UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899-

December 30, 2011

Mr. Ron Brainard
Corporate Consulting Service, Inc.
221 Beaver Street
Akron, OH 44304

Dear Mr. Brainard:

Enclosed you will find my Report of Analysis and CD for the Calibration of OREC Model DM100, serial numbers 748 Ozone Monitor.

If you have any questions, I can be reached at 301-975-3936 or by fax 301-977-8392.

Sincerely,

James E. Norris/zmr

James E. Norris
Electronics Technician
Gas Metrology Group

JEN/zmr
Enclosures as Stated

NIST

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

REPORT OF ANALYSIS

September 13, 2011

Calibration of OREC Model DM100, serial number 748 Ozone Monitor

Submitted to:

Mr. Ron Brainard
Corporate Consulting Service, Inc.
221 Beaver Street
Akron, OH 44304

Job No.: 1107
Test Folder No.: 281450-11

The OREC Model DM100, serial number 748 (OREC748) ozone monitor, owned by Corporate Consulting Service, Inc. was calibrated by comparison with the National Institute of Standards and Technology (NIST) standard reference photometer (SRP) serial number 2 (NIST SRP 2). The calibration runs were conducted at NIST in Gaithersburg, MD, over the period September 9 - 13, 2011. Each calibration run 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 OREC748 ozone monitor 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 are based on a molecular absorption coefficient of 308.32 $cm^{-1} \times atm^{-1}$ (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:

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

$$U^{+}_{95} = 2 \times u(x) \text{ nmol/mol},\ U^{-}_{95} = (-2 \times u(x) - 0.001 \times x) \text{ nmol/mol}$$

NIST does not make any claims as to the future performance of the OREC748 ozone monitor, but is merely reporting the data obtained while operated at NIST.

Calibration Parameters for the OREC748 Ozone Monitor:

Powered on: September 8, 2011, 2:30 p.m.

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

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

Data Connection: Analog.

The OREC748 ozone monitor was initially set up and powered up on September 8, 2011 at 2:30 p.m. and connected to the SRP control system via analog signal connection. The sample and reference inlets of the OREC748 ozone monitor were connected to the SRP sample/reference manifold using Teflon tubing supplied by the customer. The OREC748 was then allowed to sample approximately 1000 nmol/mol over a 2-3 hour period before beginning the official calibration runs. The first set of overnight runs failed due to the instability of the analog signal values from the OREC748. The stability settings were increased and a set of 13-comparison runs were performed overnight starting on September 9, 2011 up to a maximum ozone concentration of 1010 nmol/mol. The slope and intercept values from this set showed an unusual amount of variation so the OREC748 was keep on over a weekend sampling zero air only and a second set of 10-comparison runs were performed overnight starting on September 12, 2011 up to a maximum ozone concentration of 1007 nmol/mol. The slope and intercept values still had an unusual amount of variation which must just be due to the noise in the analog signals.

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 first set of 13-comparison runs.

$$C_{OREC748} = [(0.9980 \times C_{SRP\,2}) + 0.1]\ \text{nmol/mol}$$

Where, $C_{OREC748}$ = ozone concentration (ppbv) determined by the OREC DM100, serial # 748.
$C_{SRP\,2}$ = ozone concentration (ppbv) 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
c0909001.xls	9/9/2011 8:42	1006.7	0.99766	0.00286	0.54785	1.37395	3.04011
c0909002.xls	9/9/2011 11:13	1008.4	0.99612	0.00285	-0.42309	1.37250	3.03752
c0909003.xls	9/9/2011 13:18	1009.2	0.99357	0.00300	1.85141	1.44320	3.19371
c0909004.xls	9/9/2011 15:14	1009.4	0.99610	0.00253	0.51385	1.21786	2.69496
c0909005.xls	9/9/2011 17:10	1009.7	0.99732	0.00231	-0.11050	1.11548	2.46860
c0909006.xls	9/9/2011 19:06	1009.8	1.00014	0.00214	-0.60517	1.03354	2.28755
c0909007.xls	9/9/2011 21:03	1011.2	0.99910	0.00224	1.25455	1.08277	2.39605
c0909008.xls	9/9/2011 23:00	1009.8	0.99691	0.00290	1.31189	1.39982	3.09730
c0909009.xls	9/10/2011 0:55	1009.7	0.99656	0.00226	0.55037	1.08772	2.40701
c0909010.xls	9/10/2011 2:51	1010.4	0.99436	0.00365	1.11316	1.75993	3.89497
c0909011.xls	9/10/2011 4:49	1011.4	1.00104	0.00257	-0.98898	1.24271	2.75025
c0909012.xls	9/10/2011 6:46	1010.6	1.00064	0.00212	-1.35904	1.02360	2.26506
c0909013.xls	9/10/2011 8:42	1011.5	1.00386	0.00198	-2.39592	0.95644	2.11685
	Average:	**1009.8**	**0.99795**	**0.00257**	**0.09695**	**1.23919**	**2.74230**
	Median:	**1009.8**	**0.99732**	**0.00253**	**0.51385**	**1.21786**	**2.69496**
	Std. Dev.:	**1.3**	**0.00289**	**0.00047**	**1.21894**	**0.22480**	**0.49746**
	SD (mean):	**0.1**	**0.00022**	**0.00004**	**0.09376**	**0.01729**	**0.03827**

