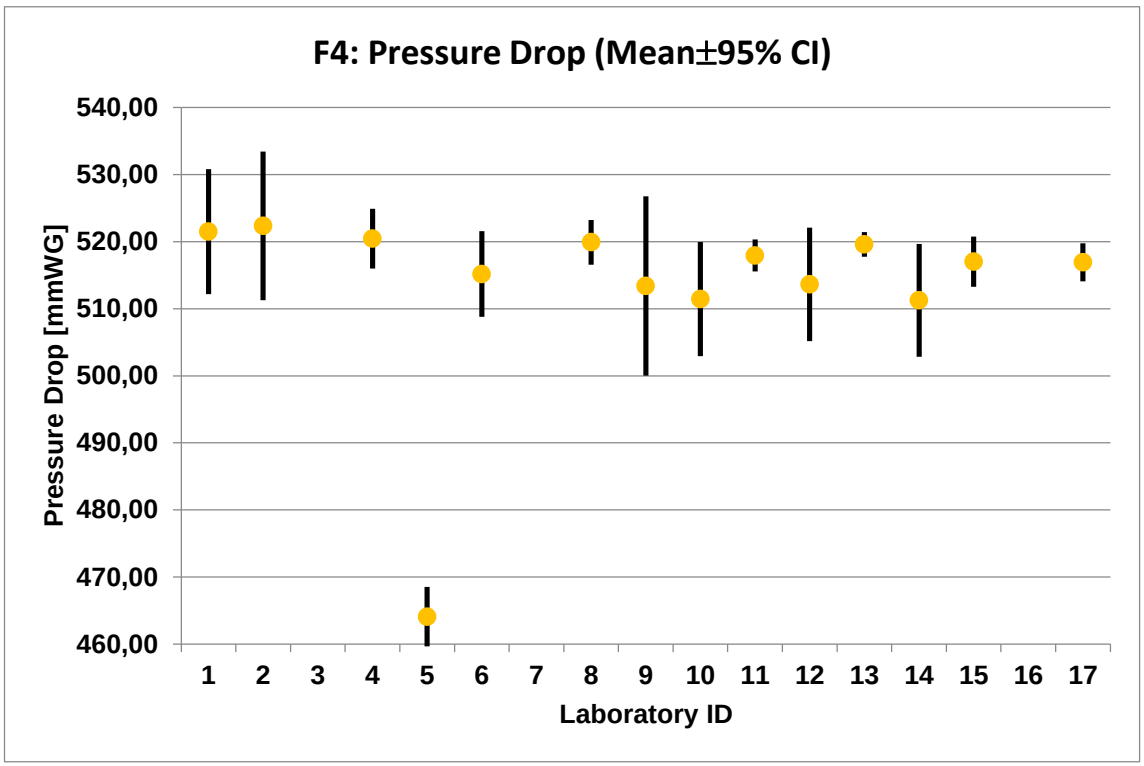

F5: Diameter (Mean±95% CI)
Diameter [mm]
7,85
7,84
7,83
7,82
7,81
7,80
7,79
7,78
7,77
7,76
7,75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

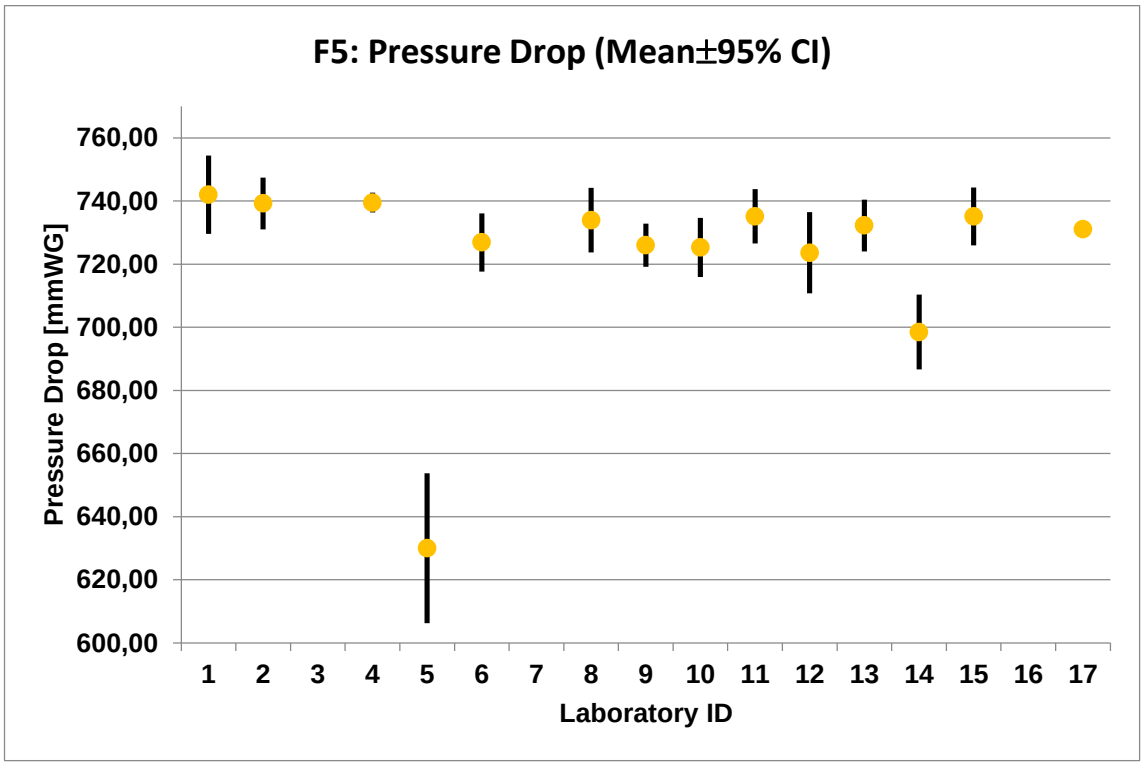
Appendix D.3: Fully encapsulated pressure drops of filters F1-F5





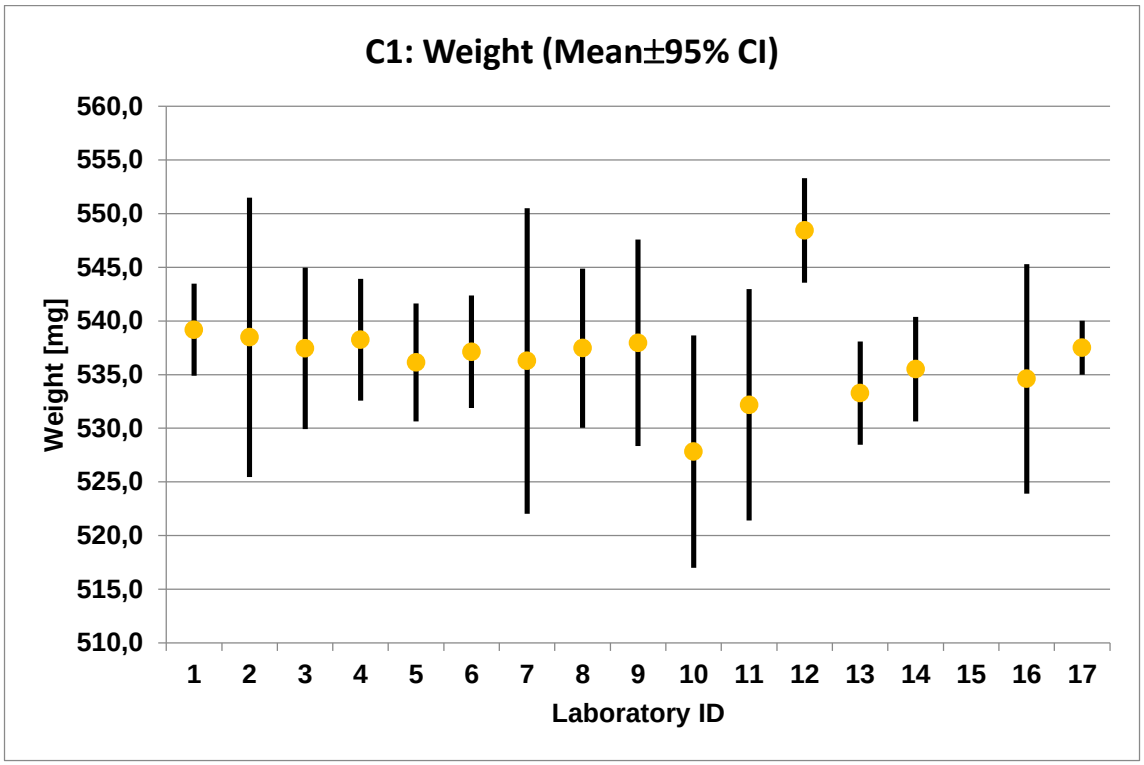

F3: Pressure Drop (Mean±95% CI)
Pressure Drop [mmWG]
305,00
300,00
295,00
290,00
285,00
280,00
275,00
270,00
265,00
260,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

