



Comparison of the Cerulean EPD-100 e-cigarette pressure drop testing instrument to the CES 508 cigarette pressure drop and ventilation tester unit for electronic cigarettes, conventional tobacco burning cigarettes and filter tips

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Purpose

The “resistance to draw” of cigarettes and cigarette-like products is a prominent experience for consumers. This poster is a comparison of two commercial instruments with different approaches towards measuring the resistance to draw or pressure drop. The instruments compared are the Cerulean EPD100 e-cigarette testing instrument and the CES 508 cigarette pressure drop and ventilation tester. The design of the two test units differ significantly as the Cerulean unit forces air out through the test article, versus the CES 508 instrument draws air through the test article. The comparison was made using samples of commercially available electronic cigarettes (e-cigs), conventional tobacco-burning cigarettes, and filter tips. Overall both test units provided comparable results within a range up to 200-mm H₂O pressure drop. This poster will present the correlation and bias between the two different unit designs. In addition, the preliminary findings of this study suggest that conventional tobacco burning products and filter tips demonstrate very low variability from unit to unit whereas the variance between units for electronic cigarettes is generally more variable, presumably due to the handmade nature of many of these type products compared to the more conventional products that are machine made.

Methods

- Six electronic cigarettes and 5 conventional cigarette varieties were purchased at retail. Four filter tip sets of varying pressure drops were manufactured internally.
 - Electronic cigarette varieties included 3 rechargeable, 2 disposable and 1 tank system.
 - The 5 conventional cigarette types ranged in pressure drop from 90 mm H₂O to 130 mm H₂O.
 - The filters were designed at pressure drops of approximately 75, 100, 125 and 150 mm H₂O.
- A total of five units of each specific product was tested and each individual unit was evaluated with 5 replicates.
- All products were conditioned according to ISO 3402:1999.
- Liggett measured the pressure drop using a Cerulean EPD 100 e-cigarette pressure drop unit.
- Eastman measured the pressure drop using a CES 508 cigarette pressure drop and ventilation tester.

Results

The Cerulean EPD100 e-cigarette testing instrument is designed to force air through the test article at the rate of 17.5 ml/sec. The CES 508 cigarette pressure drop and ventilation instrument draws air through the test article, and can be set to a flow rate of 17.5 ml/sec. Industry literature suggests that the difference in testing methodologies could lead to a bias in the data based on these air flow differences (1).

A second difference in the instruments is the means of holding the samples. The Cerulean instrument uses encapsulation sleeves, while the CES instrument uses rubber seals equivalent to how cigarettes are held in smoking machines. A third difference is the Cerulean instrument has a maximum allowable pressure drop of 200 mm H₂O whereas the CES 508 instrument can measure up to 1200 mm H₂O. The comparison data are presented in Tables 1 - 3.

Table 1. Sample for Comparing PD Instruments - CES 538 versus Cerulean EPD100 (Filter Tips)

