U.S. Department of Commerce
National Institute of Standards and Technology
Material Measurement Laboratory
Chemical Sciences Division
Gaithersburg, MD 20899-8393

REPORT OF CALIBRATION

May 14, 2024

Calibration of Thermo Environmental Instruments Model 49i-PS
Ozone Analyzer, serial number 0726724741

Submitted to:
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2B Technologies
6800 W 117th Ave
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Job Number: 24026
Online Order No.: O-0000058124
Service ID No.: 37510C

The Thermo Environmental Instruments Model 49i-PS, serial number 0726724741 (TEI2B) was calibrated by comparison with the NIST Standard Reference Photometer serial #0 (SRP 0). The comparisons were conducted at NIST in Gaithersburg, MD during the period of February 6 – 9, 2024. As requested by 2B Technologies, each comparison run consisted of measurements at the concentrations: 50, 100, 200, 300, 400, 500, 600, 700, 800, 900 nmol/mol. Concentration levels were randomly ordered, while the measurements of zero concentration were obtained at the beginning and end of each comparison run.

The TEI2B was calibrated in accordance with the Gas Sensing Metrology Group Quality Manual (QM-III-646.03), following TP 646.0312A (Calibration of Ozone Instrumentation).

The results obtained by NIST standard reference photometers are based on a molecular absorption coefficient of 308.32 cm^{-1} (natural logarithm base) [1] referenced to a temperature of 273.15 K and pressure of 101.3 kPa for ozone at a wavelength of 253.7 nm. The uncertainty with which the SRP assays ozone is fundamentally dependent on the uncertainty of this value of the ozone absorption coefficient. The estimated expanded standard uncertainties [2] [3] of the SRP-measured ozone cocentration measurements are defined by the following equation:

$$u(x) = \sqrt{(0.28)^2 + \left(1.1 \times 10^{-2}\, x\right)^2}\ nmol/mol$$

NIST does not make any claims as to the future performance of the TEI2B but is merely reporting the data obtained while operated at NIST. Results contained in this ROC apply only to the items tested or calibrated.

Calibration Parameters for the TEI2B

Powered on: Febuary 2, 2024, 5:24 PM.

Configuration: Purified air directly into TEI2B, using TEI2B Ozone Generator. SRP 0 drawing sample from TEI2B, and reference from SRP reference manifold.

Data Connection: Serial, CLINK.

Experimental

Set 1: Data Collected: February 6 - 7, 2024.
Generator: TEI2B.
Instruments Used: SRP 0, TEI2B.
Conditioning: 940 nmol/mol for 60 minutes.
Nominal concentration points (nmol/mol): 50, 100, 200, 300, 400, 500, 600, 700, 800, 900.
Maximum Ozone Concentration Average (Primary): 899.2 nmol/mol.
Comparison Runs Completed: 10.

Set 2: Data Collected: February 7 - 8, 2024.
Generator: TEI2B.
Instruments Used: SRP 0, TEI2B.
Conditioning: 940 nmol/mol for 60 minutes.
Nominal concentration points (nmol/mol): 50, 100, 200, 300, 400, 500, 600, 700, 800, 900.
Maximum Ozone Concentration Average (Primary): 989.8 nmol/mol.
Comparison Runs Completed: 10.

Set 3: Data Collected: Febuary 8 – 9, 2024.
Generator: TEI2B.
Instruments Used: SRP 0, TEI2B.
Conditioning: 940 nmol/mol for 60 minutes.
Nominal concentration points (nmol/mol): 50, 100, 200, 300, 400, 500, 600, 700, 800, 900.
Maximum Ozone Concentration Average (Primary): 899.0 nmol/mol.
Comparison Runs Completed: 10.

For all measurements, the TEI2B calibration parameters were left in their original state: Range = 500 PPB, O3 BKG = 0.0 PPB, O3 COEF = 1.008 during all tests and calibration runs. For these data sets an average linear regression equation is given along with a data summary of the individual calibration runs individual slope, uncertainty of slope (u-slope), intercept, uncertainty of intercept (u-intercept), and standard error of the residuals (SER).

A graphical representation of the calibration data sets can be found in Appendix I. A data summary and the individual calibration runs will be provided via email to 2B Technologies.