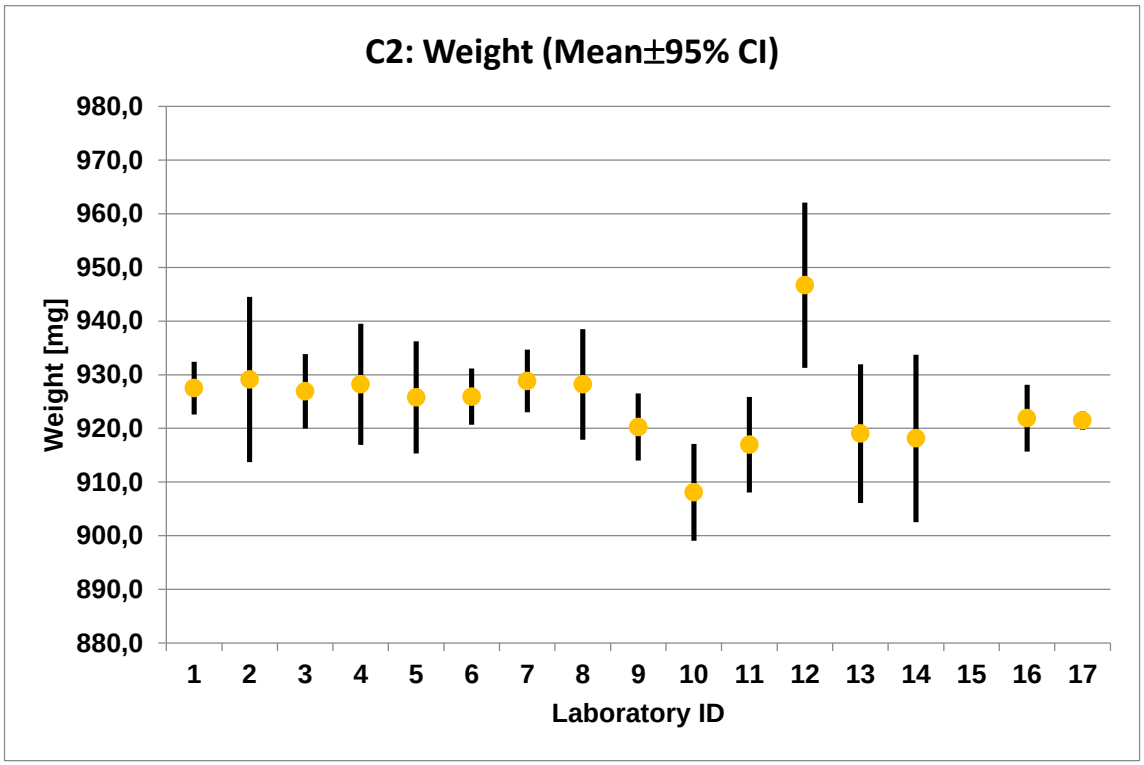

F4: Pressure Drop (Mean±95% CI)
Pressure Drop [mmWG]
540,00
530,00
520,00
510,00
500,00
490,00
480,00
470,00
460,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

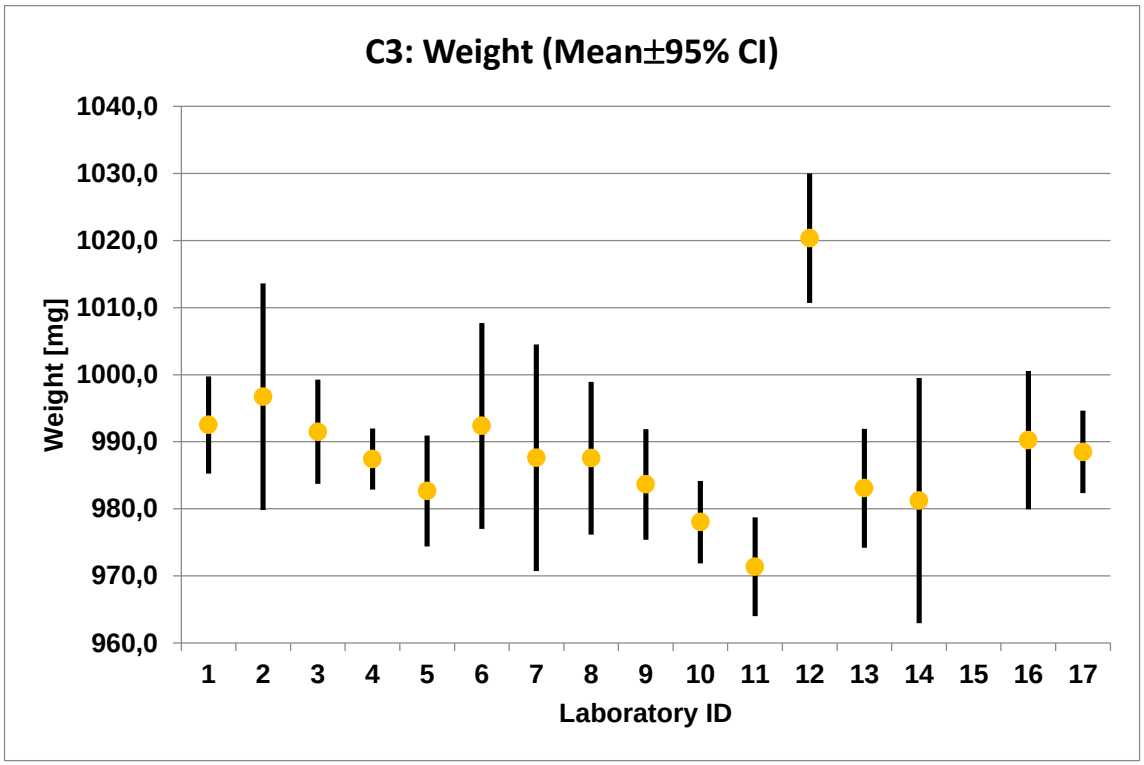

F5: Pressure Drop (Mean±95% CI)
Pressure Drop [mmWG]
760,00
740,00
720,00
700,00
680,00
660,00
640,00
620,00
600,00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Laboratory ID

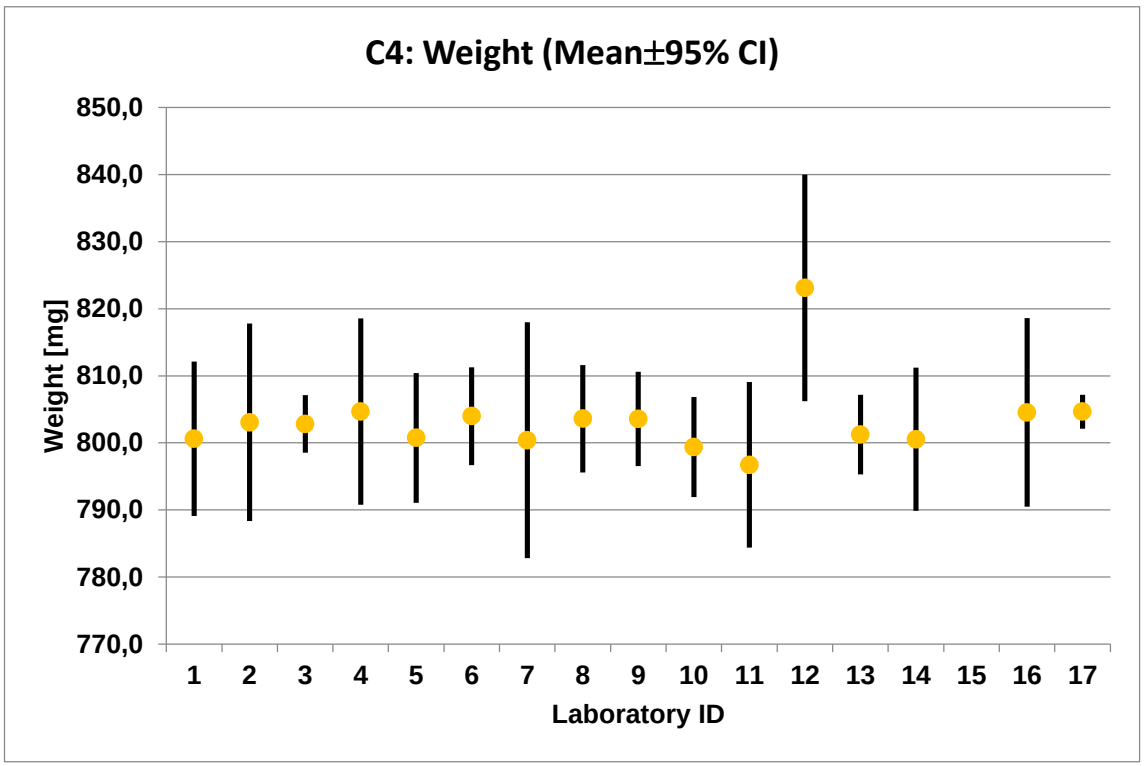
APPENDIX E – Results for Cigarettes (Diagrams)

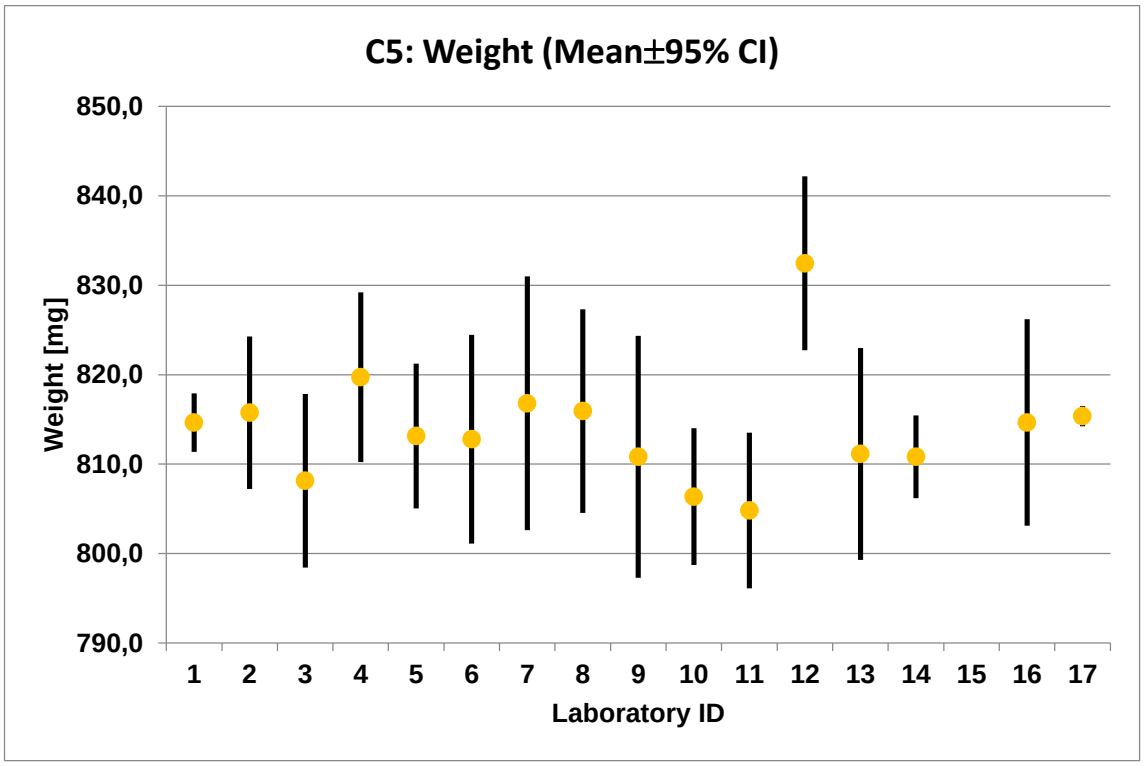
Appendix E.1: Weights of cigarettes C1-C5



