



Physical Test Methods Sub-Group

Technical Report

12th Collaborative Study (2019) on Physical Parameters of Cigarettes and Filter Rods

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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 filter rods. 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 filter rods, 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 2019 and laboratories were asked to report the results until end of August 2019.

Compared to previous inter-laboratory studies on physical parameters carried out until and including 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.

1.3 Products and Measurements

For the collaborative study cigarettes and filter rods 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 filter rods and the open draw resistance of cigarettes.

The cigarettes were manufactured by the owner of the respective brand and the filter rods were manufactured by Cerdia GmbH, at the time of production named 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 rod samples were available, this study was carried out with the normally used set of five cigarette samples and five filter rod samples. Even though the cigarettes and filter rods 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

	ID	Product Description	Length mm	Diameter mm	PD mmWG	
Filter Rods	F1	Cellulose Acetate Filter Rod	126	7,2	440	
	F2	Cellulose Acetate Filter Rod	126	5,4	500	
	F3	Cellulose Acetate Filter Rod	126	7,8	290	
	F4	Cellulose Acetate Filter Rod	126	7,8	510	
	F5	Cellulose Acetate Filter Rod	126	7,8	730	
	ID	Product Description	Length mm	Diameter mm	Open Draw Res. mmWG	Filter Ventilation %
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 filter rods 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.

Filter Rods

- 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 (filter rods) \times 5 (days) \times 3 (parameters) \times 10 (individual measurements) = 750 measurements on filter rods and 5 (cigarettes) \times 5 (days) \times 5 (parameters) \times 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 24 laboratories participated by submitting data 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 filter rods with small diameters. Some laboratories 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
British American Tobacco	Germany
Cerdia Lab	Germany
Cerulean Calibration Lab	United Kingdom
CIT Monte Paz SA	Uruguay
Enthalpy Analytical (Richmond)	USA
Essentra Scientific Services	United Kingdom
Godfrey Phillips India Ltd.	India
Imperial Tobacco (2 sample sets)	Poland
Imperial Tobacco	Ukraine
ITG Hamburg	Germany
Japan Tobacco Inc. (2 sample sets)	Japan
JTI QA Lab Trier (Mechanical Lab)	Germany
Omerica Lab	China
Papierfabrik Wattens GmbH	Austria
Philip Morris Berlin	Germany
Philip Morris Brazil	Brazil
Philips Philip Morris International	Turkey
PT Hinjaya Mandala Sampoerna	Indonesia

Participant Name	Country
Smoke Lab / Global Laboratory Services Inc.	USA
Sodim	France
Tabacalera del Este SA (2 sample sets)	Paraguay
Zhengzhou Tobacco Research Institute	China

2. STATISTICAL EVALUATION

2.1 Raw Data Treatment

In total 27 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 filter rods in Table 3 and for cigarettes in Tables 4a and b. The number (N) of data sets is also given.

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

ID	Weight				Diameter				Pressure Drop			
	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	SDw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
F1	746,82	3,52	2,91	22	7,15	0,007	0,005	22	441,87	6,72	4,18	18
F2	440,48	1,68	1,67	22	5,35	0,005	0,005	22	498,23	6,32	5,61	18
F3	826,77	2,27	2,56	24	7,81	0,006	0,005	24	291,25	3,35	2,57	20
F4	855,83	1,58	1,95	24	7,79	0,006	0,004	24	513,17	6,95	3,70	20
F5	861,02	2,24	2,58	24	7,80	0,006	0,004	24	728,90	11,05	4,86	20

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

ID	Weight				Diameter				Open Draw Resistance			
	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	Sdw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
C1	536,75	4,06	3,62	23	5,43	0,008	0,007	24	86,23	1,64	1,75	22
C2	925,74	5,36	4,96	23	7,37	0,008	0,011	24	110,29	3,65	2,64	23
C3	985,68	7,01	6,73	24	7,69	0,008	0,006	25	117,32	1,47	2,15	24
C4	803,07	4,77	5,90	24	7,81	0,012	0,007	25	85,55	1,05	1,17	24
C5	811,87	5,05	5,55	24	7,82	0,013	0,007	25	86,95	1,01	1,09	24

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

	Closed Draw Resistance				Filter Ventilation			
	MV	SDb	SDw	N	MV	SDb	SDw	N
	mmWG	mmWG	mmWG		%	%	%	
C1	347,13	18,57	6,81	20	87,53	0,637	0,425	22
C2	197,20	3,66	2,87	20	57,44	1,650	0,716	23
C3	160,27	2,24	2,82	21	34,36	1,367	0,897	24
C4	117,14	1,70	1,84	21	31,44	1,422	0,474	24
C5	153,00	2,78	2,11	21	55,76	0,955	0,537	24

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 are generally repeated as often as is necessary until no further outliers appear. In the present case only one iteration was sufficient and 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 filter rods 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 2, 3, 5, 6, 7, 14, 17, 20, 23, 24 and 27.

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	L23GBL	none	L24GBH	not applicable	not applicable	not applicable
F2			L05GBL			
F3			L05GBL			
F4			L05GBL			
F5			L05GBL			
C1		none	not applicable	L20C	L27GBL	none
C2				L03GWL, L17GWL, L06C, L06GBL	L27GBL	L06C
C3					L14C	L02GBH
C4				L17GBL	none	L17GWH, L02GBH
C5	L07GWH			L27GBL	L27GBL	L02GBH

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 filter rods are given in Table 6 and for cigarettes in Tables 7a and 7b. 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 filter rods

ID	Weight				Diameter				Pressure Drop			
	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	SDw	N
	mg	mg	mg		mm	mm	Mm		mmWG	mmWG	mmWG	
F1	747,34	2,59	2,89	21	7,15	0,007	0,005	22	440,66	4,47	4,05	17
F2	440,48	1,68	1,67	22	5,35	0,005	0,005	22	499,17	4,14	5,74	16
F3	826,77	2,27	2,56	24	7,81	0,006	0,005	24	291,69	2,44	2,45	19
F4	855,83	1,58	1,95	24	7,79	0,006	0,004	24	514,30	4,91	3,64	19
F5	861,02	2,24	2,58	24	7,80	0,006	0,004	24	730,16	6,79	5,05	18

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

ID	Weight				Diameter				Open Draw Resistance			
	MV	SDb	SDw	N	MV	SDb	SDw	N	MV	SDb	Sdw	N
	mg	mg	mg		mm	mm	mm		mmWG	mmWG	mmWG	
C1	536,75	4,06	3,62	23	5,43	0,008	0,007	24	86,39	1,50	1,27	21
C2	925,74	5,36	4,96	23	7,37	0,008	0,011	24	111,09	0,66	1,66	22
C3	985,37	7,00	6,65	23	7,69	0,008	0,006	24	117,32	1,47	2,15	24
C4	802,74	4,58	5,99	23	7,81	0,012	0,007	25	85,69	0,73	1,14	23
C5	811,87	5,05	5,55	24	7,82	0,013	0,007	25	87,11	0,61	1,07	23

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

	Closed Draw Resistance				Filter Ventilation			
	MV	SDb	SDw	N	MV	SDb	SDw	N
	mmWG	mmWG	mmWG		%	%	%	
C1	350,99	5,65	7,01	18	87,53	0,64	0,42	22
C2	197,98	1,80	2,95	18	57,47	1,68	0,73	22
C3	160,47	2,17	2,32	19	34,17	0,89	0,89	22
C4	117,14	1,70	1,83	21	31,16	0,56	0,43	22
C5	153,48	1,72	2,11	20	55,64	0,69	0,55	22

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 filter rods 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 rod weight and diameter

ID	Weight						Diameter					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mg	mg	%	mg	mg	%	mm	mm	%	mm	mm	%
F1	2,89	8,17	0,39	3,66	10,34	0,49	0,005	0,015	0,076	0,008	0,024	0,118
F2	1,67	4,73	0,38	2,25	6,37	0,51	0,005	0,014	0,093	0,007	0,018	0,122
F3	2,56	7,23	0,31	3,22	9,11	0,39	0,005	0,014	0,063	0,008	0,022	0,100
F4	1,95	5,53	0,23	2,36	6,67	0,28	0,004	0,012	0,056	0,007	0,020	0,093
F5	2,58	7,29	0,30	3,21	9,09	0,37	0,004	0,012	0,056	0,007	0,021	0,096

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

ID	Pressure Drop					
	Repeatability			Reproducibility		
	SD	Limit	CoV	SD	Limit	CoV
	mmWG	mmWG	%	mmWG	mmWG	%
F1	4,05	11,45	0,92	5,76	16,28	1,31
F2	5,74	16,25	1,15	6,60	18,67	1,32
F3	2,45	6,92	0,84	3,28	9,28	1,12
F4	3,64	10,28	0,71	5,89	16,66	1,15
F5	5,05	14,27	0,69	8,15	23,07	1,12

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

ID	Weight						Diameter					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mg	mg	%	mg	mg	%	mm	mm	%	mm	mm	%
C1	3,62	10,25	0,68	5,19	14,69	0,97	0,007	0,021	0,134	0,010	0,028	0,186
C2	4,96	14,03	0,54	6,96	19,68	0,75	0,011	0,032	0,151	0,013	0,036	0,171
C3	6,65	18,80	0,67	9,18	25,97	0,93	0,006	0,016	0,074	0,009	0,026	0,121
C4	5,99	16,93	0,75	7,05	19,93	0,88	0,007	0,019	0,086	0,013	0,037	0,166
C5	5,55	15,69	0,68	7,08	20,02	0,87	0,007	0,019	0,086	0,014	0,041	0,184

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

ID	Open Draw Resistance						Closed Draw Resistance					
	Repeatability			Reproducibility			Repeatability			Reproducibility		
	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV	SD	Limit	CoV
	mmWG	%	mmWG	mmWG	%	mmWG	mmWG	%	mmWG	mmWG	mmWG	%
C1	1,27	3,59	1,47	1,88	5,32	2,18	7,01	19,81	2,00	8,44	23,87	2,40
C2	1,66	4,68	1,49	1,62	4,58	1,46	2,95	8,33	1,49	3,19	9,03	1,61
C3	2,15	6,07	1,83	2,42	6,84	2,06	2,32	6,55	1,44	3,00	8,49	1,87
C4	1,14	3,24	1,34	1,26	3,56	1,47	1,83	5,19	1,57	2,36	6,68	2,02
C5	1,07	3,04	1,23	1,14	3,22	1,31	2,11	5,96	1,37	2,55	7,22	1,66

Table 9c – Repeatability and reproducibility statistics for the degree of filter ventilation

ID	Degree of Filter Ventilation					
	Repeatability			Reproducibility		
	SD	Limit	CoV	SD	Limit	CoV
	%	%	%	%	%	%
C1	0,42	1,20	0,49	0,74	2,10	0,85
C2	0,73	2,07	1,27	1,81	5,11	3,14
C3	0,89	2,52	2,61	1,20	3,38	3,50
C4	0,43	1,22	1,38	0,68	1,92	2,18
C5	0,55	1,56	0,99	0,85	2,39	1,52

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. For the calculation of z-scores the data sets were used as reported without any outlier elimination. The results are given first for filter rods 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 filter rods

ID	Weight					Diameter					Pressure Drop				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1															
2	-0,50	0,65	0,46	0,15	1,64	-0,89	0,18	0,16	-0,27	0,01	0,28	-0,69	0,46	0,04	1,35
3	-0,18	-0,07	1,00	0,56	-0,99	0,28	-0,01	-0,16	0,06	0,58					
4	-0,60	-0,34	-0,23	1,36	-0,11	0,16	-0,04	-0,14	-0,20	0,24	0,14	0,64	-0,68	0,50	-0,30
5	1,14	1,31	0,84	0,80	0,40	-0,55	-0,13	-0,15	-1,17	-0,29	0,94	-4,97	-4,33	-4,59	-5,54
6	-0,23	-0,79	0,66	0,31	0,09	0,21	-0,19	-0,13	-0,68	-0,28	-2,24	-2,09	-1,23	-1,38	-2,07
7	-2,09	-0,82	-0,99	-1,32	-0,24	-0,99	-1,61	-0,50	-0,13	-0,69	0,29	-1,10	-0,35	0,12	0,85
8	-0,11	0,29	-0,09	-0,58	-0,23	-0,27	-0,22	-0,21	-0,33	-0,80	-0,41	0,21	-0,84	-0,93	-1,13
9	-0,95	0,45	-1,40	-1,10	-0,65	-1,31	-1,74	-2,60	-2,72	-1,66	0,34	0,89	-0,14	1,36	0,42
10	0,74	0,61	1,16	-1,10	-0,64	1,48	1,17	1,57	0,30	1,18	-1,19	0,67	-0,36	-1,13	-1,17
11	0,08	-0,03	-0,44	0,19	1,17	1,27	1,59	1,78	1,68	0,70	0,27	0,45	-0,13	0,50	0,83
12															
13	0,46	0,18	1,23	1,09	1,05	-0,20	0,32	-0,10	-0,36	0,75	0,42	0,77	0,94	1,01	0,59
14	1,22	1,05	1,00	1,24	0,97	0,35	0,34	-0,43	0,28	0,10	0,37	1,23	2,69	1,93	1,83
15			-0,24	-0,73	-1,53			0,40	0,63	0,41			0,05	-0,33	-0,59
16			-1,70	-2,99	-0,36			-0,01	0,46	-0,63			-1,98	-1,74	-0,47
17	-1,31	-1,68	0,08	0,07	-2,52	-0,31	-1,05	-0,53	-0,83	-2,01	-0,82	-1,16	-0,18	-0,07	-0,03
18	1,53	0,50	-0,28	0,66	1,37	0,29	0,18	-0,81	0,54	-0,93	2,33	-0,16	0,14	0,13	0,61
19															
20	-0,04	-1,07	0,77	0,45	-0,11	1,03	0,36	0,31	0,30	0,66					
21	2,06	-1,71	-1,89	-0,55	-0,98	-0,06	-0,33	0,12	0,79	0,07	-0,80	-1,21	-0,18	-1,14	-0,85
22	-1,32	0,74	-0,83	0,04	-0,39	-0,38	1,42	-0,68	0,03	0,76					
23	-4,44	-2,06	-1,48	-0,88	-0,43	-2,89	-2,28	-1,52	-1,37	-2,13	0,81	1,00	1,27	1,40	2,07
24	0,25	0,23	1,39	0,91	1,51	0,33	0,69	1,15	0,99	1,83	4,87	0,03	0,24	-0,43	-0,44
25	-0,17	1,06	0,87	0,21	0,05	1,70	1,42	2,14	2,24	1,05	-0,64	1,36	0,37	-0,26	0,25
26	-0,41	-0,10	0,69	0,47	0,55	0,54	0,03	0,31	0,16	0,65	-0,11	0,03	0,65	0,42	0,07
27	0,42	1,61	-0,60	0,74	0,39	0,20	-0,10	0,03	-0,39	0,43					

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

ID	Weight					Diameter					Open Draw Resistance				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1						0,18	0,83	0,02	-1,20	-0,99		0,19	-0,59	1,47	0,79
2	-0,40	0,44	0,23	-0,29	-0,52	0,73	0,45	-0,27	-1,33	-0,94	-0,03	-0,08	1,16	0,87	0,63
3	0,73	0,57	-1,13	-0,13	-0,09	-1,19	1,71	-0,35	1,61	1,40	0,12	-0,96	-0,45	-1,05	-0,94
4	-0,69	-2,01	-1,01	-2,03	-0,22	-1,39	-0,50	-1,77	0,47	1,26	0,02	0,07	-0,08	-0,80	0,83
5	0,74	0,53	1,28	1,32	1,41	-0,04	-0,90	-0,10	0,06	0,16	0,23	-0,81	0,30	-1,24	-0,35
6	0,30	0,48	0,45	-0,18	-0,18	-0,47	-0,63	-1,03	-0,40	-0,50	1,31	-26,19	0,13	0,10	-0,68
7	-0,89	-1,07	-0,99	-1,34	-1,16	-0,44	-0,42	0,00	-0,73	-0,32	-2,92	0,10	-1,50	-1,95	-1,79
8															
9	0,16	-0,08	0,78	-0,19	0,34	-0,55	-0,58	-1,94	-1,68	-1,68	0,16	1,53	1,42	0,38	1,51
10	1,91	1,06	0,80	1,03	1,50	1,13	0,30	1,12	0,27	0,21	0,35	-0,96	0,73	0,73	1,02
11	0,24	1,71	1,39	0,72	1,14	0,36	0,56	0,97	2,17	2,06	0,49	-0,17	-0,62	-1,53	0,12
12	0,71	1,06	1,08	1,76	0,42	-0,54	0,09	-0,14	0,56	0,16	0,74	0,10	1,75	-0,14	1,02
13	0,63	0,92	1,05	0,57	1,29	1,37	-0,08	1,41	-0,88	-0,43	1,46	0,53	0,68	0,79	1,22
14	0,54	0,94	0,86	0,24	0,36	-1,31	-0,92	-1,04	0,21	0,22	-0,16	0,95	-1,52	-0,14	0,24
15	0,12	-0,26	-0,11	1,01	-0,36	0,28	0,33	0,95	-0,22	0,08					
16			-0,83	-0,37	-0,67			-1,14	0,16	0,23			-1,59	-0,17	0,34
17	-0,62	-1,57	-1,78	-2,82	-1,63	-1,33	-2,65	-1,67	0,10	0,40	-0,42	-0,38	-1,01	-5,05	-0,84
18	0,19	0,40	0,70	0,80	-0,18	1,22	0,00	0,26	-1,13	-1,28	-0,74	0,16	-0,75	2,16	-0,64
19	0,31	-0,08	1,40	0,77	1,64	-0,92	-1,08	-0,22	0,17	0,18	0,01	-2,41	0,99	-0,20	0,70
20	-2,35	-1,50	-1,36	-0,64	-1,39	-1,95	-1,10	-1,37	0,26	0,19	-2,32	1,44	0,05	-0,12	0,11
21	-2,16	-1,42	-1,45	0,30	-1,04	1,52	0,92	2,01	-0,94	-1,35	-0,72	-1,54	0,46	-0,25	-2,24
22	0,44	0,26	0,29	0,59	-0,58	0,77	0,18	0,81	1,49	1,24	0,63	-0,11	-0,23	-0,42	-0,97
23															
24	0,91	0,30	-0,48	0,57	0,76	1,29	1,95	0,32	1,76	1,83	1,03	1,41	0,36	1,72	0,40
25	0,38	0,60	0,42	0,45	0,54	0,37	0,05	0,68	0,29	0,01	0,78	0,48	0,87	0,80	0,69
26	0,37	0,15	0,43	0,26	0,44	0,38	0,14	0,69	-0,89	-1,28	-0,70	0,28	1,07	-0,53	-1,17
27	-1,56	-0,99	-0,93	-0,64	-1,82	0,52	1,33	0,02	-0,17	-0,57	-1,66	-1,72	-1,62	0,21	-6,46