Results

Set 1: TEI2B = [(1.00093 × SRP 0) – 0.030] nmol/mol, n = 10

File Name	Date	Max conc.	TEI2B Slope	TEI2B u-slope	TEI2B Intercept	TEI2B u-intercept	TEI2B SER
Cal24020600.xls	2/6/2024 19:21	899.1	1.00097	0.00022	-0.09585	0.10780	0.22381
Cal24020601.xls	2/6/2024 21:28	899.6	1.00071	0.00022	-0.00362	0.10782	0.22383
Cal24020602.xls	2/6/2024 23:35	899.3	1.00089	0.00018	-0.10297	0.08701	0.18064
Cal24020700.xls	2/7/2024 1:40	898.9	1.00095	0.00024	-0.05854	0.11634	0.24155
Cal24020701.xls	2/7/2024 3:48	899.7	1.00089	0.00019	-0.07508	0.09373	0.19462
Cal24020702.xls	2/7/2024 5:54	899.2	1.00112	0.00021	-0.06642	0.10120	0.21010
Cal24020703.xls	2/7/2024 8:00	898.9	1.00079	0.00014	0.07582	0.06966	0.14463
Cal24020704.xls	2/7/2024 10:08	899.1	1.00102	0.00016	0.04564	0.07795	0.16184
Cal24020705.xls	2/7/2024 12:15	899.3	1.00107	0.00015	-0.00176	0.07330	0.15219
Cal24020706.xls	2/7/2024 14:23	899.2	1.00092	0.00011	-0.01666	0.05433	0.11281
	Average:	**899.2**	**1.00093**	**0.00018**	**-0.02994**	**0.08891**	**0.18460**
	Median:	**899.2**	**1.00093**	**0.00019**	**-0.03760**	**0.09037**	**0.18763**
	Std. Dev.:	**0.3**	**0.00012**	**0.00004**	**0.06002**	**0.01993**	**0.04137**
	SD (mean):	**0.0**	**0.00001**	**0.00000**	**0.00600**	**0.00199**	**0.00414**

Set 2: TEI2B = [(1.00118 × SRP 0) – 0.012] nmol/mol, n = 10

File Name	Date	Max conc.	TEI2B Slope	TEI2B u-slope	TEI2B Intercept	TEI2B u-intercept	TEI2B SER
Cal24020707.xls	2/7/2024 19:42	899.0	1.00096	0.00015	0.09686	0.07393	0.15351
Cal24020708.xls	2/7/2024 21:48	899.2	1.00092	0.00021	0.01866	0.10208	0.21192
Cal24020709.xls	2/7/2024 23:55	899.1	1.00096	0.00017	-0.03626	0.08104	0.16828
Cal24020800.xls	2/8/2024 2:02	899.0	1.00121	0.00011	-0.07229	0.05163	0.10719
Cal24020801.xls	2/8/2024 4:09	898.9	1.00125	0.00017	-0.03759	0.08188	0.17001
Cal24020802.xls	2/8/2024 6:16	898.2	1.00164	0.00015	-0.05946	0.07404	0.15372
Cal24020803.xls	2/8/2024 8:24	898.9	1.00123	0.00014	0.01920	0.06816	0.14151
Cal24020804.xls	2/8/2024 10:31	898.7	1.00113	0.00010	0.02003	0.04742	0.09846
Cal24020805.xls	2/8/2024 12:38	898.7	1.00147	0.00021	-0.06716	0.10331	0.21448
Cal24020806.xls	2/8/2024 14:46	898.6	1.00106	0.00015	-0.00324	0.07480	0.15529
	Average:	**898.8**	**1.00118**	**0.00016**	**-0.01212**	**0.07583**	**0.15744**
	Median:	**898.9**	**1.00117**	**0.00015**	**-0.01975**	**0.07442**	**0.15451**
	Std. Dev.:	**0.3**	**0.00023**	**0.00004**	**0.05275**	**0.01816**	**0.03770**
	SD (mean):	**0.0**	**0.00002**	**0.00000**	**0.00527**	**0.00182**	**0.00377**