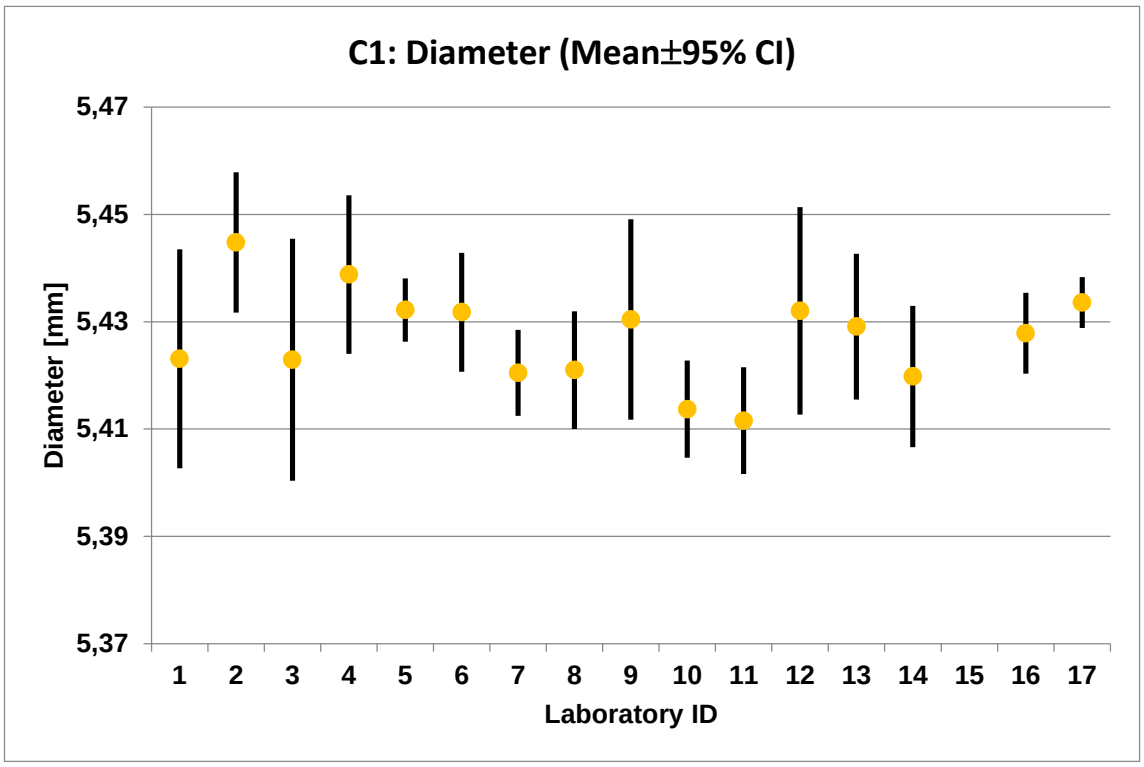


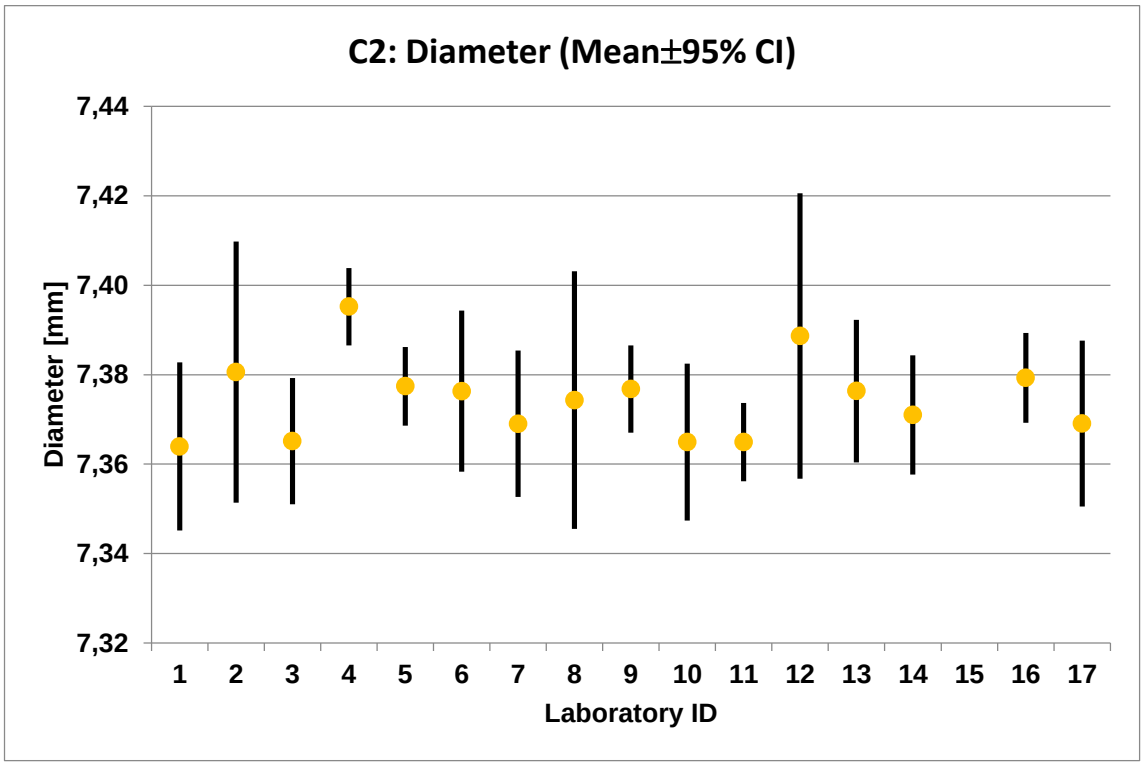

C3: Weight (Mean±95% CI)
Weight [mg]
1040,0
1030,0
1020,0
1010,0
1000,0
990,0
980,0
970,0
960,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

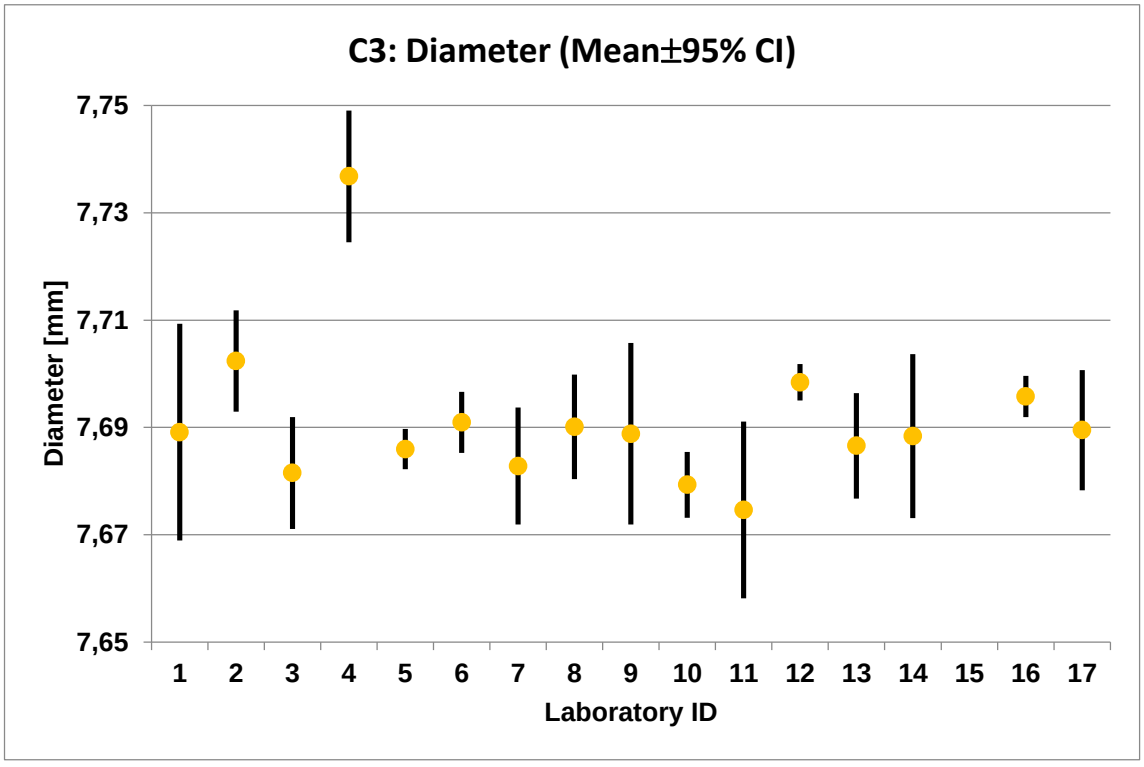

C4: Weight (Mean±95% CI)
Weight [mg]
850,0
840,0
830,0
820,0
810,0
800,0
790,0
780,0
770,0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

