CASTNET
2017 Annual Report

Prepared for:

U.S. Environmental Protection Agency
Office of Atmospheric Programs

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Contract No.: GS-10F-075AAA
Order No.: EP-G17H-00554

September 2019

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List of Acronyms and Abbreviations

% diff	percent difference
A/D	analog to digital converter
AQS	Air Quality System
ARS	Air Resource Specialists, Inc.
ASTM	American Society for Testing and Materials
BLM	Bureau of Land Management
BLM-WSO	Bureau of Land Management Wyoming State Office
CASTNET	Clean Air Status and Trends Network
CFR	Code of Federal Regulation
CMAQ	Community Multi-scale Air Quality
DAS	data acquisition system
DC	direct current
DEP	Department of Environmental Protection
deg	degree
DQO	data quality objectives
DVM	digital voltmeter
EEMS	Environmental, Engineering & Measurement Services, Inc.
EPA	U.S. Environmental Protection Agency
ESC	Environmental Systems Corporation
FSAD	Field Site Audit Database
g-cm	gram centimeter
GPS	goblal positioning system
k	kilo (1000)
km	kilometer
lpm	liters per minute
MLM	Multilayer Model
m/s	meters per second
mv	millivolt
NADP	National Atmospheric Deposition Program
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPAP	National Performance Audit Program
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards
PE	Performance Evaluation
ppb	parts per billion
QA	quality assurance
QA/QC	quality assurance/quality control

QAPP	Quality Assurance Project Plan
RH	relative humidity
RTD	Resistance Temperature Detector
SJRWMD	Saint John's Water Management District
SOP	standard operating procedure
SRP	standard reference photometer
SSRF	Site Status Report Forms
TEI	Thermo Environmental Instruments
TTP	Through The Probe
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USNO	United States Naval Observatory
V	volts
VDC	volts direct current
WRR	World Radiation Reference

1.0 Introduction

The Clean Air Status and Trends Network (CASTNET) is a national air monitoring program established in 1988 by the US EPA. Nearly all CASTNET sites measure weekly concentrations of acidic gases and particles to provide accountability for EPA's emission reduction programs. Most sites measure ground-level ozone as well as supplemental measurements such as meteorology and/or trace gas concentrations. Hourly averages of surface ozone concentrations and selected meteorological variables are also measured.

Ambient concentrations are used to estimate deposition rates of the various pollutants with the objective of determining relationships between emissions, air quality, deposition, and ecological effects. In conjunction with other national monitoring networks, CASTNET data are used to determine the effectiveness of national emissions control programs and to assess temporal trends and spatial deposition patterns in atmospheric pollutants. CASTNET data are also used for long-range transport model evaluations and critical loads research.

Historically, CASTNET pollutant flux measurements have been reported as the aggregate product of weekly measured concentrations and model-estimated deposition velocities. The Multi-layer Model (MLM) was used to derive deposition velocity estimates from on-site meteorological parameters, land use types, and site characteristics. In 2011, EPA discontinued meteorological measurements at most EPA-sponsored CASTNET sites.

Currently, CASTNET pollutant flux estimates are calculated as the aggregate product of weekly measured chemical concentrations and gridded model-estimated deposition velocities. Total deposition is assessed using the NADP's Total Deposition Hybrid Method (TDEP; EPA, 2015c; Schwede and Lear, 2014), which combines data from established ambient monitoring networks and chemical-transport models. To estimate dry deposition, ambient measurement data from CASTNET and other networks were merged with dry deposition rates and flux output from the Community Multiscale Air Quality (CMAQ) modeling system.

Since 2011 nearly all CASTNET ozone monitors have adhered to the requirements for State or Local Air Monitoring Stations (SLAMS) as specified by the EPA in 40 CFR Part 58. As such, the ozone data collected must meet the requirements in 40 CFR Part 58 Appendix A, which defines the quality assurance (QA) requirements for gaseous pollutant ambient air monitoring. The audits performed by EEMS under this contract fulfilled the requirement for annual performance evaluation audits of pollutant monitors in the network. The QA requirements can be found at:
https://www3.epa.gov/ttn/amtic/files/ambient/pm25/qa/APP_D%20validation%20template%20version%2003_2017_for%20AMTIC%20Rev_1.pdf

Currently 81 sites at 79 distinct locations measure ground-level ozone concentrations. Annual performance evaluation ozone audit QA data are submitted to the Air Quality System (AQS) database.

As of January 2018, the network is comprised of 95 active rural sampling sites across the United States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), Bureau of Land Management – Wyoming State Office (BLM-WSO) and several independent partners. AMEC Foster Wheeler is responsible for operating the EPA sponsored sites, and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS and BLM-WSO sponsored sites.

2.0 Project Objectives

The objectives of this project are to establish an independent and unbiased program of performance and systems audits for all CASTNET sampling sites. Ongoing Quality Assurance (QA) programs are an essential part of any long-term monitoring network.

Performance audits verify that all reported parameters are consistent with the accuracy goals as defined in the CASTNET Quality Assurance Project Plan (QAPP). The acceptance criteria have changed over the years and EEMS relies on the CASTNET contractor to provide updates to the acceptance criteria. The current criteria are included in Table 2-1.

Due to budgetary necessity, the meteorological measurements were shifted to operating on an as-funded basis. The meteorological sensors were audited on an as directed basis.

Table 2-1. Performance Audit Challenge and Acceptance Criteria

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Precipitation	Response	10 manual tips	1 DAS count per tip
Precipitation	Accuracy	2 introductions of known amounts of water	≤ ±10.0% of input amount
Relative Humidity	Accuracy	Compared to reference instrument or standard solution	≤ ±10.0%
Solar Radiation	Accuracy	Compared to WRR traceable standard	≤ ±10.0% of daytime average
Surface Wetness	Response	Distilled water spray mist	Positive response
Surface Wetness	Sensitivity	1% decade resistance	N/A
Shelter Temperature	Average Difference	Comparison to RTD at 3 observed points	2 °C
Temperature	Accuracy	Comparison to 3 NIST measured baths (~ 0° C, ambient, ~ full-scale)	≤ ± 0.5° C

Sensor	Parameter	Audit Challenge	Acceptance Criteria
Delta Temperature	Accuracy	Comparison to temperature sensor at same test point	≤ ± 0.50° C
Wind Direction	Orientation Accuracy	Parallel to alignment rod/crossarm, or sighted to distant point	≤ ±5° from degrees true
Wind Direction	Linearity	Eight cardinal points on test fixture	≤ ±5° mean absolute error
Wind Direction	Response Threshold	Starting torque tested with torque gauge	< 10 g-cm Climatronics; < 20 g-cm R. M. Young
Wind Speed	Accuracy	Shaft rotational speed generated and measured with certified synchronous motor	≤ ±0.5 mps below 5.0 mps input; ≤ ±5.0% of input at or above 5.0 mps
Wind Speed	Starting Threshold	Starting torque tested with torque gauge	< 0.5 g-cm
Mass Flow Controller	Flow Rate	Comparison with Primary Standard	≤ ± 5.0% of designated rate
Ozone	Slope	Linear regression of multi-point test gas concentration as measured with a certified transfer standard	0.9000 ≤ m ≤ 1.1000
	Intercept		-5.0 ppb ≤ b ≤ 5.0 ppb
	Correlation Coefficient		0.9950 ≤ r
	Percent Difference	Comparison with Standard Concentration	≤ ±15.1% of test gas concentration*
DAS	Accuracy	Comparison with certified standard	≤ ± 0.003 VDC

* The CASTNET QAPP differs from the EPA OAQPS SLAMS for the Acceptance Criterion for Ozone Percent Difference. The EPA OAQPS for SLAMS criterion is ≤ ±10.0% of test gas concentration.

In addition to the accuracy goals defined in the CASTNET QAPP the ozone monitors fall under the requirements of 40 CFR, Part 58 Appendix A, for quality assurance. To comply with Appendix A, the CASTNET audit program includes annual independent ozone performance evaluations (PE). The EEMS field scientists who conduct ozone PE maintain annual certification from the Office of Air Quality Planning and Standards (OAQPS). Audit methods and procedures used are compliant with the National Performance Audit Program (NPAP).

EEMS personnel performed the NPAP Through-The-Probe (TTP) pollutant monitor audits following EPA's Quality Assurance Guidance Document – Method Compendium – Field Standard Operating Procedures (SOP) for the Federal PM2.5 Performance Evaluation Program and NPAP-TTP Audit Standard Operating Procedures (SOP). All procedures and guidance documents used to perform these audits can be found at the EPA OAQPS website:
https://www3.epa.gov/ttn/amtic/npepqa.html

The NPAP is a QA program implemented by the OAQPS to conduct audits of gaseous air pollutant monitors by standard methods throughout each region of the U.S. The method includes introduction of National Institute of Standards and Traceability (NIST) audit gases to the station monitors through the ambient sample inlet, through all filters and fittings. This method evaluates measurement system accuracy through the entire sample train. The audit gas concentrations are also measured and verified with an audit analyzer on-site. For gases other than ozone the audit analyzer is calibrated at the time of the audit.

Performance audits are conducted using standards that are certified as currently traceable to the NIST or another authoritative organization. All standards are certified annually with the exception of ozone standards which are verified as level 2 standards at EPA regional labs at least twice per year.

Site systems audits are intended to provide a qualitative appraisal of the total measurement system. Site planning, organization, and operation are evaluated to ensure that good Quality Assurance/Quality Control (QA/QC) practices are being applied. At a minimum the following audit issues are addressed at each site systems audit:

- Site locations and configurations match those provided in the CASTNET QAPP.
- Meteorological instruments are in good physical and operational condition and are sited to meet EPA ambient monitoring guidelines (EPA-600/4-82-060).
- Sites are accessible, orderly, and if applicable, compliant with OSHA safety standards.
- Sampling lines are free of leaks, kinks, visible contamination, weathering, and moisture.
- Site shelters provide adequate temperature control.

- All ambient air quality instruments are functional, being operated in the appropriate range, and the zero air supply desiccant is unsaturated.
- All instruments are in current calibration.
- Site documentation (maintenance schedules, on-site SOPs, etc.) is current and log book records are complete.
- All maintenance and on-site SOPs are performed on schedule.
- Corrective actions are documented and appropriate for required maintenance/repair activity.
- Site operators demonstrate an adequate knowledge and ability to perform required site activities, including documentation and maintenance activities.

3.0 CASTNET Sites Visited in 2017

This report covers the CASTNET sites audited in 2017. Only those variables that were supported by the CASTNET program were audited. From February through December 2017, EEMS conducted field performance and systems audits at 59 monitoring sites. Meteorological sensors at ten of the sites were also audited. The locations, sponsor agency and dates of the audits along with states and EPA Regions are presented in Table 3-1.

Table 3-1. Site Audits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
CVL151	EPA	Coffeeville	MS / R4	02/21/2017
PAL190	EPA	Palo Duro	TX / R6	02/27/2017
BBE401	NPS	Big Bend NP	TX / R6	03/02/2017
CKT136	EPA	Crockett	KY / R4	03/14/2017
EVE419	NPS	Everglades NP	FL / R4	03/15/2017
MCK131	EPA	Mackville	KY / R4	03/15/2017
MCK231	EPA	Mackville (precision site)	KY / R4	03/15/2017
ALC188	EPA	Alabama-Coushatta	TX / R6	03/28/2017
KNZ184	EPA	Konza Prairie	KS / R7	04/04/2017
KIC003	EPA	Kickapoo Tribe	KS / R7	04/05/2017
CAD150	EPA	Caddo Valley	AR / R6	04/06/2017
CDZ171	EPA	Cadiz	KY / R4	04/07/2017
CHE185	EPA	Cherokee Nation	OK / R6	05/09/2017
CHC432	NPS	Chaco NHP	NM / R6	05/10/2017
DCP114	EPA	Deer Creek St. Park	OH / R5	05/22/2017
OXF122	EPA	Oxford	OH / R5	05/23/2017
SEK430	NPS	Sequoia NP - Ash Mountain	CA / R9	05/23/2017
QAK172	EPA	Quaker City	OH / R5	05/24/2017
YOS404	NPS	Yosemite NP	CA / R9	05/24/2017

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
PIN414	NPS	Pinnacles	CA / R9	05/25/2017
LAV410	NPS	Lassen Volcanic NP	CA / R9	05/30/2017
PND165	BLM	Pinedale	WY / R8	07/15/2017
BAS601	BLM	Basin	WY / R8	07/17/2017
SHE604	BLM	Sheridan	WY / R8	07/18/2017
VPI120	EPA	Horton Station	VA / R3	07/18/2017
BUF603	BLM	Buffalo	WY / R8	07/19/2017
CDR119	EPA	Cedar Creek St. Park	WV / R3	07/20/2017
CNT169	EPA	Centennial	WY / R8	07/21/2017
NEC602	BLM	Newcastle	WY / R8	07/21/2017
PAR107	EPA	Parsons	WV / R3	07/21/2017
PED108	EPA	Prince Edward	VA / R3	07/25/2017
ROM406	NPS	Rocky Mountain NP (NPS)	CO / R8	08/01/2017
ROM206	EPA	Rocky Mountain NP	CO / R8	08/08/2017
YEL408	NPS	Yellowstone NP	WY / R8	08/16/2017
LRL117	EPA	Laurel Hill St. Park	PA / R3	08/17/2017
THR422	NPS	Theodore Roosevelt NP	ND / R8	08/29/2017
VOY413	NPS	Voyageurs NP	MN / R5	09/01/2017
SAN189	EPA	Santee Sioux	NE / R7	09/07/2017
NIC001	EPA	Nicks Lake	NY / R2	09/26/2017
WFM105	EPA	Whiteface Mountain	NY / R2	09/27/2017
UND002	EPA	Underhill	VT / R1	09/28/2017
WFM007	EPA	Whiteface Mountain Summit	NY / R2	10/02/2017
GTH161	EPA	Gothic	CO / R8	10/03/2017
DIN431	NPS	Dinosaur NM	UT / R8	10/04/2017
ACA416	NPS	Acadia NP	ME / R1	10/10/2017

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
WNC429	NPS	Wind Cave NP	SD / R8	10/12/2017
EGB181	EPA	Egbert, Ontario	Ontario CA	10/13/2017
PRK134	EPA	Perkinstown	WI / R5	10/22/2017
STK138	EPA	Stockton	IL / R5	10/25/2017
ALH157	EPA	Alhambra	IL / R5	10/27/2017
VIN140	EPA	Vincennes	IN / R5	10/30/2017
BVL130	EPA	Bondville	IL / R5	11/09/2017
MAC426	NPS	Mammoth Cave NP	KY / R4	11/13/2017
GRS420	NPS	Great Smoky Mountains NP	TN / R4	11/15/2017
CND125	EPA	Candor	NC / R4	11/19/2017
BFT142	EPA	Beaufort	NC / R4	11/27/2017
BWR139	EPA	Blackwater NWR	MD / R3	11/27/2017
WSP144	EPA	Washington Crossing St. Park	NJ / R2	11/28/2017
SHN418	NPS	Shenandoah NP - Big Meadows	VA / R3	11/29/2017

In addition to the sites listed in Table 3-1 that were visited for complete systems and performance audits, the 29 sites listed in Table 3-2 were visited to conduct NPAP Through-The-Probe (TTP) ozone Performance Evaluations (PE).