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

ID	Closed Draw Resistance					Degree of Filter Ventilation				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1						-0,36	0,32	-0,73	-0,53	
2	0,89	0,22	0,76	2,24	-0,38	1,16	2,87	5,81	11,63	4,85
3	1,28	-0,76	-1,46	-0,44	-1,08	0,94	0,34	-0,08	1,45	1,21
4	-0,96	-0,90	-0,82	-0,70	-0,44	-1,03	-0,87	-1,91	-1,96	-2,05
5	-0,63	-0,04	-0,01	-0,21	-0,37	-0,60	-0,38	-0,67	-0,29	-0,71
6	0,21	-1,32	0,65	0,14	-0,59	-0,57	2,77	-0,26	-0,89	-0,77
7						0,41	-0,64	0,31	-0,36	-0,66
8										
9	1,07	1,91	1,48	1,03	1,88	0,18	-0,21	-0,78	-0,86	-0,02
10	2,16	-0,15	0,05	0,53	0,91	2,40	0,56	-0,40	0,13	1,86
11	-0,29	-0,67	-0,09	-0,66	0,81	0,46	-0,25	0,12	-0,32	0,56
12	-0,47	0,53	0,59	-0,23	0,10	0,93	0,21	-1,30	-0,08	0,14
13	0,40	0,85	0,80	0,86	1,65	-1,61	-0,40	-0,37	0,15	0,63
14	0,39	1,27	-1,80	0,00	-1,78	-1,68	-0,72	1,08	-0,67	-1,62
15										
16			-0,18	-0,40	-0,30			1,78	0,32	0,40
17	-0,92	-1,29	-0,71	-2,91	0,70	-0,42	-0,92	-0,78	-1,07	-0,07
18						0,03	-0,62	1,41	0,50	-0,33
19	-0,02	-0,75	0,16	-0,03	0,22	-0,36	0,04	-1,00	0,21	0,11
20	-1,79	0,29	0,09	0,21	-0,43	-1,24	-0,76	-0,17	-0,23	-1,15
21	-1,63	-1,81	-0,23	-0,06	-0,23	-0,40	-0,28	0,69	1,84	0,75
22	-0,03	-0,24	-0,45	-0,43	-2,08	0,91	0,35	0,16	0,54	1,08
23										
24	0,41	1,10	-0,15	1,31	0,25	-0,88	-0,50	-1,33	-0,61	-1,10
25	0,24	0,34	0,74	0,23	0,35	0,87	0,00	0,49	1,82	1,36
26	0,09	0,74	1,43	0,44	0,84	0,47	-0,10	0,02	1,05	0,73
27	-14,04	-8,04	-2,78	-0,93	-5,89	0,04	-0,51	2,00	0,47	-0,52

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 (ISO 2971, ISO 6565, ISO 9512). 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 rod 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 filter rods. The reproducibility of the measurement of flow parameters like pressure drop, draw resistances and degree of filter ventilation is also higher for cigarettes by a factor of about 2 compared to filter rods, 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 filter rods 23 of 313 determinations, i.e. 7,3 %, resulted in absolute z-scores of 2 or higher and 6 of 313 determinations, i.e. 1,9 %, in absolute z-scores of 3 or higher. For the cigarettes 32 of 578 determinations (5,5 %) provided absolute z-scores of 2 or higher and 9 determinations (1,6 %) 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 filter rods. For the measurements on cigarettes laboratory 2 measured several high values for the degree of filter ventilation leading to z-scores above 3 and laboratory 27 measured low draw resistance values on cigarettes with three of five z-scores below -3.

Furthermore laboratory 6 had a tendency to measure low pressure drops on filter rods and laboratory 23 generally measured low values on weight and diameter for filter rods.

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 7 of the 27 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, 8, 12, 13, 15 and 26.

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 to 9th Proficiency Test on Physical Parameters (2014, 2015, 2016) and the 10th to 12th Collaborative Study on Physical Parameters (2017, 2018, 2019) is 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 six 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 filter rods

Parameter	Robust Coefficient of Variation					
	%					
	2014	2015	2016	2017	2018	2019
Weight	0,239	0,392	0,421	0,332	0,300	0,290
Diameter	0,070	0,063	0,089	0,080	0,084	0,085
Pressure Drop	2,710	1,715	1,357	1,105	1,124	0,914

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	2019
Weight	0,528	0,852	0,817	0,721	0,625	0,647
Diameter	0,126	0,104	0,103	0,172	0,150	0,132
Open Draw Resistance	2,104	1,476	1,370	1,632	1,354	1,029
Closed Draw Resistance	2,403	2,732	2,305	1,984	1,673	1,289
Degree of Filter Ventilation	2,785	2,211	2,524	1,347	1,432	1,860

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 filter rods is generally lower than for cigarettes, which is likely to be due to the higher homogeneity of filter rods and their higher resistance to mechanical damage during transport and handling.

The observed variation for pressure drop, draw resistance and degree of filter ventilation is in good agreement with the variability reported in ISO 6565 and ISO 9512, respectively. This supports the conclusion that the laboratories are properly applying these standards. As the methods have not changed from 2014 to 2019 the observed changes may mostly be attributable to differences in the test pieces and to the laboratories that have taken part in the collaborative studies.

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 from 2017 to 2019. Tables 14a and 14b show these parameters for the filter rods and Tables 15a and 15b for the cigarettes.

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

Parameter	Repeatability Coefficient of Variation		
	%		
	2017	2018	2019
Weight	0,292	0,338	0,321
Diameter	0,071	0,073	0,069
Pressure Drop	0,820	0,826	0,861

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

Parameter	Reproducibility Coefficient of Variation		
	%		
	2017	2018	2019
Weight	0,422	0,428	0,408
Diameter	0,102	0,105	0,106
Pressure Drop	1,336	1,382	1,203

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

Parameter	Repeatability Coefficient of Variation		
	%		
	2017	2018	2019
Weight	0,733	0,628	0,663
Diameter	0,088	0,097	0,106
Open Draw Resistance	1,477	1,430	1,471
Closed Draw Resistance	2,087	1,842	1,573
Degree of Filter Ventilation	1,037	1,438	1,348

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

Parameter	Reproducibility Coefficient of Variation		
	%		
	2017	2018	2019
Weight	0,973	0,856	0,880
Diameter	0,190	0,175	0,165
Open Draw Resistance	2,100	1,874	1,695
Closed Draw Resistance	2,767	2,372	1,913
Degree of Filter Ventilation	1,640	1,986	2,239

For the filter rods and for the cigarettes no substantial changes in these parameters could be observed from 2017 to 2019.

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 2019, 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 12th Collaborative Study (2019) 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 supplier's 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 $\pm 0,5\%$ 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 to 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 hour 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 B. Reier - latest by August 31st

Set e-mail subject line: Collaborative Study 2019 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 filter rods over all laboratories (ID)

ID	Weight					Diameter					Pressure Drop				
	mg					mm					mmWG				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1															
2	746,05	441,58	827,81	856,08	864,70	7,14	5,35	7,81	7,79	7,80	441,90	496,32	292,82	514,48	739,36
3	746,88	440,36	829,04	856,72	858,80	7,15	5,35	7,80	7,80	7,80					
4	745,80	439,90	826,24	857,98	860,76	7,15	5,35	7,81	7,79	7,80	441,28	501,82	290,02	516,74	728,14
5	750,30	442,68	828,68	857,10	861,92	7,14	5,35	7,81	7,79	7,79	444,88	478,56	281,10	491,74	692,56
6	746,74	439,16	828,26	856,32	861,22	7,15	5,35	7,81	7,79	7,79	430,66	490,50	288,68	507,52	716,12
7	741,94	439,10	824,52	853,74	860,48	7,14	5,35	7,80	7,79	7,79	441,98	494,60	290,84	514,88	735,96
8	747,06	440,96	826,56	854,92	860,50	7,14	5,35	7,80	7,79	7,79	438,84	500,05	289,64	509,74	722,48
9	744,88	441,24	823,60	854,10	859,56	7,14	5,34	7,79	7,78	7,79	442,20	502,84	291,34	520,98	732,98
10	749,26	441,50	829,40	854,10	859,58	7,16	5,36	7,82	7,80	7,80	435,32	501,96	290,80	508,74	722,18
11	747,56	440,44	825,77	856,14	863,64	7,15	5,36	7,82	7,81	7,80	441,85	501,05	291,38	516,75	735,82
12															
13	748,54	440,78	829,56	857,56	863,38	7,14	5,35	7,81	7,79	7,80	442,56	502,36	293,98	519,24	734,14
14	750,50	442,24	829,03	857,80	863,19	7,15	5,35	7,80	7,80	7,80	442,34	504,28	298,26	523,80	742,56
15			826,22	854,68	857,58			7,81	7,80	7,80			291,82	512,66	726,15
16			822,92	851,10	860,20			7,81	7,80	7,79			286,86	505,76	726,96
17	743,96	437,66	826,94	855,94	855,36	7,14	5,35	7,80	7,79	7,78	436,98	494,38	291,26	513,96	729,96
18	751,30	441,32	826,14	856,88	864,08	7,15	5,35	7,80	7,80	7,79	451,10	498,52	292,04	514,96	734,30
19															
20	747,24	438,68	828,52	856,54	860,78	7,15	5,35	7,81	7,80	7,80					
21	752,69	437,61	822,49	854,97	858,82	7,15	5,35	7,81	7,80	7,80	437,10	494,14	291,24	508,72	724,40
22	743,94	441,72	824,88	855,90	860,14	7,14	5,36	7,80	7,80	7,80					
23	735,86	437,02	823,40	854,44	860,06	7,13	5,34	7,80	7,79	7,78	444,30	503,32	294,78	521,20	744,22
24	747,98	440,86	829,92	857,28	864,40	7,15	5,36	7,81	7,80	7,81	462,44	499,28	292,28	512,18	727,18
25	746,90	442,26	828,74	856,16	861,12	7,16	5,36	7,82	7,81	7,80	437,82	504,82	292,59	513,00	731,87
26	746,28	440,32	828,34	856,58	862,24	7,15	5,35	7,81	7,80	7,80	440,16	499,30	293,28	516,34	730,60
27	748,44	443,18	825,40	857,00	861,90	7,15	5,35	7,81	7,79	7,80					

Appendix B.2a: Mean values of weight, diameter and open draw for all laboratories (ID)

ID	Weight					Diameter					Open Draw Resistance				
	mg					mm					mmWG				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1						5,43	7,38	7,69	7,80	7,80		111,22	116,46	86,76	87,60
2	535,13	928,03	986,97	801,39	809,23	5,43	7,38	7,69	7,79	7,80	86,34	111,04	119,04	86,32	87,50
3	539,72	928,70	977,46	802,12	811,44	5,42	7,39	7,69	7,83	7,83	86,56	110,46	116,66	84,92	86,54
4	533,96	914,78	978,28	793,46	810,78	5,42	7,37	7,67	7,82	7,83	86,42	111,14	117,20	85,10	87,62
5	539,74	928,52	994,30	808,78	819,00	5,43	7,37	7,69	7,81	7,82	86,74	110,56	117,76	84,78	86,90
6	537,98	928,22	988,52	801,90	810,98	5,43	7,37	7,68	7,81	7,81	88,36	93,82	117,52	85,76	86,70
7	533,12	919,84	978,42	796,58	806,02	5,43	7,37	7,69	7,80	7,81	82,00	111,16	115,12	84,26	86,02
8															
9	537,40	925,20	990,80	801,88	813,58	5,43	7,37	7,67	7,79	7,79	86,62	112,10	119,42	85,96	88,04
10	544,50	931,38	990,94	807,46	819,44	5,44	7,37	7,70	7,81	7,82	86,92	110,46	118,40	86,22	87,74
11	537,71	934,88	995,09	806,03	817,62	5,43	7,38	7,70	7,83	7,84	87,13	110,98	116,42	84,57	87,19
12	539,62	931,38	992,94	810,78	813,98	5,43	7,37	7,69	7,82	7,82	87,50	111,16	119,90	85,58	87,74
13	539,30	930,62	992,72	805,34	818,40	5,44	7,37	7,70	7,80	7,81	88,58	111,44	118,32	86,26	87,86
14	538,96	930,73	991,40	803,83	813,69	5,42	7,36	7,68	7,81	7,82	86,14	111,72	115,08	85,58	87,26
15	537,22	924,36	984,60	807,38	810,04	5,43	7,37	7,70	7,81	7,82					
16			979,54	801,04	808,48			7,68	7,81	7,82			114,98	85,56	87,32
17	534,24	917,14	972,90	789,82	803,62	5,42	7,35	7,68	7,81	7,82	85,76	110,84	115,84	82,00	86,60
18	537,52	927,78	990,24	806,38	810,94	5,44	7,37	7,69	7,80	7,80	85,28	111,20	116,22	87,26	86,72
19	538,00	925,18	995,14	806,28	820,14	5,42	7,36	7,69	7,81	7,82	86,40	109,50	118,78	85,54	87,54
20	527,22	917,52	975,84	799,82	804,88	5,41	7,36	7,68	7,81	7,82	82,90	112,04	117,40	85,60	87,18
21	527,98	917,93	975,24	804,13	806,61	5,44	7,38	7,70	7,80	7,80	85,30	110,08	118,00	85,50	85,74
22	538,52	927,04	987,40	805,44	808,96	5,44	7,37	7,69	7,83	7,83	87,34	111,02	116,98	85,38	86,52
23															
24	540,44	927,24	982,02	805,34	815,70	5,44	7,39	7,69	7,83	7,84	87,94	112,02	117,86	86,94	87,36
25	538,30	928,86	988,32	804,78	814,62	5,43	7,37	7,69	7,81	7,82	87,56	111,41	118,60	86,27	87,54
26	538,24	926,46	988,40	803,94	814,12	5,43	7,37	7,69	7,80	7,80	85,34	111,28	118,90	85,30	86,40
27	530,40	920,28	978,88	799,82	802,70	5,43	7,38	7,69	7,81	7,81	83,90	109,96	114,94	85,84	83,16

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

ID	Closed Draw Resistance					Degree of Filter Ventilation				
	mg					%				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1							56,86	34,46	30,75	55,27
2	356,02	198,38	162,12	120,94	152,82	88,27	62,30	39,35	37,68	58,98
3	358,24	196,62	157,30	116,38	151,62	88,13	58,04	34,11	31,97	56,47
4	345,56	196,36	158,68	115,94	152,72	86,88	56,01	32,47	30,07	54,23
5	347,42	197,92	160,46	116,78	152,84	87,15	56,84	33,58	31,00	55,15
6	352,16	195,60	161,88	117,38	152,46	87,17	62,14	33,94	30,66	55,11
7						87,79	56,39	34,45	30,96	55,19
8										
9	357,02	201,42	163,68	118,88	156,72	87,65	57,11	33,48	30,68	55,62
10	363,18	197,72	160,58	118,04	155,04	89,06	58,42	33,82	31,23	56,92
11	349,37	196,77	160,28	116,02	154,88	87,83	57,05	34,28	30,98	56,02
12	348,34	198,94	161,76	116,74	153,66	88,12	57,83	33,01	31,11	55,73
13	353,24	199,52	162,22	118,60	156,32	86,51	56,79	33,85	31,25	56,07
14	353,18	200,28	156,56	117,14	150,42	86,46	56,26	35,13	30,78	54,52
15										
16			160,08	116,46	152,96			35,76	31,34	55,92
17	345,78	195,66	158,92	112,20	154,68	87,27	55,93	33,48	30,56	55,59
18						87,55	56,43	35,43	31,44	55,41
19	350,90	196,64	160,82	117,08	153,86	87,30	57,54	33,28	31,28	55,72
20	340,86	198,50	160,66	117,50	152,74	86,74	56,19	34,02	31,03	54,85
21	341,76	194,72	159,98	117,04	153,08	87,27	56,99	34,79	32,19	56,16
22	350,82	197,56	159,50	116,40	149,90	88,11	58,05	34,31	31,46	56,38
23										
24	353,32	199,96	160,14	119,36	153,92	86,97	56,63	32,99	30,82	54,88
25	352,34	198,61	162,07	117,52	154,08	88,08	57,48	34,61	32,18	56,57
26	351,50	199,32	163,58	117,88	154,92	87,83	57,30	34,20	31,75	56,14
27	271,60	183,50	154,44	115,56	143,34	87,56	56,61	35,95	31,42	55,28