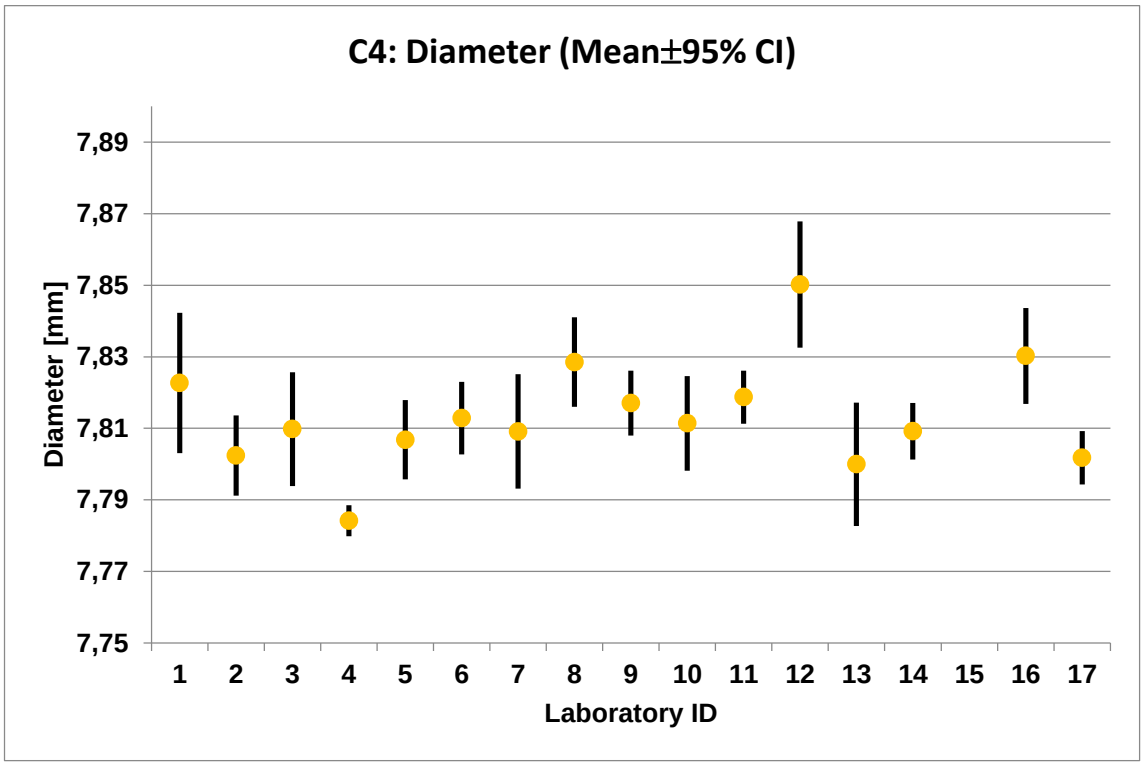


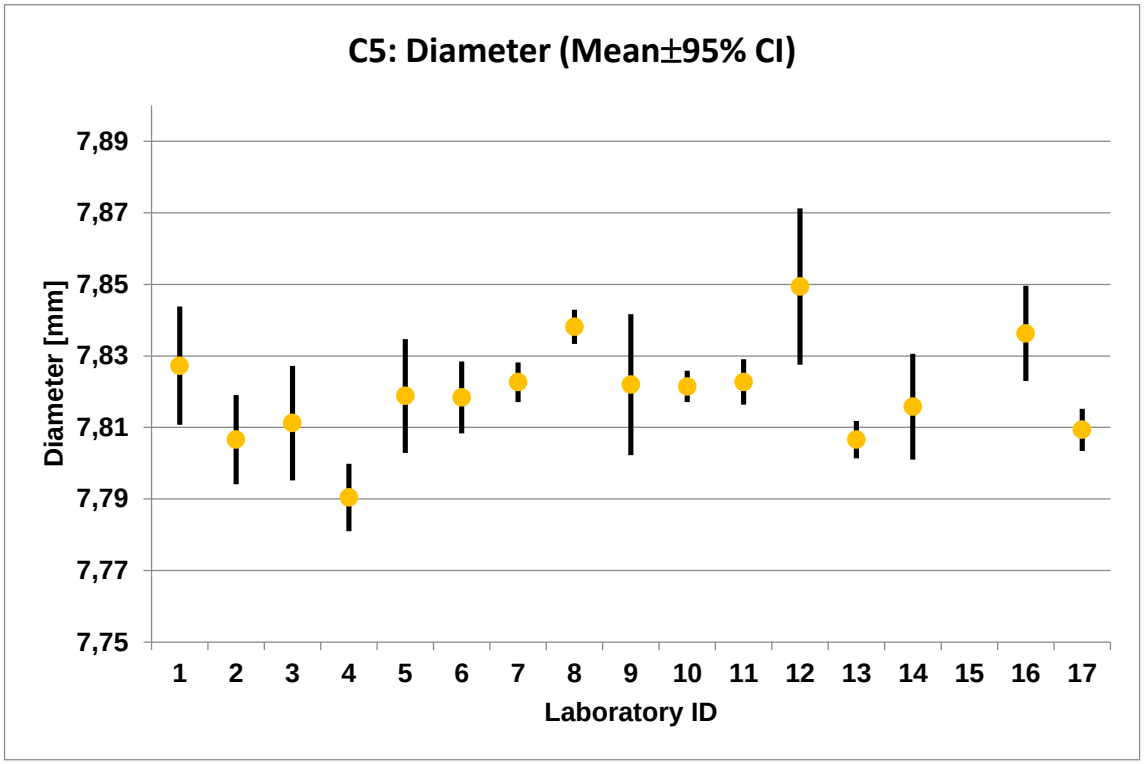
Appendix E.2: Diameters of cigarettes C1-C5



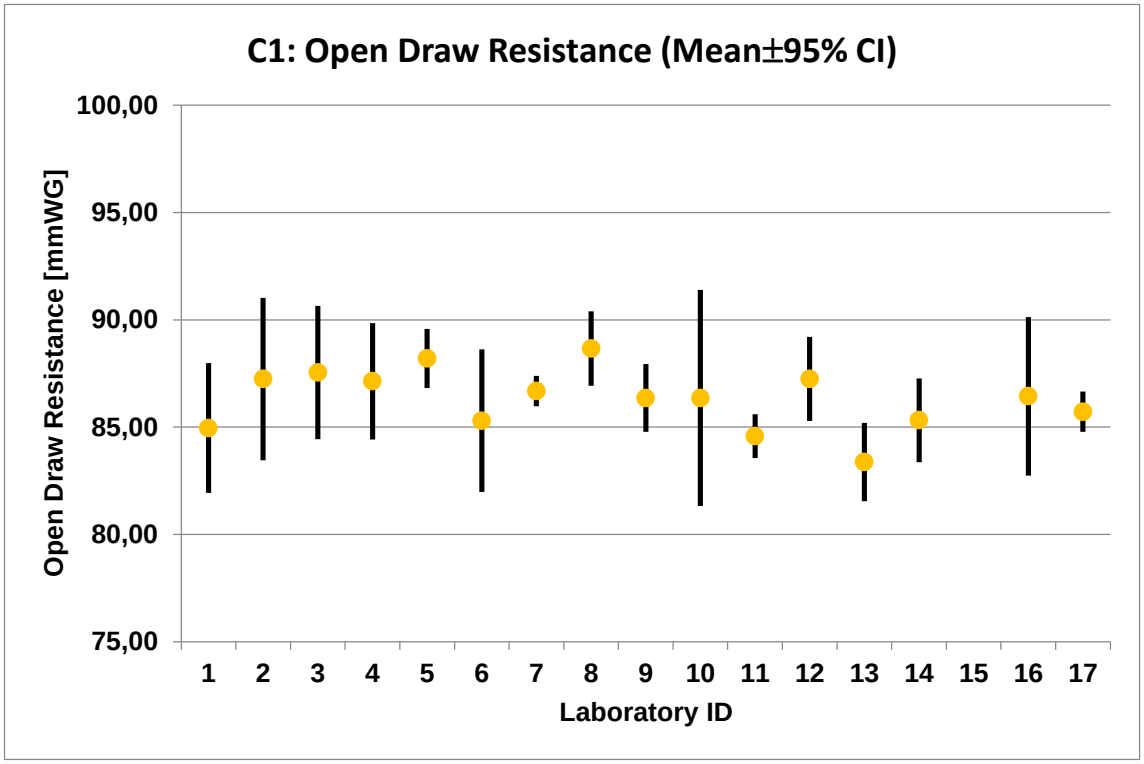

C2: Diameter (Mean±95% CI)
Diameter [mm]
7,44
7,42
7,40
7,38
7,36
7,34
7,32
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

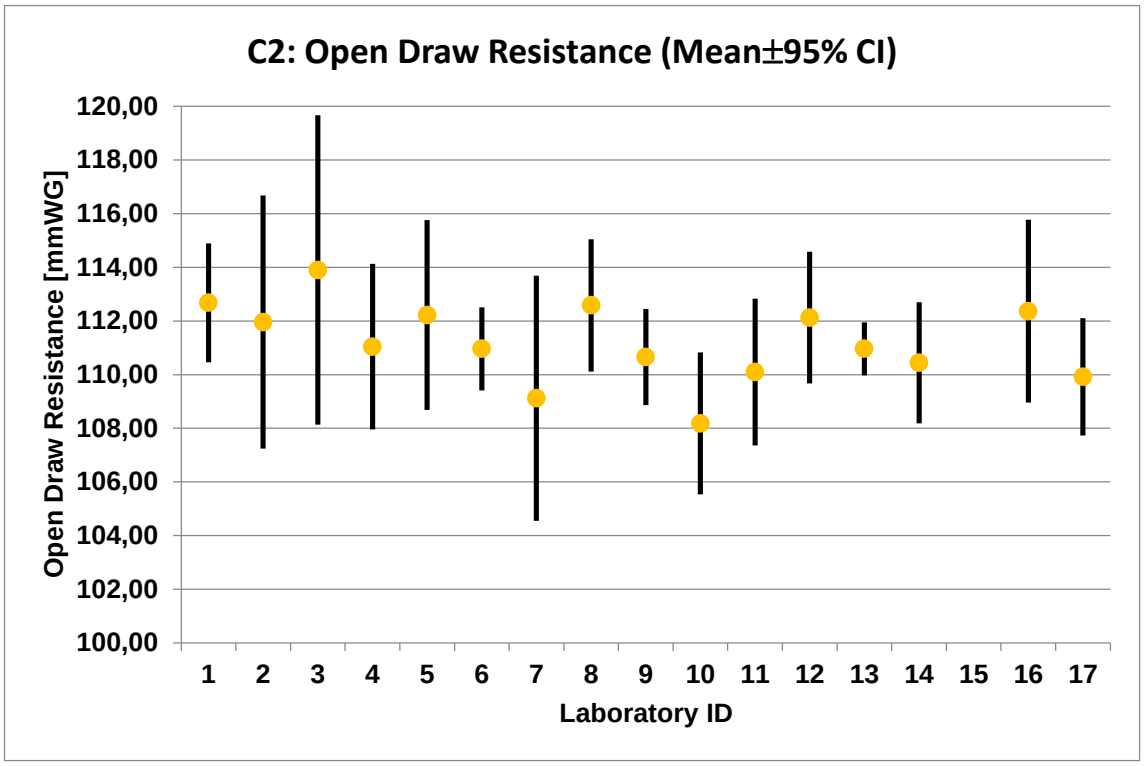

C3: Diameter (Mean±95% CI)
Diameter [mm]
7,75
7,73
7,71
7,69
7,67
7,65
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