Table 3-2. Site Ozone PE Visits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
SUM156	EPA	Sumatra	FL / R4	02/23/2017
GAS153	EPA	Georgia Station	GA / R4	02/27/2017
SND152	EPA	Sand Mountain	AL / R4	02/28/2017
SPD111	EPA	Speedwell	TN / R4	03/13/2017
ESP127	EPA	Edgar Evins St. Park	TN / R4	03/16/2017

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
IRL141	EPA	Indian River Lagoon	FL / R4	03/17/2017
COW137	EPA	Coweeta	NC / R4	03/23/2017
PET427	NPS	Petrified Forest NP	AZ / R9	04/24/2017
CHA467	NPS	Chiricahua NM	AZ / R9	04/26/2017
GRC474	NPS	Grand Canyon NP	AZ / R9	04/28/2017
CAN407	NPS	Canyonlands NP	UT / R8	05/01/2017
GRB411	NPS	Great Basin NP	NV / R9	06/08/2017
KEF112	EPA	Kane Experimental Forest	PA / R3	08/16/2017
MKG113	EPA	M. K. Goddard St. Park	PA / R3	08/17/2017
ABT147	EPA	Abington	CT / R1	08/21/2017
NPT006	EPA	Nez Perce Tribe	ID / R10	08/22/2017
ARE128	EPA	Arendtsville	PA / R3	10/08/2017
PSU106	EPA	Penn State University	PA / R3	10/09/2017
CTH110	EPA	Connecticut Hill	NY / R2	10/11/2017
HOW191	EPA	Howland AmeriFlux	ME / R1	10/12/2017
ASH135	EPA	Ashland	ME / R1	10/13/2017
HWF187	EPA	Huntington Wildlife Forest	NY / R2	10/17/2017
ANA115	EPA	Ann Arbor	MI / R5	10/19/2017
SAL133	EPA	Salamonie Reservoir	IN / R5	10/19/2017
HOX148	EPA	Hoxeyville	MI / R5	10/20/2017
UVL124	EPA	Unionville	MI / R5	10/20/2017
DEN417	NPS	Denali NP	AK / R10	10/24/2017
PNF126	EPA	Cranberry	NC / R4	11/16/2017
BEL116	EPA	Beltsville	MD / R3	11/20/2017

4.0 Performance Audit Results

This section provides the summarized performance evaluation (audit) results of each variable challenged at each station visited except for trace gas audit results. CASTNET operates trace gas monitors at several sites including two sites that are part of the NCore Network (GRS420 and BVL130). Performance evaluation audits of the CASTNET trace gas monitors were performed at BVL130, ROM206, PND165, HWF187, MAC426, GRS420, and PNF126 in 2017. Results of the NO_y, CO, and SO_2 monitor audits for those sites have been uploaded to the EPA AQS database and are not included in this report. All PE results for all monitors were within acceptance limits.

Performance audit results are discussed for each variable in the following sections. Tables are included to summarize the average and maximum error between the audit challenges and site results as recorded by the on-site Data Acquisition System (DAS). Linear regression and percent difference (% diff) calculation results are included where appropriate. Results that are outside the CASTNET QAPP acceptance criteria are shaded in the tables.

The errors presented in the tables in the following sections are reported as the difference of the measurement recorded by the DAS and the audit standard. Where appropriate, negative values indicate readings that were lower than the standard, and positive values indicate readings that were above the standard value. The errors appear to be random and without bias. The results are also arranged by audit date. Viewing the results in this order helps to detect any errors that could have been caused by the degradation or drift of the audit standards during the year. The audit standards are transported and handled with care, and properly maintained to help prevent such occurrences. No known problems with the standards were apparent during the year. All standards were within specifications when re-certified at the end of the year.

Detailed reports of the field site audits, which contain all of the test points for each variable at each site, can be found in the Appendices of each of the 2017 Quarterly reports. The variable specific data forms included in Appendix A of each quarter's report contain the challenge input values, the output of the DAS, additional relevant information pertaining to the variable and equipment, and all available means of identification of the sensors and equipment for each site.

Table 4.1 summarizes the number of test failures by variable tested. All station data are recorded from the station’s primary datalogger.

Table 4-1. Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	79	2	2.5
Flow Rate	58	1	2.1
Shelter Temperature (average)	50	1	2
Wind Direction Orientation Average Error	10	3	30
Orientation Maximum Error	10	3	30
Wind Direction Linearity Average Error	10	0	0.0
Linearity Maximum Error	10	0	0.0
Wind Direction Starting Torque	10	0	0.0
Wind Speed Low Range Average Error	10	0	0.0
Low Range Maximum Error	10	0	0.0
Wind Speed High Range Average Error	10	0	0.0
High Range Maximum Error	10	0	0.0
Wind Speed Starting Torque	10	0	0.0
Temperature	40	1	2.5
2 Meter Temperature	20	1	5
Relative Humidity	10	1	10
Solar Radiation	9	1	11
Precipitation	10	0	0.0
DAS Analog to Digital	32	0	0.0

4.1 Ozone

Seventy nine ozone monitor audits were performed in 2017. All ozone challenges were conducted to comply with the OAQPS NPAP-TTP Standard Operating Procedures (SOP) which can be found at https://www3.epa.gov/ttn/amtic/npapsop.html. Each ozone monitor was challenged with ozone-free air and four up-scale concentrations. The ozone test gas concentrations were generated and measured with a NIST-traceable photometer that was verified as a level 2 standard by USEPA. The results of the ozone audits were uploaded to the AQS database at the end of each quarter.

Results of all ozone audits performed are included in Table 4-2. Two monitors tested failed the annual PE (SAN189 and CHE185). The site monitor response at SAN189 to the level 2 audit gas was 2.25 ppb low. The site monitor response to ozone-free gas was also low.

During the audit at CHE185 in May, the site monitor response to ozone-free test gas was high, at approximately 7.7 ppb which caused a high response at the other test points. The results of 3 previous audits by other agencies within the past year indicate that there is an increasing zero value response to ozone free audit gas over time. A second day of extensive testing by EEMS following the ozone PE was performed at the site to help resolve the discrepancy.

Several different test gas delivery configurations were employed. Calibration and audit gas was introduced at different points in the sample train, and directly to the back of the monitor which eliminated the sample train entirely. The tests indicated that the monitor is properly calibrated to match the site calibration standard and site zero air system. Zero audit gas from the mobile lab was introduced to the site level-3 standard. A response of approximately 3 ppb was observed, which was expected since the offset was set to -2.5 and the site standard was reading zero when sampling the site zero air system. A portable T-API zero air system from the mobile lab was tested and the results matched those of the routine audit zero air system (high zero). None of the changes improved the response to the audit gas.

The monitor is configured to perform nightly zero/span tests internally, without a second standard photometer to measure the QC gas. Since the monitor is calibrated correctly to match the calibration standards, the QC tests match the expected values. Bi-weekly and monthly QC and calibration checks are performed with the same level-3 (49CPS) standard and zero air system, that were tested during the original audit, so those results also match the expected values.

It was agreed that the discrepancy is caused by the zero air systems. It was recommended that a new monitor and portable zero air system be purchased for the site if funding is available. The Monitor Labs 9811 is approximately 20 years old.

Table 4-2. Performance Audit Results for Ozone

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
PAL190	0.16	-1.7	-0.2	0.99653	0.67934	0.99995	01110	02/27/2017
BBE401	-0.69	-1	-0.4	1.00088	-0.58293	0.99999	01110	03/02/2017
PET427	-0.57	-2.6	-2.2	0.9762	-0.08736	0.99999	01110	04/24/2017
CHA467	-1.53	-5.4	-4	0.97036	-1.19028	0.99995	01110	04/26/2017
GRC474	-0.64	-3.2	-2.6	0.96858	0.24999	0.99991	01110	04/28/2017
CAN407	-0.21	-1.1	-0.7	0.99043	0.03773	0.99999	01110	05/01/2017
CHC432	1.33	7.8	8.1	1.07855	-0.05935	0.99998	01110	05/10/2017
SEK430	0.55	3.6	4.4	1.04283	-0.13773	0.99997	01110	05/23/2017
YOS404	0.64	4.5	5.4	1.04019	0.0393	0.99997	01110	05/24/2017
PIN414	1.26	4.3	4.6	1.03381	0.64621	1	01110	05/25/2017
LAV410	-0.33	0.2	0.7	1.00815	-0.31491	0.99999	01110	05/30/2017
GRB411	-1.21	-2.7	-2.1	0.9809	-0.47139	0.99997	01110	06/08/2017
PND165	-0.99	-3.4	-2.6	0.97341	-0.24393	0.99995	01110	07/15/2017
BAS601	0.22	-0.1	-0.1	0.99633	0.2252	1	01110	07/17/2017
CNT169	1.13	6.9	8.2	0.99332	0.51699	1	01110	07/21/2017
NEC602	-0.92	-3.7	-3.4	1.05083	0.66404	0.99992	01110	07/21/2017
ROM406	-1.06	-3.9	-3.4	0.9626	-0.14012	0.99997	01110	08/01/2017
ROM206	-0.37	-0.5	-0.3	0.9924	-0.04905	0.99998	01110	08/08/2017
YEL408	-0.71	-1.2	-0.8	0.99672	1.07383	0.99998	01110	08/16/2017
GLR468	1.18	5.8	6.9	0.98064	0.48616	0.99999	01110	08/17/2017
NPT006	-0.55	-2.5	-1.9	0.95995	-0.27325	0.99995	01110	08/22/2017
THR422	-0.92	-4.9	-3.9	1.03949	-0.12822	0.99999	01110	08/29/2017
VOY413	0.39	3.8	4.2	0.9378	-2.35573	0.99979	01110	09/01/2017
SAN189	-2.58	-9.8	-8.6	0.9858	2.61367	0.99987	01110	09/07/2017
GTH161	1.24	3.5	6.8	0.99511	-0.47792	0.99999	01110	10/03/2017
DIN431	-0.58	-1.5	-0.9	0.99071	0.45652	0.99998	01110	10/04/2017
WNC429	-0.53	-3.8	-3.8	0.96148	-0.00563	1	01110	10/12/2017
DEN417	1.19	8.8	8.9	1.01407	-0.0614	0.99998	01110	10/24/2017
CVL151	0.06	1.3	2.6	1.0025	0.49278	0.99997	01111	02/21/2017
SUM156	0.32	-0.3	0.4	0.98801	0.48935	1	01111	02/23/2017
GAS153	0.45	0.4	1	0.99023	-0.05742	0.99989	01111	02/27/2017

