

Laboratory Air Pollution / Environmental Technology

Certificate-No. 5214015421-O3-1

Calibration Laboratory accredited by the Swiss Accreditation Service

Date: 2017-05-12

The Swiss Accreditation Service is one of the signatories to the EA

Multilateral Agreement for the recognition of calibration certificates

Pages: 6

Client: ISAC-CNR
Via Gobetti 101
I-40129 Bologna

Order-No. 5214015421
Contact person: Dr. Paolo Cristofanelli

Calibration Certificate

Test object:	Ozone calibrator Calibration settings	Type: TEI 49i-PS S/N 1118511036 COEF 1.015, BKG -0.2
Primary standard:	Ozone primary standard NIST, Gaithersburg	type SRP S/N 15
Measurement Conditions:	Date of the calibration: Location: Environmental conditions: Absorption coefficient (α): Warm-up time: Conditioning: Zero air / ozone generator:	2017-04-04/05 Empa Dübendorf Air-conditioned laboratory (LA 028) Temperature: 22.5 ± 1.0 °C Pressure: 970.1 – 972.2 hPa $308.32 \text{ cm}^{-1}\text{atm}^{-1}$ (Base e, 1013hPa, 273.15K, 253.7nm) >24 hours >2 hours at 380 nmolmol^{-1} ozone The zero air unit and the ozone generator of the SRP were used.
Measurement program:	A measurement cycle consisted of ozone measurements at 11 mole fractions, ranging between 0 – 250 nmolmol^{-1} . 14 measurement cycles were made.	
Measurement uncertainty:	The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approx. 95%.	

This certificate documents the traceability to national standards, which realize the physical unit of measurements (SI).

The measurements, the uncertainty with confidence probability and calibration methods are given on the following pages and are part of the certificate.

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Results:

No.	Reference		TEI 49i-PS #1118511036			
	SRP#15	s _d	s _d	deviation to reference		
	nmolmol ⁻¹	nmolmol ⁻¹	nmolmol ⁻¹	nmolmol ⁻¹	nmolmol ⁻¹	%
1	0.09	0.31	0.22	0.12	0.13	NA
2	77.42	0.25	77.77	0.16	0.35	0.45
3	49.72	0.23	49.91	0.13	0.18	0.37
4	12.79	0.28	12.96	0.09	0.16	1.27
5	146.32	0.20	146.85	0.10	0.53	0.36
6	98.18	0.42	98.47	0.05	0.29	0.30
7	197.22	0.28	197.47	0.14	0.25	0.12
8	172.11	0.20	172.54	0.05	0.43	0.25
9	123.36	0.29	123.78	0.09	0.42	0.34
10	215.92	0.25	216.53	0.05	0.61	0.28
11	242.33	0.30	243.12	0.06	0.79	0.32
12	77.52	0.17	77.69	0.06	0.18	0.23
13	98.10	0.27	98.50	0.08	0.40	0.40
14	49.75	0.33	50.11	0.07	0.35	0.71
15	196.65	0.29	197.27	0.12	0.62	0.32
16	0.08	0.10	0.31	0.11	0.23	NA
17	124.38	0.42	124.66	0.08	0.28	0.23
18	215.74	0.23	216.17	0.14	0.42	0.20
19	172.15	0.18	172.56	0.12	0.41	0.24
20	146.47	0.12	147.03	0.13	0.56	0.38
21	13.03	0.21	13.11	0.16	0.07	0.57
22	242.17	0.23	242.91	0.16	0.75	0.31
23	171.96	0.18	172.57	0.14	0.62	0.36
24	98.23	0.26	98.59	0.09	0.36	0.37
25	77.63	0.31	78.02	0.09	0.39	0.50
26	49.72	0.53	50.10	0.08	0.38	0.77
27	215.76	0.27	216.34	0.15	0.59	0.27
28	-0.23	0.16	0.19	0.11	0.42	- NA
29	196.99	0.09	197.79	0.20	0.80	0.40
30	123.55	0.24	124.12	0.11	0.57	0.46
31	146.82	0.38	147.10	0.09	0.28	0.19
32	12.81	0.27	13.08	0.13	0.27	2.12
33	242.82	0.24	243.31	0.10	0.48	0.20
34	196.96	0.28	197.49	0.13	0.52	0.27
35	0.19	0.26	0.11	0.09	-0.07	- NA
36	50.24	0.22	50.34	0.12	0.10	0.19
37	124.38	0.29	124.60	0.11	0.22	0.18
38	98.65	0.14	98.97	0.11	0.33	0.33
39	172.36	0.21	172.90	0.10	0.54	0.31
40	13.05	0.41	13.03	0.13	-0.02	-0.12
41	147.01	0.41	147.46	0.17	0.45	0.30
42	215.82	0.34	216.43	0.12	0.61	0.28
43	77.64	0.18	78.15	0.17	0.50	0.65
44	242.69	0.35	243.20	0.21	0.52	0.21
45	98.59	0.34	98.93	0.11	0.33	0.34
46	77.84	0.25	78.12	0.13	0.28	0.36
47	197.07	0.39	197.66	0.08	0.59	0.30
48	216.17	0.25	216.66	0.12	0.49	0.23
49	50.21	0.28	50.23	0.08	0.01	0.03
50	12.90	0.29	12.92	0.08	0.01	0.09
51	124.37	0.28	124.65	0.19	0.28	0.22
52	172.77	0.22	173.20	0.14	0.43	0.25
53	147.11	0.24	147.42	0.09	0.31	0.21
54	-0.09	0.13	0.16	0.13	0.25	- NA

