

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

REPORT OF ANALYSIS

August 19, 2009

Calibration of OREC Model DM100, serial numbers 748, 318, and 757 Ozone Monitors

Submitted to:

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Job No.: 9103
 Test Folder No.: 278607-09

The OREC Model DM100, serial numbers: 748 (OREC748), 318 (OREC318), and 757 (OREC757) ozone monitors, owned by Corporate Consulting Service, Inc., were calibrated by comparison with the NIST Standard Reference Photometer serial # 2 (NIST SRP 2). The comparisons were conducted at National Institute of Standards and Technology (NIST) in Gaithersburg, MD, over the period August 18-19, 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 OREC ozone monitors were 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 OREC ozone monitors, but is merely reporting the data obtained while operated at NIST.

Calibration Parameters for all three OREC Ozone Monitors:

Powered on: August 18, 2009, 2:45 p.m.

Conditioning: 2 – 3 hours around 970 nmol/mol prior to calibration.

Configuration: All instruments drawing sample and reference gas from NIST SRP dual manifold.

Data Connection: Analog

The OREC748, OREC318, and OREC757 ozone monitors were initially set up and powered up on August 18, 2009 at 2:45 p.m. and connected to the SRP control system via analog signal connection. The sample and reference inlets of all three OREC ozone monitors were connected to the SRP sample/reference manifold using approximately 1 meter of Teflon tubing for each. They were then allowed to sample approximately 970 nmol/mol over a 3 – 4 hour period before beginning the official calibration runs. A set of 8-comparison runs were performed overnight starting on August 18, 2009 up to a maximum ozone concentration of 985 nmol/mol.

The results of the comparison runs performed in this report are given below. A graphical representation of the data presented in this report can be found in appendix I. The individual 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 for the OREC DM100, serial # 748 from the set of 8-comparison runs.

$$C_{\text{OREC748}} = [(0.97131 \times C_{\text{SRP 2}}) - 2.7] \text{ nmol/mol}$$

Where, C_{OREC748} = ozone concentration nmol/mol determined by the OREC DM100, serial # 748.
 $C_{\text{SRP 2}}$ = ozone concentration nmol/mol determined by the NIST SRP 2.

Data summary from individual calibration runs:

FileName	Date/Time	Max conc.	OREC748 Slope	OREC748 u-slope	OREC748 Intercept	OREC748 u-intercept	OREC748 SER
c0818001.xls	8/18/2009 17:57	982.3	0.97209	0.00321	-1.82317	1.52314	3.35543
c0818002.xls	8/18/2009 20:59	983.6	0.97477	0.00200	-4.51446	0.94779	2.08762
c0818003.xls	8/18/2009 23:09	984.0	0.97305	0.00314	-3.02697	1.48812	3.27800
c0818004.xls	8/19/2009 1:07	984.3	0.97472	0.00493	-4.82033	2.34120	5.15891
c0818005.xls	8/19/2009 3:02	984.5	0.96539	0.00411	-1.45723	1.94939	4.29444
c0818006.xls	8/19/2009 5:05	984.8	0.96447	0.00351	1.75850	1.66890	3.67698
c0818007.xls	8/19/2009 7:01	985.1	0.97592	0.00238	-4.33233	1.13099	2.49165
c0818008.xls	8/19/2009 8:58	985.1	0.97008	0.00401	-3.07835	1.90343	4.19381
Average:		984.2	0.97131	0.00341	-2.66179	1.61912	3.56711
Median:		984.4	0.97257	0.00336	-3.05266	1.59602	3.51621
Std. Dev.:		0.9	0.00434	0.00095	2.16737	0.45184	0.99582
SD (mean):		0.1	0.00054	0.00012	0.27092	0.05648	0.12448

u = uncertainty, SER = standard error of the residuals.

The following average linear regression equation was obtained for the OREC DM100, serial # 318 from the set of 8-comparison runs.

$$C_{\text{OREC318}} = [(0.97945 \times C_{\text{SRP2}}) - 8.2] \text{ nmol/mol}$$

Where, C_{OREC318} = ozone concentration nmol/mol determined by the OREC DM100, serial # 318.

C_{SRP2} = ozone concentration nmol/mol determined by the NIST SRP 2.