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
SND152	0.03	-0.2	-0.2	0.99386	0.30399	0.99999	01111	02/28/2017
SPD111	-0.11	0.7	0.9	1.01002	-0.31528	0.99999	01111	03/13/2017
CKT136	0.15	0.6	2.1	0.99472	0.52205	0.99996	01111	03/14/2017
MCK131	-0.11	-0.4	0.4	1.00169	-0.13324	0.99996	01111	03/15/2017
MCK231	0.21	-0.1	0.4	0.99477	0.33424	0.99997	01111	03/15/2017
ESP127	-0.19	1.6	2.9	1.00432	0.47637	0.99995	01111	03/16/2017
COW137	0.34	0.2	0.7	0.99635	0.41148	0.99997	01111	03/23/2017
ALC188	-0.83	-2.6	-1	0.98751	-0.38549	0.99987	01111	03/28/2017
CAD150	0.14	0.2	1.4	0.99828	0.38094	0.99973	01111	04/06/2017
CDZ171	0.53	-0.5	-0.3	0.9866	0.6018	0.99999	01111	04/07/2017
DCP114	0.44	-0.2	0.4	0.9861	0.73952	1	01111	05/22/2017
OXF122	0.5	-0.1	0	0.99353	0.51736	0.99999	01111	05/23/2017
QAK172	0.08	-1.5	-1.1	0.98407	0.26089	0.99998	01111	05/24/2017
VPI120	0.18	-0.1	0.5	0.99078	0.53153	0.99999	01111	07/18/2017
CDR119	0.53	-0.9	0	0.97705	0.99177	0.99996	01111	07/20/2017
PAR107	0.62	0.1	0.4	0.96612	-0.15807	0.99999	01111	07/21/2017
PED108	0.19	-0.6	1	0.97661	0.77925	0.99999	01111	07/25/2017
KEF112	0.74	1.5	2.2	0.99392	-0.33439	0.99998	01111	08/16/2017
LRL117	0.53	0.5	1.7	0.98678	0.9274	0.99993	01111	08/17/2017
MKG113	0.03	0.9	3.5	0.9901	0.82411	1	01111	08/17/2017
ABT147	0.15	-1.1	-0.4	0.98264	-0.30433	0.99999	01111	08/21/2017
ARE128	0.2	-0.4	-0.2	0.99541	0.54301	0.99998	01111	10/08/2017
PSU106	0.18	0.5	0.9	1.02812	-0.51449	0.99981	01111	10/09/2017
CTH110	0.06	-1.5	-1.2	0.99829	0.15345	0.99999	01111	10/11/2017
ANA115	0.73	2.5	4	1.01745	-0.13909	0.99999	01111	10/19/2017
HOX148	0.13	1.6	1.9	0.9819	0.28944	1	01111	10/20/2017
UVL124	-0.29	-1.3	-0.3	0.98024	0.26213	0.99999	01111	10/20/2017
PRK134	-0.07	-1.3	-1	1.08821	-0.05394	1	01111	10/22/2017
STK138	0.35	0.9	1.6	0.99956	-0.04828	0.99996	01111	10/25/2017
ALH157	0.31	0	0.5	0.99697	-0.04294	0.99999	01111	10/27/2017
VIN140	-0.32	-0.2	0	0.99042	-0.2865	0.99999	01111	10/30/2017
CND125	0.66	-0.2	0	1.01315	-0.98232	0.99998	01111	11/19/2017

Site ID	Actual Difference for Level 2	Ozone Average (% diff) for Levels 3, 4 and 6	Ozone Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	Standard	Date
BFT142	0.07	-1	-0.8	1.02079	-0.55573	0.99995	01111	11/27/2017
IRL141	-0.82	-2.8	-2.1	0.98534	-0.72332	1	01113	03/17/2017
CHE185	7.53	15.3	24.3	1.0242	7.38922	0.99998	01113	05/09/2017
ACA416	0.09	2.3	4.2	0.98668	0.0491	0.99999	01113	10/10/2017
HOW191	-0.15	0.4	1.4	1.00608	0.12752	0.99995	01113	10/12/2017
ASH135	-0.03	1.5	2.8	0.98417	-0.06763	0.99999	01113	10/13/2017
HWF187	-0.28	-1.8	-1.4	1.00596	0.81566	0.99995	01113	10/17/2017
SAL133	-0.5	1	1.3	1.01563	-0.44556	0.99997	01113	10/19/2017
BVL130	-0.18	-1.3	-1.2	0.98285	0.16574	0.99998	01113	11/09/2017
MAC426	0.35	-1.6	-1.5	1.00748	0.18955	1	01113	11/13/2017
GRS420	0.11	1.1	1.2	0.99614	-0.53512	0.99997	01113	11/15/2017
PNF126	-0.96	-0.9	-0.4	0.99229	0.44188	0.99999	01113	11/16/2017
BEL116	-0.8	-0.5	0.5	0.98365	0.45817	0.99999	01113	11/20/2017
BWR139	-0.15	0.8	2	0.97433	-0.75095	0.99999	01113	11/27/2017
WSP144	-1.37	-4.1	-3.2	0.97938	-0.18335	0.99997	01113	11/28/2017
SHN418	-0.01	-2.8	-2.1	1.0025	0.49278	0.99997	01113	11/29/2017

4.1.1 Ozone Bias

EEMS is aware of the EPA *Technical Assistance Document* "Transfer Standards for Calibration of Air Monitoring Analyzers for Ozone" *October 2013* which can be found at the AMTIC website:
https://www3.epa.gov/ttn/amtic/files/ambient/qaqc/OzoneTransferStandardGuidance.pdf.

The document provides the rationale for standard photometer designation and the procedures required to ensure photometer stability. The process involves comparisons to a higher level standard (in this case a regional EPA level 1 standard) and also multiple comparisons on separate days, known as "6x6 verification". As described in the document, once the transfer standard comparison relationship with the level 1 standard has been established and the stability requirements are met, the actual ozone concentration is calculated by:

$$Std. O_3\ conc. = \frac{1}{\bar{m}}\ (Indicated\ O_3\ conc. - \bar{I})$$

Where:
$\bar{m}$ = average slope

$\bar{I}$ = average intercept

EEMS uses this equation with the running 6x6 average slope and intercept to correct level 2 standard photometer measurements back to the regional EPA level 1 standard reference photometer (SRP) for ozone PE audits. Since the technical assistance document also states that if any adjustments are made to the transfer standard a new 6x6 verification is required, EEMS does not adjust the physical settings (background and span) of the level 2 standards unless the photometer does not meet the criteria (+/- 3 %) comparison to the level 1 standard.

This procedure may have introduced a bias to the standard since the level 2 standards are only compared to the level 1 SRP two or three times per year. The running 6x6 slope and intercept averages may not reflect the current relationship between the level 2 and the level 1 standards. This bias was observed in the data from the 2016 ozone PE audits.

EEMS has chosen to deviate from the EPA Technical Assistance Document. In 2017, EEMS began correcting the level 2 standard photometer using the most recent verification results rather than the running 6x6 results. Ozone PE audit data are presented in Figures 1 and 2 which show the actual concentration difference for level 2 audits, and the average percent differences of the ozone PE audits greater than level 2 performed in 2017. The data appear to indicate little if any bias.

Figure 1. 2017 Ozone PE Actual Difference Level 2 Audits

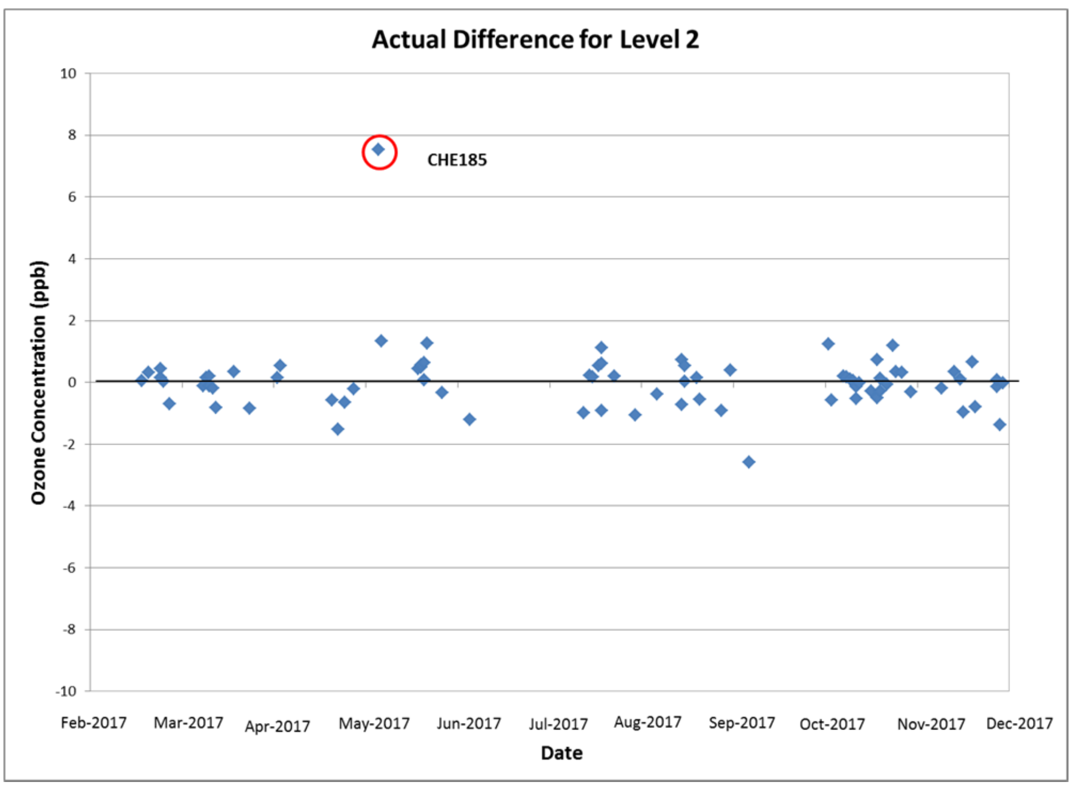
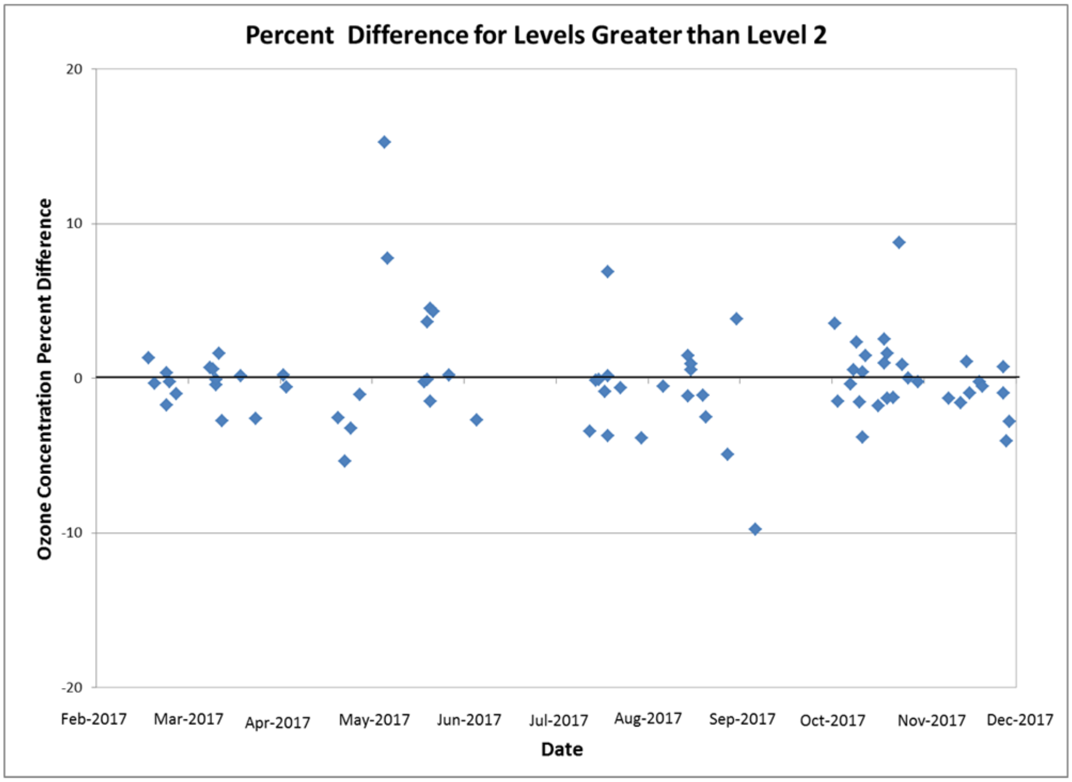


Figure 2. 2017 Average % Difference Ozone Audits Greater Than Level 2



4.2 Flow Rate

The controlled flow rate operated by the CASTNET filter pack system was audited at 58 sites in 2017. One site (MAC426) was outside the acceptance criterion of ± 5.0%. All flow rates are in standard temperature and pressure (at 25 oC) (STP). A NIST-traceable dry-piston primary flow rate device was used for the tests. The readings obtained from this primary standard are the STP flow rate observed, while the DAS flow rate was read from the on-site data logger.

4.3 Shelter Temperature

At each site reporting ozone concentrations to AQS, the hourly average shelter temperature must be between 20 and 30 degrees C, or the hourly ozone data may be invalidated. Shelter temperature was audited at 50 of the sites visited. All but one (BAS601) of the shelter temperature data accuracy results were found to be within the acceptance limit. The method consisted of placing the audit standard in close proximity (in situ) to the shelter temperature sensor and recording either instantaneous observations of both sensors, or averages from both sensors. The audit sensors used are either a Resistance Temperature Detector (RTD) or a Thermocouple.

Nearly all the site sensors were observed to lag behind the audit sensor during the rapid changes in temperature inside the shelter as the air conditioning or heating cycled on and off. The shelter temperature sensors never reached the minimum or maximum temperature measured with the audit sensor. This is not likely to add a large error to the hourly averaged shelter temperature measurements. However, since the output of the shelter temperature sensors follow a sine wave curve but the actual shelter temperature does not change following a sine wave curve, if the shelter temperature is set near the lower or higher allowable limits (20 to 30 degrees C) the actual hourly averages may be lower or higher than those measured by the site sensors.

The CASTNET QAPP does not make a distinction between shelter temperature and any other temperature sensor regarding accuracy criteria. However the sensors were evaluated using a 2 degree C acceptance criterion. This criterion better follows the EPA OAQPS guidelines.

The shelter temperature and flow rate audit results are summarized in Table 4-3. Flow rate and shelter temperature data are reported only for the sites that were visited for complete systems and performance audits.