55	243.63	0.61	244.58	0.67	0.95	0.39
56	12.83	0.30	13.05	0.07	0.23	1.77
57	172.86	0.27	173.46	0.40	0.60	0.35
58	123.82	0.12	124.41	0.09	0.60	0.48
59	0.15	0.27	0.22	0.06	0.07	NA
60	147.85	0.21	148.37	0.11	0.52	0.35
61	78.07	0.16	78.35	0.14	0.29	0.37
62	216.29	0.22	217.03	0.17	0.74	0.34
63	98.62	0.21	98.96	0.11	0.34	0.35
64	197.12	0.27	197.80	0.13	0.68	0.35
65	49.91	0.17	49.99	0.09	0.08	0.16
66	243.07	0.31	243.62	0.19	0.55	0.23
67	172.48	0.25	172.86	0.13	0.38	0.22
68	0.30	0.34	0.20	0.13	-0.10	- NA
69	147.98	0.27	148.40	0.20	0.42	0.28
70	50.21	0.34	50.41	0.06	0.20	0.40
71	98.88	0.31	99.18	0.12	0.30	0.30
72	13.01	0.31	13.07	0.10	0.06	0.47
73	216.77	0.45	217.68	0.67	0.90	0.42
74	124.27	0.27	124.43	0.12	0.16	0.13
75	197.55	0.40	198.12	0.11	0.57	0.29
76	77.45	0.37	77.83	0.15	0.38	0.49
77	242.97	0.29	243.49	0.25	0.52	0.21
78	98.40	0.36	98.63	0.09	0.22	0.23
79	77.76	0.23	77.93	0.11	0.17	0.22
80	216.35	0.37	216.89	0.21	0.54	0.25
81	-0.12	0.21	0.16	0.06	0.28	- NA
82	174.12	0.56	174.68	0.38	0.56	0.32
83	123.90	0.26	124.43	0.18	0.53	0.43
84	12.94	0.13	13.00	0.11	0.05	0.42
85	50.16	0.28	50.34	0.12	0.17	0.35
86	197.69	0.27	198.06	0.13	0.38	0.19
87	146.65	0.24	147.37	0.13	0.71	0.48
88	242.60	0.41	243.29	0.25	0.69	0.29
89	77.54	0.33	77.88	0.04	0.34	0.43
90	0.09	0.26	0.16	0.08	0.07	NA
91	216.67	0.27	217.32	0.36	0.65	0.30
92	123.81	0.32	124.14	0.09	0.34	0.27
93	172.40	0.23	172.91	0.13	0.51	0.29
94	196.81	0.17	197.16	0.10	0.35	0.18
95	12.81	0.30	13.00	0.08	0.19	1.46
96	50.22	0.18	50.29	0.08	0.08	0.15
97	98.58	0.12	99.11	0.12	0.53	0.54
98	147.06	0.22	147.35	0.10	0.28	0.19
99	242.62	0.37	243.43	0.17	0.81	0.33
100	77.59	0.35	77.76	0.09	0.16	0.21
101	172.32	0.15	172.93	0.19	0.61	0.35
102	12.83	0.37	13.03	0.12	0.20	1.54
103	98.96	0.47	99.28	0.08	0.32	0.33
104	216.27	0.37	216.87	0.15	0.60	0.28
105	146.66	0.20	147.12	0.10	0.46	0.31
106	49.95	0.26	49.84	0.20	-0.11	-0.21
107	-0.08	0.23	0.18	0.16	0.26	- NA
108	197.80	0.31	198.41	0.29	0.61	0.31
109	123.84	0.30	124.40	0.12	0.56	0.45
110	242.76	0.18	243.43	0.21	0.67	0.28
111	123.61	0.32	124.25	0.14	0.64	0.52
112	49.84	0.29	50.05	0.08	0.20	0.40
113	216.21	0.38	216.81	0.11	0.59	0.27
114	196.88	0.15	197.34	0.09	0.46	0.23
115	77.64	0.21	77.76	0.10	0.12	0.15