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 filter rods over all laboratories (ID)

ID	Weight					Diameter					Pressure Drop				
	mg					mm					mmWG				
	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5	F1	F2	F3	F4	F5
1															
2	2,10	2,44	3,09	1,59	2,93	0,005	0,004	0,003	0,005	0,003	4,88	6,13	1,97	2,85	2,96
3	3,01	2,63	2,04	1,53	3,51	0,004	0,006	0,005	0,005	0,002					
4	2,10	1,12	3,18	2,38	3,44	0,002	0,005	0,005	0,001	0,006	2,07	2,15	1,68	1,52	2,85
5	3,36	1,40	1,58	0,52	0,58	0,007	0,007	0,002	0,004	0,004	5,17	4,33	1,94	4,70	3,35
6	1,63	2,29	2,18	1,92	2,21	0,005	0,004	0,005	0,003	0,002	1,38	8,17	3,64	4,35	7,88
7	4,28	2,08	0,96	1,22	2,04	0,006	0,007	0,001	0,003	0,007	4,19	8,49	2,23	3,40	7,86
8	2,60	1,66	3,95	1,56	2,29	0,010	0,002	0,008	0,007	0,004	4,63	4,28	3,23	3,81	4,39
9	3,68	1,21	3,31	2,06	1,73	0,009	0,002	0,004	0,005	0,002	3,62	4,35	1,67	2,41	3,32
10	2,71	1,83	3,42	3,44	3,16	0,004	0,004	0,003	0,001	0,005	5,09	9,27	2,48	3,00	6,37
11	2,06	1,72	1,42	2,44	3,04	0,007	0,004	0,003	0,004	0,003	4,64	5,30	3,46	3,74	0,87
12															
13	2,77	1,26	2,72	2,16	2,15	0,004	0,003	0,002	0,004	0,003	2,53	2,66	2,73	2,53	5,91
14	2,40	1,54	1,99	1,63	1,53	0,006	0,003	0,004	0,004	0,003	3,66	10,05	2,87	2,52	1,88
15			1,68	2,06	3,02			0,011	0,004	0,004			4,90	4,99	7,13
16			3,59	2,61	0,96			0,005	0,003	0,003			2,62	3,00	3,05
17	3,11	1,46	1,19	2,18	4,88	0,003	0,007	0,002	0,005	0,010	1,79	6,50	0,86	3,43	1,60
18	4,10	1,61	2,90	1,36	2,21	0,003	0,004	0,002	0,005	0,002	4,96	4,76	2,80	7,26	3,69
19															
20	1,57	1,95	2,43	1,35	0,72	0,004	0,003	0,005	0,003	0,004					
21	0,50	0,41	0,61	0,67	1,10	0,003	0,001	0,003	0,003	0,003	5,53	2,06	2,33	5,25	6,05
22	1,67	2,03	1,61	1,29	1,91	0,004	0,003	0,004	0,003	0,002					
23	3,27	1,05	3,58	2,34	2,09	0,005	0,007	0,004	0,005	0,008	3,85	3,81	2,39	3,35	6,84
24	4,47	1,74	2,08	1,72	1,76	0,005	0,009	0,006	0,003	0,003	5,93	4,22	1,57	2,97	3,47
25	3,20	0,63	2,77	3,47	1,08	0,007	0,007	0,004	0,009	0,004	3,11	1,97	1,43	2,37	6,11
26	0,98	0,72	1,18	0,44	2,30	0,002	0,002	0,008	0,004	0,004	4,46	0,98	1,00	1,61	1,34
27	4,06	1,89	3,56	1,25	4,97	0,005	0,006	0,005	0,006	0,005					

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

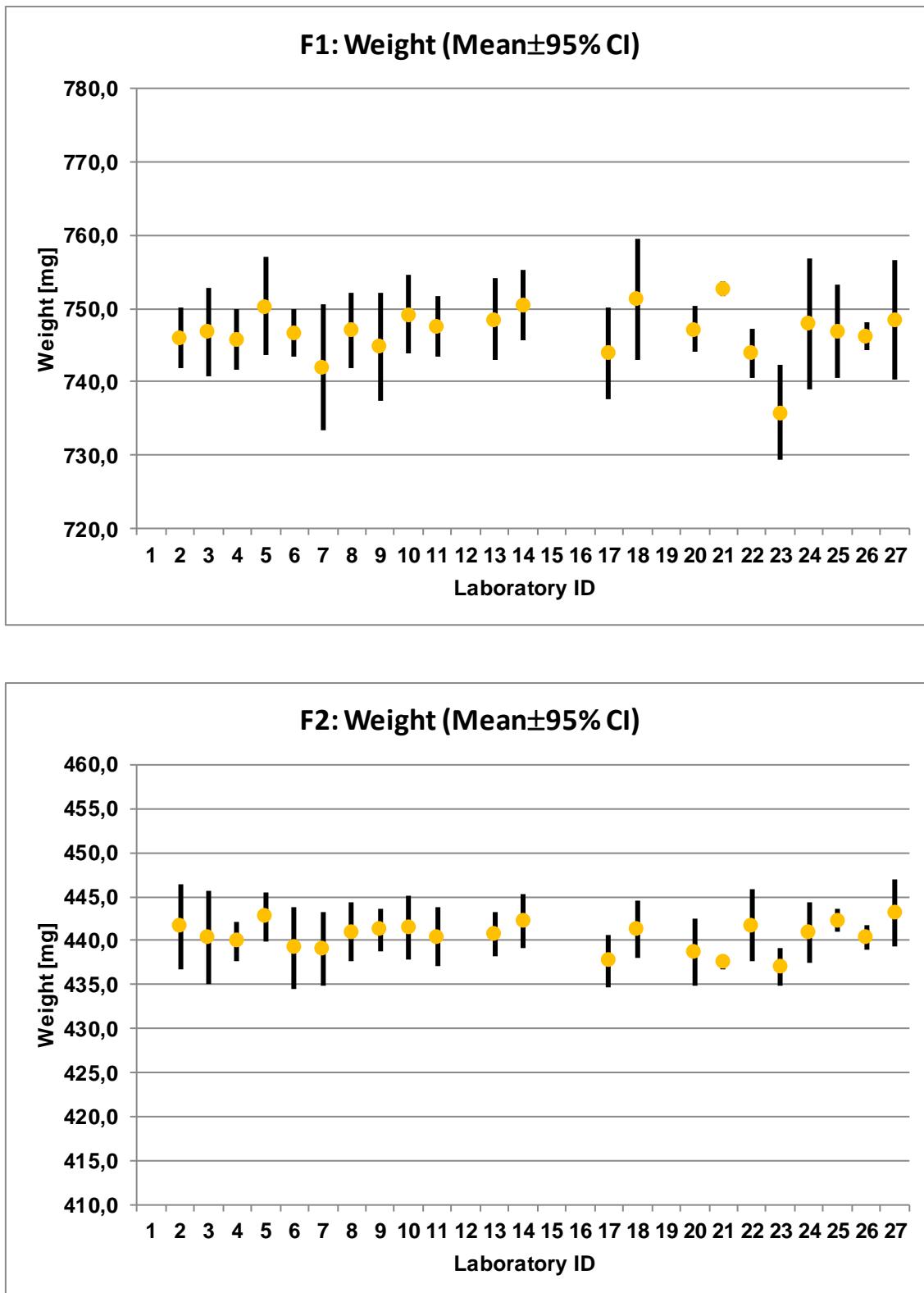
ID	Weight					Diameter					Open Draw Resistance				
	mg					mm					mmWG				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1						0,005	0,012	0,005	0,006	0,004		2,12	2,23	1,00	1,66
2	2,43	6,55	6,54	12,53	3,79	0,009	0,010	0,007	0,006	0,006	1,15	2,72	4,05	1,34	1,00
3	3,51	4,32	1,85	2,16	10,00	0,004	0,014	0,004	0,006	0,004	1,73	1,44	1,77	1,70	1,34
4	3,88	5,00	10,01	10,31	3,12	0,007	0,010	0,010	0,011	0,012	1,32	1,40	1,66	0,91	0,81
5	4,96	4,14	5,27	4,45	3,55	0,010	0,006	0,002	0,002	0,002	0,46	1,13	1,46	1,28	1,13
6	3,53	5,26	8,34	3,34	6,22	0,004	0,013	0,004	0,002	0,005	0,73	9,81	2,39	0,67	1,16
7	3,08	7,15	2,78	4,97	5,91	0,009	0,012	0,009	0,005	0,008	1,00	1,43	2,88	0,95	0,83
8															
9	4,81	5,93	6,84	8,44	2,94	0,003	0,009	0,007	0,008	0,008	0,98	2,69	1,24	0,99	1,47
10	3,87	3,50	3,71	8,49	6,76	0,008	0,011	0,004	0,007	0,007	1,53	0,99	1,45	1,58	1,10
11	3,44	2,57	10,50	7,86	6,24	0,008	0,017	0,007	0,008	0,009	2,11	1,19	0,28	1,37	0,65
12	2,05	5,17	8,38	3,26	4,68	0,003	0,014	0,004	0,004	0,002	1,24	1,64	2,79	1,24	0,72
13	4,76	7,35	3,60	6,61	4,35	0,011	0,012	0,011	0,004	0,010	1,19	2,65	0,73	1,16	0,84
14	4,77	6,42	2,56	4,56	1,61	0,005	0,008	0,005	0,006	0,007	1,98	1,66	2,87	0,62	1,72
15	3,39	3,73	10,81	4,18	10,34	0,002	0,015	0,005	0,006	0,011					
16			6,87	5,87	3,68			0,006	0,008	0,005			3,00	0,82	0,76
17	4,35	4,68	9,62	5,91	4,47	0,007	0,009	0,008	0,008	0,008	1,32	1,38	1,13	1,35	0,91
18	3,01	7,54	9,28	4,77	7,67	0,008	0,013	0,005	0,003	0,004	1,21	0,99	1,94	1,52	1,11
19	2,13	2,89	5,55	1,96	4,97	0,008	0,006	0,002	0,005	0,002	0,68	2,92	3,25	0,67	0,66
20	5,33	5,35	5,12	5,56	6,54	0,007	0,010	0,008	0,012	0,009	5,82	1,89	3,01	0,75	0,92
21	0,38	0,31	0,72	0,97	1,02	0,004	0,009	0,005	0,007	0,003	1,42	0,97	1,46	2,00	1,01
22	4,33	5,03	8,99	4,69	7,54	0,005	0,018	0,004	0,006	0,004	1,32	1,24	1,81	0,66	0,45
23															
24	4,42	2,24	7,53	5,71	6,10	0,006	0,007	0,003	0,010	0,008	1,07	0,93	1,78	1,48	1,69
25	1,51	3,63	1,79	3,90	2,97	0,015	0,009	0,003	0,004	0,011	0,87	0,96	0,80	0,83	0,81
26	1,25	3,46	2,44	1,18	0,54	0,004	0,003	0,006	0,006	0,002	0,42	0,79	0,85	0,67	0,64
27	2,86	4,68	5,24	3,86	4,53	0,006	0,003	0,005	0,005	0,006	1,38	1,71	1,78	1,17	1,41

Appendix C.2b: Standard deviations of closed draw resistance and degree of filter ventilation of cigarettes for all laboratories (ID)

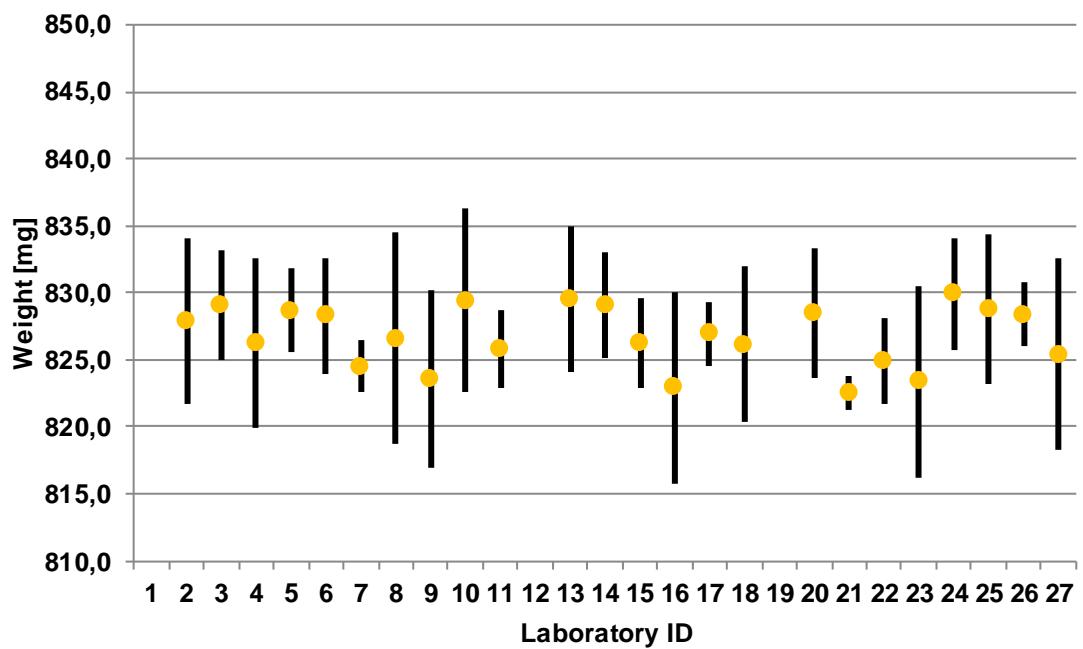
ID	Closed Draw Resistance					Degree of Filter Ventilation				
	mg					%				
	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
1							0,43	0,80	0,69	0,20
2	5,86	5,52	3,43	2,71	1,98	0,17	0,66	1,05	0,50	0,28
3	9,08	1,37	1,36	2,98	4,13	0,50	0,48	0,73	0,60	0,76
4	4,19	2,56	1,96	1,75	2,16	0,19	0,36	0,64	0,34	0,49
5	6,84	1,98	0,99	2,30	2,85	0,20	0,22	0,83	0,58	0,35
6	3,42	3,91	3,12	1,15	1,92	0,35	2,12	0,65	0,50	0,84
7						0,21	0,43	1,30	0,43	0,66
8										
9	1,26	3,35	2,22	2,28	1,52	0,24	0,67	0,66	0,57	0,70
10	4,90	0,98	1,41	2,55	1,98	0,28	0,30	0,54	0,35	0,33
11	5,05	1,19	0,95	1,74	0,66	0,42	0,62	0,84	0,43	0,45
12	3,94	3,72	1,63	2,05	1,16	0,57	0,63	1,27	0,42	0,19
13	6,26	4,00	0,89	0,90	2,69	0,27	0,67	0,60	0,33	0,89
14	9,36	2,23	8,03	0,99	3,54	0,23	0,22	0,99	0,36	0,55
15										
16			1,49	1,17	0,67			1,83	0,45	0,83
17	10,60	2,71	3,43	1,06	2,73	0,88	0,29	1,06	0,88	0,63
18						0,32	0,58	0,62	0,58	0,31
19	8,46	2,91	3,72	1,33	0,97	0,58	0,84	0,81	0,53	0,22
20	9,37	2,52	2,75	1,02	1,53	0,88	0,64	1,25	0,21	0,83
21	5,48	1,36	1,80	1,84	0,88	0,17	0,31	0,74	0,31	0,47
22	9,95	2,13	3,36	1,18	1,29	0,36	0,96	0,77	0,20	0,28
23										
24	9,54	2,94	2,70	2,52	2,27	0,24	0,55	0,60	0,39	0,47
25	6,29	3,02	1,77	1,38	2,04	0,46	0,78	0,56	0,57	0,32
26	2,22	2,17	0,76	1,39	0,77	0,17	0,86	0,28	0,28	0,37
27	2,40	2,56	1,40	1,95	2,15	0,50	0,29	0,67	0,20	0,31

APPENDIX D – Results for Filter Rods (Diagrams)