Table 4-3. Performance Audit Results Shelter Temperature, and Flow Rate

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
CVL151	-0.36	-0.41	1.53	1.50	-1.75
PAL190	-0.05	-0.35	3.04	3.01	-0.99
BBE401	0.27	0.95	3.02	2.99	-1.06
CKT136	-0.04	-0.33	1.53	1.50	-1.96
EVE419			3.00	3.02	0.55
MCK131	-0.82	-0.95	1.54	1.51	-1.95
MCK231	-0.43	-0.94	1.53	1.50	-1.75
ALC188	-0.84	-0.87	1.53	1.50	-1.96
KNZ184	0.50	1.43	3.06	2.99	-2.18
KIC003			3.00	2.99	-0.11
CAD150	-0.19	-0.58	1.51	1.50	-0.66
CDZ171	-0.17	-0.38	1.52	1.50	-1.32
CHE185	0.56	0.64	1.54	1.50	-2.52
CHC432	-0.68	-0.82			
DCP114	0.80	1.34	1.53	1.50	-1.96

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
OXF122	-0.15	-0.20	1.52	1.50	-1.32
SEK430	0.25	0.68	2.97	2.99	0.53
QAK172	0.12	0.23	1.50	1.50	0.00
YOS404	1.08	2.26	3.03	3.02	-0.25
PIN414	0.20	1.03	3.01	3.03	0.64
LAV410	0.52	2.03	2.93	2.97	1.34
PND165	0.60	1.12	3.05	3.01	-1.31
BAS601	2.16	2.72	3.15	3.28	3.98
SHE604			3.25	3.21	-1.36
VPI120	0.99	1.64	1.49	1.50	0.67
BUF603			3.42	3.35	-2.12
CDR119	0.18	0.35	1.53	1.51	-1.09
CNT169	-1.74	-1.92	3.03	3.01	-0.55
NEC602	-0.34	-0.97	3.75	3.64	-3.02
PAR107	-0.09	0.60	1.54	1.50	-2.81
PED108	0.11	-0.45	1.47	1.50	2.04
ROM406	1.62	1.86	3.04	3.00	-1.17
ROM206	0.84	0.99	3.02	2.99	-0.77
YEL408	-0.74	-1.07	2.90	2.89	-0.34
GLR468	-0.8	-1.28	2.94	3.01	2.38
LRL117	0.00	-0.92	1.49	1.50	0.45
THR422	1.93	2.17	2.99	3.00	0.22
VOY413	0.24	0.80	2.99	3.00	0.33
SAN189	-0.75	-1.11	2.98	3.00	0.78
NIC001			3.03	3.00	-0.89
WFM105			3.04	3.00	-1.42
UND002			2.97	3.01	1.23
WFM007			3.02	3.00	-0.77
GTH161	0.69	1.55	2.99	3.00	0.33
ACA416	0.32	1.05	1.50	1.52	0.91

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)
WNC429	-0.21	-1.74	2.97	3.00	1.01
EGB181	-0.26	-0.26	1.58	1.52	-3.80
PRK134	-0.02	-0.31	1.52	1.50	-1.32
STK138	1.11	1.28	1.53	1.50	-1.75
ALH157	0.44	0.67	1.52	1.50	-1.01
VIN140	0.30	1.10	1.51	1.50	-0.49
BVL130	-0.27	-0.54	1.54	1.50	-2.60
MAC426	0.29	0.51	1.65	1.54	-6.61
GRS420	-0.12	-1.65	3.01	3.01	-0.24
CND125	0.72	1.16	1.53	1.50	-1.96
BFT142	-0.22	-0.32	1.49	1.50	0.89
BWR139	1.43	1.96	1.54	1.50	-2.60
WSP144	0.70	1.99	1.51	1.49	-1.54
SHN418	0.92	0.95	1.53	1.51	-1.53

4.4 Wind Speed

The wind speed sensors at ten sites equipped for meteorological measurements were audited. Wind speed data accuracy results at all sites were found to be well within the acceptance limit. The results of the wind speed performance audits are presented in Table 4-4.

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings were evaluated as part of the performance audits. The data acceptance criterion for wind speed bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind speed bearing torque should be ≤ 0.2 g-cm. To establish the wind speed bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set at approximately one-half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacturers' specifications for a properly maintained system. All of the systems were found to be within the acceptance limit.

4.5 Wind Direction

Two separate tests were performed to evaluate the accuracy of each wind direction sensor:

- A linearity test was performed to evaluate the ability of the sensor to function properly and accurately throughout the range from 1 to 360 degrees. This test evaluates the sensor independently of orientation and can be performed with the sensor mounted on a test fixture.
- An orientation test was used to determine if the sensor was aligned properly when installed to measure wind direction accurately in degrees true. An audit standard compass was used to perform the orientation tests.

Using the average error of the orientation tests for the ten sensors tested, three sites were outside the acceptance criterion of ± 5 degrees. These sites were CHE185, CHC432 and NEC6002.
The results of the wind direction performance audits are presented in Table 4-4.

4.5.1 Wind Direction Starting Threshold

The condition of the wind direction bearings were evaluated as part of the performance audits. The data acceptance criterion for wind direction bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind direction bearing torque should be ≤ 10 g-cm for R. M. Young sensors. The manufacturer states that a properly maintained sensor will be accurate up to a starting threshold of 11 g-cm. To establish the wind direction bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set to approximately one-half the DQO. For audit purposes 20 g-cm was used for the acceptance limit for R. M. Young sensors. Climatronics sensors typically have a lower starting torque. For audit purposes a threshold of 10 g-cm was selected for Climatronics sensors. None of the sensors tested were outside of acceptance limits for wind direction starting threshold. The test results are provided in Table 4-4. Do you want that many decimal places for wind speed % diff high range?

Table 4-4. Performance Audit Results for Wind Sensors

	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
Site	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
PAL190	2	4	1.5	3	16	0.03	0.10	0.00	0.00	0.20
CHE185	8.75	10	0.75	1	13	0.07	0.20	-0.02	-0.02	0.30

	Wind Direction					Wind Speed				
	Orientation Error		Linearity Error		Starting Torque (g-cm)	Low Range Error		High Range Error		Starting Torque (g-cm)
Site	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)		Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	
CHC432	8.25	12	1	2	9	0.05	0.20	0.00	0.00	0.30
PND165	2.75	4	0.73	1.6	10	0.05	0.20	0.00	0.00	0.30
BAS601	1.75	3				0.18	0.30	-0.00	0.01	0.40
SHE604	2	5				0.22	0.40	-0.00	0.01	0.30
BUF603	1.5	3				0.19	0.30	0.00	0.01	0.20
NEC602	18.25	21				0.15	0.25	0.01	0.01	0.00
ACA416	3.5	4	1.81	4.99	9	0.18	0.20	-0.01	0.00	0.40
BVL130	2	3	0.88	1.8	11	0.06	0.20	0.00	0.00	0.35

* Note: The wind systems acceptance criteria were applied to the average of the results. The data validation section of the CASTNET QAPP states that if any wind direction or wind speed challenge result is outside the acceptance criterion the variable is flagged.

4.6 Temperature and Two-Meter Temperature

The EPA sponsored site temperature measurement systems consist of a temperature sensor mounted at approximately 9 meters above ground-level on a tower. Sites operated by the Park Service have recently moved the temperature sensors to two meters from the ground (2 meter temperature). Temperature sensors utilized by the BLM are not the same type as those at other CASTNET sites. The BLM temperature sensors are combined relative humidity and temperature sensors and not standalone RTD or encased thermistor temperature sensors. Due to the design of the RH/Temperature sensor, it cannot be submerged in water baths in order to challenge the sensor at different temperature audit levels. For that reason the combination RH/Temperature sensors were audited by placing the sensor in a watertight chamber (RH salt chamber) and then placing the chamber in an ice-water bath, ambient bath, and hot water bath. Therefore the audit results are not directly comparable to audit results of RTD or encased thermistor sensors.

All sites use shields to house the sensors that are either mechanically aspirated with forced air, or naturally aspirated. In all cases the sensors were removed from the sensor shields, and placed in a uniform temperature bath with a precision NIST-traceable RTD, during the audit.

Results of the tests indicate that 28 of the 29 (9-meter) sensors tested were within the acceptance criterion. One site (NEC602) was just slightly above the acceptance criteria.

Twenty 2-meter temperature sensors were tested, with one (BUF603) above acceptance criterion. It should be noted that both NEC602 and BUF603 are sponsored by the BLM and operate a combination RH/Temperature sensor as described above and cannot be submersed in a water-bath. The average errors for all sensors are presented in Table 4-5.

4.6.1 Temperature Shield Blower Motors

All of the 9-meter temperature sensor shield blower motors encountered during the site audits conducted during 2017 were found to be functioning. All but one (PAL190) 2-meter temperature sensor shield blowers were functioning properly.

4.7 Relative Humidity

The ten relative humidity systems that were audited were tested with a combination of primary standard salt solutions, and a certified transfer standard relative humidity probe. The results of the average and maximum errors throughout the measurement range of approximately 30% to 95% are presented in Table 4-5.

As in previous years, operation of humidity sensors with respect to natural or forced-air aspiration can vary between sites. At most EPA sponsored sites humidity sensors are operating in naturally aspirated shields. At most NPS sponsored sites humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers.

During audit tests with the primary standard salt solutions, the sensors were removed from the shields and placed in a temperature controlled enclosure. During audit tests with the transfer standard probe, the sensor and transfer were placed in the same ambient conditions. Therefore the audit tests do not account for differences in the operation of the sensors due to the different shield configurations.

All but one of the sensors tested were within the acceptance criterion. The sensor at BVL130 failed to meet the criteria for either the average or maximum response. The results of the tests are included in Table 4-5.

Table 4-5. Performance Audit Results for Temperature and Relative Humidity

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity Range 0 – 100% Ave. Error (%)	Relative Humidity Range 0 – 100% Max. Error (%)
CVL151	-0.01			
PAL190	-0.04	-0.02	-1.87	3.25
BBE401		-0.02		
CKT136	0.11			
MCK131	0.09			
MCK231	0.00			
ALC188	0.05			
KNZ184	-0.04			
KIC003	0.07			
CAD150	-0.08			
CDZ171	0.03			
CHE185	-0.03	0.12	0.70	2.30
CHC432		-0.50	6.63	8.40
DCP114	0.05			
OXF122	0.05			
SEK430		-0.07		
QAK172	0.03			
YOS404	-0.09			
PIN414		0.06		
LAV410		0.07		
PND165	0.20	0.16	-2.66	-0.69
BAS601		0.20	-3.29	-1.10
SHE604		0.08	-2.07	0.50
VPI120	-0.21			
BUF603		1.57	-3.53	-1.70

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
CDR119	-0.04			
CNT169	-0.03			
NEC602	0.63		0.20	1.60
PAR107	0.06			
PED108	0.04			
ROM406		0.36		
ROM206	0.00			
YEL408		-0.14		
GLR468		-0.39		
LRL117	0.15			
THR422		0.11		
VOY413		0.38		
SAN189	0.06			
NIC001	0.03			
WFM105	0.18			
UND002	-0.05			
WFM007	0.01			
GTH161	0.06			
ACA416		-0.11	0.58	6.25
WNC429		-0.15		
EGB181	-0.10			
PRK134	-0.10			
STK138	0.01			
ALH157	0.09			
VIN140	-0.08			
BVL130	-0.04	-0.01	15.12	24.92

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
MAC426		-0.10		
GRS420		-0.02		
CND125	-0.05			
BFT142	-0.12			
BWR139	0.10			
WSP144	0.00			
SHN418		-0.08		

4.8 Solar Radiation

The ambient conditions encountered during the audit visits were suitable (high enough light levels) for accurate comparisons of solar radiation measurements. A World Radiation Reference (WRR) traceable Eppley PSP radiometer and translator were used as the audit standard system.

Nine sites were tested. All but one site, (PAL190), had daytime average results that were within the acceptance criterion. The results of the individual tests for each site are included in Table 4-6. The percent difference of the maximum single-hour average solar radiation value observed during each site audit is also reported in Table 4-6 although this criterion is not part of the CASTNET data quality indicators. Those values greater than ±10% are bold.

4.9 Precipitation

The ten sites audited used a tipping bucket rain gauge for obtaining precipitation measurement data. The audit challenges consisted of entering multiple amounts of a known volume of water into the tipping bucket funnel at a rate equal to approximately 2 inches of rain per hour. Equivalent amounts of water entered were compared to the amount recorded by the DAS. The results are summarized in Tables 4-6.

Table 4-6. Performance Audit Results for Solar Radiation and Precipitation

	Site	Solar Radiation Error				Precipitation Ave. Error (% diff)
		Daytime Ave. (% diff)	Std. Max. Value (w/m2)	Site Max. Observed (w/m2)	Max. Value (% diff)	
2/27/2017	PAL190	16.63	830	972	**17.16**	-2.0
5/9/2017	CHE185	0.57	778	780	0.22	0.0
5/10/2017	CHC432					0.0
7/15/2017	PND165	-2.60	880	906	2.95	-4.6
7/17/2017	BAS601	-2.45	985	942	-4.37	-9.7
7/18/2017	SHE604	0.80	862	877	1.74	5.4
7/19/2017	BUF603	1.24	942	950	0.85	-1.5
7/21/2017	NEC602	-3.56	821	768	-6.50	1.8
10/10/2017	ACA416	-4.77	630	612	-2.86	-5.0
11/9/2017	BVL130	-8.47	588	529	**-10.09**	1.0

4.10 Data Acquisition Systems (DAS)

All of the NPS sponsored sites visited utilized an ESC logger as the primary and only DAS. All EPA sites visited operated Campbell Scientific loggers as their only DAS. The results presented in table 4-7 include the tests performed on the logger at each site. The BLM sites utilize a Campbell Scientific CR1000. The CR1000 is not configured to allow analog tests.

4.10.1 Analog Test

The accuracy of each logger was tested on two different channels (if two channels were available to be used) with a NIST-traceable Fluke digital voltmeter. At the EPA sponsored sites the channels above analog channel 8 could not be tested since there were no empty channels available to test. All EPA sponsored site data loggers were within the acceptance criterion of ± 0.003 volts. Three of the NPS sponsored site data loggers were outside the acceptance criterion of ± 0.003 volts.