Set 3: TEI2B = [(1.00119 × SRP 0) - 0.026] nmol/mol, n = 10

File Name	Date	Max conc.	TEI2B Slope	TEI2B u-slope	TEI2B Intercept	TEI2B u-intercept	TEI2B SER
Cal24020807.xls	2/8/2024 20:22	899.2	1.00122	0.00014	-0.04087	0.06871	0.14265
Cal24020808.xls	2/8/2024 22:28	899.1	1.00113	0.00018	0.02631	0.08771	0.18211
Cal24020900.xls	2/9/2024 0:36	899.2	1.00123	0.00019	-0.04074	0.09269	0.19244
Cal24020901.xls	2/9/2024 2:43	898.7	1.00123	0.00014	-0.03134	0.06844	0.14209
Cal24020902.xls	2/9/2024 4:50	899.2	1.00116	0.00014	-0.06687	0.06589	0.13681
Cal24020903.xls	2/9/2024 6:56	898.6	1.00134	0.00016	-0.04810	0.07784	0.16161
Cal24020904.xls	2/9/2024 9:03	898.8	1.00109	0.00010	0.00747	0.04861	0.10094
Cal24020905.xls	2/9/2024 11:09	898.9	1.00129	0.00014	-0.07602	0.06868	0.14258
Cal24020906.xls	2/9/2024 13:16	899.4	1.00099	0.00014	0.02142	0.06637	0.13780
Cal24020907.xls	2/9/2024 15:23	898.7	1.00126	0.00013	-0.01384	0.06562	0.13624
	Average:	**899.0**	**1.00119**	**0.00015**	**-0.02626**	**0.07106**	**0.14753**
	Median:	**899.0**	**1.00122**	**0.00014**	**-0.03604**	**0.06856**	**0.14234**
	Std. Dev.:	**0.3**	**0.00010**	**0.00003**	**0.03556**	**0.01243**	**0.02581**
	SD (mean):	**0.0**	**0.00001**	**0.00000**	**0.00356**	**0.00124**	**0.00258**

Environmental Conditions

The laboratory environmental conditions were recorded at 2-minute intervals during the measurements contained in this report. The results of measurement sets are below:

Set 1:

	Pressure (hPa)	Temperature (°C)	Humidity (%)
Average:	1007.8	20.9	12.6
Std. Dev.:	1.5	0.2	0.7

Set 2:

	Pressure (hPa)	Temperature (°C)	Humidity (%)
Average:	1008.4	20.8	16.1
Std. Dev.:	1.0	0.1	0.9

Set 3:

	Pressure (hPa)	Temperature (°C)	Humidity (%)
Average:	1002.2	20.8	22.0
Std. Dev.:	2.2	0.1	1.4