Data summary from individual calibration runs:

FileName	Date/Time	Max conc.	OREC318 Slope	OREC318 u-slope	OREC318 Intercept	OREC318 u-intercept	OREC318 SER
c0818001.xls	8/18/2009 17:57	982.3	0.97826	0.00247	-11.57758	1.16828	2.57368
c0818002.xls	8/18/2009 20:59	983.6	0.97733	0.00233	-8.37262	1.10438	2.43253
c0818003.xls	8/18/2009 23:09	984.0	0.97962	0.00076	-9.68234	0.36144	0.79618
c0818004.xls	8/19/2009 1:07	984.3	0.97836	0.00083	-9.14780	0.39297	0.86593
c0818005.xls	8/19/2009 3:02	984.5	0.97896	0.00076	-8.61599	0.35901	0.79089
c0818006.xls	8/19/2009 5:05	984.8	0.98080	0.00377	-2.24483	1.78908	3.94177
c0818007.xls	8/19/2009 7:01	985.1	0.98103	0.00215	-7.45667	1.02277	2.25324
c0818008.xls	8/19/2009 8:58	985.1	0.98126	0.00107	-8.80153	0.50874	1.12090
Average:		984.2	0.97945	0.00177	-8.23742	0.83833	1.84689
Median:		984.4	0.97929	0.00161	-8.70876	0.76576	1.68707
Std. Dev.:		0.9	0.00146	0.00109	2.70116	0.51848	1.14226
SD (mean):		0.1	0.00018	0.00014	0.33764	0.06481	0.14278

u = uncertainty, SER = standard error of the residuals.

The following average linear regression equation was obtained for the OREC DM100, serial # 757 from the set of 8-comparison runs.

$$C_{\text{OREC757}} = [(0.96685 \times C_{\text{SRP2}}) + 2.0] \text{ nmol/mol}$$

Where, C_{OREC757} = ozone concentration nmol/mol determined by the OREC DM100, serial # 757.

C_{SRP2} = ozone concentration nmol/mol determined by the NIST SRP 2.

Data summary from individual calibration runs:

FileName	Date/Time	Max conc.	OREC757 Slope	OREC757 u-slope	OREC757 Intercept	OREC757 u-intercept	OREC757 SER
c0818001.xls	8/18/2009 17:57	982.3	0.96560	0.00100	1.94098	0.47207	1.03995
c0818002.xls	8/18/2009 20:59	983.6	0.96512	0.00153	2.69036	0.72767	1.60278
c0818003.xls	8/18/2009 23:09	984.0	0.97015	0.00167	0.24911	0.79365	1.74825
c0818004.xls	8/19/2009 1:07	984.3	0.96455	0.00285	3.29839	1.35092	2.97680
c0818005.xls	8/19/2009 3:02	984.5	0.96499	0.00166	3.29550	0.78651	1.73265
c0818006.xls	8/19/2009 5:05	984.8	0.96736	0.00127	1.22200	0.60504	1.33305
c0818007.xls	8/19/2009 7:01	985.1	0.96734	0.00080	2.57792	0.37801	0.83278
c0818008.xls	8/19/2009 8:58	985.1	0.96966	0.00097	0.83830	0.46270	1.01946
Average:		984.2	0.96685	0.00147	2.01407	0.69707	1.53572
Median:		984.4	0.96647	0.00140	2.25945	0.66636	1.46792
Std. Dev.:		0.9	0.00216	0.00065	1.14624	0.30743	0.67746
SD (mean):		0.1	0.00027	0.00008	0.14328	0.03843	0.08468

u = uncertainty, RSD = residual standard deviation.