4.10.2 Functionality Tests

Other performance tests used to evaluate the DAS included the verification of the date and time, and operation of the battery backup system used to save the DAS date, time, and configuration during a power outage. All EPA sponsored site data loggers were found to be set to the correct date and within ±5 minutes per the acceptance criterion for time. The NPS sponsored site data loggers and the NPS sponsored site data loggers were found to be set to the correct date and within ±5 minutes of the acceptance criterion for time. However, most of the NPS clocks were found to be 1 to 3 minutes different than the standard, whereas the EPA sponsored site clocks were all within 2-3 seconds. The Campbell Scientific logger clocks at the EPA sites are synchronized with the internet, whereas the ESC loggers at the NPS sites are not.

Table 4-7. Performance Audit Results for Data Acquisition Systems

		Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
		Low Channel		High Channel			
	Site	Average	Maximum	Average	Maximum		
2/21/2017	CVL151	0.0000	0.0000			Y	0
2/27/2017	PAL190	0.0000	0.0003			Y	0
3/2/2017	BBE401			0.0001	0.0003	Y	1.27
3/14/2017	CKT136	0.0001	0.0002			Y	0
3/15/2017	EVE419	-0.0001	0.0000			Y	2.5
3/15/2017	MCK131	0.0002	0.0002			Y	0
3/15/2017	MCK231	0.0001	0.0002			Y	0
3/28/2017	ALC188	-0.0001	0.0000			Y	0
4/6/2017	CAD150	0.0001	0.0002			Y	0.02
4/7/2017	CDZ171	0.0000	0.0000			Y	0
5/9/2017	CHE185	-0.0004	-0.0003			Y	0.02
5/10/2017	CHC432			0.0004	0.0008	Y	3
5/22/2017	DCP114	0.0001	0.0001			Y	0
5/23/2017	OXF122	0.0000	0.0001			Y	0
5/23/2017	SEK430			0.0002	0.0004	Y	1.5
5/24/2017	QAK172	0.0000	0.0001			Y	0
5/24/2017	YOS404	-0.0001	0.0001			Y	1.87
5/25/2017	PIN414			0.0001	0.0004	Y	0.57
5/30/2017	LAV410			-0.0002	0.0001	Y	0.33
7/17/2017	BAS601					Y	0
7/18/2017	SHE604					Y	0

	Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
		Low Channel		High Channel			
		Average	Maximum	Average	Maximum		
7/18/2017	VPI120	0.0000	0.0001			Y	0
7/19/2017	BUF603	0.0000	0.0001			Y	5
7/20/2017	CDR119	0.0001	0.0001			Y	0
7/21/2017	CNT169	0.0000	0.0001			Y	0
7/21/2017	NEC602					Y	8.15
7/21/2017	PAR107	0.0000	0.0001			Y	0.02
7/25/2017	PED108	-0.0001	0.0000			Y	0
8/1/2017	ROM406	0.0001	0.0011			Y	0.9
8/8/2017	ROM206	-0.0001	0.0000			Y	0.42
8/16/2017	YEL408			0.0000	0.0002	Y	2.53
08/17/2017	GLR468			-0.0001	-0.0003	Y	1.17
8/17/2017	LRL117	0.0000	0.0000			Y	0
8/29/2017	THR422	0.0000	0.0002			Y	1.25
9/1/2017	VOY413			0.0000	0.0003	Y	3.08
9/7/2017	SAN189	0.0000	0.0002			Y	0
10/3/2017	GTH161	-0.0004	0.0001			Y	0
10/10/2017	ACA416	0.0000	0.0000			Y	2.6
10/12/2017	WNC429	0.0000	0.0003			Y	3.32
10/13/2017	EGB181	0.0000	0.0001			Y	0
10/22/2017	PRK134	0.0000	0.0000			Y	0
10/25/2017	STK138	0.0001	0.0001			Y	0
10/27/2017	ALH157	0.0000	0.0001			Y	0
10/30/2017	VIN140	0.0001	0.0002			Y	0
11/10/2017	BVL130	0.0000	0.0001			Y	0
11/13/2017	MAC426			0.0000	0.0002	Y	2.38
11/15/2017	GRS420	0.0000	0.0000			Y	0.72

	Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
		Low Channel		High Channel			
		Average	Maximum	Average	Maximum		
11/19/2017	CND125	0.0000	0.0000			Y	0.02
11/27/2017	BFT142	0.0000	0.0001			Y	0
11/27/2017	BWR139	0.0000	0.0001			Y	0.03
11/28/2017	WSP144	0.0000	0.0000			Y	0.03
11/29/2017	SHN418	0.0003	0.0005			Y	1.42

5.0 Systems Audit Results

The following sections summarize the site systems audit findings and provide information observed regarding the measurement processes at the sites. Conditions that directly affect data accuracy have been reported in the previous sections. Other conditions that affect data quality and improvements to some measurement systems or procedures are suggested in the following sections.

5.1 Siting Criteria

All of the sites that were visited have undergone changes during the period of site operation which include population growth, road construction, and foresting activities. None of those changes were determined to have a significant impact on the siting criteria that did not exist when the site was initially established.

Some sites that are located in state and national parks are not in open areas, and have trees within the 50 meter criterion established in the QAPP. Given the land use and aesthetic concerns, these sites are acceptable and represent an adequate compromise with regard to siting criteria and the goal of long-term monitoring. For sites that measure ozone data designated as NAAQS compliant, these sites may violate recommended siting criteria in 40 CFR Part 58.

5.2 Sample Inlets

With consideration given to the siting criteria compromises described in the previous section, all but two sites (LAV410 and CDR119) visited in 2017 have ozone monitor sample trains that are sited properly and in accordance with the CASTNET QAPP. All ozone sample inlets are currently being evaluated with respect to obstructions above the inlet. The acceptance criterion requires that there should be no obstructions (including trees) within a 22.5 degree angle (object distance must be at least two times the height) above the ozone inlet. There are trees that violate the 22.5 degree sample inlet requirement at the LAV410 and the CDR119 sites.

Ozone sample inlets are between 3 and 15 meters. With the exception of one site (WNC429) Teflon tubing of the proper diameter is used for the ozone inlets. The ozone sample train at WNC429 is primarily glass with an exhaust fan downstream of the ozone sample port. The ozone analyzer at WNC429 (South Dakota) is operated by the State.

With the exception of WNC429, the ozone zero, span, and precision calibration test gases are introduced at the ozone sample inlet, through all filters and the entire sample train. All sample trains are comprised of only Teflon fittings and materials. Sample inlet particulate filters of 5 micron are present at most sites.

The dry deposition filter packs are designed to sample from 10 meters. Most of the filter pack sample lines are also Teflon. Inline filters are present in the sample trains to prevent moisture and particulates from damaging the flow rate controller.

5.3 Infrastructure

Sites continue to be improved by repairing the site shelters which had deteriorated throughout the years of operation. The installation and upgrade of the data loggers and replacement of degrading signal cables, has been very beneficial to the network. A few of the site shelters are still in need of repair, but overall the condition of the sites has improved again during the past year.

5.4 Site Operators

Generally the site operators are very conscientious and eager to complete the site activities correctly. They are willing to, and have performed sensor replacements and repairs at the sites with support provided by the AMEC and ARS field operations centers. In some cases, where replacements or repairs were made, documentation of the activities was not complete, and did not include serial numbers of the removed and installed equipment.

Many of the CASTNET site operators also perform site operator duties for the National Atmospheric Deposition Program (NADP). Many of the NPS site operators also perform other air, or environmental quality functions within their park. All are a valuable resource for the program.

Still many of the site operators have not been formally trained to perform the CASTNET duties by either AMEC or ARS. They had been given instructions by the previous site operators and over the phone instructions from the field operation centers at AMEC and ARS.

5.5 Documentation

There were some documentation problems with the Site Status Report Forms (SSRF) completed by the site operators each week during the regular site visits. Common errors included improper reporting of “initial flow”, “final flow”, and “leak check” values.

The NPS site operator procedures are well developed and readily accessible at all of the NPS sites visited. There is an electronic interface (DataView 2) available to view, analyze, and print site data. There are electronic “checklists” for the site operator to complete during the site visits; however, all of the CASTNET filter pack procedures are not included in the “checklists”. Flow rates and leak check results are not recorded electronically.

An electronic logbook is included in the interface software. This system permits easy access to site documentation data. Complete calibration reports have been added to the system and accessible through the site computer, however the reports available on-site are not up to date.

5.6 Site Sensor and FSAD Identification

Continued improvement has also been made in the area of documentation of sensors and systems used at the sites. It is important to maintain proper sensor identification for the purposes of site inventory and to properly identify operational sensors for data validation procedures. Many sensors have had new numbers affixed for proper identification.

Where possible the identification numbers assigned (serial numbers and barcodes) are used within the field site audit database for all the sensors encountered during the site audits. The records are used for both the performance and systems audits. If a sensor is not assigned a serial number by the manufacturer, that field is entered as “none”. If it is unknown whether an additional client ID number is assigned to a sensor, and a number is not found, the client ID is also entered as “none”. If it is typical for a manufacturer and/or client ID number to be assigned to a sensor, and that number is not present, the field is entered as “missing”. If either the serial number or the client ID numbers cannot be read, the field is entered as “illegible”. An auto-number field is assigned to each sensor in the database in order to make the records unique.

6.0 Summary and Recommendations

The CASTNET Site Audit Program has been successful in evaluating the field operations of the sites. The results of performance and systems audits are recorded and archived in a relational database, the Field Site Audit Database (FSAD). CASTNET site operations are generally acceptable and continue to improve. Some differences between actual site operations and operations described in the QAPP have been identified and described. Procedural differences between EPA and NPS sponsored sites have also been described.

As discussed previously the shelters have received some much needed attention. It was also observed that improvements were made to the shelter temperature control systems. As a requirement in 40 CFR Part 58 for ozone monitoring, shelter temperature is an important variable. Additional improvement could be made to accurately measure and report shelter temperature.

The previous paragraphs and sections included some recommendations for improving the field operations systems. One recommendation for improving the audit program is presented in the following section.

6.1 In Situ Comparisons

An improvement to the audit procedures designed to evaluate the differences in measurement technique would be to develop an “In Situ” audit measurement system. This would require a suite of sensors that would be collocated with the site sensors. Ideally the audit sensors would address the inconsistent sensor installations observed throughout the network. By deploying a suite of certified NIST traceable sensors installed and operating as recommended by the manufacturer and to EPA guidelines, subtle differences in the operation of the existing CASTNET measurement systems could be evaluated. The “In Situ” sensors would be operated at each site for a 24 hour period and the measurements would be compared to the CASTNET measurements. A portable system of meteorological sensors would be beneficial for meteorological measurement evaluations particularly at BLM sponsored sites. EEMS is still pursuing this type of audit system.

7.0 References

Office of Air Quality and Planning Standards AMTIC website, SOP and guidance documents: www.epa.gov/ttn/amtic/

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II - Ambient Air Specific Methods – EPA.

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume IV - Meteorological Measurements – EPA.

Clean Air Status and Trends Network (CASTNET) Quality Assurance Project Plan (2003) – EPA.

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I: - A Field Guide To Environmental Quality Assurance – EPA.

Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II: Part1 Ambient Air Quality Monitoring Program Quality System Development – EPA.

Sensitivity of the National Oceanic and Atmospheric Administration multilayer model to instrument error and parameterization uncertainty: Journal of Geophysical Research, Vol. 105. No. D5, March 16, 2000.

Wind System Calibration, Recommended Calibration Interval, Procedure, and Test Equipment: November 1999, R. M. Young Company

Bowker, G.E., Schwede, D.B.; Lear, G.G.; Warren-Hicks, W.J., and Finkelstein, P.L., 2011. Quality assurance decisions with air models: a case study of imputation of missing input data using EPA's multi-layer model. Water, Air, and Soil Pollution 222, 391e402.

APPENDIX 1

Audit Standards Certifications

Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions[1]

1. Scope

1.1 This practice describes two methods for generating constant relative humidity (rh) environments in relatively small containers.

1.2 This practice is applicable for obtaining constant relative humidities ranging from dryness to near saturation at temperatures spanning from 0 to 50°C.

1.3 This practice is applicable for closed systems such as environmental conditioning containers and for the calibration of hygrometers.

1.4 This practice is not recommended for the generation of continuous (flowing) streams of constant humidity unless precautionary criteria are followed to ensure source stability. (See Section 9.)

1.5 **Caution**—Both saturated salt solutions and sulfuric acid-water solutions are extremely corrosive, and care should be taken in their preparation and handling.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (For more specific safety precautionary information see 1.5 and 10.1.)

2. Referenced Documents

2.1 *ASTM Standards:*

D 1193 Specification for Reagent Water[2]

D 4023 Definitions of Terms Relating to Humidity Measurements[3]

E 126 Test Method for Inspection and Verification of Hydrometers[4]

2.2 *Other Document:*

DIN50008 "Konstantklimate uber waBerigen Losungen" (Constant Climates Over Aqueous Solutions).
Part 1: Saturated Salt and Glycerol Solutions.
Part 2: Sulfuric Acid Solutions. (1981)[5]

3. Definitions

3.1 *non-hygroscopic material*—material which neither absorbs nor retains water vapor.

3.2 For definitions of other terms used in this practice refer to Definitions D 4023.

4. Summary of Practice

4.1 Standard value relative humidity environments are generated using selected aqueous saturated salt solutions or various strength sulfuric acid-water systems.

5. Significance and Use

5.1 Standard value relative humidity environments are important for conditioning materials in shelf-life studies or in the testing of mechanical properties such as dimensional stability and strength. Relative humidity is also an important operating variable for the calibration of many species of measuring instruments.