116	12.80	0.29	12.94	0.09	0.14	1.07
117	99.11	0.24	99.45	0.15	0.34	0.34
118	172.85	0.25	173.36	0.07	0.50	0.29
119	-0.06	0.26	0.17	0.10	0.23	NA
120	148.05	0.28	148.58	0.17	0.54	0.36
121	243.40	0.32	244.14	0.27	0.74	0.30
122	77.80	0.18	78.00	0.11	0.20	0.26
123	172.69	0.34	173.28	0.11	0.59	0.34
124	123.62	0.26	124.06	0.09	0.44	0.36
125	146.74	0.18	147.26	0.14	0.52	0.35
126	197.07	0.18	197.54	0.15	0.47	0.24
127	12.72	0.15	12.93	0.10	0.21	1.67
128	216.56	0.40	217.38	0.53	0.82	0.38
129	49.75	0.21	50.10	0.05	0.35	0.70
130	0.00	0.18	0.15	0.05	0.16	- NA
131	99.11	0.35	99.55	0.09	0.44	0.44
132	243.38	0.48	244.58	0.41	1.20	0.49
133	0.07	0.19	0.25	0.12	0.18	NA
134	78.18	0.24	78.51	0.17	0.33	0.42
135	124.09	0.19	124.71	0.12	0.62	0.50
136	49.98	0.30	50.37	0.15	0.39	0.77
137	197.28	0.33	198.06	0.15	0.78	0.40
138	216.14	0.30	216.89	0.11	0.76	0.35
139	12.77	0.17	12.86	0.09	0.09	0.72
140	147.06	0.39	147.72	0.21	0.67	0.45
141	98.45	0.20	98.84	0.11	0.40	0.40
142	172.29	0.19	172.89	0.13	0.60	0.35
143	242.51	0.38	243.33	0.19	0.82	0.34
144	77.59	0.30	77.84	0.06	0.25	0.32
145	146.63	0.25	147.08	0.10	0.45	0.31
146	12.72	0.19	12.85	0.08	0.13	1.05
147	197.57	0.39	198.26	0.40	0.69	0.35
148	172.52	0.18	172.95	0.12	0.43	0.25
149	98.31	0.33	98.51	0.12	0.20	0.20
150	49.72	0.26	50.16	0.12	0.44	0.88
151	-0.04	0.33	0.22	0.15	0.27	- NA
152	124.80	0.46	125.01	0.11	0.22	0.17
153	216.68	0.32	217.31	0.23	0.63	0.29
154	242.41	0.33	243.33	0.29	0.92	0.38

s_d : standard deviation (n = 10 measurement values)