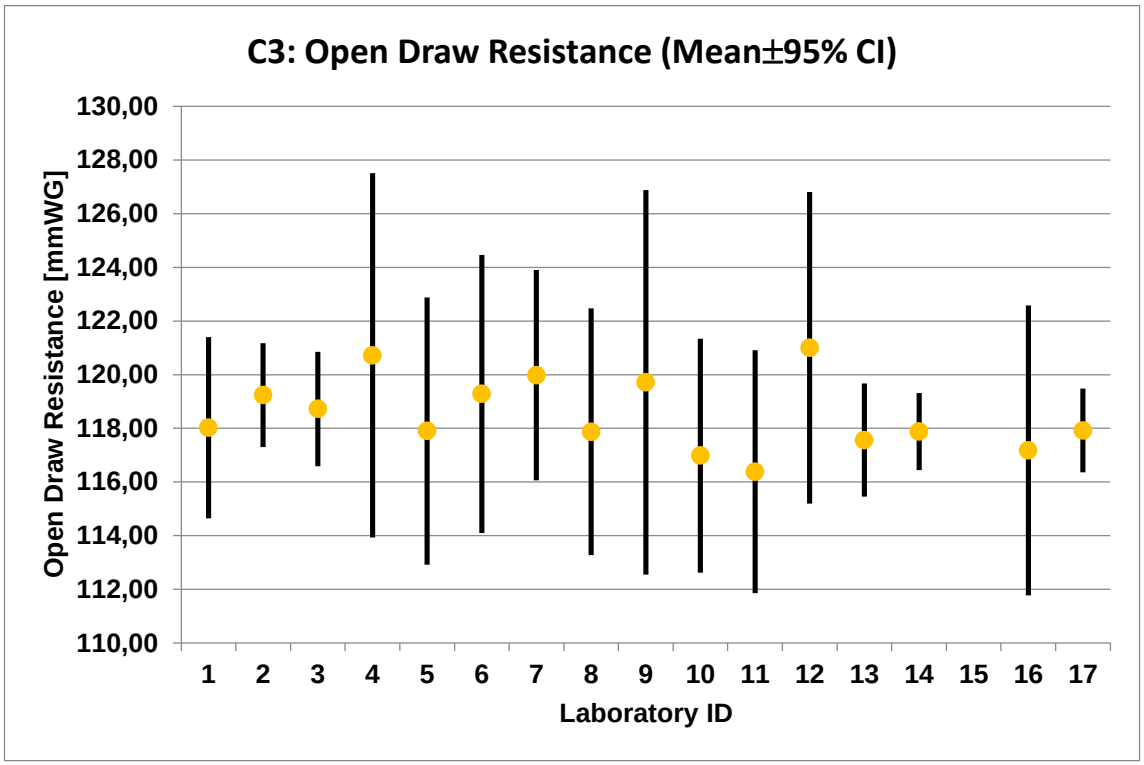

C4: Diameter (Mean±95% CI)
Diameter [mm]
7,89
7,87
7,85
7,83
7,81
7,79
7,77
7,75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

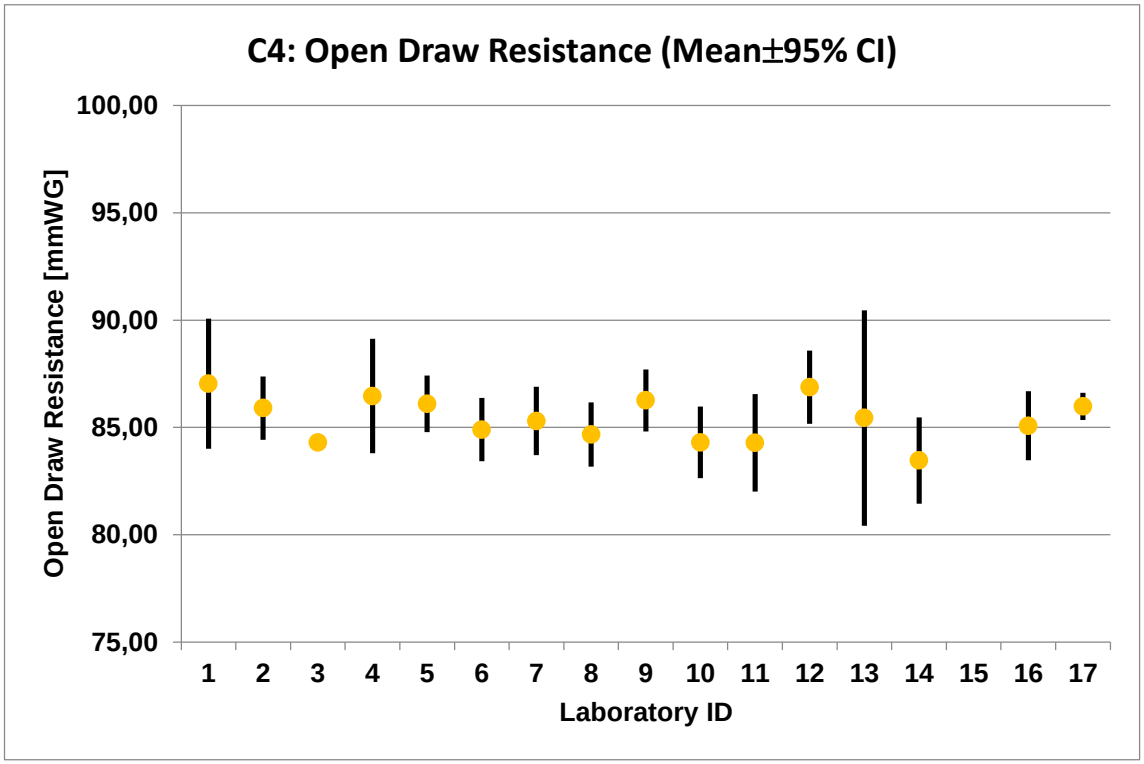

C5: Diameter (Mean±95% CI)
Diameter [mm]
7,89
7,87
7,85
7,83
7,81
7,79
7,77
7,75
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

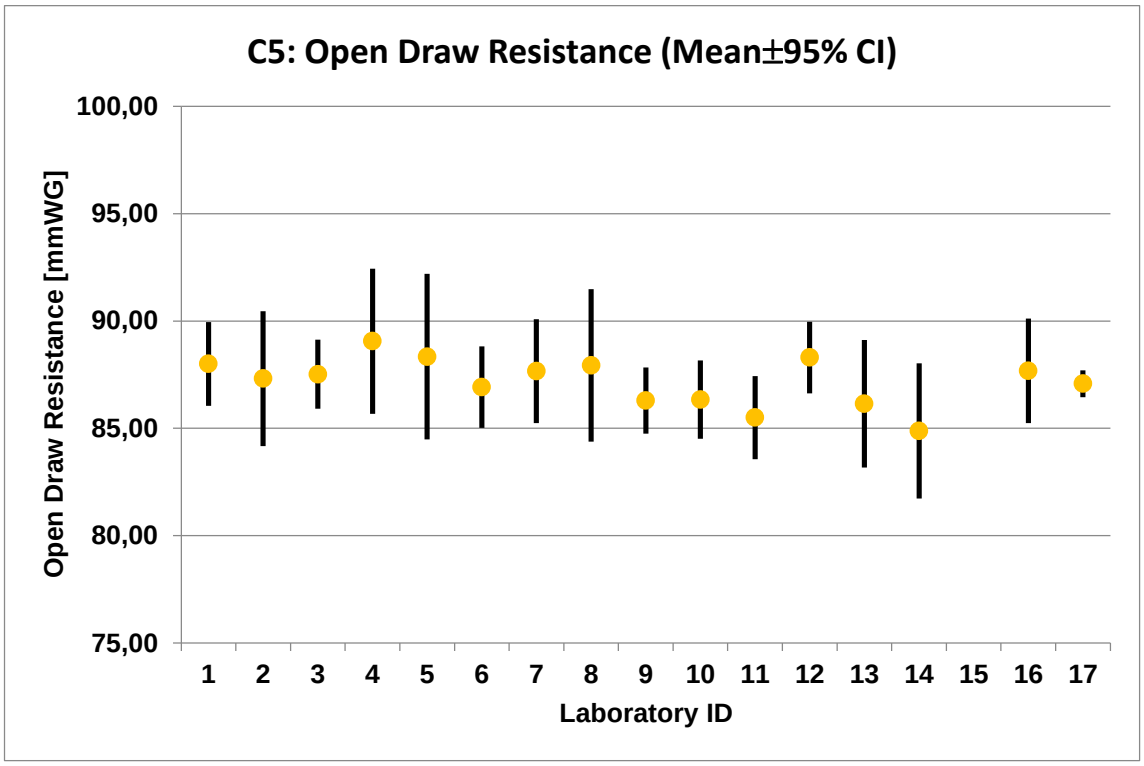
Appendix E.3: Open draw resistances of cigarettes C1-C5