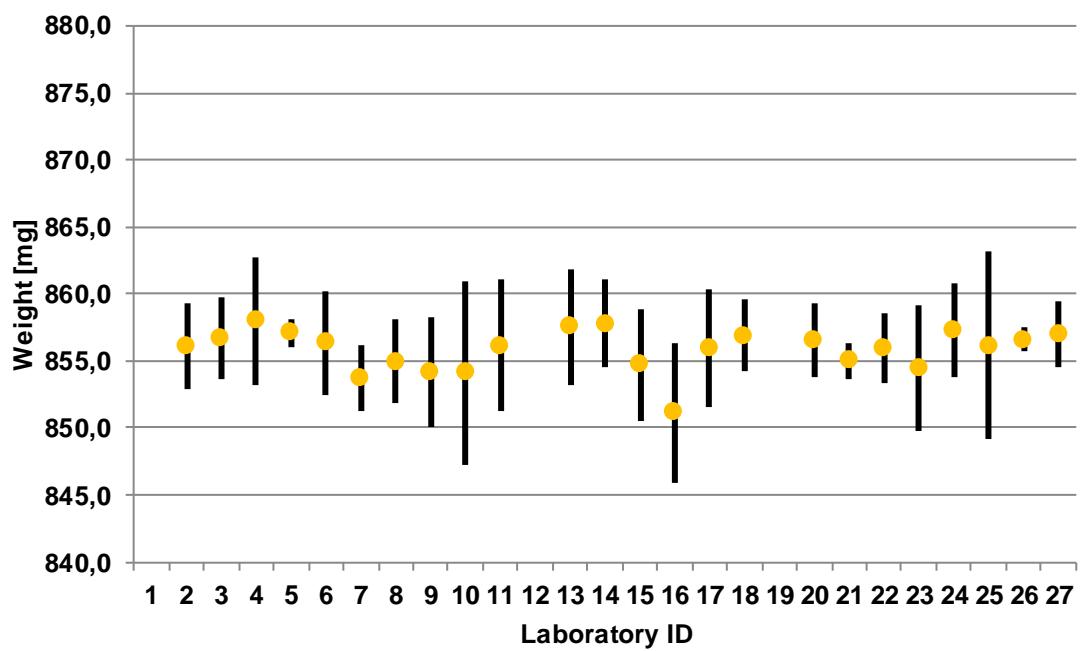
Appendix D.1: Weights of filter rods F1-F5

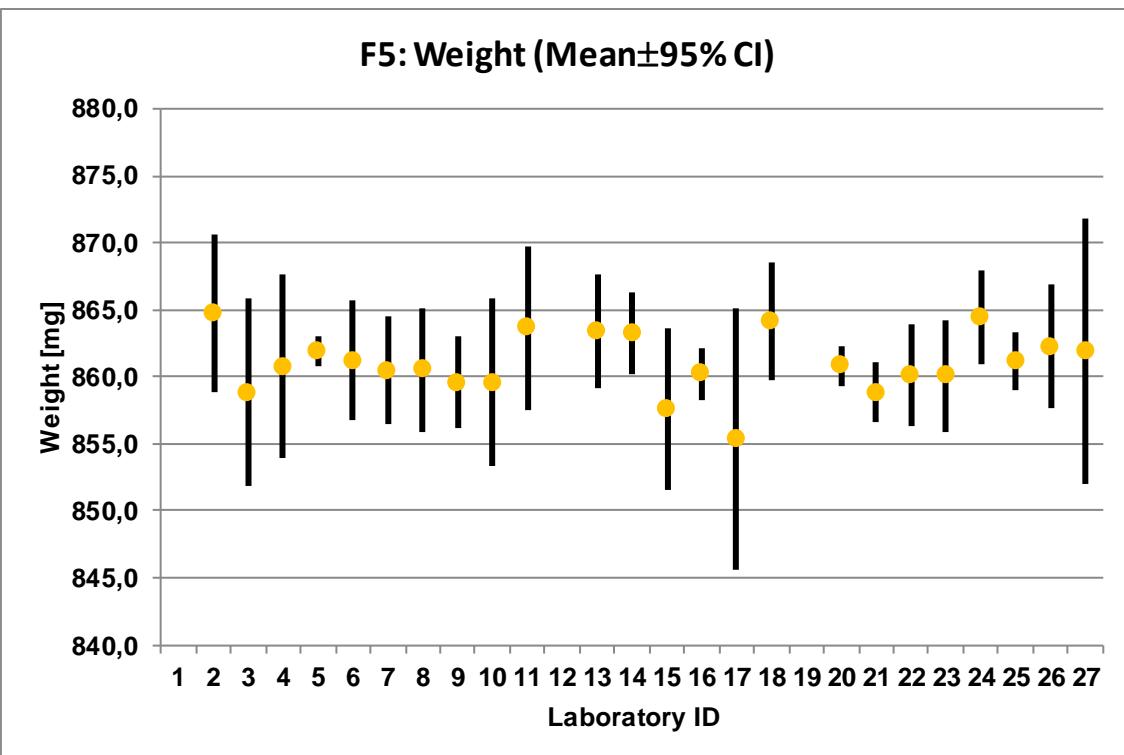


F3: Weight (Mean \pm 95% CI)

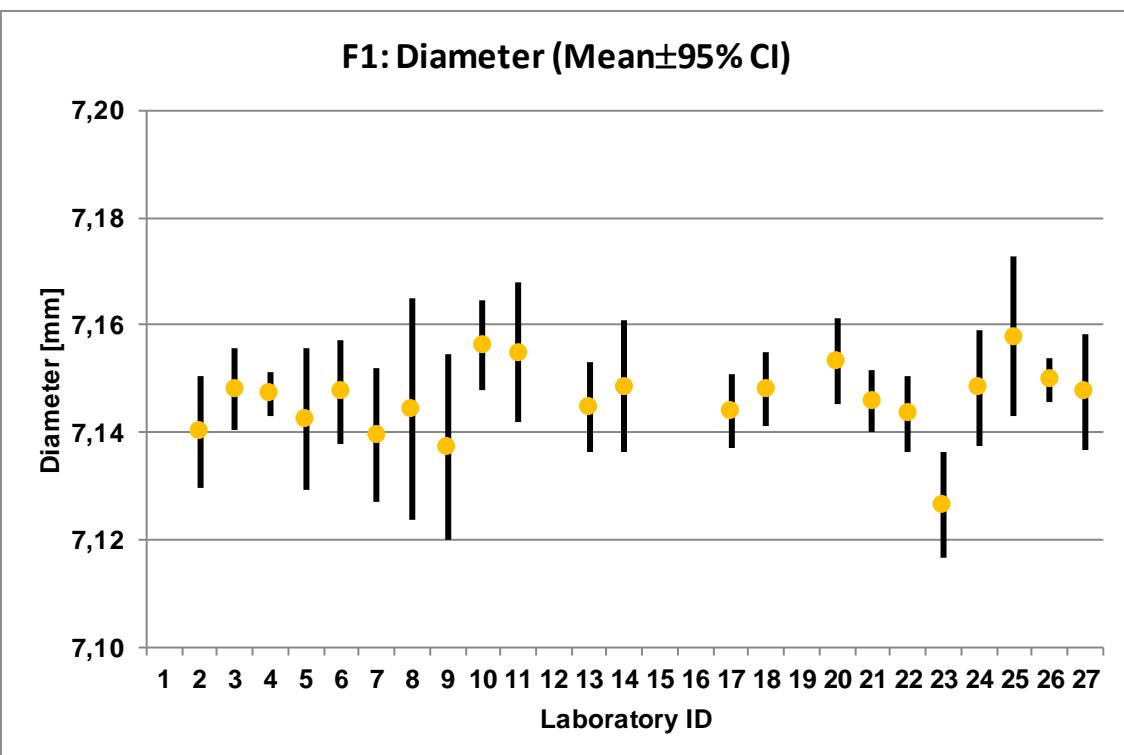


F4: Weight (Mean \pm 95% CI)

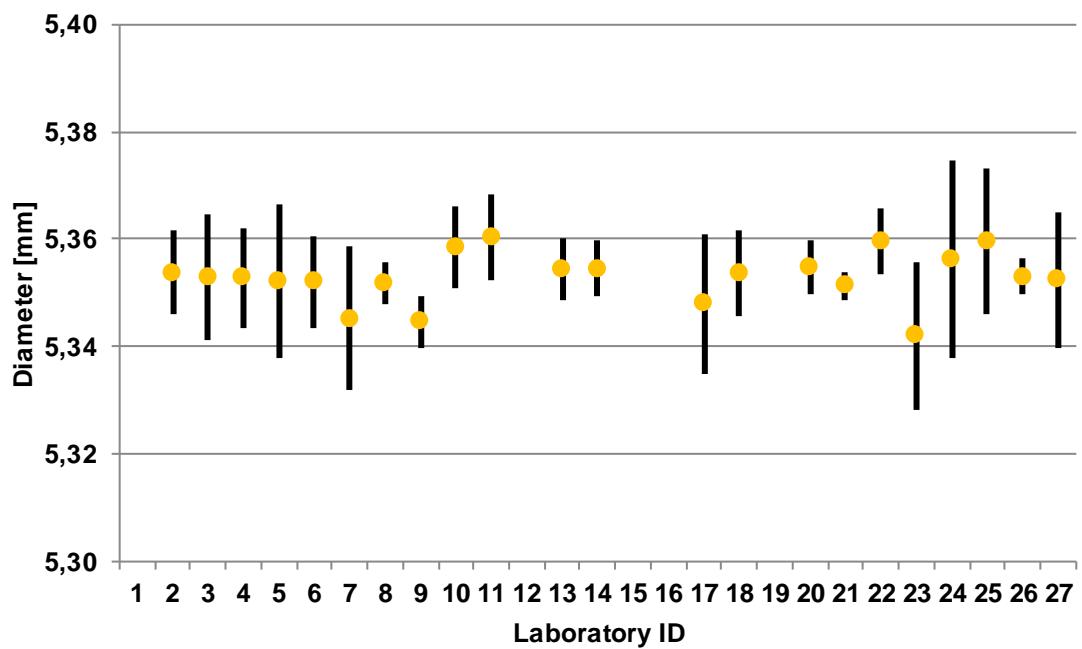




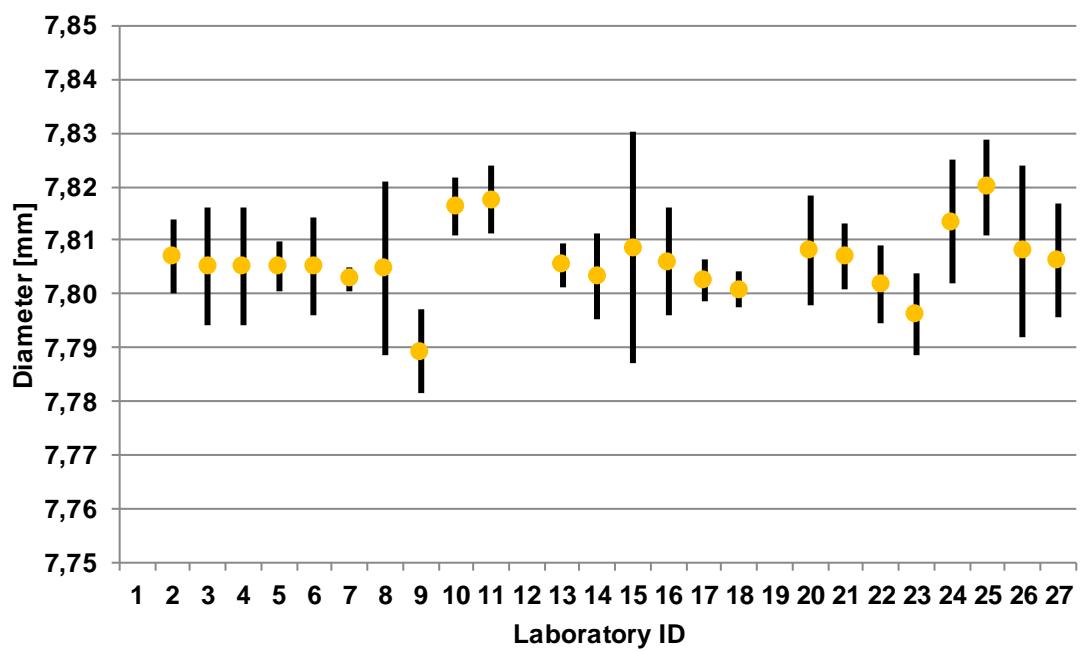
Appendix D.2: Diameters of filter rods F1-F5



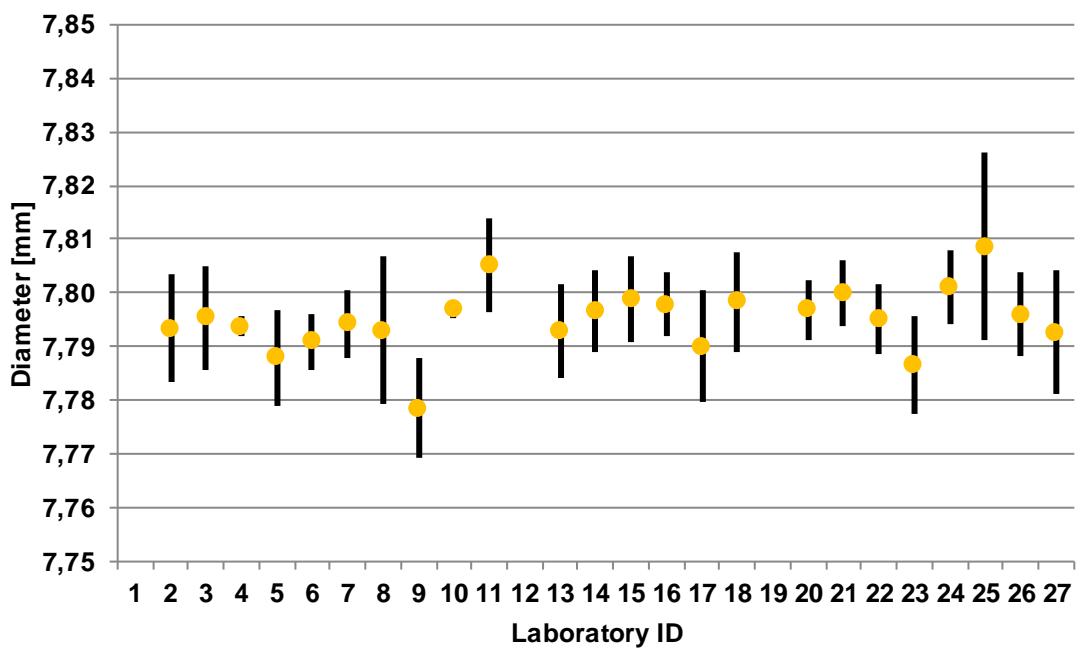
F2: Diameter (Mean \pm 95% CI)



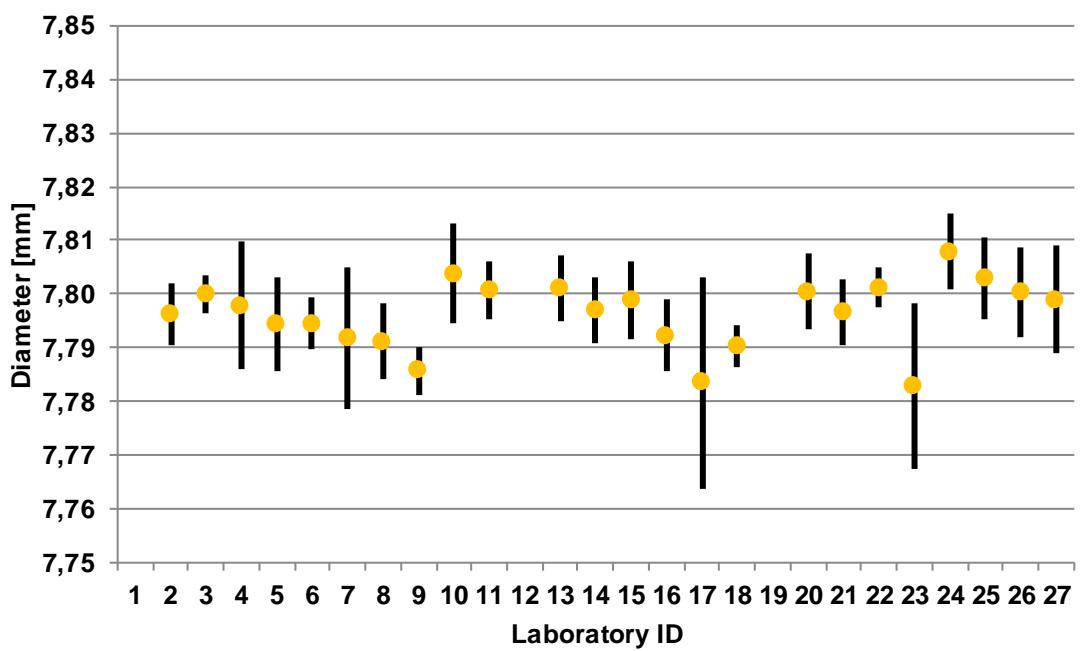
F3: Diameter (Mean \pm 95% CI)