NA: not applicable

Pressure sensor: The pressure sensor of the TEI 49i-PS #1118511036 was compared to the reference barometer (GB-1, meteolabor AG) at ambient pressure. The reading of the TEI 49i-PS (970.2 hPa) was adjusted to the reference pressure (971.1 hPa) before the calibration.

Calibration settings: The calibration settings of the TEI 49i-PS #1118511036 were not changed (BKG -0.2, COEF 1.013).

Calibration function: The following calibration function for the range between 0-250 nmolmol⁻¹ was determined from the comparison on 2017-04-04/05 at a temperature of 22.5±1°C and a pressure of 970.1 – 972.2 hPa.

Reference value (SRP#15) = 0.9976 x TEI 49i-PS #1118511036 - 0.11) nmolmol⁻¹

Measurement uncertainty: of the calibration	reference value (SRP#15)	value (TEI 49i-PS)	± uncertainty
	0 nmolmol ⁻¹	0.1	± 1.0 nmolmol ⁻¹
	25 nmolmol ⁻¹	25.2	± 1.1 nmolmol ⁻¹
	50 nmolmol ⁻¹	50.2	± 1.5 nmolmol ⁻¹
	75 nmolmol ⁻¹	75.3	± 2.0 nmolmol ⁻¹
	100 nmolmol ⁻¹	100.4	± 2.5 nmolmol ⁻¹
	125 nmolmol ⁻¹	125.4	± 3.0 nmolmol ⁻¹
	150 nmolmol ⁻¹	150.5	± 3.6 nmolmol ⁻¹
	175 nmolmol ⁻¹	175.5	± 4.1 nmolmol ⁻¹
	200 nmolmol ⁻¹	200.6	± 4.7 nmolmol ⁻¹
	225 nmolmol ⁻¹	225.7	± 5.2 nmolmol ⁻¹
	250 nmolmol ⁻¹	250.7	± 5.8 nmolmol ⁻¹

The measurement uncertainty given in the above table was determined in the Empa calibration laboratory under well known, ideal conditions. It reflects the minimal uncertainty, which can be guaranteed for the actual state of the tested instrument. To estimate the complete uncertainty budget of a specific instrument, additional parameters such as long-term drift, temperature and pressure variability, maintenance and competence of the staff have to be considered. Thus, a careful evaluation of the uncertainty budget is indicated considering customer specific circumstances.

Figure 1 shows the linear regression of the difference (TEI 49i-PS #1118511036 - SRP#15) versus SRP#15, including the prediction interval (95%). The measurement values of the inter-comparison are within the range of the prediction interval with a probability of 95%. The prediction interval is a measure of the uncertainty of the calibration function.

Figure 2 shows the regression residuals versus the run index (time dependence) and the mole fraction. The absence of a temporal trend indicates stable instrument conditions. The absence of mole fraction dependence in the residuals indicates linearity of the instrument.