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

The following average linear regression equation was obtained for the OREC DM100, serial # 748 from the second set of 10-comparison runs.

$$C_{OREC748} = [(1.004 \times C_{SRP\,2}) - 0.05]\ \text{nmol/mol}$$

Where, $C_{OREC748}$ = ozone concentration (ppbv) determined by the OREC DM100, serial # 748.
$C_{SRP\,2}$ = ozone concentration (ppbv) 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
c0912001.xls	9/12/2011 14:00	997.8	1.00186	0.00169	0.97062	0.80592	1.78266
c0912002.xls	9/12/2011 16:57	1004.5	1.00494	0.00279	1.43308	1.33651	2.95769
c0912003.xls	9/12/2011 18:53	1006.6	0.99687	0.00259	2.06331	1.24264	2.75005
c0912004.xls	9/12/2011 20:48	1007.6	1.00441	0.00155	0.37394	0.74607	1.65093
c0912005.xls	9/12/2011 22:43	1008.5	1.00065	0.00256	-1.69628	1.23017	2.72268
c0912006.xls	9/13/2011 0:39	1008.0	1.00972	0.00234	-3.13975	1.12800	2.49647
c0912007.xls	9/13/2011 2:35	1008.4	1.00949	0.00244	-0.96070	1.17635	2.60359
c0912008.xls	9/13/2011 4:30	1009.0	1.00348	0.00258	-0.15266	1.24242	2.74997
c0912009.xls	9/13/2011 6:27	1009.8	1.00747	0.00261	-2.26140	1.26009	2.78901
c0912010.xls	9/13/2011 8:23	1010.6	1.00319	0.00185	2.91896	0.89357	1.97812
	Average:	**1007.1**	**1.00421**	**0.00230**	**-0.04509**	**1.10617**	**2.44812**
	Median:	**1008.2**	**1.00395**	**0.00250**	**0.11064**	**1.20326**	**2.66314**
	Std. Dev.:	**3.7**	**0.00399**	**0.00044**	**1.96323**	**0.21075**	**0.46658**
	SD (mean):	**0.4**	**0.00040**	**0.00004**	**0.19632**	**0.02107**	**0.04666**

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

Prepared by:

James E. Norris
Electronics Technician

Reviewed by:

Franklin R. Guenther, Ph.D.
Group Leader
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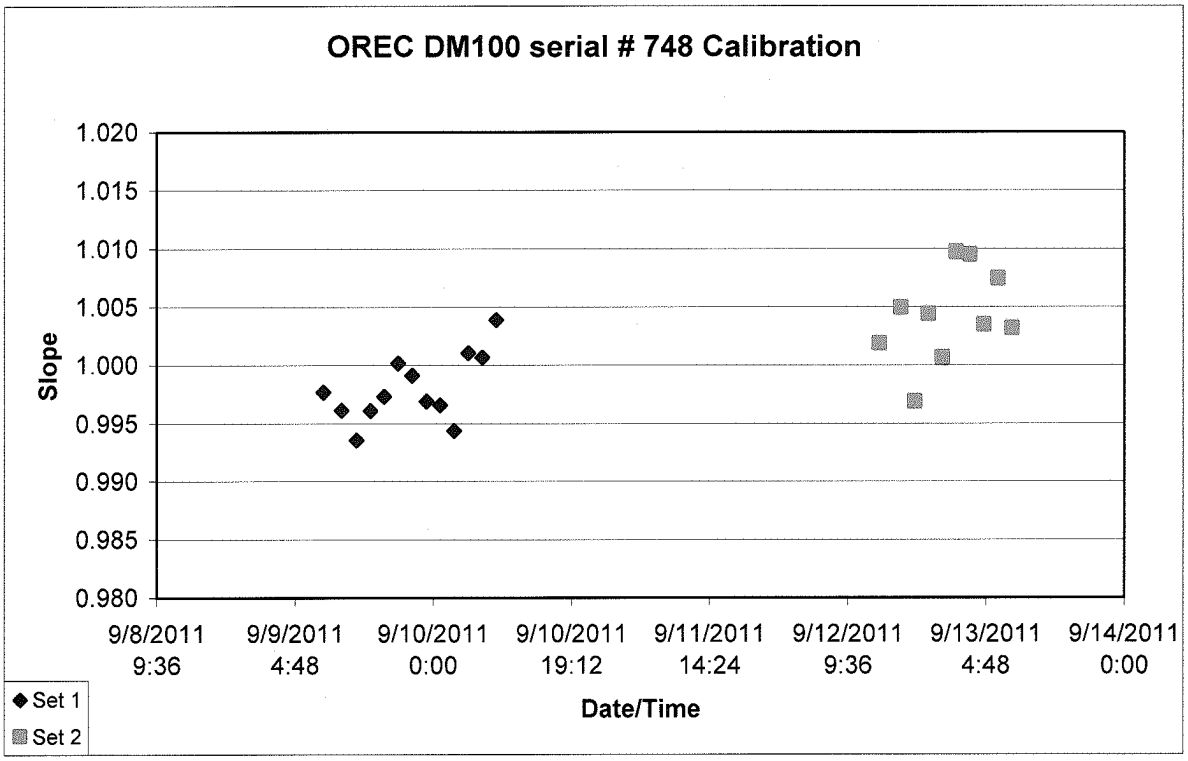
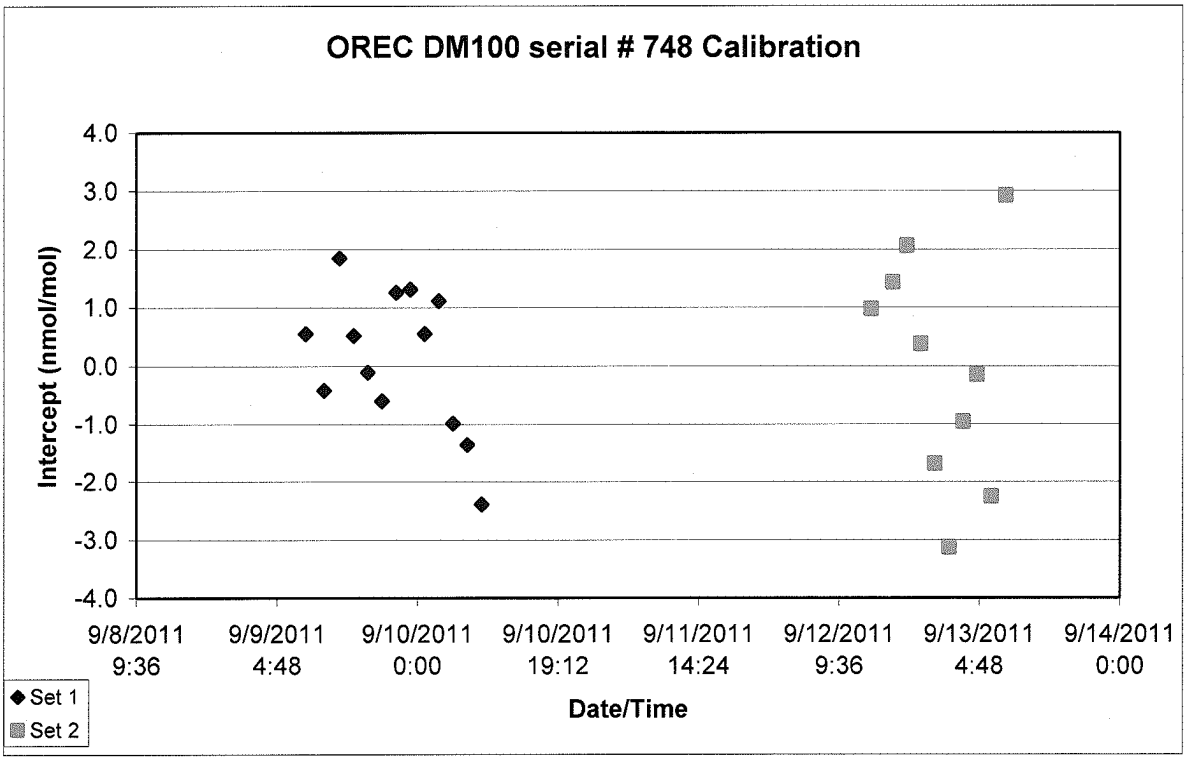
Appendix I.: Graphical representation of calibration data.





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).