Sample Description	Bias, abs.	Bias, Relative	Eastman PD Results on CES 508					Average	STDEV	Liggett PD Results on Cerulean EPD100					Average	STDEV
			1	2	3	4	5			1	2	3	4	5		
Filter Rod A	0	1.3	78	76	78	76	77	77	1.0	76	77	78	78	78	77	0.9
Filter Rod A	0	0.0	82	81	82	80	81	81	0.7	80	80	81	81	81	80	0.5
Filter Rod A	-2	1.0	85	84	83	83	84	84	0.8	83	83	83	83	83	83	0.9
Filter Rod A	-2	2.4	84	84	85	84	83	84	0.7	82	82	82	83	83	82	0.5
Filter Rod A	0	2.4	84	84	84	84	84	84	0.0	82	83	84	84	85	84	1.1
Filter Rod B	-3	3.4	101	101	101	102	102	101	0.5	98	98	98	98	99	98	0.5
Filter Rod B	-2	3.0	107	106	108	107	108	107	0.8	104	105	105	106	107	105	1.1
Filter Rod B	0	9.1	117	117	117	116	117	117	0.5	112	112	113	114	114	113	0.8
Filter Rod B	-2	2.6	114	115	115	115	115	115	0.7	112	113	113	114	114	113	0.8
Filter Rod B	4	-2.8	109	109	109	109	109	109	0.0	112	112	114	114	114	113	0.9
Filter Rod C	-3	3.1	127	127	127	127	127	127	0.0	123	124	124	124	125	124	0.7
Filter Rod C	-3	3.7	128	129	129	129	129	129	0.0	124	125	125	126	127	125	1.1
Filter Rod C	4	3.7	130	130	130	130	130	130	0.4	130	130	130	130	130	130	0.8
Filter Rod C	-4	3.4	134	134	134	133	133	134	0.5	129	129	130	131	131	130	1.0
Filter Rod C	-4	3.7	135	135	135	135	135	135	0.0	130	131	131	131	131	131	0.7
Filter Rod D	5	3.5	149	149	149	149	149	149	0.0	144	144	144	145	145	144	0.5
Filter Rod D	6	4.3	153	155	153	154	153	154	0.9	147	147	148	148	149	148	0.8
Filter Rod D	5	4.5	154	155	155	155	155	155	0.7	148	149	150	150	151	150	1.1
Filter Rod D	6	4.4	160	160	160	160	160	160	0.0	153	154	154	154	155	154	0.7
Filter Rod D	5	3.8	162	163	163	162	161	162	0.8	156	156	157	157	158	157	0.8

We found both test units provided similar results with good correlations seen for the glass capillaries (R²=0.999), filter rods (R²=0.991) and conventional cigarettes (R²=0.832) as shown in Figure 1. Comparing best fitting lines we see evidence of a bias which is likely due to the difference in air flow directions and flow rate control. The conventional method of using negative pressure to draw air into a sample uses flow rate control at the sample's exit flow, while using positive pressure which blows air through the sample uses flow rate control at the sample's entrance. The difference causes bias proportional to the expansion of air (1).

Table 2. Sample for Comparing PD Instruments - CES 538 versus Cerulean EPD100 (Conventional Cigarettes)

Sample Description	Bias, abs.	Bias, Relative	Eastman PD Results on CES 508					Average	STDEV	Liggett PD Results on Cerulean EPD100					Average	STDEV
			1	2	3	4	5			1	2	3	4	5		
Conventional Cigarette A	2	-2.8	109	109	109	109	109	109	0.5	112	112	110	110	110	111	1.1
Conventional Cigarette A	1	-2.0	110	110	110	110	110	110	0.4	112	111	111	111	110	111	0.7
Conventional Cigarette A	1	-1.7	107	107	107	107	108	107	0.4	109	109	109	108	108	109	0.5
Conventional Cigarette A	1	-1.9	108	107	108	108	108	108	0.7	110	110	109	109	109	109	0.5
Conventional Cigarette A	2	-2.4	107	107	108	108	107	107	0.5	110	110	110	109	109	110	0.5
Conventional Cigarette B	-13	8.6	124	127	127	128	126	127	0.8	121	122	121	121	121	121	0.4
Conventional Cigarette B	-20	13.8	135	135	136	136	136	136	0.0	121	121	121	121	121	121	0.4
Conventional Cigarette B	-13	8.8	139	131	140	140	135	137	3.9	125	124	123	123	123	124	0.9
Conventional Cigarette B	4	-3.2	120	118	120	118	119	119	0.5	115	115	115	115	114	115	0.7
Conventional Cigarette B	7	-5.5	124	124	127	123	123	124	1.6	131	131	131	132	132	131	0.5
Conventional Cigarette C	-4	2.5	132	133	134	135	133	133	1.1	130	130	130	129	129	130	0.5
Conventional Cigarette C	1	-1.3	136	136	137	135	135	136	0.8	134	134	135	135	135	135	0.5
Conventional Cigarette C	-5	4.2	135	136	131	139	136	137	2.5	122	122	123	123	123	123	0.5
Conventional Cigarette C	-5	3.3	135	133	136	135	135	134	1.3	130	129	129	129	130	129	0.5
Conventional Cigarette C	-5	3.6	135	137	135	138	136	136	1.3	131	131	131	132	132	131	0.5
Conventional Cigarette D	5	-5.4	101	101	100	100	101	101	0.5	106	106	105	105	105	105	0.5
Conventional Cigarette D	1	1.4	117	117	117	116	116	116	0.4	116	117	117	117	117	117	0.4
Conventional Cigarette D	2	-2.2	110	110	109	110	109	110	0.5	112	112	112	112	112	112	0.0
Conventional Cigarette D	4	-3.9	97	97	97	97	98	97	0.4	101	101	101	101	101	101	0.0
Conventional Cigarette D	0	-0.9	112	112	112	112	112	112	0.7	113	113	112	112	112	112	0.5
Conventional Cigarette E	-10	3.0	102	100	106	112	104	109	7.3	99	99	98	98	98	98	0.5
Conventional Cigarette E	-11	1.1	101	106	110	110	99	105	5.1	99	98	98	98	98	98	0.7
Conventional Cigarette E	-3	1.8	94	96	100	96	101	95	2.7	91	92	92	92	92	92	0.4
Conventional Cigarette E	-6	7.2	92	93	94	99	95	95	3.8	88	88	88	88	89	88	0.5
Conventional Cigarette E	-9	10.3	89	94	99	95	97	95	3.8	85	85	86	86	86	86	0.4