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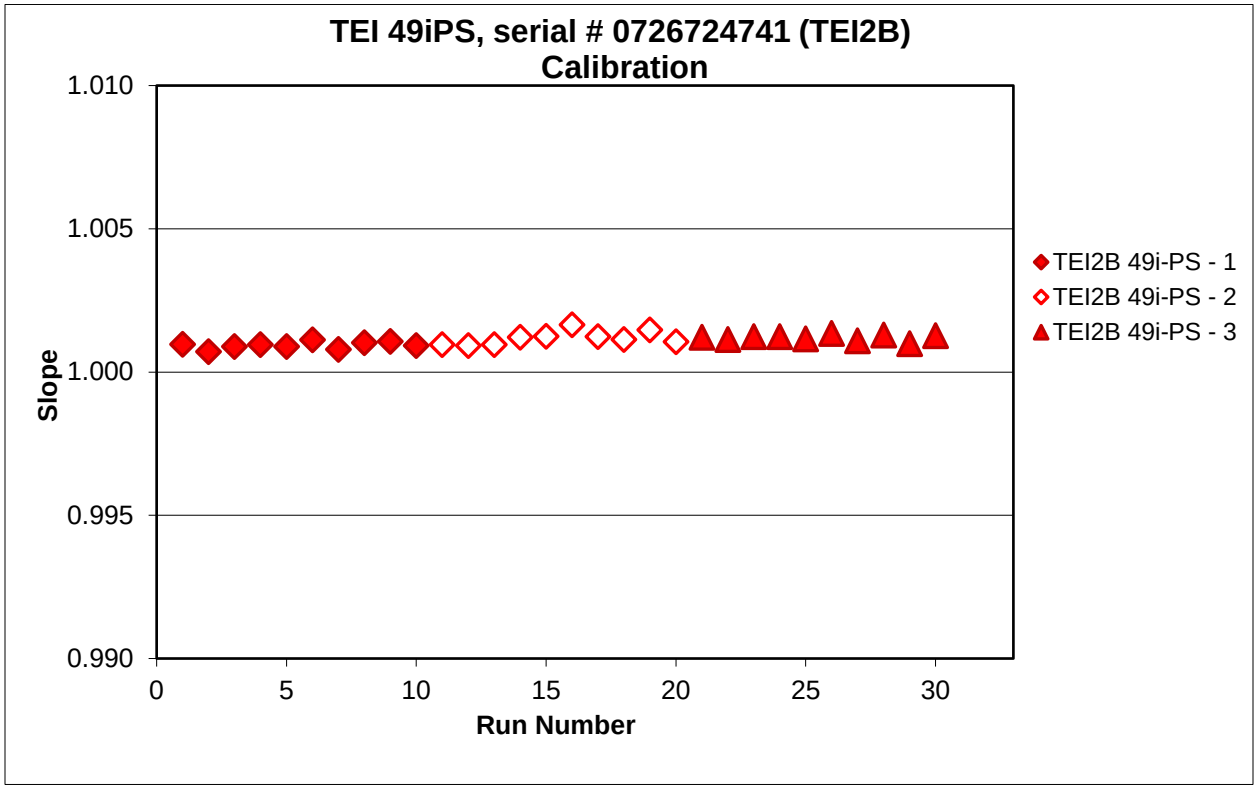
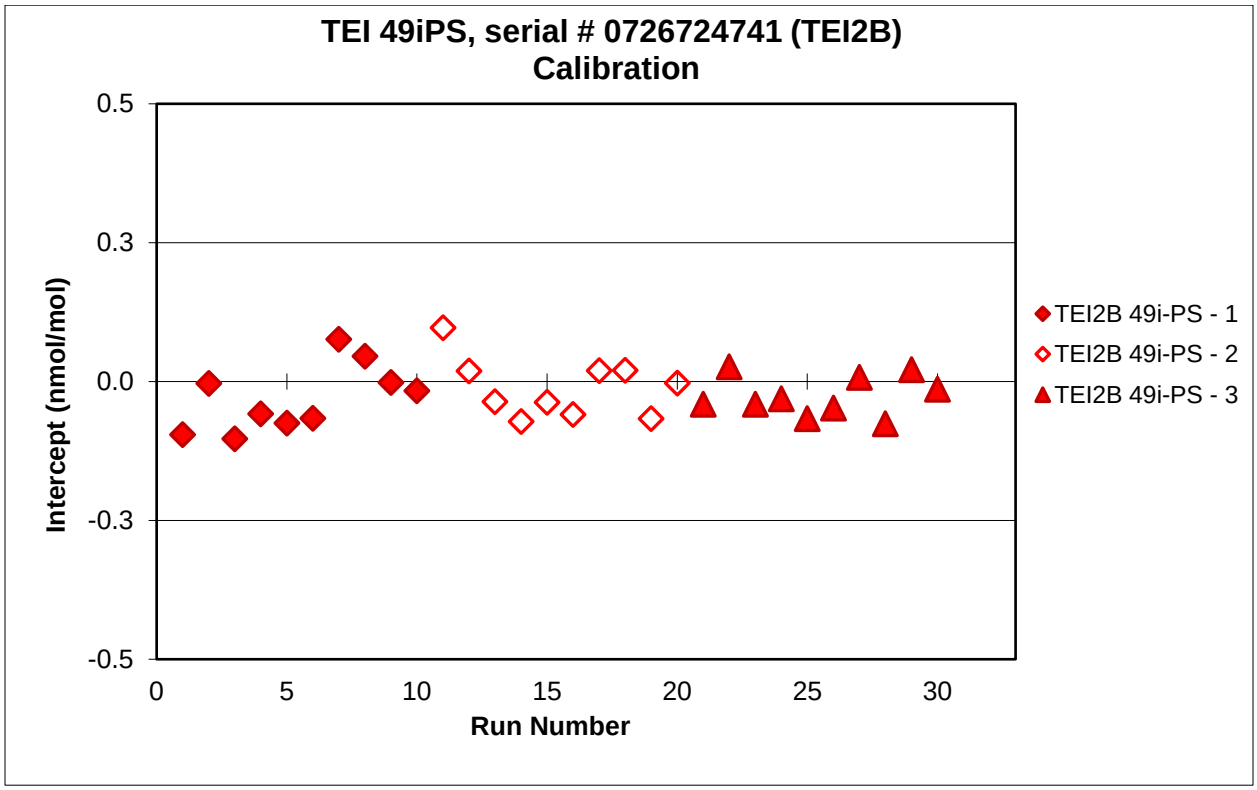
For the Director of the National Institute of Standards and Technology

Appendix I: Graphical representation of data





References

1. "Transfer Standards for the Calibration of Air Monitoring Analyzers for Ozone" *U.S. Environmental Protection Agency Technical Assistance Document, EPA-454/B-10-001*, November 2010.

2. JCGM 100:2008; Evaluation of Measurement Data — Guide to the Expression of Uncertainty in Measurement (GUM 1995 with Minor Corrections); Joint Committee for Guides in Metrology (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2011); see also Taylor, B.N.; Kuyatt, C.E.; Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results; NIST Technical Note 1297; U.S. Government Printing Office: Washington, DC (1994); available at http://www.nist.gov/pml/pubs/index.cfm

3. Viallon, J., P.Moussay, J.E. Norris, F.R. Guenther, and R.I. Wielgosz. 2006. A study of systematic biases and measurement uncertainties in ozone mole fraction measurements with the NIST Standard Reference Photometer. Metrologia 43:441-450. Doi:10.1088/0026-1394/43/5/016.