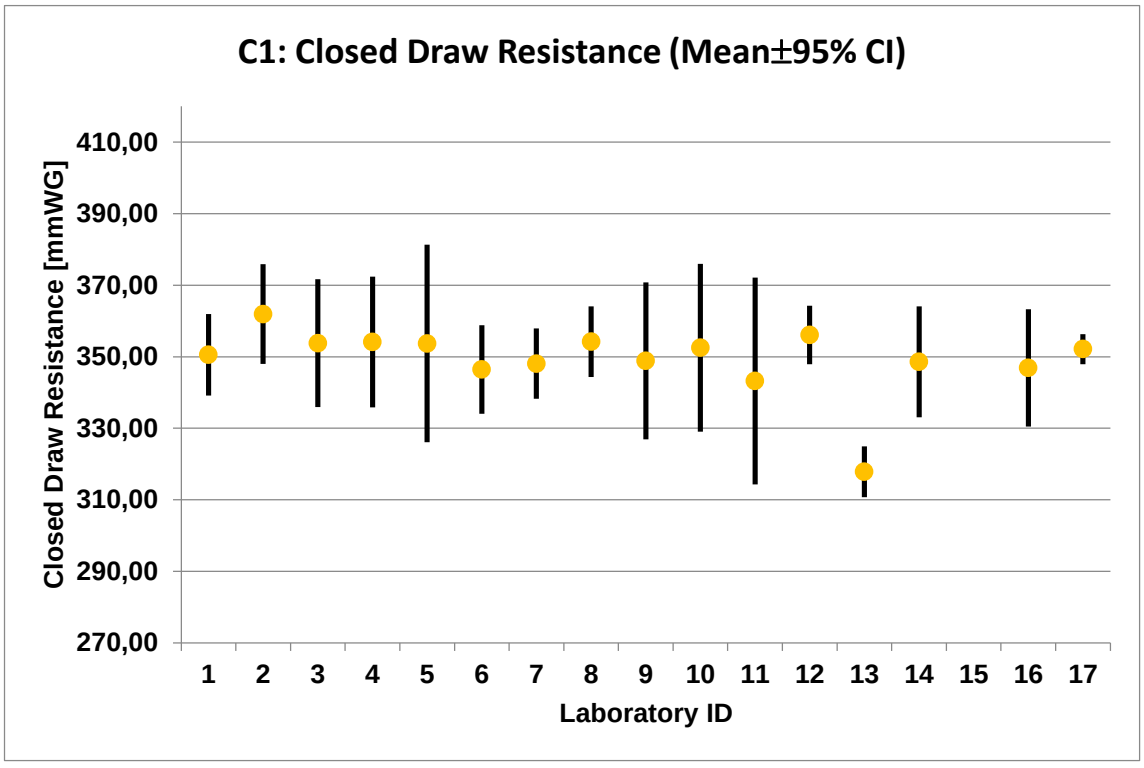


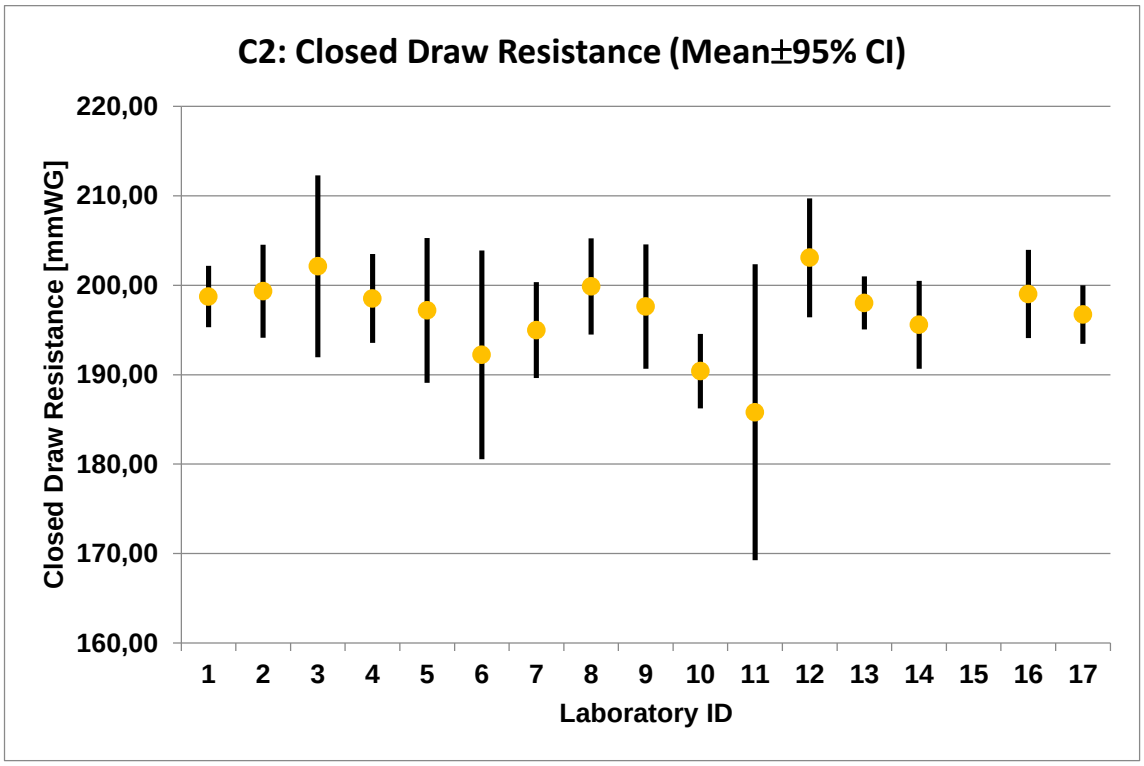

C3: Open Draw Resistance (Mean±95% CI)
Open Draw Resistance [mmWG]
130,00
128,00
126,00
124,00
122,00
120,00
118,00
116,00
114,00
112,00
110,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

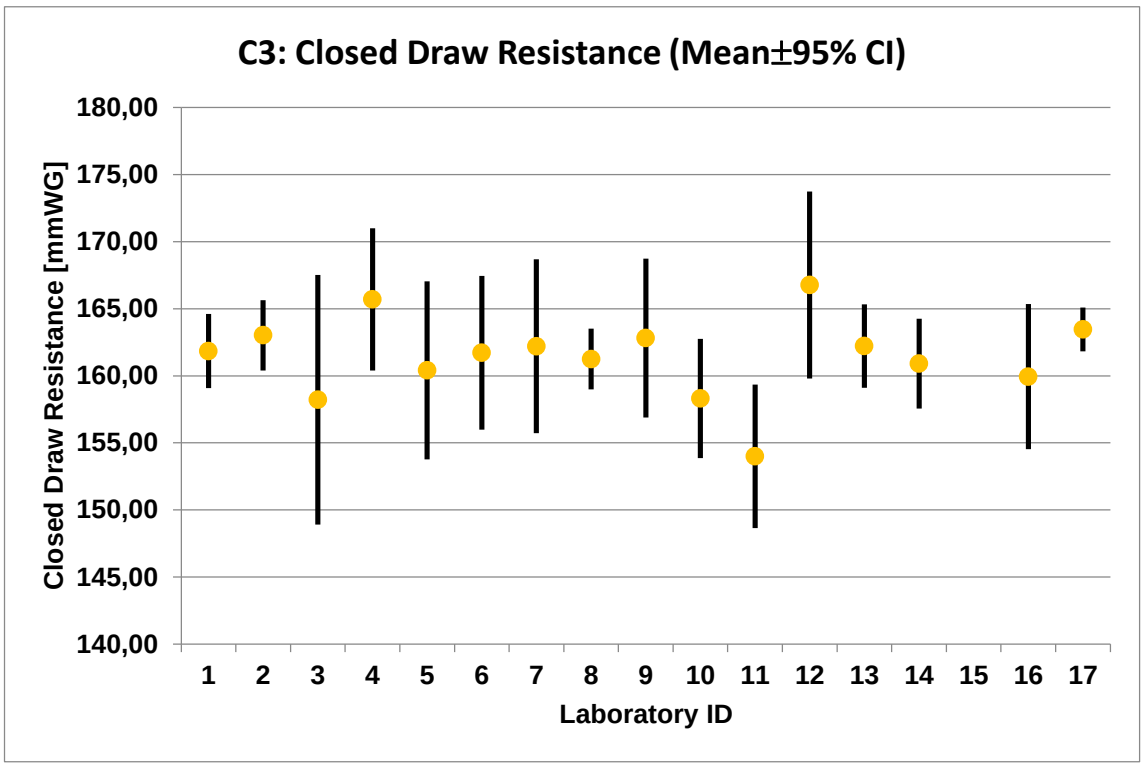

C4: Open Draw Resistance (Mean±95% CI)
Open Draw Resistance [mmWG]
100,00
95,00
90,00
85,00
80,00
75,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