6. Interferences

6.1 Temperature regulation of any solution-head space environment to ±0.1°C is essential for realizing generated relative humidity values within ±0.5 % (expected).

6.2 *Sulfuric Acid*—Water systems are strongly hygroscopic and can substantially change value by absorption and desorption if stored in an open container. Only freshly prepared solutions, or solutions which values have been independently tested for strength should be used.

6.3 Some aqueous saturated salt solutions change composition following preparation by hydrolysis or by reaction with environmental components (for example, carbon dioxide absorption by alkaline materials). These solutions should be freshly prepared on each occasion of use.

7. Apparatus

7.1 *Container*—The container, including a cover or lid which can be secured airtight, should be made of corrosion resistant, non-hygroscopic material such as glass. A metal or plastic container is acceptable if the solution is retained in a dish or tray made of appropriate material. Refer also to 9.2 for size restrictions.

7.2 *Hydrometers*—One or more hydrometers may be used to test sulfuric acid solution densities for the range of humidities concerned. The hydrometer(s) should have a minimum scale division of 0.001 gm/cm³. (Refer to Test Method E 126.)

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[1] This practice is under the jurisdiction of ASTM Committee D-22 on Sampling and Analysis of Atmospheres and is the direct responsibility of Subcommittee D22.11 on Meteorology.

Current edition approved Feb. 22, 1985. Published June 1985.

[2] *Annual Book of ASTM Standards*, Vol 11.01.

[3] *Annual Book of ASTM Standards*, Vol 11.03.

[4] *Annual Book of ASTM Standards*, Vol 14.03.

[5] Published by Deutsches Institut für Normung, 4-10 Burggrzfenstrasse Postfach 1107, D-1000 Berlin, Federal Republic of Germany. Also available from ANSI Publication Office, New York, NY.

8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used for preparation of all standard solutions. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[6] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.1.1 Saturated salt solutions may be prepared using either amorphous or hydrated reagents (that is, reagents containing water of crystallization). Hydrated reagents are often preferred to amorphous forms for their solvating characteristics.

8.2 *Purity of Water*—Reagent water produced by distillation, or by ion exchange, or reverse osmosis followed by distillation shall be used. See Specification D 1193.

9. Technical Precautions

9.1 Although a container capable of airtight closure is described in Section 7, it may be desirable to have a vent under certain conditions of test or with some kinds of containers (changes in pressure may produce undesirable cracks in some types of containers). The vent should be as small as practical to minimize loss of desired equilibrium conditions when in use.

9.2 The container should be small to minimize the influence of any temperature variations acting upon the container and contents. A maximum proportion of 25 cm^3 volume/cm^2 of solution surface area is suggested, and overall container headspace volume should be no larger than necessary to confine a stored item.

9.3 Measurement accuracy is strongly dependent on the ability to achieve and maintain temperature stability during actual use of any solution system. Temperature instability of ±0.1°C can cause corresponding instabilities in generated values of relative humidity of ±0.5 %.

9.4 The compatibility of any constant relative humidity system used for instrument calibration testing should be confirmed by reference to the instrument manufacturer's instructions.

9.5 Important considerations leading to stability should include (but are not necessarily limited to) the following:

9.5.1 Elimination of leakage paths.

9.5.2 Elimination of heat sources or heat sinks, or both, for temperature stability.

9.5.3 Limiting flow rate to preclude source carry-over.

[6] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

10. Preparations of Aqueous Solutions

10.1 Caution—Saturated salt-water systems and sulfuric acid solutions should be regarded as hazardous materials. Refer to 1.6 for guidelines.

10.2 *Saturated Salt-Water Systems:*

10.2.1 Select a salt of characteristic value from Annex A1.

NOTE —The reference document by Greenspan[7] contains information on many other saturated salt solutions which may be used. These additional systems, however, are less accurately or less completely defined in value. Also, some may only be used when freshly prepared (to limit the influence of chemical instability such as hydrolysis or acid gas absorption). The salts listed in Annex A1 can be used for a year or more.

10.2.2 Place a quantity of the selected salt in the bottom of a container or an insert tray to a depth of about 4 cm for low rh salts, or to a depth of about 1.5 cm for high rh salts.

10.2.3 Add water in about 2-mL increments, stirring well after each addition, until the salt can absorb no more water as evidenced by free liquid. Although a saturated solution system is defined when any excess quantity of undissolved solute is present, it is preferred to keep the excess liquid present to a minimum for ease in handling and for minimal impact on stability should temperature variations occur.

10.2.4 Close the container and allow 1 h for temperature stabilization.

10.2.5 The container may be used as a reservoir from which quantities of slush can be transferred for use, or the entire container may be used for conditioning tests.

10.3 *Sulfuric Acid-Water Solutions:*

10.3.1 Determine the acid concentration corresponding to the desired relative humidity value from Annex A2, interpolating as necessary.

10.3.2 Measure sufficient working quantities of sulfuric acid reagent and reagent water so that, when mixed in proper proportion, a sufficient depth of liquid is available for proper floatation of a test hydrometer. (See Section 9.)

10.3.3 Measure solution density after the sulfuric acid-water solution has cooled following mixing. Refer to Annex A2 for desired values.

10.3.4 Store the prepared mixture in a container with a tight-fitting lid. Check solution density before each occasion of use.

11. Precision and Bias

11.1 Under ideal conditions, the bias (accuracy) of the sources generated by this practice are equal to the uncertainty figures associated with each source value, as stated in the Annex tables. In actual use, lack of temperature equilibrium (±0.5°C) and other functional losses can reduce the bias statement to ±2.5 %. Precision is ±0.5 % rh.

[7] Greenspan, L., "Humidity Fixed Points of Binary Saturated Aqueous Solutions," *Journal of Research*, National Institute of Standards and Technology, Vol. 81A, 1977, pp. 89–96.

ANNEXES

(Mandatory Information)

A1.1 EQUILIBRIUM RELATIVE HUMIDITY VALUES FOR SELECTED SATURATED AQUEOUS SALT SOLUTIONS

Temperature (°C)	Lithium Chloride[A] LiCl, %	Potassium Acetate[A] CH_3COOK	Magnesium Chloride[A] $MgCl_2 \cdot 6H_2O$, %	Potassium Carbonate[A] K_2CO_3, %	Magnesium Nitrate[A] $Mg(NO_3)_2 \cdot 6H_2O$, %	Sodium Chloride[A] NaCl, %	Potassium Chloride[A] KCl, %	Barium Chloride[B] $BaCl_2 \cdot H_2O$, %	Potassium Nitrate[A] KNO_3, %	Potassium Sulfate[A] K_2SO_4, %
0	11.2 ± 0.5	...	33.7 ± 0.3	43.1 ± 0.7	60.4 ± 0.6	75.5 ± 0.3	88.6 ± 0.5	...	96.3 ± 2.9	98.8 ± 2.1
5	11.3 ± 0.5	...	33.6 ± 0.3	43.1 ± 0.5	58.9 ± 0.4	75.7 ± 0.3	87.7 ± 0.5	93 ± 2	96.3 ± 2.1	98.5 ± 0.9
10	11.3 ± 0.4	23.4 ± 0.5	33.5 ± 0.2	43.1 ± 0.4	57.4 ± 0.3	75.7 ± 0.2	86.8 ± 0.4	93 ± 2	96.0 ± 1.4	98.2 ± 0.8
15	11.3 ± 0.4	23.4 ± 0.3	33.3 ± 0.2	43.2 ± 0.3	55.9 ± 0.3	75.6 ± 0.2	85.9 ± 0.3	92 ± 2	95.4 ± 1.0	97.9 ± 0.6
20	11.3 ± 0.3	23.1 ± 0.3	33.1 ± 0.2	43.2 ± 0.3	54.4 ± 0.2	75.5 ± 0.1	85.1 ± 0.3	91 ± 2	94.6 ± 0.7	97.6 ± 0.5
25	11.3 ± 0.3	22.5 ± 0.3	32.8 ± 0.2	43.2 ± 0.4	52.9 ± 0.2	75.3 ± 0.1	84.3 ± 0.3	90 ± 2	93.6 ± 0.6	97.3 ± 0.5
30	11.3 ± 0.2	21.6 ± 0.5	32.4 ± 0.1	43.2 ± 0.5	51.4 ± 0.2	75.1 ± 0.1	83.6 ± 0.3	89 ± 2	92.3 ± 0.6	97.0 ± 0.4
35	11.3 ± 0.2	...	32.1 ± 0.1	...	49.9 ± 0.3	74.9 ± 0.1	83.0 ± 0.3	88 ± 2	90.8 ± 0.8	96.7 ± 0.4
40	11.2 ± 0.2	...	31.6 ± 0.1	...	48.4 ± 0.4	74.7 ± 0.1	82.3 ± 0.3	87 ± 2	89.0 ± 1.2	96.4 ± 0.4
45	11.2 ± 0.2	...	31.1 ± 0.1	...	46.9 ± 0.5	74.5 ± 0.2	81.7 ± 0.3	...	87.0 ± 1.8	96.1 ± 0.4
50	11.1 ± 0.2	...	30.5 ± 0.1	...	45.4 ± 0.6	74.4 ± 0.2	81.2 ± 0.3	...	84.8 ± 2.5	95.8 ± 0.5

[A] See "Humidity Fixed Points of Binary Saturated Aqueous Solutions," by L. Greenspan. Published in the *Journal of Research* by the National Institute of Standards and Technology, Vol 81A, 1977, pp. 89–96.

[B] See the German standard, DIN 50008, Constant Climates Over Aqueous Solutions, (referenced in 2.2).

A2. EQUILIBRIUM RELATIVE HUMIDITY VALUES FOR SULFURIC ACID-WATER SOLUTIONS

NOTE—The values shown in this table are stated with an uncertainty of ±1 % rh

Weight % H_2SO_4	Density, g/mL at 20°C	Density, g/mL at 23°C	Density, g/mL at 25 %	Equilibrium Relative Humidity in % at t°C			
				5°C	23°C	25°C	50°C
5	10 317	10 307	10 300	98	98	98	98
10	10 661	10 648	10 640	96	96	96	96
15	11 020	11 005	10 994	92	92	92	93
20	11 394	11 376	11 365	88	88	88	89
25	11 783	11 764	11 750	82	82	82	83
30	12 185	12 164	12 150	74	75	75	77
35	12 599	12 577	12 563	65	66	67	69
40	13 028	13 005	12 991	54	56	57	59
45	13 476	13 452	13 437	43	46	46	49
50	13 591	13 972	13 911	32	35	35	38
55	14 453	14 428	14 412	23	25	25	28
60	14 983	14 957	14 940	14	16	16	19
65	15 533	15 507	15 490	8	9	9	11
70	16 105	16 077	16 059	4	4	5	6

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01220

Description: HYGROMER
Manufacturer: ROTRONIC
Model Number: A1H
Serial Number: 75296
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments:

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: TMI-M-HYGROTHERMOGRAPHS Rev: 2/22/2011
Temperature: 72 F
Humidity: 41 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain
Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
0710649	THUNDER SCIENTIFIC	2500ST	2/11/2016	2/11/2017

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

Certificate Number
A2380172
Issue Date: 01/23/17

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	15.0	14.6	15.4	15.0	15.0	C	
Temperature Accuracy	25.0	24.6	25.4	24.8	24.8	C	
Temperature Accuracy	35.0	34.6	35.4	34.8	34.8	C	
Humidity Accuracy	33.0	31.4	34.6	33.4	33.4	%	
Humidity Accuracy	50.0	48.4	51.6	50.1	50.1	%	
Humidity Accuracy	75.0	73.4	76.6	74.8	74.8	%	

EEMS # 01220

$m = 0.9978$
$b = 0.0685$
$r^2 = 0.99994$

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2380228
Issue Date: 01/23/17

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01225

Description: THERMO HYGROMETER
Manufacturer: ROTRONIC
Model Number: HYGROPALM
Serial Number: 40861 002/124431
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments:

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: TMI-M-HYGROTHERMOGRAPHS Rev: 2/22/2011
Temperature: 72 F
Humidity: 41 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
0710649	THUNDER SCIENTIFIC	2500ST	2/11/2016	2/11/2017

Certificate Number
A2380228
Issue Date: 01/23/17

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	15.0	14.6	15.4	15.4	15.4	C	
Temperature Accuracy	25.0	24.6	25.4	25.2	25.2	C	
Temperature Accuracy	35.0	34.6	35.4	35.2	35.2	C	
Humidity Accuracy	33.0	31.4	34.6	33.1	33.1	%	
Humidity Accuracy	50.0	48.4	51.6	50.1	50.1	%	
Humidity Accuracy	75.0	73.4	76.6	75.0	75.0	%	

FEMS# 01225

$m = 0.9944$
$b = 0.3839$
$r^2 = 0.99999$

TMI Technical Maintenance, Inc.

12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Rev. 10
3/14/16

Certificate Number
A2380051
ate: 01/23/17

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01226

Description: DIGITAL STIK THERMOMETER
Manufacturer: FLUKE
Model Number: 1551A EX
Serial Number: 2085085
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments: TUR is 2 to 1

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: FLUKE 1551A EX,52A EX
Rev: 11/1/2010
Temperature: 72 F
Humidity: 41 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
899976	FLUKE	5618B-12	12/6/2016	2/21/2018
A06118	HART SCIENTIFIC	9103	5/8/2016	10/25/2017
A11967	HART SCIENTIFIC	9140	6/27/2016	6/27/2018
A88072	FLUKE/HART	1502A	1/17/2017	4/15/2017

TMI
Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Certificate Number
A2380051
Issue Date: 01/23/17

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	-25.00	-25.05	-24.95	-25.03	-25.03	°C	
Temperature Accuracy	0.00	-0.05	0.05	0.00	0.00	°C	
Temperature Accuracy	100.00	99.95	100.05	100.03	100.03	°C	
Temperature Accuracy	150.00	149.95	150.05	150.04	150.04	°C	

EEMS # 01226

m = 1.0003664
b = -0.010611
r^2 = 1.00000

TMI Technical Maintenance, Inc.