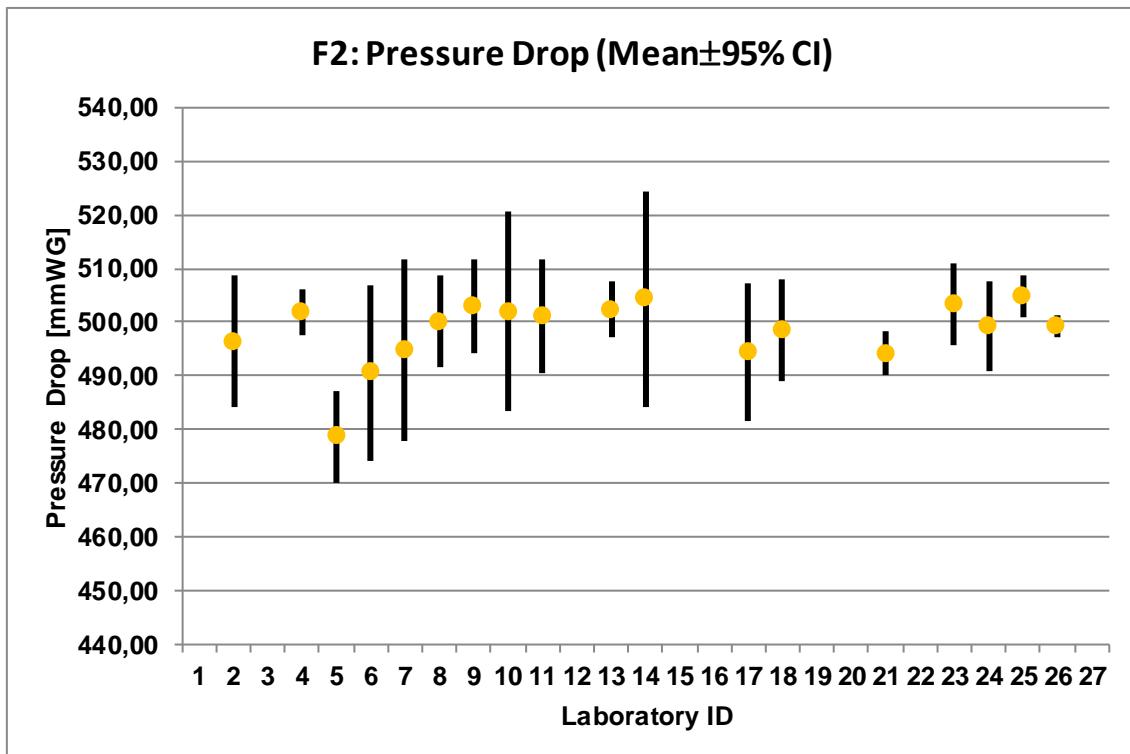
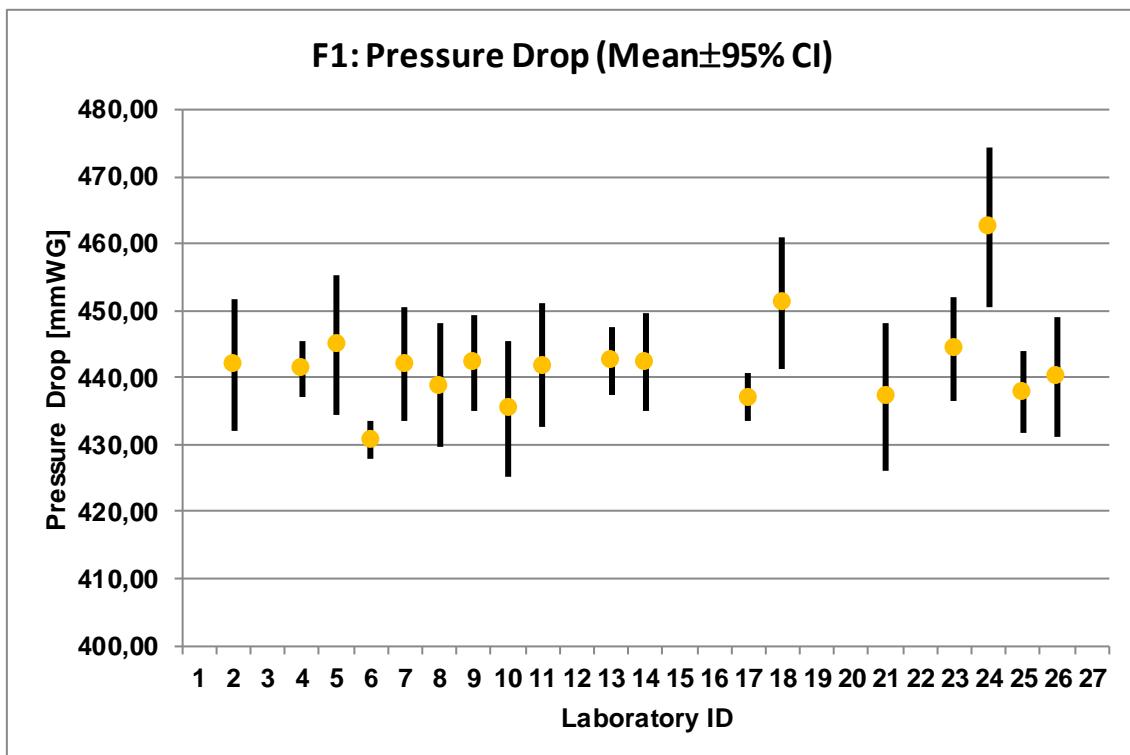
F4: Diameter (Mean \pm 95% CI)



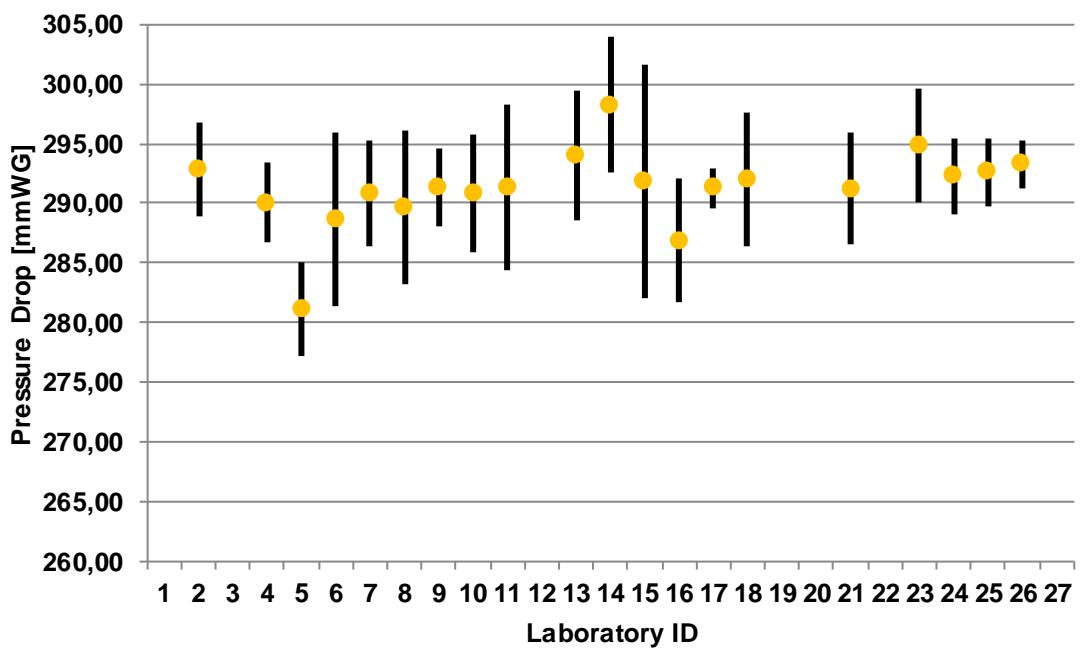
F5: Diameter (Mean \pm 95% CI)



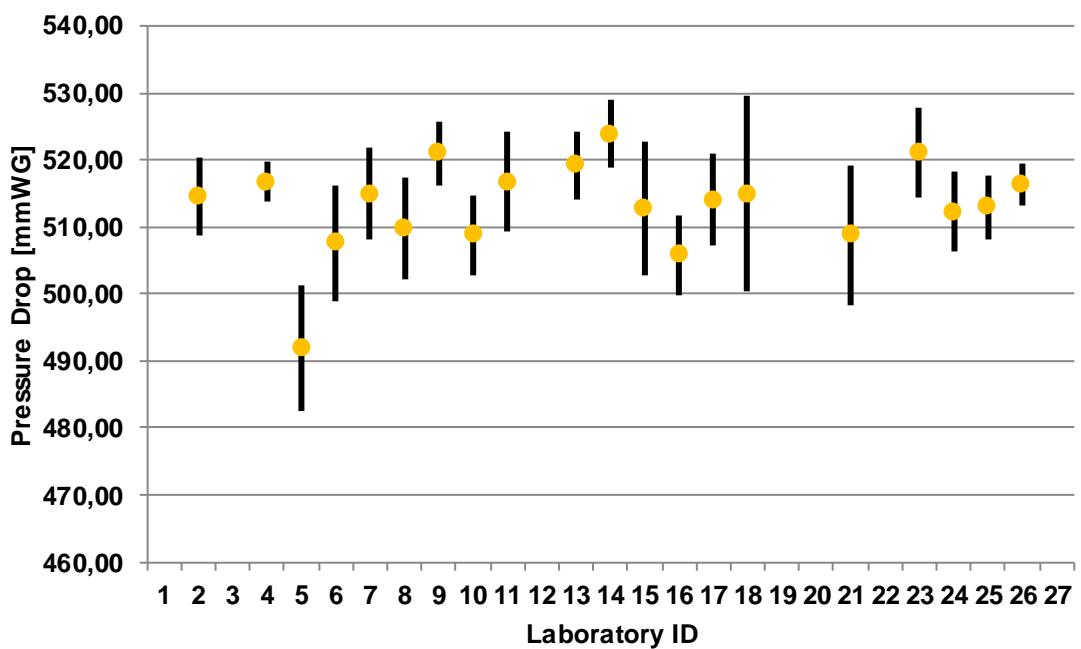
Appendix D.3: Fully encapsulated pressure drops of filter rods F1-F5



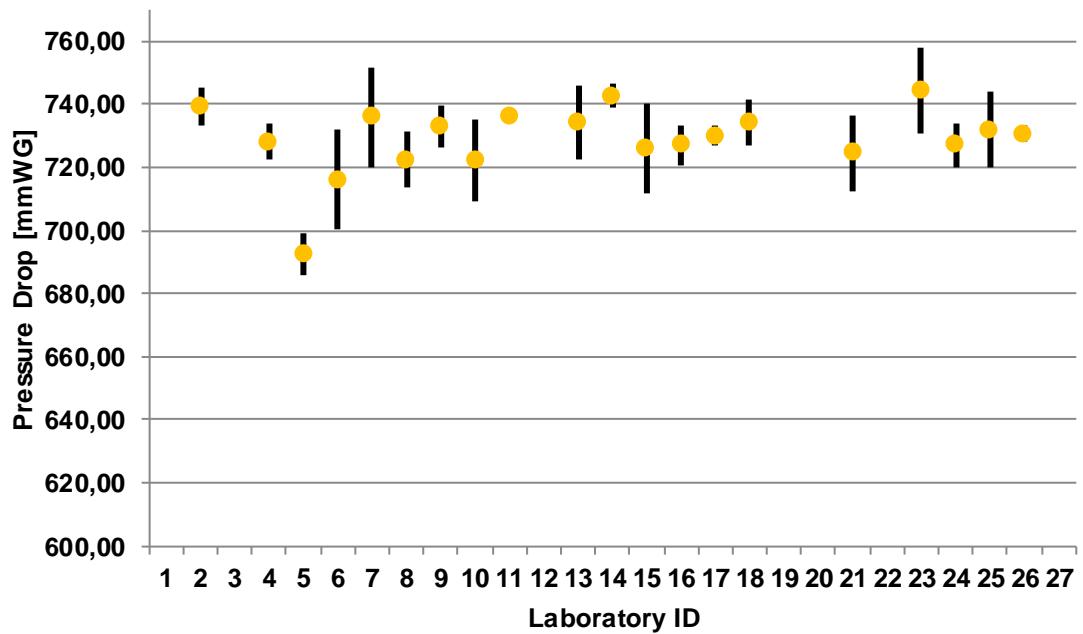
F3: Pressure Drop (Mean \pm 95% CI)



F4: Pressure Drop (Mean \pm 95% CI)

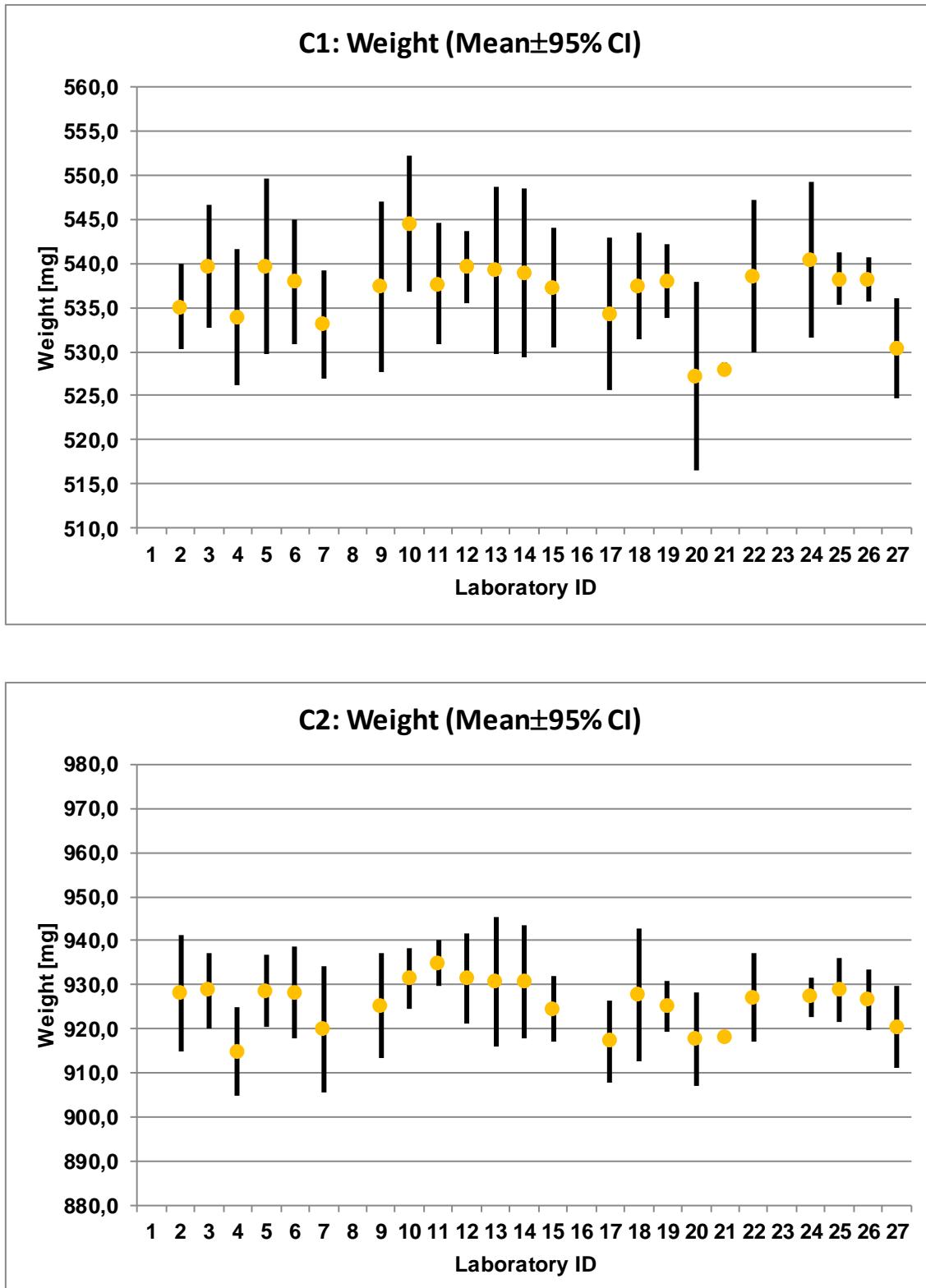


F5: Pressure Drop (Mean \pm 95% CI)

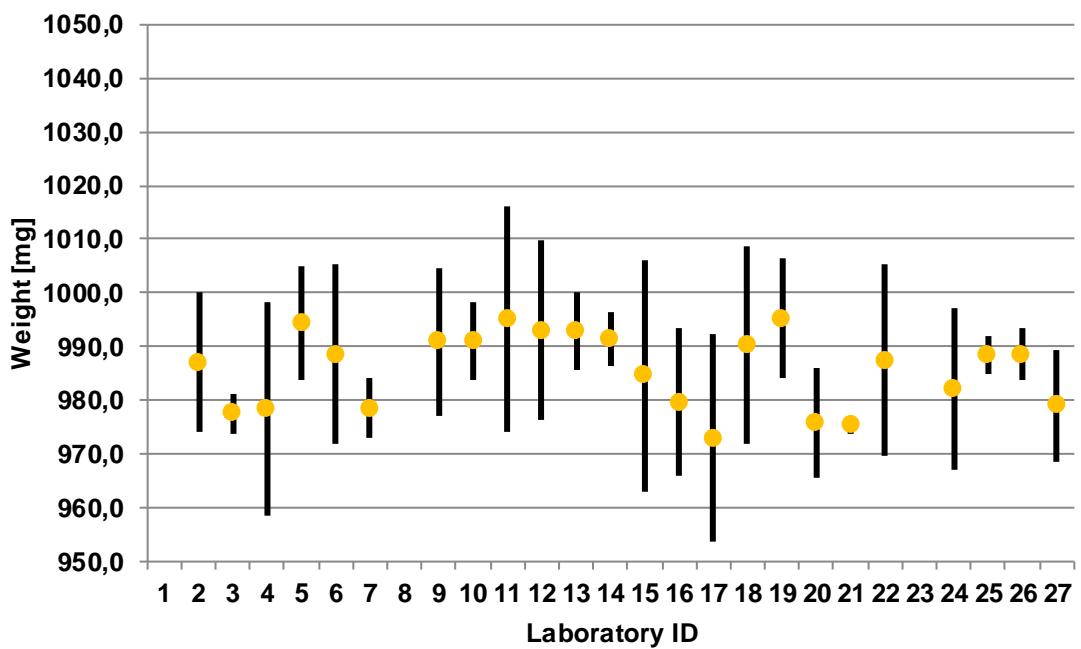


APPENDIX E – Results for Cigarettes (Diagrams)