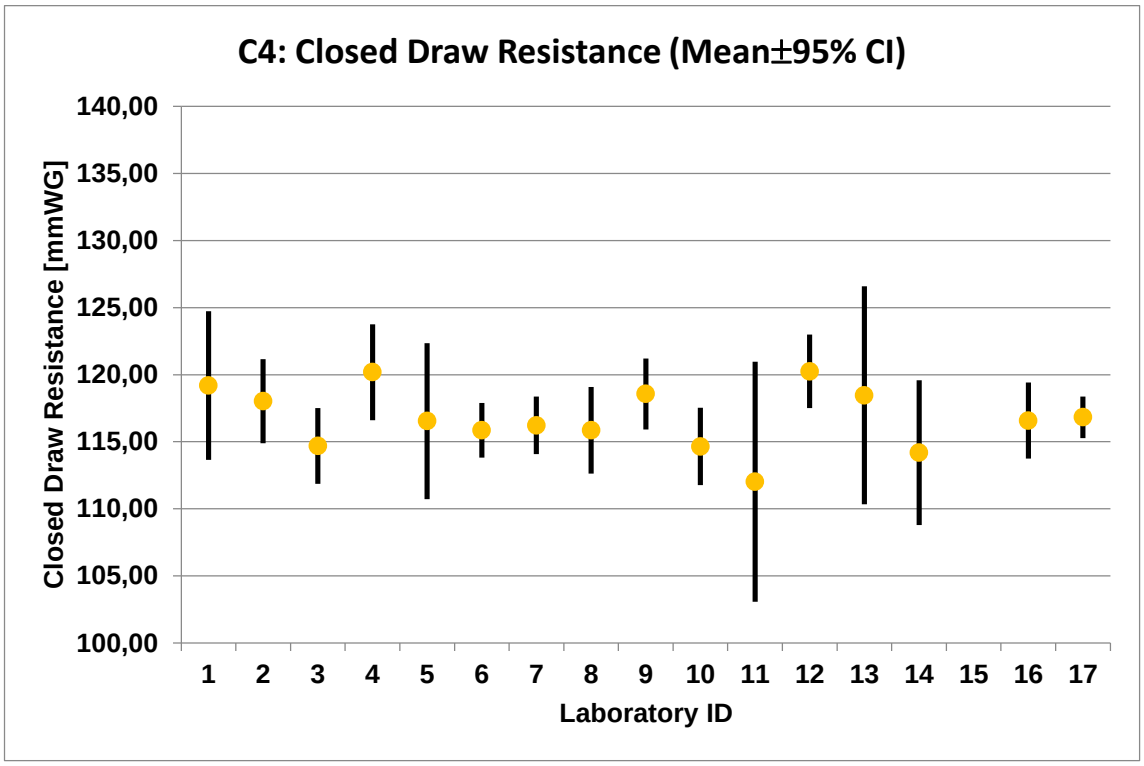


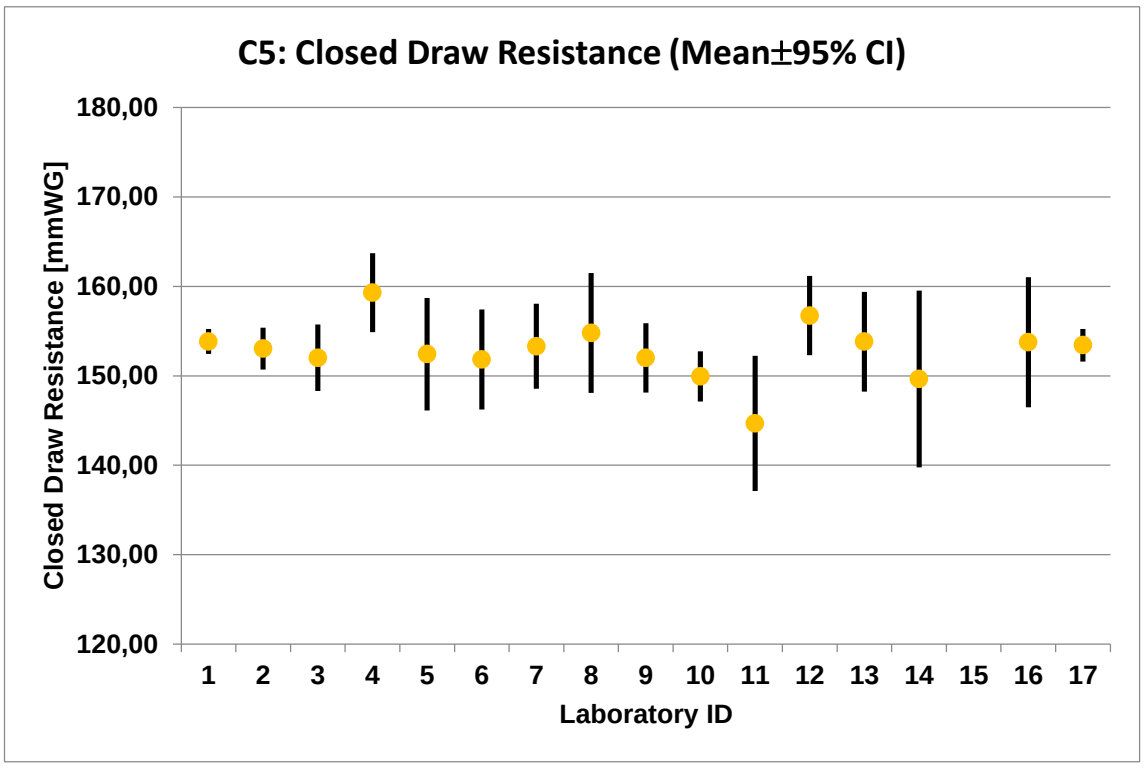
Appendix E.4: Closed draw resistances of cigarettes C1-C5



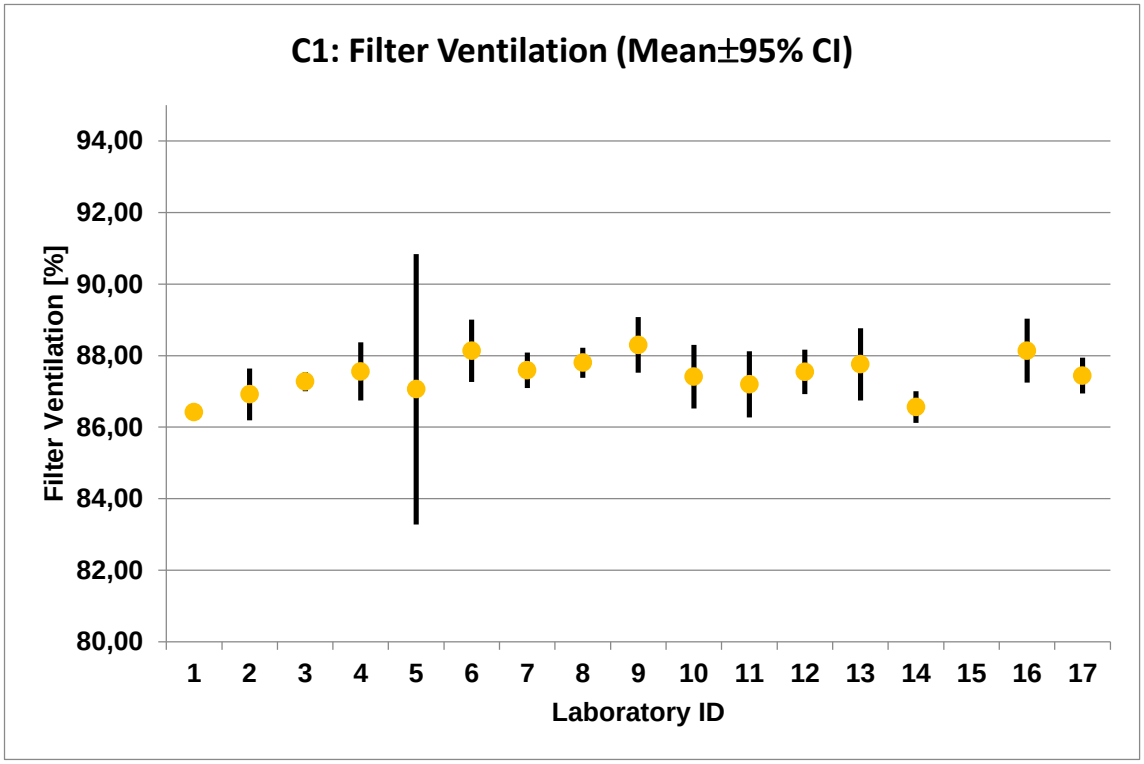

C2: Closed Draw Resistance (Mean±95% CI)
Closed Draw Resistance [mmWG]
220,00
210,00
200,00
190,00
180,00
170,00
160,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

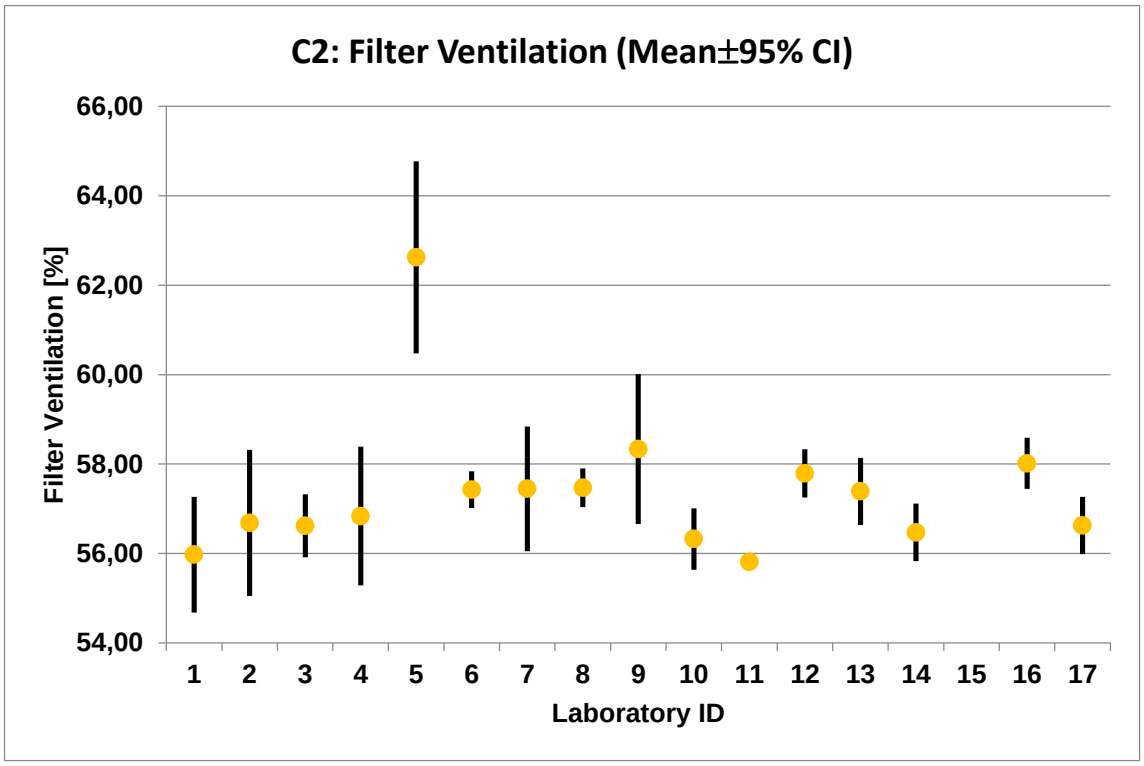

C3: Closed Draw Resistance (Mean±95% CI)
Closed Draw Resistance [mmWG]
180,00
175,00
170,00
165,00
160,00
155,00
150,00
145,00
140,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