We also noted a bias between some individual samples up to 14% for the rod and cigarette samples, which we believe are due to the instrument's holding or sealing methods. The encapsulated sleeve is a more secure means of holding samples, but cannot be used for the ventilation measurements.

Table 3. Sample for Comparing PD Instruments - CES 538 versus Cerulean EPD100 (Electronic Cigarettes)

Sample Description	Bias, abs.	Bias, Relative	Eastman PD Results on CES 508					Average	STDEV	Liggett PD Results on Cerulean EPD100					Average	STDEV
			1	2	3	4	5			1	2	3	4	5		
E-Cigarette A (Tank, rechargeable)	13	-17.6	77	74	73	73	73	74	1.7	87	85	87	83	82	87	3.3
E-Cigarette A (Tank, rechargeable)	8	-9.3	88	83	88	89	89	88	3.2	87	82	78	79	74	74	4.8
E-Cigarette A (Tank, rechargeable)	-9	12.4	89	87	88	73	71	70	2.4	61	63	63	63	64	61	4.1
E-Cigarette A (Tank, rechargeable)	-16	19.2	74	74	80	87	77	80	6.5	62	62	62	62	62	61	1.4
E-Cigarette A (Tank, rechargeable)	-4	7.9	60	54	64	62	64	61	4.1	56	55	55	55	59	59	2.0
E-Cigarette B (disposable)	0	2.3	84	86	87	87	87	87	2.5	85	86	85	89	88	87	1.8
E-Cigarette B (disposable)	0	10.6	95	116	115	116	115	115	8.9	99	101	104	105	105	104	4.2
E-Cigarette B (disposable)	2	-0.8	93	93	93	97	110	97	7.4	88	99	100	100	100	100	1.1
E-Cigarette B (disposable)	-7	8.9	90	92	96	107	109	99	8.7	90	92	91	92	94	92	1.5
E-Cigarette B (disposable)	5	-1.9	118	118	119	122	130	111	5.1	122	127	136	128	129	127	2.3
E-Cigarette C (disposable)	11	-3.9	104	107	107	108	108	107	1.6	111	116	120	121	120	118	4.2
E-Cigarette C (disposable)	0	6.2	88	88	88	88	88	88	0.9	84	84	84	84	84	84	0.9
E-Cigarette C (disposable)	8	3.9	104	104	105	107	107	105	1.5	95	97	98	99	98	97	1.5
E-Cigarette C (disposable)	-8	7.6	126	126	126	126	126	126	0.9	115	119	118	119	118	118	1.2
E-Cigarette C (disposable)	6	-14.0	114	115	116	116	116	115	0.9	105	112	109	114	106	109	1.8
E-Cigarette D (rechargeable)	-14	12.5	120	120	120	120	120	120	0.0	105	106	109	106	106	106	1.5
E-Cigarette D (rechargeable)	-16	15.5	126	125	125	126	125	125	0.5	106	108	110	111	113	110	2.7
E-Cigarette D (rechargeable)	17	16.2	117	118	118	119	119	118	0.8	99	101	101	102	103		