12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Date

2/4/2017 - - **Calibration and verification of three RTD meters with most recent certification of EEMS RTD**

TMI Cert data -- 1/23/2017

	TMI STD	EEMS RTD 01229	diff	corrected
Cert #	A2380069			
	-25.00	-24.96	-0.040	-24.991
	0.00	0.02	-0.020	-0.012
	100.00	100.04	-0.040	100.003
	150.00	150.04	-0.040	150.000

RTD 01229

2016 correction: slope= 1.000055

intercept= 0.0319084

corr= 1.0000000

2/4/2017

At EEMS RTD 01229 raw	Date 2/4/2017 corrected	RTD 01230 / 01231 EEMS AER raw	corrected	RTD 01227 / 1 EEMS SEG raw	corrected	RTD 01228 / 3 EEMS van1 raw	corrected
0.02	-0.01	0.04	-0.03	0.14	-0.01	-0.05	-0.02
11.25	11.22	11.28	11.22	11.45	11.03	11.26	11.41
19.82	19.79	19.84	19.79	20.07	19.58	19.88	19.97
31.53	31.50	31.55	31.51	31.90	31.51	31.69	31.52
40.39	40.36	40.39	40.36	40.81	40.36	40.59	40.36
48.82	48.79	48.78	48.76	49.30	48.78	49.06	48.77
24.91	24.88	24.93	24.89	25.21	24.87	25.00	24.87
	slope =	**0.998954**		**1.007593**		**1.006555**	
	intercept =	**0.069678**		**0.147536**		**-0.03341**	
	correlation =	**1.0000**		**1.0000**		**1.0000**	

Date

2/4/2017 - - Calibration and verification of three RTD meters with most recent certification of EEMS RTD

TMI Cert data -- 1/23/2017

	TMI STD	EEMS RTD 01229	diff	corrected
Cert #	A2380069			
	-25.00	-24.96	-0.040	-24.991
	0.00	0.02	-0.020	-0.012
	100.00	100.04	-0.040	100.003
	150.00	150.04	-0.040	150.000

RTD 01229

2016 correction: slope= 1.000055

intercept= 0.0319084

corr= 1.0000000

Eric Hebert 2/4/2017

At EEMS RTD 01229 raw	Date 2/4/2017 corrected	RTD 01230 / 01231 EEMS AER raw	corrected	RTD 01227 / 1 EEMS SEG raw	corrected	RTD 01228 / 3 EEMS van1 raw	corrected
0.02	-0.01	0.04	-0.03	0.14	-0.01	-0.05	-0.02
11.25	11.22	11.28	11.22	11.45	11.03	11.26	11.41
19.82	19.79	19.84	19.79	20.07	19.58	19.88	19.97
31.53	31.50	31.55	31.51	31.90	31.51	31.69	31.52
40.39	40.36	40.39	40.36	40.81	40.36	40.59	40.36
48.82	48.79	48.78	48.76	49.30	48.78	49.06	48.77
24.91	24.88	24.93	24.89	25.21	24.87	25.00	24.87

	RTD 01230 / 01231	RTD 01227 / 1	RTD 01228 / 3
slope =	**0.998954**	**1.007593**	**1.006555**
intercept =	**0.069678**	**0.147536**	**-0.03341**
correlation =	**1.0000**	**1.0000**	**1.0000**

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01229

Description: DIGITAL STIK THERMOMETER
Manufacturer: FLUKE
Model Number: 1551A EX
Serial Number: 3275143
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments: TUR is 2 to 1

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: FLUKE 1551A EX,52A EX Rev: 11/1/2010
Temperature: 72 F
Humidity: 41 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain
Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
899976	FLUKE	5618B-12	12/6/2016	2/21/2018
A06118	HART SCIENTIFIC	9103	5/8/2016	10/25/2017
A11967	HART SCIENTIFIC	9140	6/27/2016	6/27/2018
A88072	FLUKE/HART	1502A	1/17/2017	4/15/2017

Certificate Number A2380069
Issue Date: 01/23/17

Certificate of Calibration

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Temperature Accuracy	-25.00	-25.05	-24.95	-24.96	-24.96	°C	
Temperature Accuracy	0.00	-0.05	0.05	0.02	0.02	°C	
Temperature Accuracy	100.00	99.95	100.05	100.04	100.04	°C	
Temperature Accuracy	150.00	149.95	150.05	150.04	150.04	°C	

EEMS # 01229

m = 1.000055
b = 0.0319084
r^2 = 1.00000

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument: Precision Spectral Pyranometer, Model PSP, Serial Number 34341F3

Procedure: This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.

Transfer Standard: Eppley Precision Spectral Pyranometer, Model PSP, Serial Number 21231F3

Results: **Sensitivity:** **S = 9.40 µV / Wm^{-2}**
Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2)
Resistance: 699 Ω at 23°C

Date of Test: February 10, 2017

EEMS #
01245 / 01246

EOH

Traceability: This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".

Due Date: Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

Customer: EEMS
Gainsville, FL

Signatures: In Charge of Test: Debra L. Slinity Reviewed by: Thomas D. Kirk

Eppley SO: 64903

Certificate Date: February 14, 2017

Remarks: Amplifier #10765 set so that 1 V = 1400 Wm^{-2} (Gain = 75.99) M. VIEIRA

End of Report

PACKING LIST

The Eppley Laboratory, Inc.
12 Sheffield Ave.

Phone # 401-847-1020   Fed. ID No. 05-0136490

S.O. No. 64903

2/10/2017

Page 2 of 2
EEMS#
01245/01246

EOH

Name / Address

EEMS
Att: Erik Hebert
1128 NW 39th Drive
Gainesville, FL 32605

Ship To

EEMS
Att: Eric Hebert
1128 NW 39th Drive
Gainesville, FL 32605

P.O... verbal   Ship Date 2/17/2017   Ship Via FedEx COLLECT

	Or[redacted]
Recalibration of Model PSP # 34341F3 w/o CASE w/ SHIELD	[redacted]
Reset Amplifier # 10765	

SET GAIN SO $1V = 1400\ Wm^{-2}$

$1400 \times S = V_{full}$

$S = 9.40$

$V_{full} = 13160$

$V = 0.013160$

$GAIN = \frac{1V}{V_{full}(0V)} = 75.99$

Made in USA

Terms Credit Card

FOB Newport, RI USA

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

EEMS # 01247

Instrument: Black & White Pyranometer, Model 8-48, Serial Number 23824

Procedure: This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.

Transfer Standard: Eppley Black & White Pyranometer, Model 8-48, Serial Number 14061

Results:

Sensitivity: $\mathbf{S = 8.86\ \mu V / Wm^{-2}}$

Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2)

Resistance: 347 Ω at 23°C

Date of Test: February 16, 2017

Traceability: This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".

Due Date: Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

Customer: EEMS
Gainesville, FL

Signatures: Debra L. Gentry — In Charge of Test: Thomas J. Kirk — Reviewed by:

Eppley SO 64909

Date of Certificate February 17, 2017

Remarks:

End of Report

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

YOUNG

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802/18811
Serial Number: CA04013

Description: Anemometer Drive - 2 motors, 20 to 15,000 RPM
(18802 comprised of 18820A Control Unit and 18830A Motor Assembly)
(18811 comprised of 18820A Control Unit and 18831A Motor Assembly)

R. M. Young Company certifies that the above equipment was inspected and calibrated prior to shipment in accordance with established manufacturing and testing procedures. Standards established by R.M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology.

EEMS # 01253, 01254, 01255

Nominal Motor RPM RPM	27106D Output Frequency Hz (1)	Calculated RPM (2)	Indicated RPM (3)
18802	☑ Clockwise and Counterclockwise rotation verified.		
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10200	1700	10200	10200
12600	2100	12600	12600
15000	2500	15000	15000
18811	☑ Clockwise and Counterclockwise rotation verified.		
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

Vaul

(1) Measured output frequency of YOUNG model 27106D standard anemometer attached to motor shaft.
(2) YOUNG model 27106D produces 10 pulsed per revolution of the anemometer shaft.
(3) Indicated on the Control Unit LCD.

* Indicates out of tolerance.

☐ New Unit ☑ Service / Repair Unit ☐ As found
☑ No calibration adjustments required ☐ As left

Traceable frequency meter used for calibration:
Model: 34405A Serial Number: 53020093

Date: 28 June 2017
Calibration Interval: One year

Page 1 of 1 Tested By : EC

YOUNG

CALIBRATION PROCEDURE
18802/18811 ANEMOMETER DRIVE

DWG: CP18802(C)
REV: C101107 PAGE: 2 of 4
BY: TJT DATE: 10/11/07
CHK: JC W.C. GAS-12

CERTIFICATE OF CALIBRATION AND TESTING

MODEL: **18802** (Comprised of Models 18820A Control Unit & 18830A Motor Assembly)
SERIAL NUMBER: CA2777
EEMS # 01260 / # 01262

R. M. Young Company certifies that the above equipment was inspected and calibrated prior to shipment in accordance with established manufacturing and testing procedures. Standards established by R.M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology.

Nominal Motor Rpm	27106D Output Frequency Hz (1)	Calculated Rpm (1)	Indicated Rpm (2)
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10,200	1700	10,200	10,200
12,600	2100	12,600	12,600
15,000	2500	15,000	15,000
☒ Clockwise and Counterclockwise rotation verified			

(1) Measured frequency output of RM Young Model 27106D standard anemometer attached to motor shaft 27106D produces 10 pulses per revolution of the anemometer shaft
(2) Indicated on the Control Unit LCD display

* Indicates out of tolerance

☐ New Unit	☒ Service / Repair Unit ☒ No Calibration Adjustments Required	☐ As Found ☐ As Left

Traceable frequency meter used in calibration Model: 34405A SN: 53020093

Date of inspection 1/26/2017
Inspection Interval One Year

Tested By SS

CERTIFICATE OF CALIBRATION AND TESTING

R. M. Young Company certifies that the equipment listed below was inspected and calibrated prior to shipment in accordance with established manufacturing and testing procedures. Standards established by R.M. Young Company for calibrating the measuring and test equipment used in controlling product quality are traceable to the National Institute of Standards and Technology.

MODEL: **18802 / 18811** SERIAL NUMBER: CA4353
(18802 Comprised of Models 18820A Control Unit & 18830A Motor Assembly)
(18811 Comprised of Models 18820A Control Unit & 18831A Motor Assembly)

EEMS # 01457 and 01456

Nominal Motor RPM	27106D Output Frequency (Hz) - (1)	Calculated Rpm (1)	Indicated Rpm (2)
18802	-	☒ CW / CCW rotation verified	
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10,200	1700	10,200	10,200
12,600	2100	12,600	12,600
15,000	2500	15,000	15,000
18811	-	☒ CW / CCW rotation verified	
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

(1) Measured frequency output of RM Young Model 27106D standard anemometer attached to motor shaft - 27106D produces 10 pulses per revolution of the anemometer shaft.
(2) Indicated on the Control Unit LCD display.
* Indicates out of tolerance

☐ New Unit(s)	☒ Service / Repair Unit ☒ No Calibration Adjustments Required	☐ As Found ☒ As Left

Traceable frequency meter used in calibration Model: 34405A SN: 53020093

Date of inspection 4/13/2017
Inspection Interval One Year

Tested By SS

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

CERTIFICATION OF CALIBRATION AND CONFORMANCE

We hereby certify that the equipment below has been manufactured and/or inspected by standards traceable to NIST. Calibration of the specified instrument has been performed in compliance with ANSI Z540-1 requirements. It is warranted that the equipment has been calibrated to be in full conformance with the drawings and specifications of the instrument. Calibration tests were performed on the material specified below and were in accordance with all applicable quality assurance requirements with data on file at our facility.

Customer Name:	E.E. & M.S.
Purchase Order #:	
Instrument:	Ushikata Tracon S-25 Compass
Serial Number:	191832
Quantity:	1 Property of BEC
Calibration Due:	02/2018 (Sandy Grenville)

Page 1 of 1

John Noga, Quality Control

February 8, 2017

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 01/19/17 Due 01/19/18 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-7020 S/N 5167 Calibration 02/12/14 Due 02/12/19 731/244084-89 731/2216117

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

CERTIFICATION OF CALIBRATION AND CONFORMANCE

We hereby certify that the equipment below has been manufactured and/or inspected by standards traceable to NIST. Calibration of the specified instrument has been performed in compliance with ANSI Z540-1 requirements. It is warranted that the equipment has been calibrated to be in full conformance with the drawings and specifications of the instrument. Calibration tests were performed on the material specified below and were in accordance with all applicable quality assurance requirements with data on file at our facility.