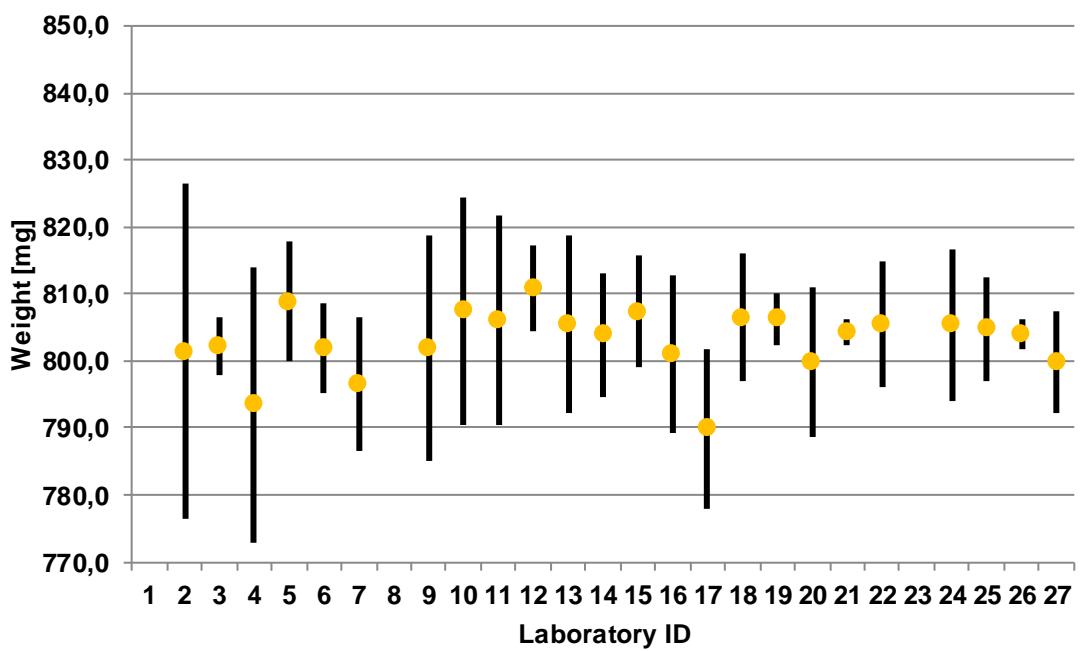
Appendix E.1: Weights of cigarettes C1-C5

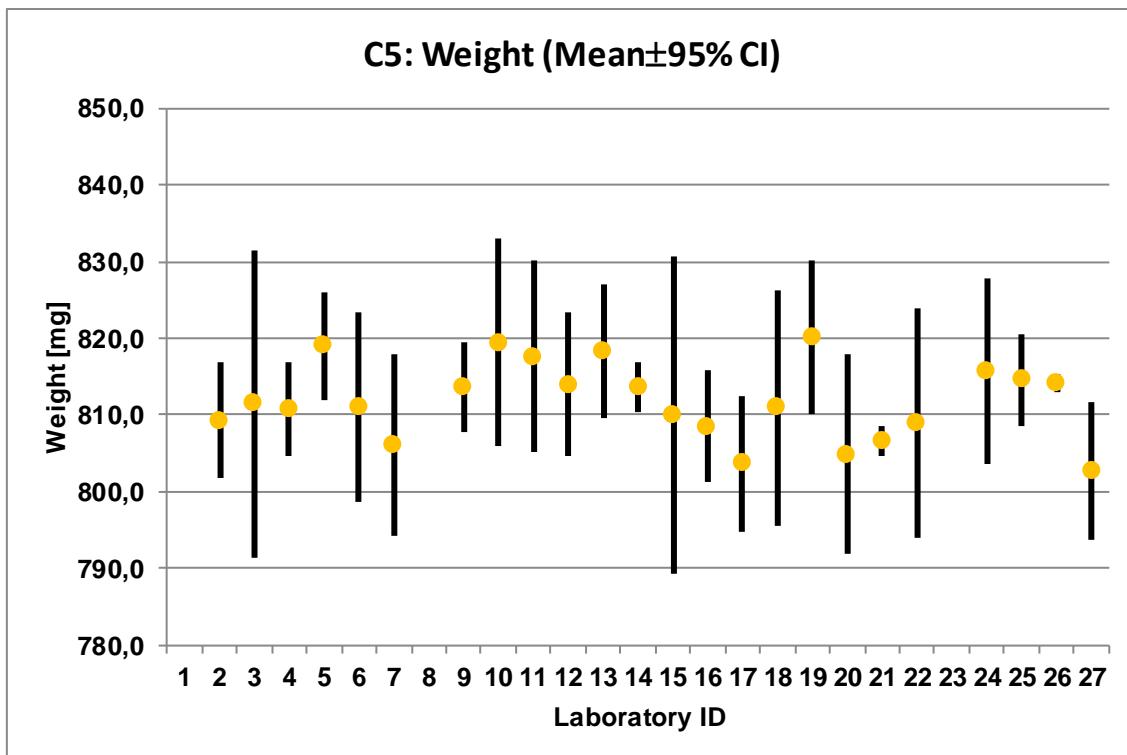


C3: Weight (Mean \pm 95% CI)

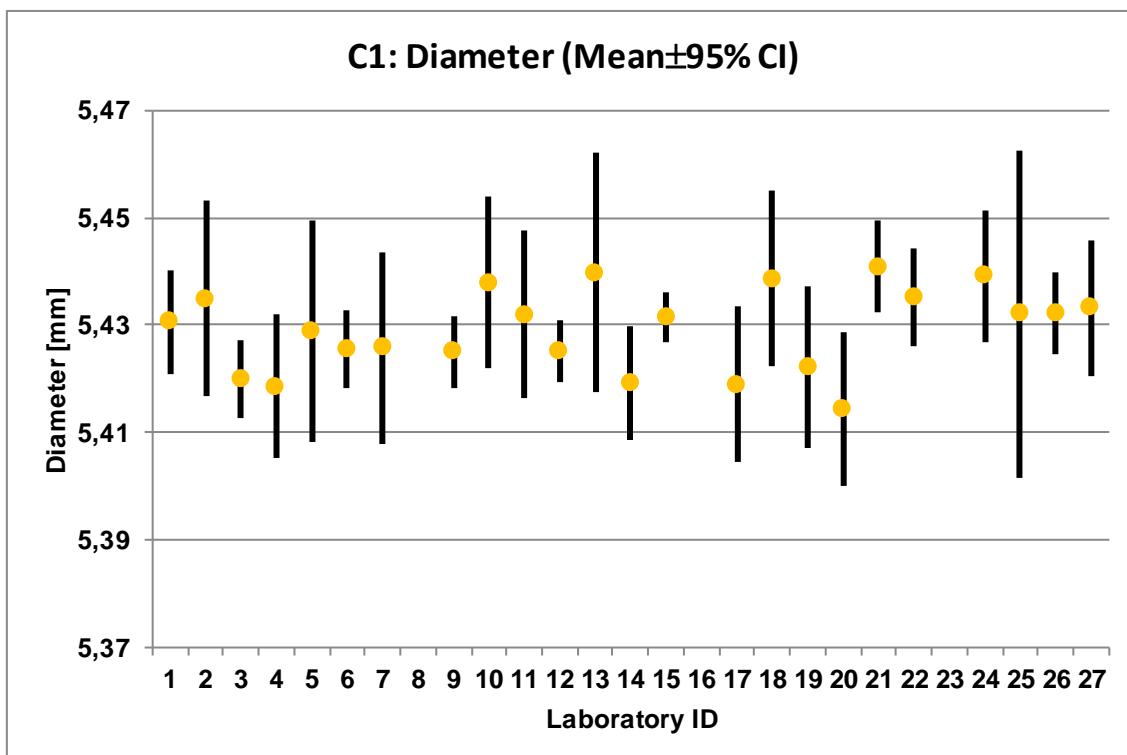


C4: Weight (Mean \pm 95% CI)

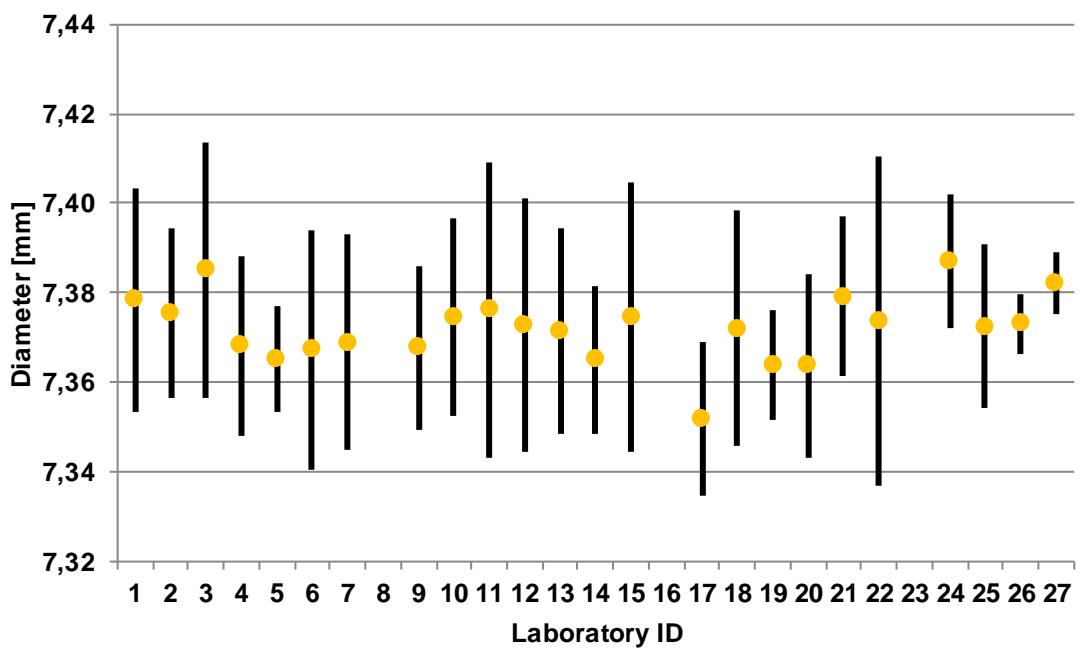




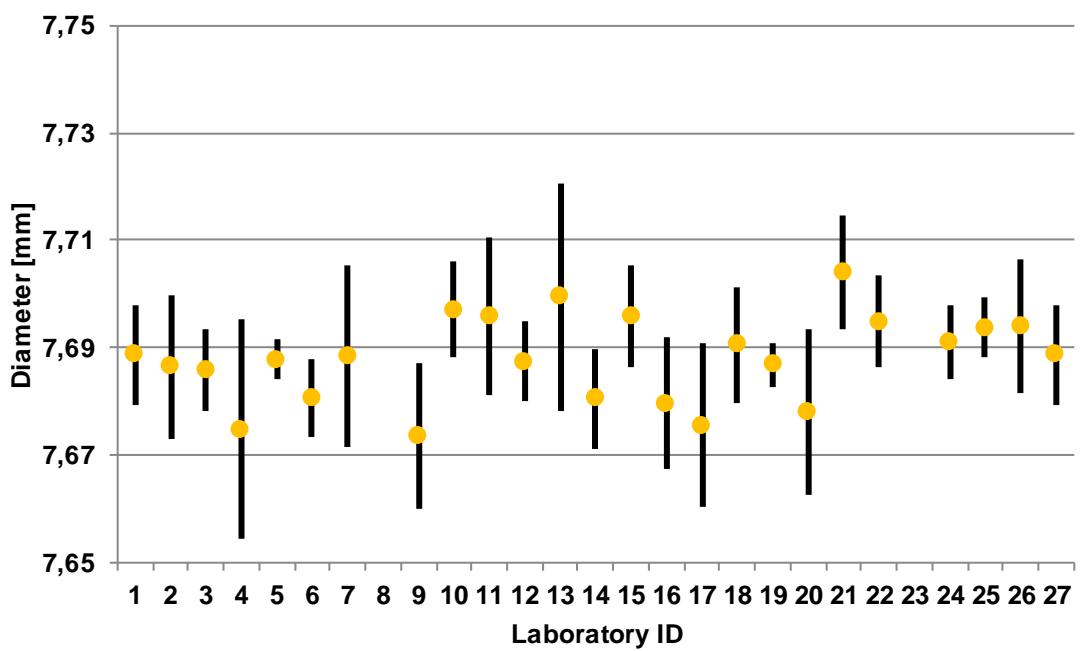
Appendix E.2: Diameters of cigarettes C1-C5



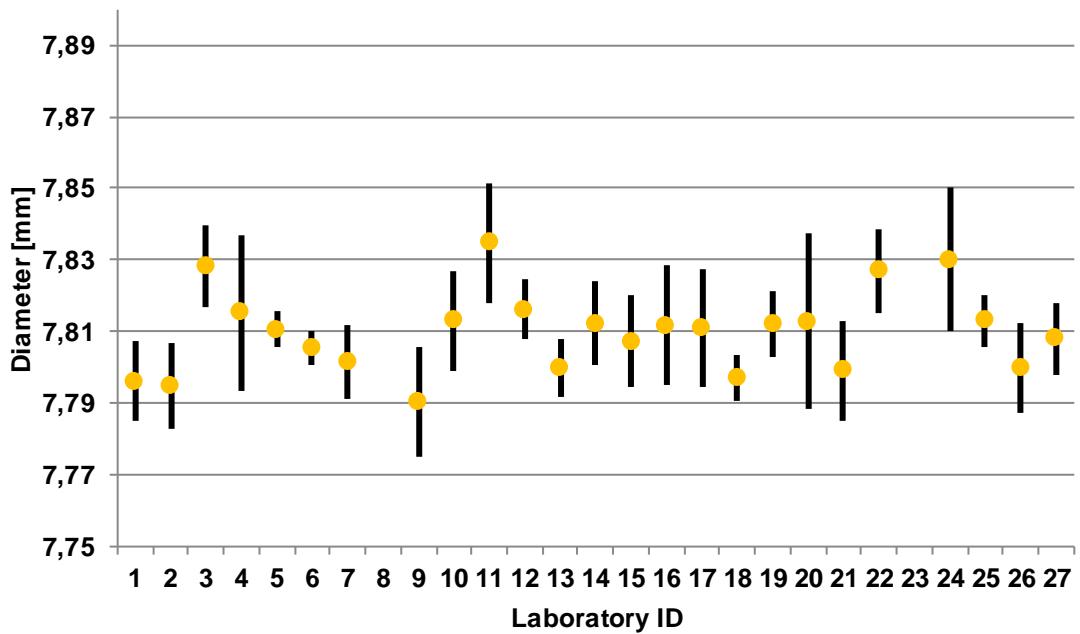
C2: Diameter (Mean \pm 95% CI)



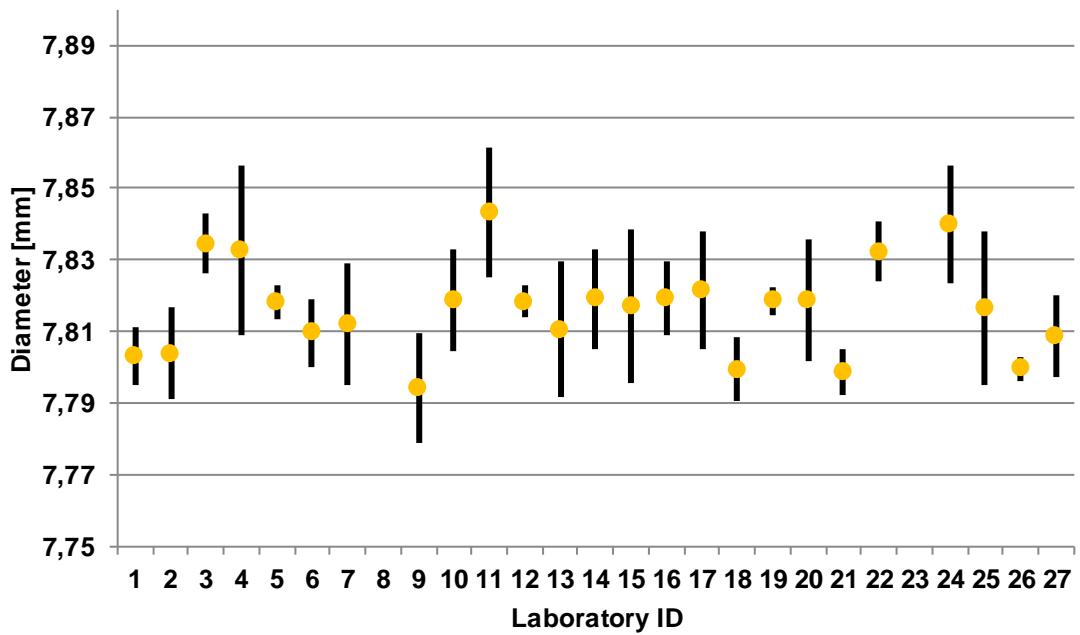
C3: Diameter (Mean \pm 95% CI)



