

U.S. Department of Commerce
National Institute of Standards and Technology
Chemical Science and Technology Laboratory
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Gaithersburg, MD 20899-8393

REPORT OF ANALYSIS

October 21, 2009

Calibration of TEI 49i PS, serial number 0726724741 Ozone Calibrator

Submitted to:

2B Technologies, Inc.
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The Thermo Electron, Inc., serial number 0726724741 (TEI2B) ozone calibrator, owned by 2B Technologies, Inc. was calibrated by comparison with the National Institute of Standards and Technology (NIST) standard reference photometer serial # 0 (SRP 0). The comparisons were conducted at NIST in Gaithersburg, MD, over the period October 20-21, 2009. Each calibration consisted of measurements of ten different concentration levels and two measurements of zero concentration. The measurements of the ten 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 Metrology Group Quality Manual (QM-III-839.03), following TP 839.0312A (calibration of ozone instrumentation).

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

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

$$U_{95} = 2 \times u(x) \text{ nmol/mol}, U_{95} = (-2 \times u(x) - 0.001 \times x) \text{ nmol/mol}$$

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.

Calibration Parameters for the TEI2B Ozone Calibrator:

Powered on: October 16, 2009, 10:30 a.m.

Conditioning: Zero air, then 30 minutes at 1000 ppbv prior to calibration.

Configuration: SRP 0 and TEI2B drawing sample from TEI2B sample manifold.
SRP 0 drawing reference from SRP reference manifold.
TEI2B drawing reference from TEI2B internal reference manifold.

Data Connection: RS-232.

The TEI2B ozone calibrator was initially set up and powered up on October 16, 2009, at 10:30 p.m. with pressurized zero air feeding itself and sampling zero air. The TEI2B was connected to the SRP control system via RS-232 communication. The SRP 0 Teflon 1-meter sample inlet line was connected to the TEI2B sample manifold and the SRP 0 Teflon 1-meter reference inlet line remained connected to the SRP reference manifold. The TEI2B sample inlet is connected to the TEI2B sample manifold internally and the TEI2B reference is drawn from its own internal manifold.

During a short period of testing with a 500 nmol/mol ozone concentration a difference of approximately 66 % was noticed between the TEI2B and SRP 0. After checking all system diagnostics and discussions over the phone with 2B Technologies and Thermo Environmental Instruments personnel, no change was seen. The TEI2B was powered down and during a final overview of the instruments internal components it was discovered that both TEI2B cells were loose. After tightening the cells and re-powering up the TEI2B, a quick check against SRP 0 showed a difference of approximately 1 %. The calibration was then performed.

A set of 11-comparison runs were performed overnight starting on October 20, 2009, up to a maximum ozone concentration of 999 ppbv as measured by SRP 0.

The results of the comparison runs performed in this report are given below. The individual Excel calibration report files and an Excel spreadsheet summary are provided on a CD with this report.

Results

The following average linear regression equation was obtained from the 11-calibration runs of the TEI 49i PS, serial # 0726724741:

$$\text{TEI2B} = [(0.99132 \times \text{SRP 0}) - 0.265] \text{ ppbv}$$

Where, TEI2B = ozone concentration (ppbv) determined by the TEI2B.
SRP 0 = ozone concentration (ppbv) determined by the SRP 0.

Data summary from individual calibration runs:

FileName	Date	Max conc.	TEI2B Slope	TEI2B u-slope	TEI2B Intercept	TEI2B u-intercept	TEI2B SER
c1020001.xls	10/20/2009 12:14	998.8	0.99163	0.00012	-0.20576	0.06323	0.14002
c1020002.xls	10/20/2009 15:08	998.8	0.99132	0.00015	-0.22662	0.07767	0.17197
c1020003.xls	10/20/2009 17:01	999.4	0.99109	0.00016	-0.22135	0.07911	0.17519
c1020004.xls	10/20/2009 18:55	999.3	0.99091	0.00009	-0.13415	0.04793	0.10613
c1020005.xls	10/20/2009 20:50	999.0	0.99107	0.00012	-0.15125	0.05901	0.13067
c1020006.xls	10/20/2009 22:49	999.1	0.99146	0.00032	-0.37912	0.16497	0.36523
c1020007.xls	10/21/2009 0:42	999.2	0.99129	0.00023	-0.27152	0.11909	0.26369
c1020008.xls	10/21/2009 2:36	998.9	0.99124	0.00014	-0.20556	0.07308	0.16181
c1020009.xls	10/21/2009 4:30	998.9	0.99158	0.00019	-0.41252	0.09801	0.21697
c1020010.xls	10/21/2009 6:28	998.7	0.99170	0.00026	-0.36127	0.13247	0.29327
c1020011.xls	10/21/2009 8:25	998.7	0.99127	0.00029	-0.34354	0.14688	0.32518
Average:		999.0	0.99132	0.00019	-0.26479	0.09650	0.21365
Median:		998.9	0.99129	0.00016	-0.22662	0.07911	0.17519
Std. Dev.:		0.2	0.00025	0.00008	0.09526	0.03887	0.08605
SD (mean):		0.0	0.00002	0.00001	0.00866	0.00353	0.00782

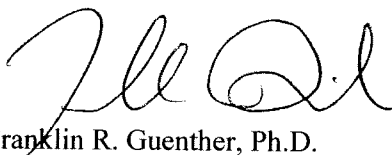
u = uncertainty, RSD = residual standard deviation.

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References:

1. Paur, R.J., and McElroy, F.F., "Technical Assistance Document for the Calibration of Ambient Ozone Monitors," pp. 3-9, *U.S. Environmental Protection Agency Research Report, EPA-600/4-79-057*, September 1979.
2. Taylor, B.N., and Kuyatt, C.E., "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," *National Institute of Standards and Technology Technical Note 1297*, 1994 Edition (U.S. Government Printing Office, Washington, D.C., September 1994).