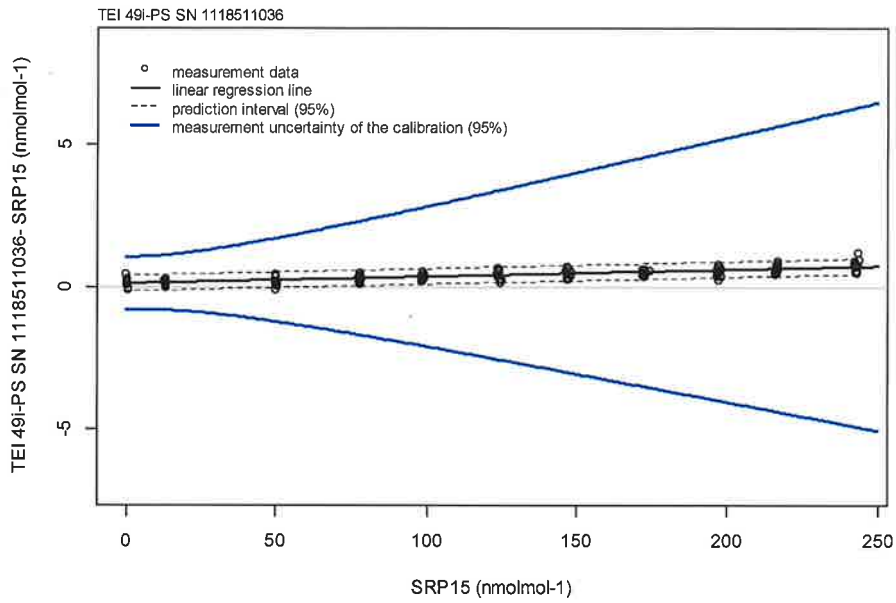


Figure 1: Linear regression of the difference (TEI 49i-PS #1118511036- SRP#15) vs. SRP#15.

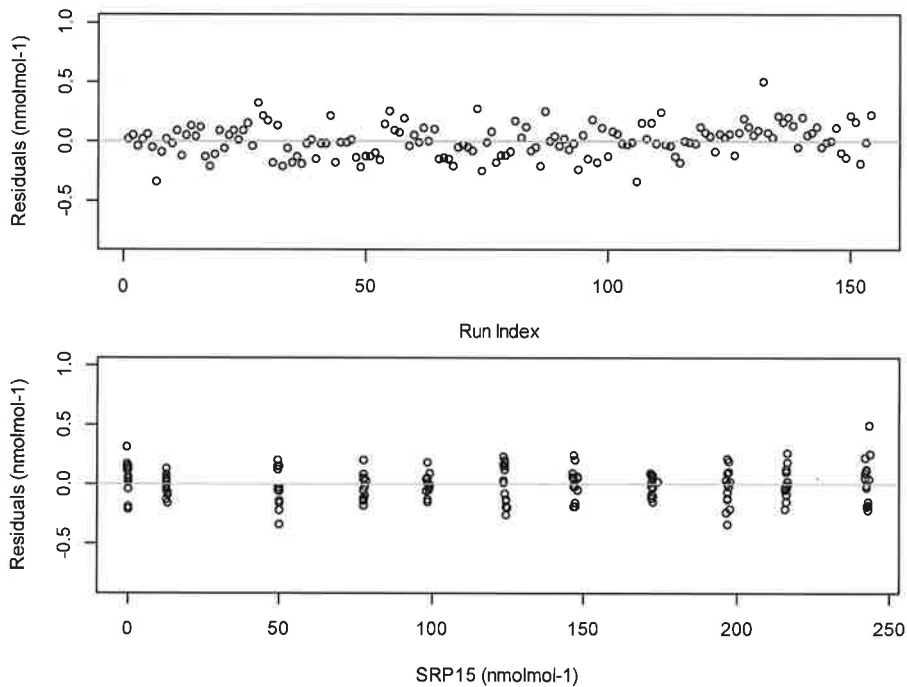


Figure 2: Regression residuals of the ozone inter-comparison as a function of run index (upper panel) and mole fraction (lower panel).

Dübendorf, 12. May 2017

Empa Dübendorf,
 Laboratory Air Pollution/Environmental Technology

Head of the calibration service

Head of the Laboratory

Dr. C. Zellweger

Dr. L. Emmenegger