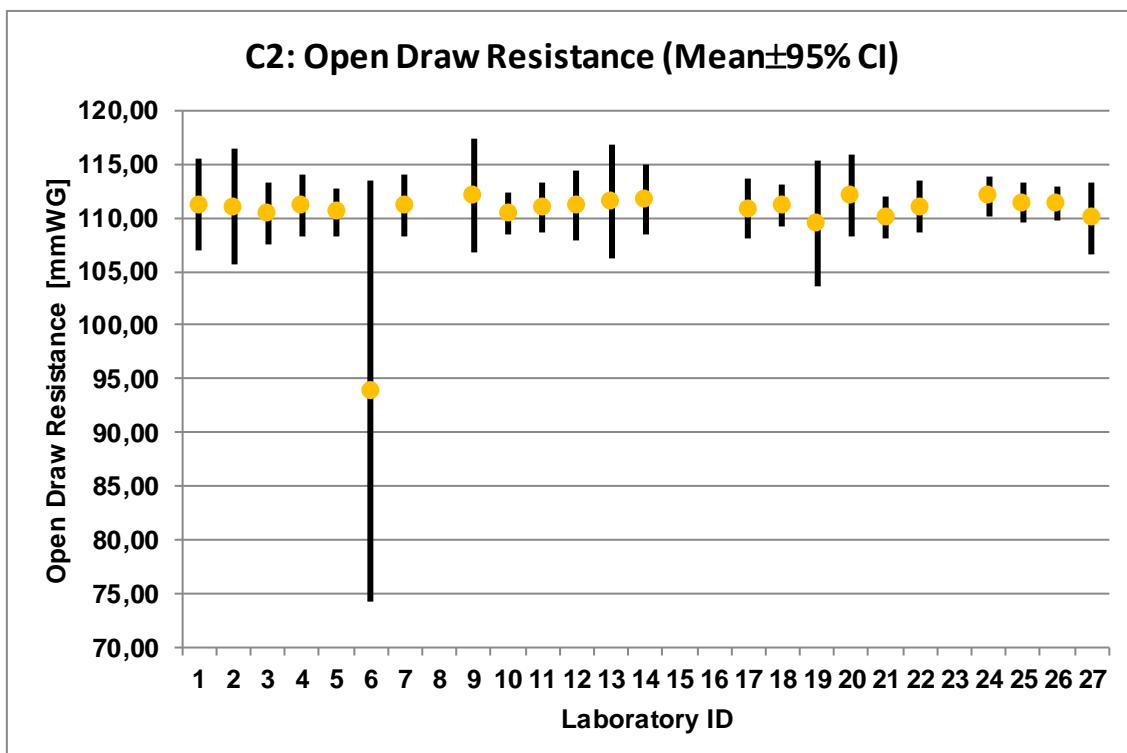
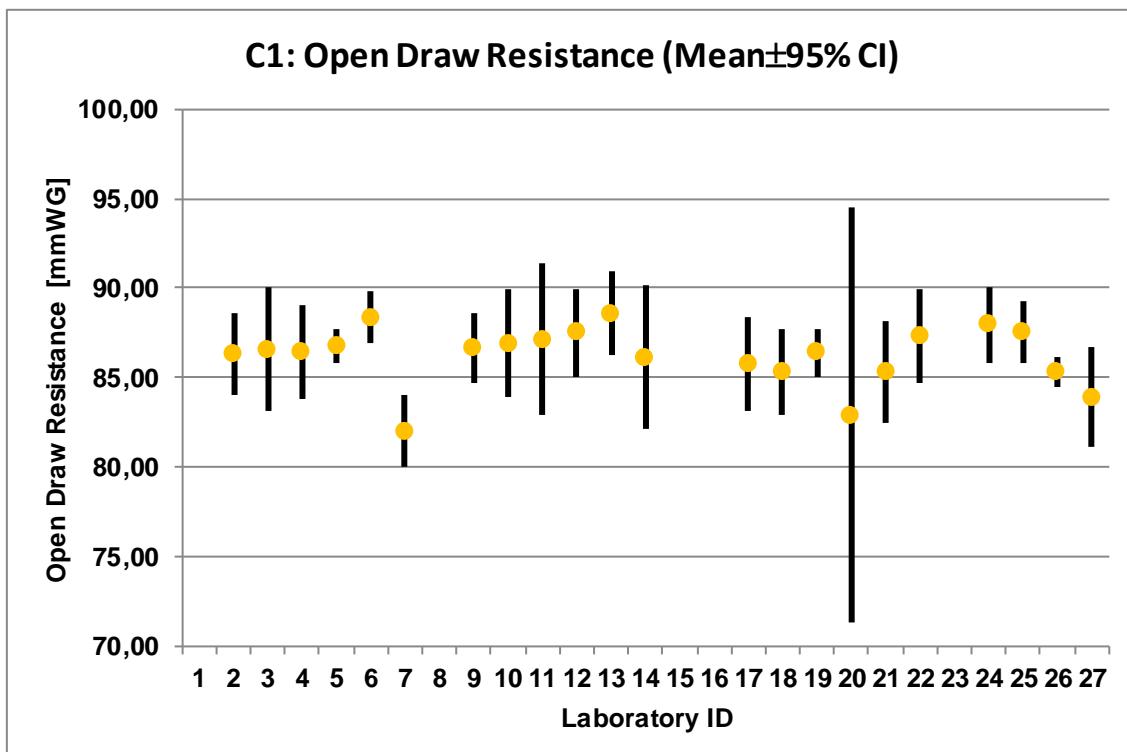
C4: Diameter (Mean \pm 95% CI)



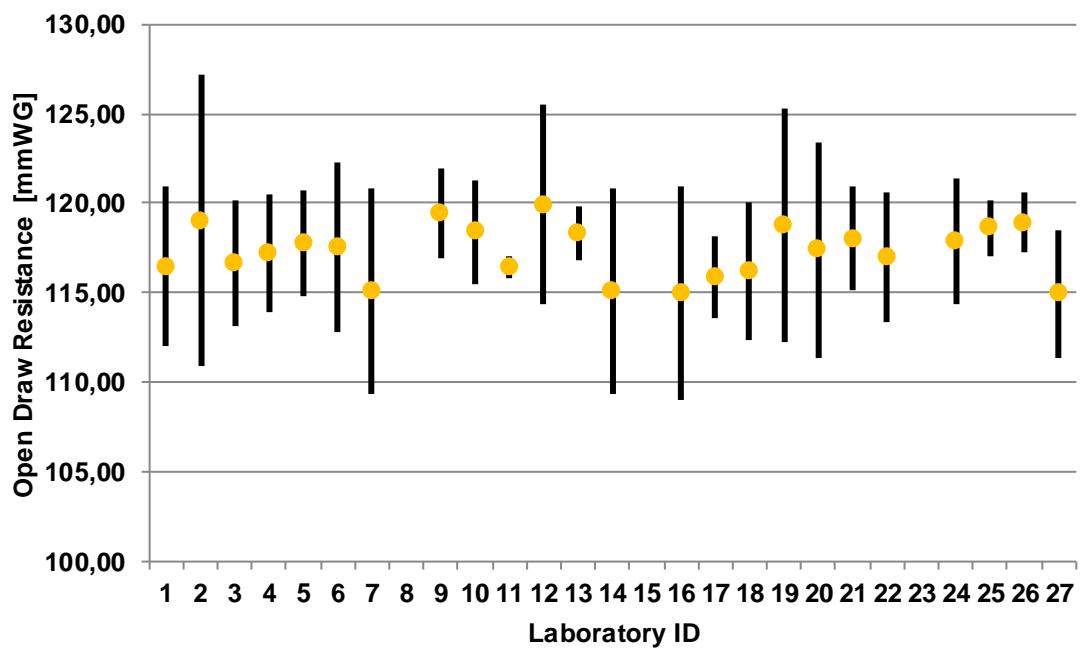
C5: Diameter (Mean \pm 95% CI)



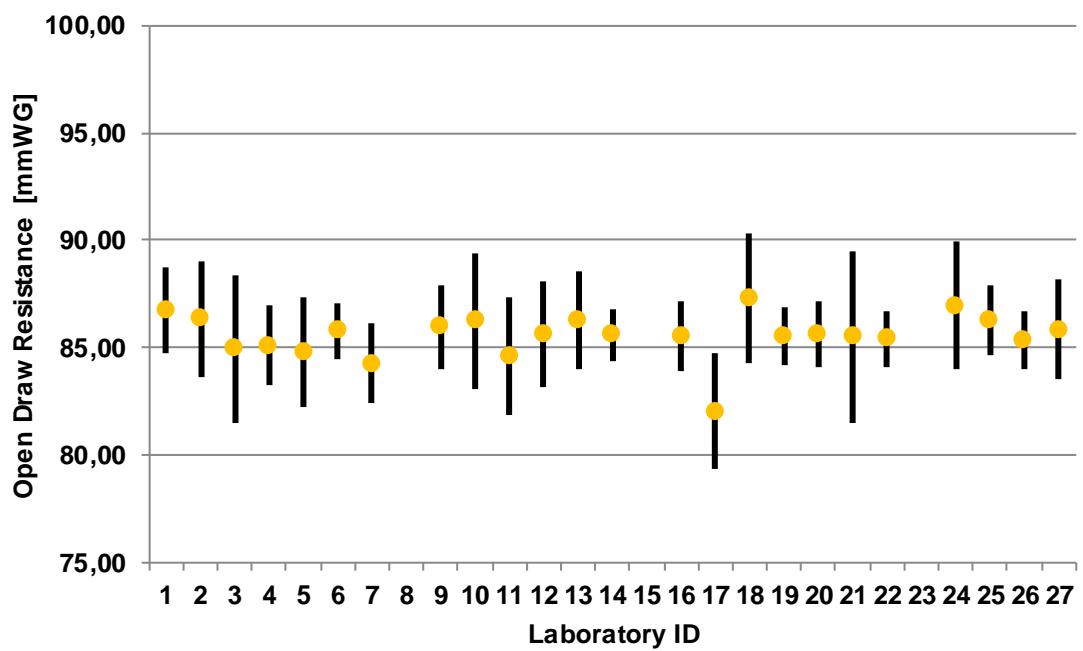
Appendix E.3: Open draw resistances of cigarettes C1-C5

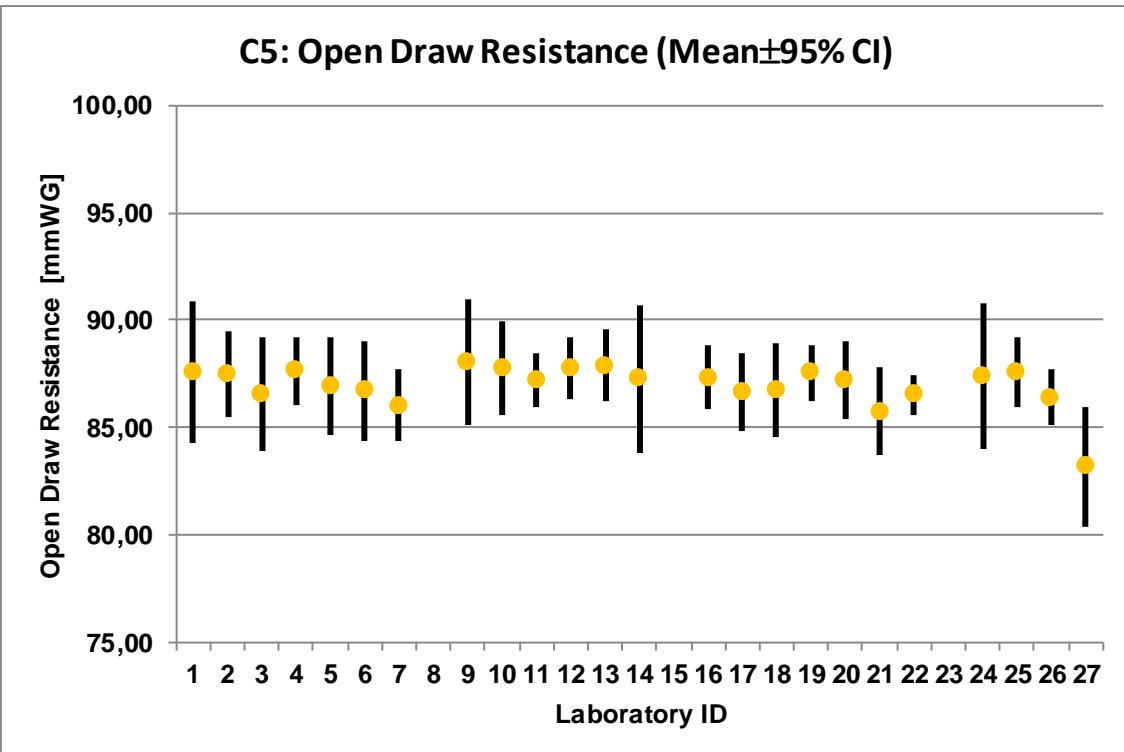


C3: Open Draw Resistance (Mean \pm 95% CI)

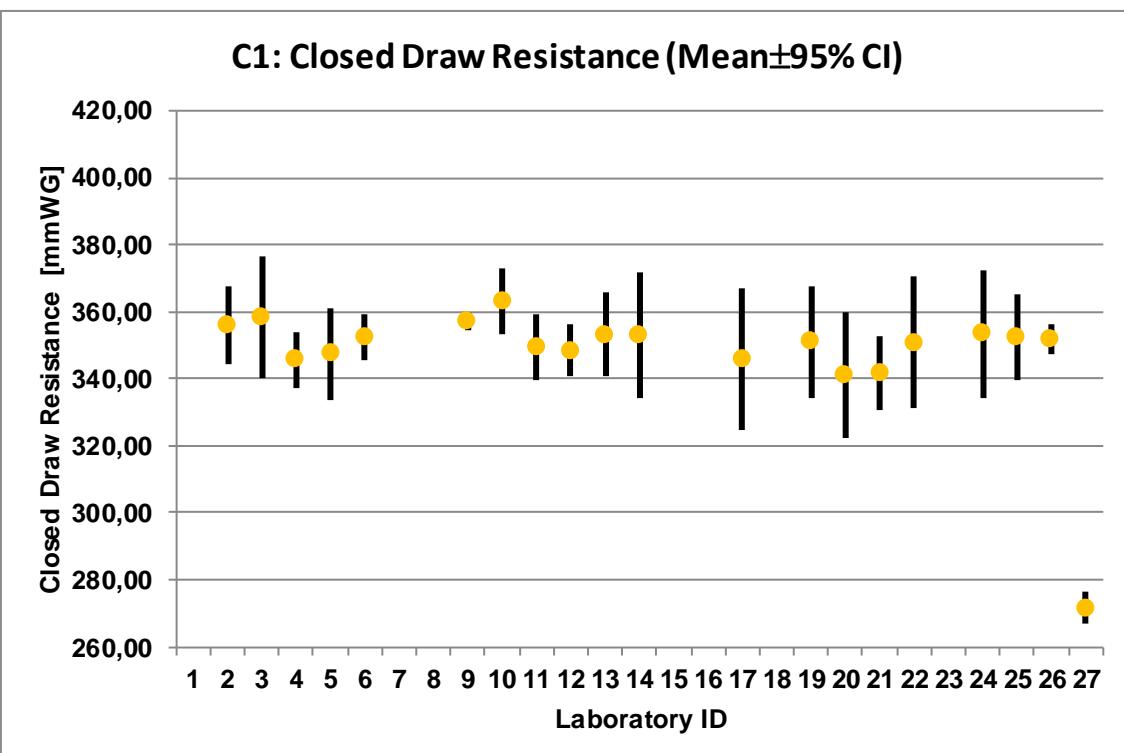


C4: Open Draw Resistance (Mean \pm 95% CI)