Prepared by:



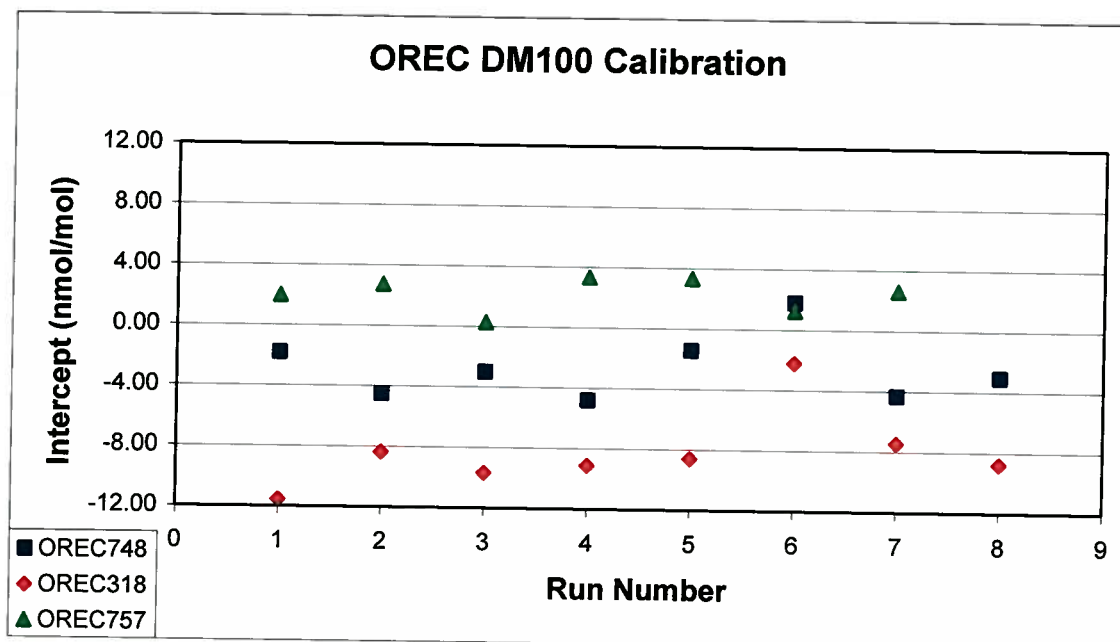
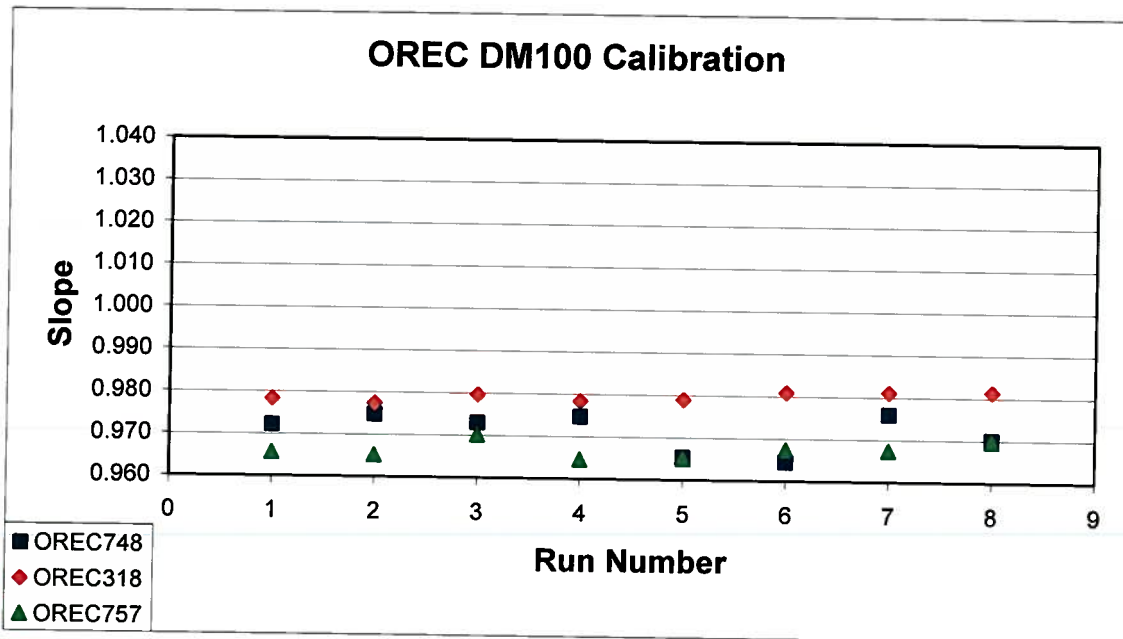
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Reviewed by:



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Appendix I: Graphical Representation of Calibration Data

**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).