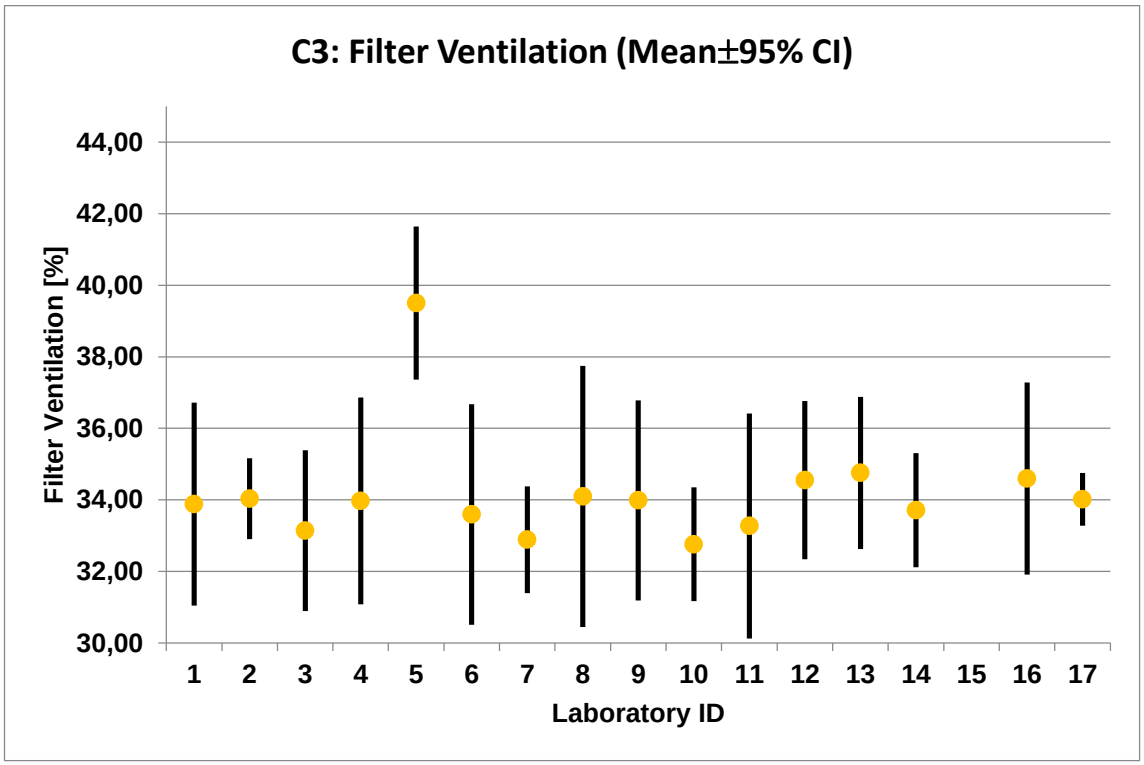

C4: Closed Draw Resistance (Mean±95% CI)
Closed Draw Resistance [mmWG]
140,00
135,00
130,00
125,00
120,00
115,00
110,00
105,00
100,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

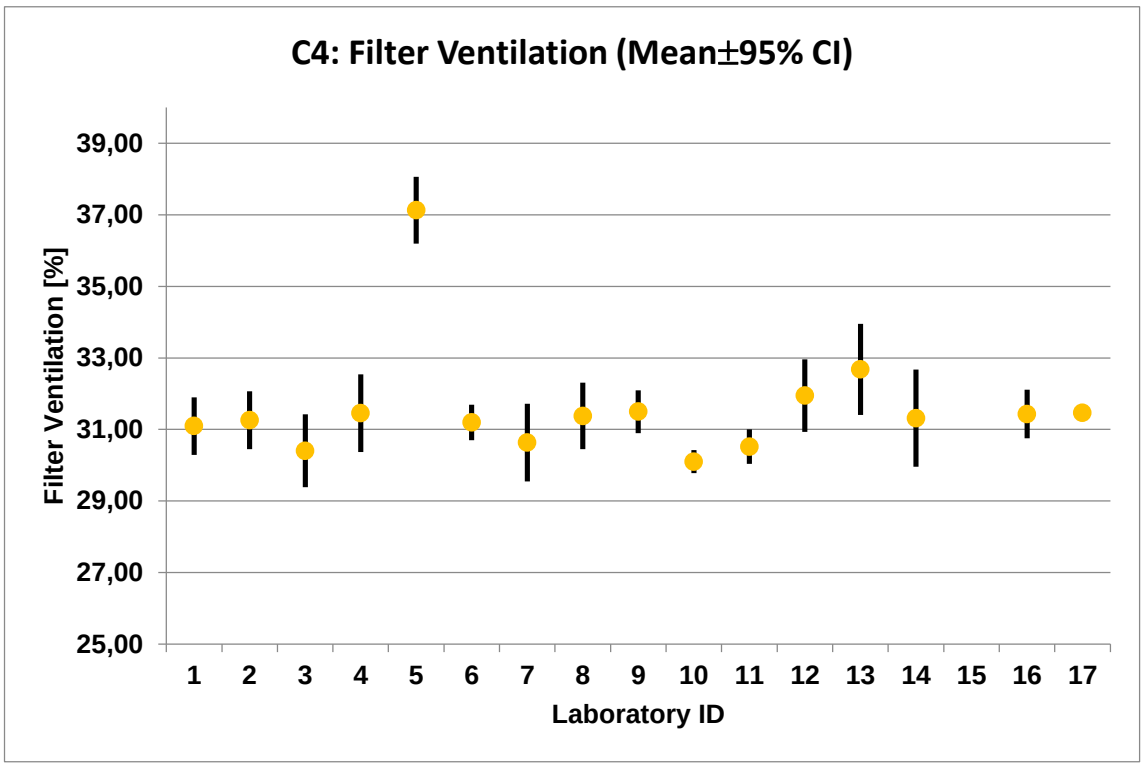

C5: Closed Draw Resistance (Mean±95% CI)
Closed Draw Resistance [mmWG]
180,00
170,00
160,00
150,00
140,00
130,00
120,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID

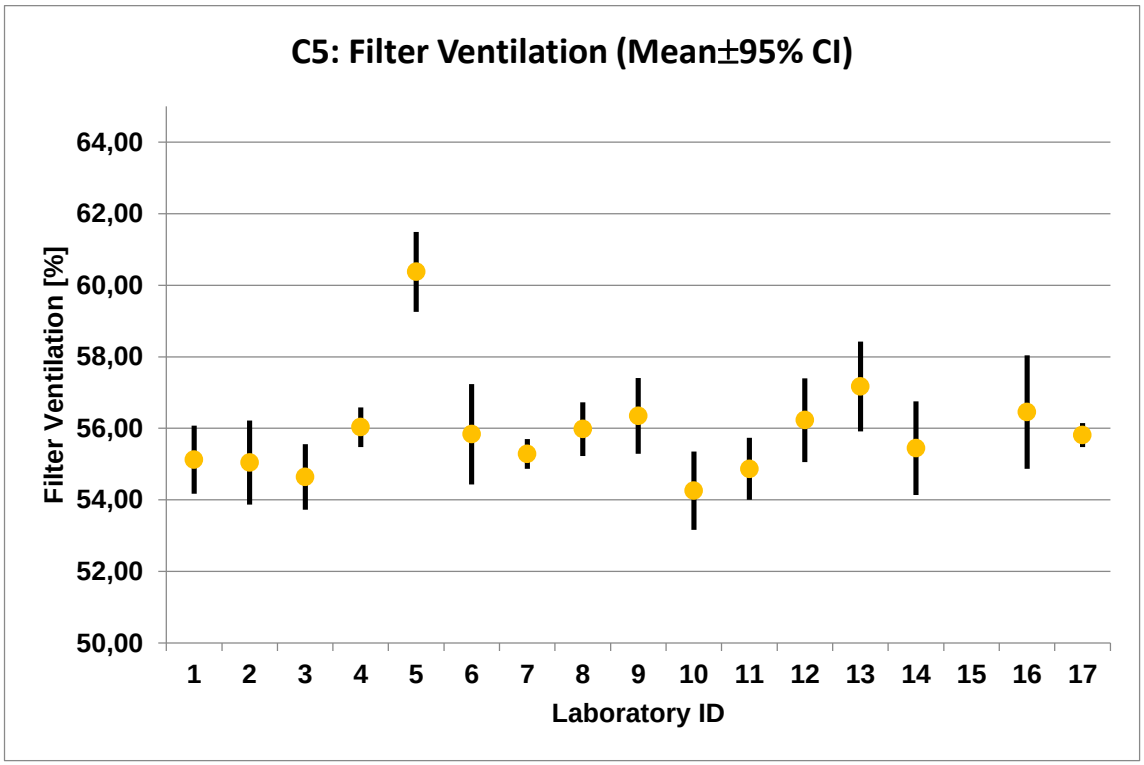
Appendix E.5: Degrees of filter ventilation of cigarettes C1-C5






C3: Filter Ventilation (Mean±95% CI)
Filter Ventilation [%]
44,00
42,00
40,00
38,00
36,00
34,00
32,00
30,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID


C4: Filter Ventilation (Mean±95% CI)
Filter Ventilation [%]
39,00
37,00
35,00
33,00
31,00
29,00
27,00
25,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Laboratory ID


C5: Filter Ventilation (Mean±95% CI)
Filter Ventilation [%]
64,00
62,00
60,00
58,00
56,00
54,00
52,00
50,00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Laboratory ID