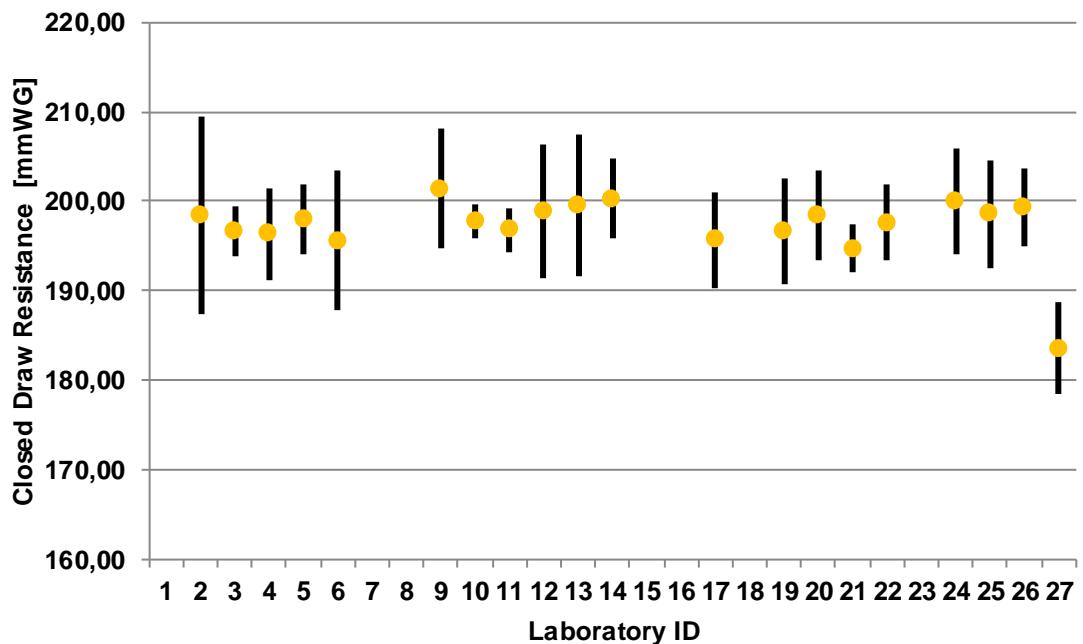




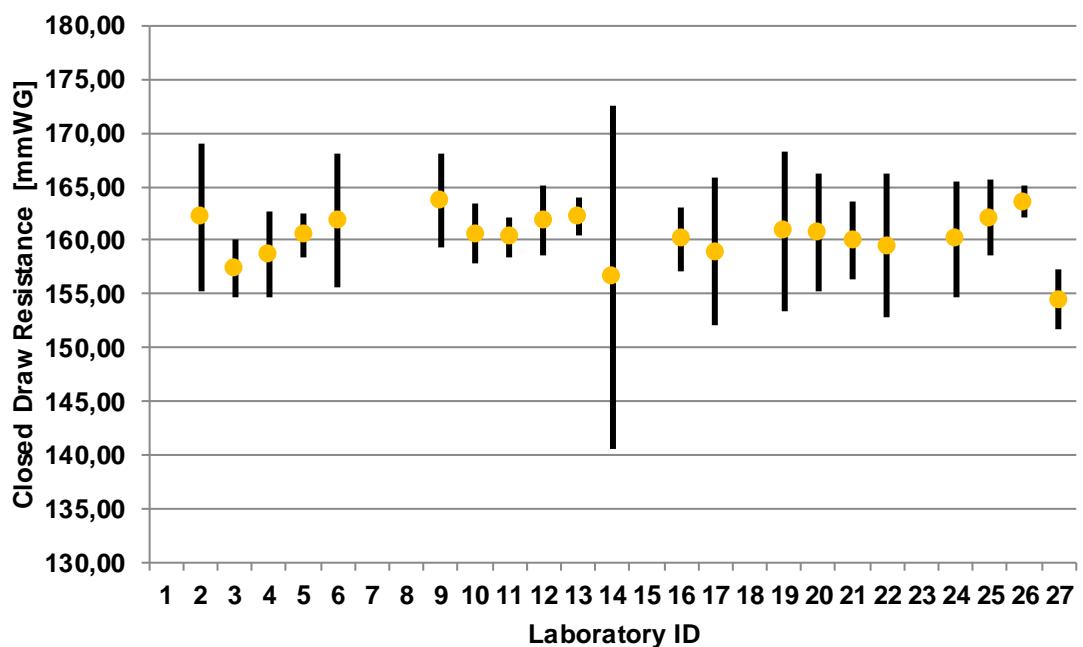
Appendix E.4: Closed draw resistances of cigarettes C1-C5



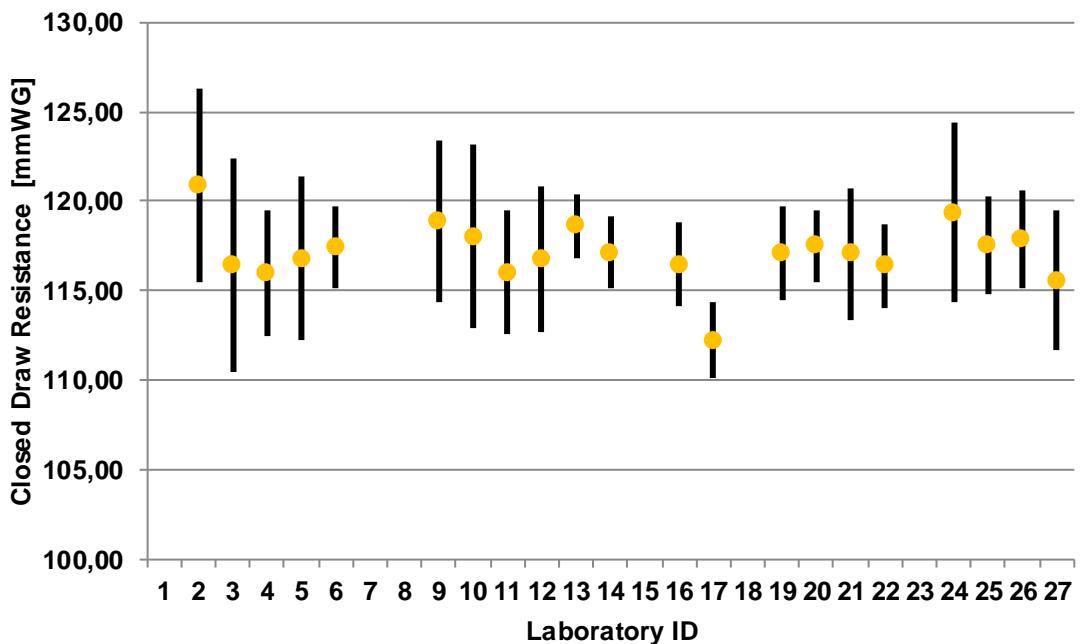
C2: Closed Draw Resistance (Mean \pm 95% CI)



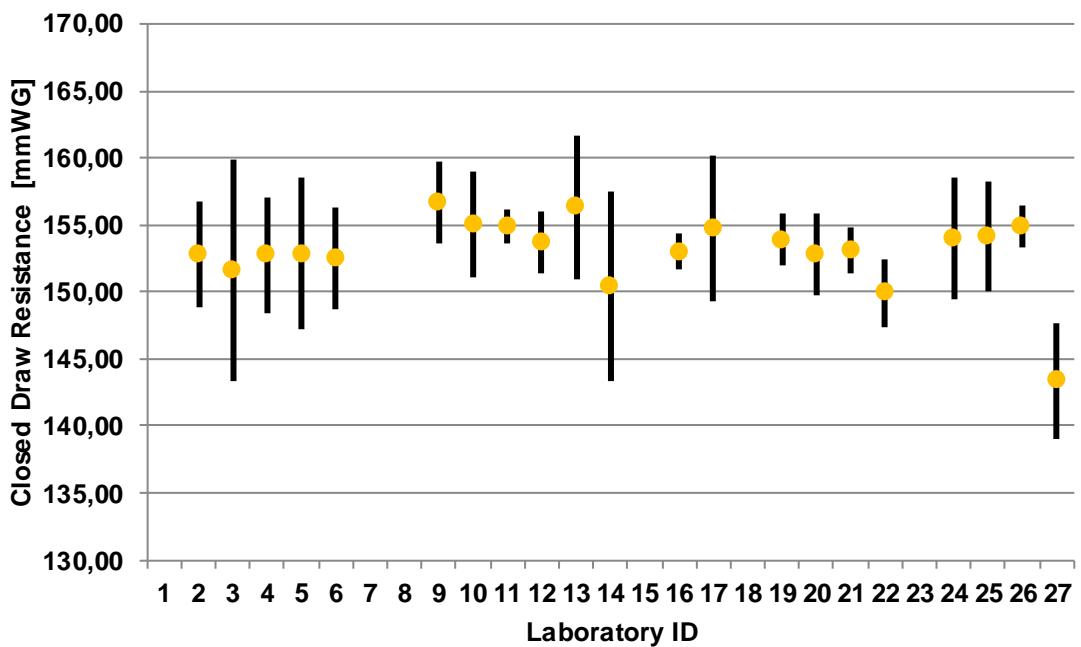
C3: Closed Draw Resistance (Mean \pm 95% CI)



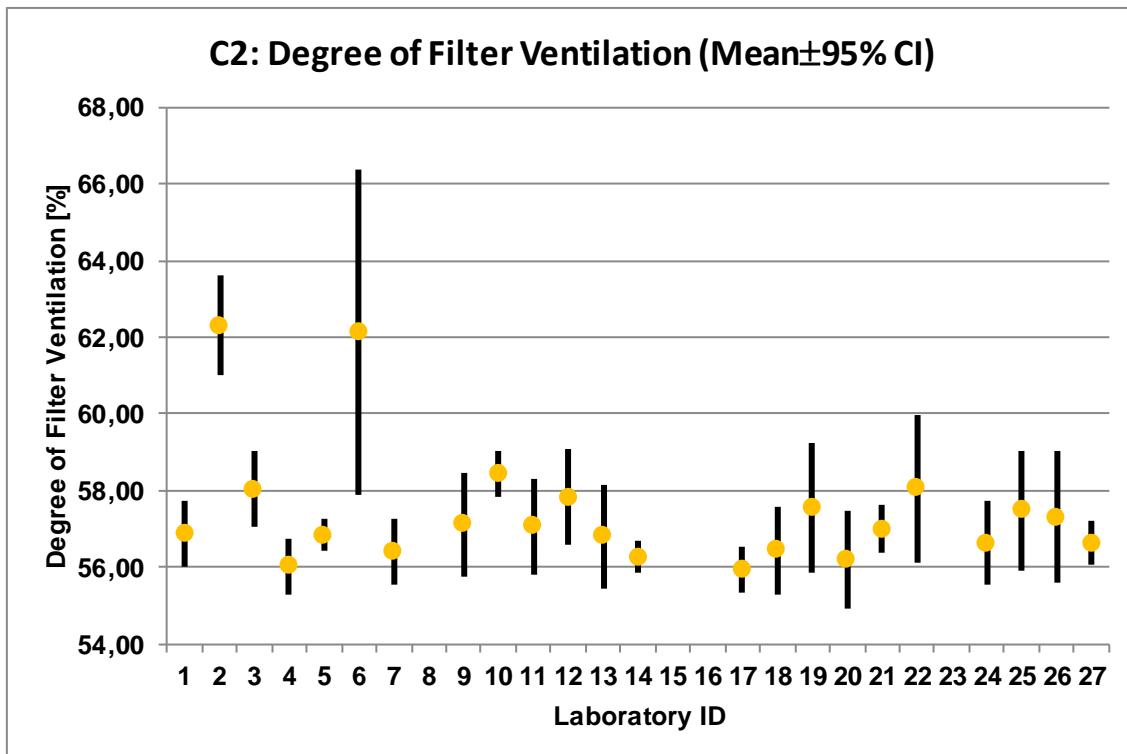
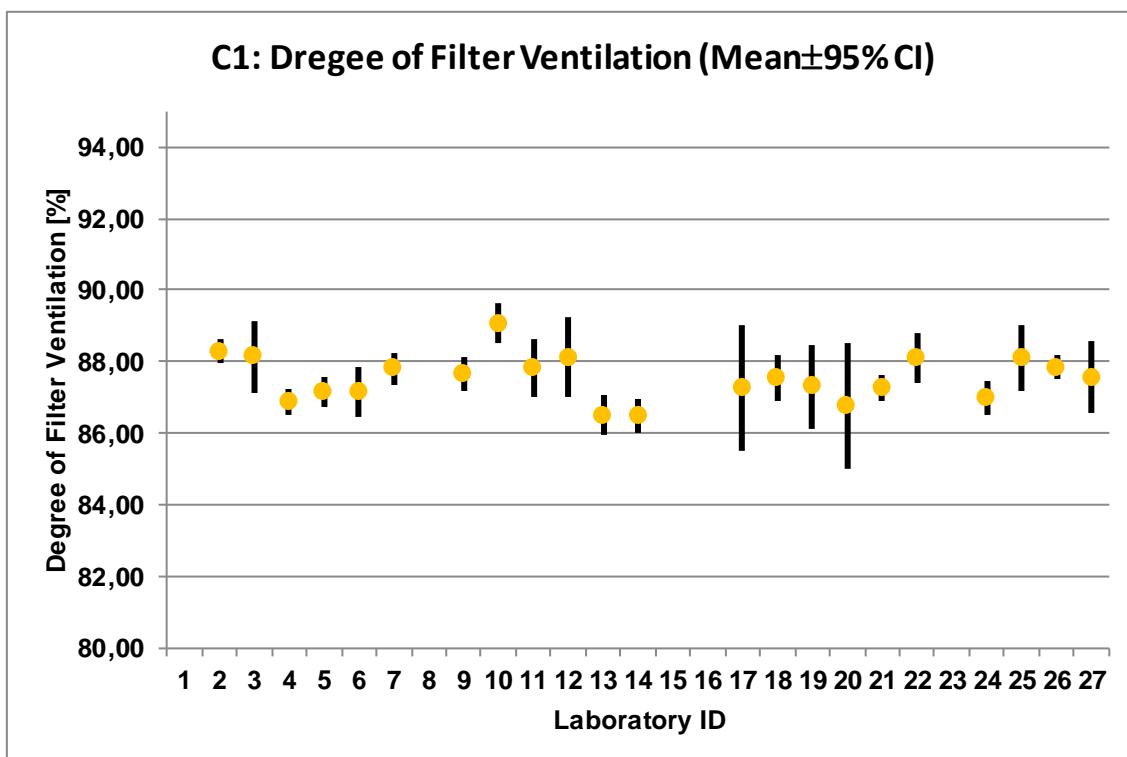
C4: Closed Draw Resistance (Mean \pm 95% CI)



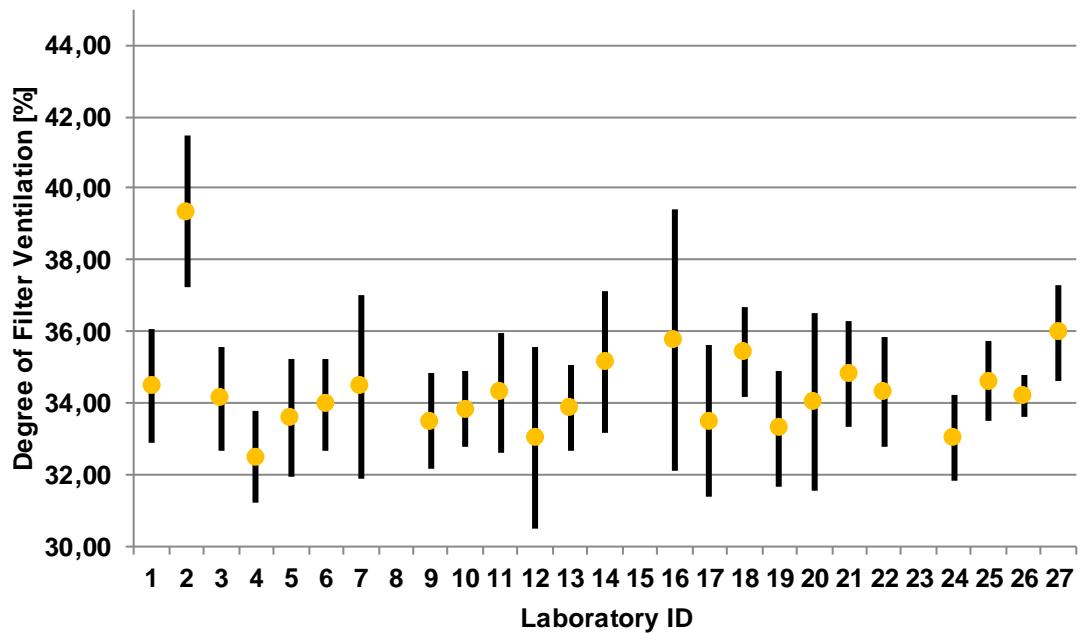
C5: Closed Draw Resistance (Mean \pm 95% CI)



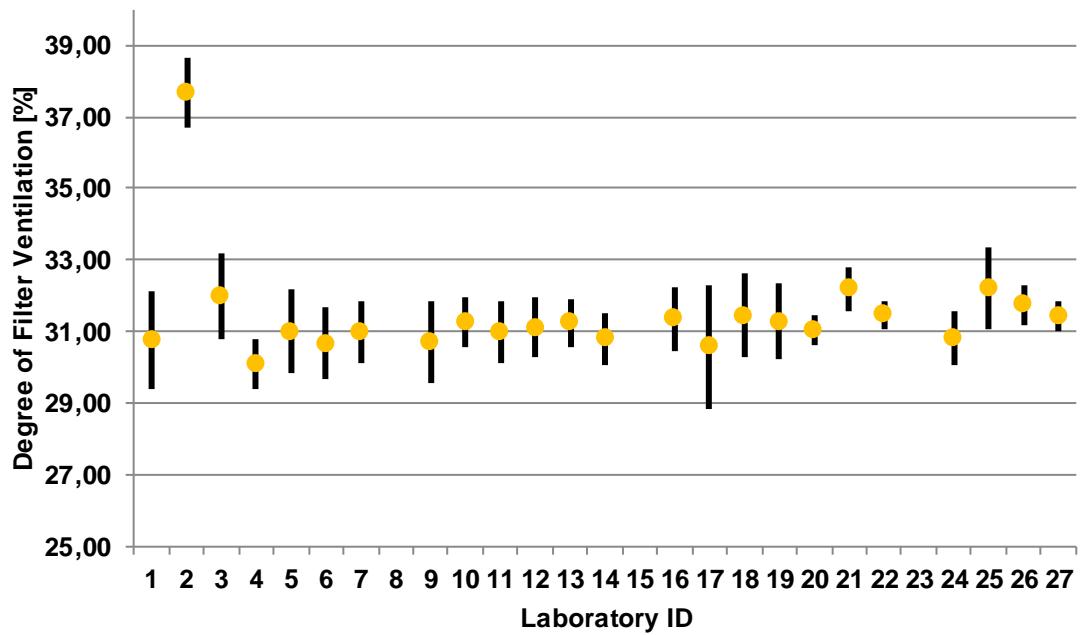
Appendix E.5: Degrees of filter ventilation of cigarettes C1-C5



C3: Degree of Filter Ventilation (Mean \pm 95% CI)



C4: Degree of Filter Ventilation (Mean \pm 95% CI)



C5: Degree of Filter Ventilation (Mean \pm 95% CI)