Customer Name:	E.E. & M.S.
Purchase Order #:	
Instrument:	Ushikata Tracon S-25 Compass
Serial Number:	190037 ✓
Quantity:	1 EEMS # 01265
Calibration Due:	02/2018 Van 2

Page 1 of 1

John Noga, Quality Control

✓

February 8, 2017

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 01/19/17 Due 01/19/18 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-7020 S/N 5167 Calibration 02/12/14 Due 02/12/19 731/244084-89 731/2216117

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2045 Bennett Road
Philadelphia, PA 19116
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CERTIFICATION OF CALIBRATION AND CONFORMANCE

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Customer Name:	E.E. & M.S.	2/14/17
Purchase Order #:	Brunton	
Instrument:	Burton Compass	
Serial Number:	5064612690	EEMS # 01269
Quantity:	1	
Calibration Due:	02/2018	

Page 1 of 1 (AER)

John Noga, Quality Control

February 8, 2017

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 01/19/17 Due 01/19/18 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-7020 S/N 5167 Calibration 02/12/14 Due 02/12/19 731/244084-89 731/2216117

Warren-Knight Instrument Company
2045 Bennett Road
Philadelphia, PA 19116
Phone: 215-464-9300; Fax: 215-464-9303
Web: http://www.warrenind.com

CERTIFICATION OF CALIBRATION AND CONFORMANCE

We hereby certify that the equipment below has been manufactured and/or inspected by standards traceable to NIST. Calibration of the specified instrument has been performed in compliance with ANSI Z540-1 requirements. It is warranted that the equipment has been calibrated to be in full conformance with the drawings and specifications of the instrument. Calibration tests were performed on the material specified below and were in accordance with all applicable quality assurance requirements with data on file at our facility.

Customer Name:	E.E. & M.S.
Purchase Order #:	
Instrument:	Ushikata Tracon S-25 Compass
Serial Number:	~~199278~~ 199578 (initials) 2/14/17
Quantity:	1
Calibration Due:	02/2018 EEMS # D1272

Van 1

Page 1 of 1

John Noga, Quality Control

February 8, 2017

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 01/19/17 Due 01/19/18 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-7020 S/N 5167 Calibration 02/12/14 Due 02/12/19 731/244084-89 731/2216117

Certificate Number
A2411549
Issue Date: 02/23/17

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number: EEMS #
ID Number: 01310

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 187
Serial Number: 86590148
Technician: JOHN FARRELL
On-Site Calibration: ☐
Comments:

Calibration Date: 02/23/2017
Calibration Due: 02/23/2018
Procedure: METCAL FLUKE 187 Rev: 6/15/2015
Temperature: 72 F
Humidity: 41 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
7040208	FLUKE	5520A	8/10/2016	8/10/2017

Certificate Number
A2379653
Issue Date: 01/23/17

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01311

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740135
Technician: JOHN FARRELL
On-Site Calibration: ☐
Comments:

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: METCAL FLUKE 287 Rev: 6/15/2015
Temperature: 72 F
Humidity: 40 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

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Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
7040208	FLUKE	5520A	8/10/2016	8/10/2017

Certificate Number
A2379638
Issue Date: 01/23/17

Certificate of Calibration

Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT SERVICES
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number:
ID Number: EEMS 01312

Description: DIGITAL MULTIMETER
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740243
Technician: JOHN FARRELL
On-Site Calibration: ☐
Comments:

Calibration Date: 01/23/2017
Calibration Due: 01/23/2018
Procedure: METCAL FLUKE 287 Rev: 6/15/2015
Temperature: 72 F
Humidity: 40 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

This instrument has been calibrated using standards traceable to the National Institute of Standards and Technology, derived from natural physical constants, ratio measurements or compared to consensus standards. Unless otherwise noted, the method of calibration is direct comparison to a known standard.

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. A TUR of 4:1 is routinely observed unless otherwise noted on the certificate. Statements of compliance are based on test results falling within specified limits with no reduction by the uncertainty of the measurement.

TMI's Quality System is accredited to ISO/IEC 17025:2005 and ANSI/NCSL Z540-1-1994. ISO/IEC17025:2005 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. The instrument listed on this certificate has been calibrated to the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

Results contained in this document relate only to the item calibrated. Calibration due dates appearing on the certificate or label are determined by the client for administrative purposes and do not imply continued conformance to specifications.

FRANK BAHMANN, BRANCH MANAGER

Scott Chamberlain, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
7040208	FLUKE	5520A	8/10/2016	8/10/2017

TMI Technical Maintenance, Inc.
12530 TELECOM DRIVE, TEMPLE TERRACE, FL 33637
Phone: 813-978-3054 Fax 813-978-3758
www.tmicalibration.com

ANSI/NCSL Z540-1-1994

Project:	**Bios NEXUS EEMS # 01420/01410 Certification**	Flow Rate Standard:	**BIOS Definer 220-H**
Project #:		EEMS #	**01421**
Contact Name:		Certification Date:	**1/25/2017**
Contact Phone #:		Certification #:	**143707**
Contact Address:		**slope =**	1.001525
		inter =	0.003662

environmental, engineering & measurement services

Date:

2/7/2017 Flow rates are corrected to STP of one atmosphere and 25.0 degrees C. were plumbed together in series.
All tests were conducted with dry air. Nexus #1420, Definer 220-H EEMS# 01421

UNADJUSTED:

BIOS Nexus, EEMS # 01420 / 01410

Flow Rate Standard--Definer 220-H

01420 / 01410	
Slope =	**0.998252**
Intercept =	**0.004972**
Correl =	**0.99991**

	Temp deg C	Press mmHg
Definer	20.7	756
NEXUS	21.1	757

SL/m: standard liters per minute

Definer 220-H	**9100**	**NEXUS / DC-LITE**		
STP SL/M Corrected X	SL/m Flow setting	reading SL/m Y	Diff Y - X	% Diff (Y - X)/X
0.892	1	0.900	0.008	0.9%
1.130	1.2	1.124	-0.006	-0.6%
1.36	1.4	1.36	-0.002	-0.1%
1.74	1.8	1.74	0.008	0.5%
2.13	2.1	2.14	0.013	0.6%
2.66	2.7	2.65	-0.008	-0.3%
	Average Error (SL/m) =		0.002	% 0.2%

NEXUS / DC_LITE Corrected Values (using slope and intercept)		
SL/m	Diff	% Diff
0.897	0.005	0.5%
1.121	-0.009	-0.8%
1.360	-0.004	-0.3%
1.742	0.006	0.4%
2.143	0.011	0.5%
2.647	-0.009	-0.3%
Average Error (Sl/m)	0.002	% 0.1%

MesaLabs

NVLAP

NVLAP Lab Code 200661-0

Calibration Certificate

CertificateNo. 140039

Product 200-220H Definer 220 High Flow

Serial No. 131818

Cal. Date 12-Jan-2017

EEMS
01417

Sold To: Environmental Engineering & Measurement Services
8010 SW 17th Place
Gainesville, FL 32607
US

All calibrations are performed at Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, an ISO 17025:2005 accredited laboratory through NVLAP of NIST. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

As Received Calibration Data

Technician Lilianna Malinowska

Lab. Pressure 759 mmHg
Lab. Temperature 22.4 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
26801.1 sccm	26347.62 sccm	1.72%	1.00%	Out of Tolerance
5380.85 sccm	5284.34 sccm	1.83%	1.00%	Out of Tolerance
1644.22 sccm	1616.23 sccm	1.73%	1.00%	Out of Tolerance
16.6 °C	21.2 °C	-	± 0.8°C	Out of Tolerance
762 mmHg	758 mmHg	-	± 3.5 mmHg	Out of Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	103521	06-Jul-2016	06-Jul-2017
Percision Thermometer	305460	19-Sep-2016	19-Sep-2017
Precision Barometer	2981392	12-Jul-2016	12-Jul-2017

MesaLabs

NVLAP Lab Code 200661-0

As Shipped Calibration Data

Certificate No 140039
Technician Lilianna Malinowska

Lab. Pressure 763 mmHg
Lab. Temperature 22.4 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
26375.8 sccm	26360.92 sccm	0.06%	1.00%	In Tolerance
5296.15 sccm	5289.14 sccm	0.13%	1.00%	In Tolerance
1619.78 sccm	1617.68 sccm	0.13%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	± 0.8°C	In Tolerance
761 mmHg	761 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	18-Jul-2016	18-Jul-2017
Percision Thermometer	305460	19-Sep-2016	19-Sep-2017
Precision Barometer	2981392	12-Jul-2016	12-Jul-2017

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

Pressure testing is in accordance with our test number PR18-11 with an expanded uncertainty of 0.16 mmHg.

Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

#01417 date= 1/12/2017

Technician Notes:

Slope = 1.000467
Int. = ~~2.812622~~
R^2 = 1.00000

Louis Guido, Chief Metrologist

int. = 0.002813 Eric Hebert 4/6/2017

MesaLabs

NVLAP

NVLAP Lab Code 200661-0

Calibration Certificate

CertificateNo. 140038

Product 200-220L Definer 220 Low Flow

Serial No. 143301

Cal. Date 13-Jan-2017

EGMS
01418

Sold To: Environmental Engineering & Measurement Services
8010 SW 17th Place
Gainesville, FL 32607
US

All calibrations are performed at Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, an ISO 17025:2005 accredited laboratory through NVLAP of NIST. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

As Received Calibration Data

Technician Lilianna Malinowska

Lab. Pressure 760 mmHg
Lab. Temperature 22.1 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
486.65 sccm	479.77 sccm	1.43%	1.00%	Out of Tolerance
108.26 sccm	108 sccm	0.24%	1.00%	In Tolerance
32.7 sccm	33.24 sccm	-1.62%	1.00%	Out of Tolerance
19.4 °C	22.1 °C	-	± 0.8°C	Out of Tolerance
767 mmHg	759 mmHg	-	± 3.5 mmHg	Out of Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	103743	13-Apr-2016	13-Apr-2017
Percision Thermometer	305460	19-Sep-2016	19-Sep-2017
Precision Barometer	2981392	12-Jul-2016	12-Jul-2017

MesaLabs

NVLAP

NVLAP Lab Code 200661-0

As Shipped Calibration Data

Certificate No 140038
Technician Lilianna Malinowska
Lab. Pressure 763 mmHg
Lab. Temperature 22.1 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
448.34 sccm	450.085 sccm	-0.39%	1.00%	In Tolerance
100.32 sccm	100.22 sccm	0.1%	1.00%	In Tolerance
30.656 sccm	30.7205 sccm	-0.21%	1.00%	In Tolerance
22.1 °C	22.1 °C	-	± 0.8°C	In Tolerance
763 mmHg	763 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	105329	14-Nov-2016	14-Nov-2017
Percision Thermometer	305460	20-Sep-2016	20-Sep-2017
Precision Barometer	2981392	13-Jul-2016	13-Jul-2017

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

Pressure testing is in accordance with our test number PR18-11 with an expanded uncertainty of 0.16 mmHg.

Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

#01418 Date= 1/13/2017

Technician Notes:

Slope = 0.995583

Int. = 0.285635

R^2 = 0.99999

Louis Guido, Chief Metrologist

MesaLabs

Page 1 of 2

EEMS # 01421

NVLAP

NVLAP Lab Code 200661-0

Calibration Certificate

CertificateNo. 143707

Product 200-220H Definer 220 High Flow

Serial No. 148613

Cal. Date 25-Jan-2017

Sold To:
Environmental Engineering & Measurement Services
8010 SW 17th Place
Gainesville, FL 32607
US

All calibrations are performed at Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, an ISO 17025:2005 accredited laboratory through NVLAP of NIST. This report shall not be reproduced except in full without the written approval of the laboratory. Results only relate to the items calibrated. This report must not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the Federal Government.

As Received Calibration Data

Technician Lilianna Malinowska

Lab. Pressure 736 mmHg
Lab. Temperature 22.8 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
0 sccm	26318.68 sccm	-100.0%	1.00%	Out of Tolerance
0 sccm	5280.02 sccm	-100.0%	1.00%	Out of Tolerance
0 sccm	1613.47 sccm	-100.0%	1.00%	Out of Tolerance
56.4 °C	22.2 °C	-	± 0.8°C	Out of Tolerance
734 mmHg	736 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	103521	06-Jul-2016	06-Jul-2017
Percision Thermometer	305460	19-Sep-2016	19-Sep-2017
Precision Barometer	2981392	12-Jul-2016	12-Jul-2017

1/25/2017

Page 2 of 2
EEMS #01421

MesaLabs

NVLAP®

NVLAP Lab Code 200661-0

As Shipped Calibration Data

Certificate No	143707	**Lab. Pressure**	737 mmHg
Technician	Lilianna Malinowska	**Lab. Temperature**	22.8 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
26355.1 sccm	26311.42 sccm	0.17%	1.00%	In Tolerance
5290.76 sccm	5278.27 sccm	0.24%	1.00%	In Tolerance
1617.6 sccm	1612.14 sccm	0.34%	1.00%	In Tolerance
22.7 °C	22.7 °C	-	± 0.8°C	In Tolerance
737 mmHg	737 mmHg	-	± 3.5 mmHg	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	103521	06-Jul-2016	06-Jul-2017
Percision Thermometer	305460	19-Sep-2016	19-Sep-2017
Precision Barometer	2981392	12-Jul-2016	12-Jul-2017

Calibration Notes

The expanded uncertainty of flow, temperature, and pressure measurements all have a coverage factor of k = 2 for a confidence interval of approximately 95%.

Flow testing is in accordance with our test number PR18-13 with an expanded uncertainty of 0.18% using high-purity nitrogen or filtered laboratory air. Flow readings in sccm are performed at STP of 21.1°C and 760 mmHg.

Pressure testing is in accordance with our test number PR18-11 with an expanded uncertainty of 0.16 mmHg.

Temperature testing is in accordance with our test number PR18-12 with an expanded uncertainty of 0.04 °C.

Traceability to the International System of Units (SI) is verified by accreditation to ISO/IEC 17025 by NVLAP under NVLAP Code 200661-0.

Technician Notes:

$m = 1.001525$
$b = 0.003662$
$r^2 = 1.0000$

Louis Guido, Chief Metrologist

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Adam Zachary	Eric Hebert
Make:	NIST	TEI
Model:	SRP-10	49CPS
S/N:	10	517112175

SESD Project #: 17-0307 **Guest Test Status:** **PASS**
Test #: #1 "as found" **Guest Known Offset:** 0

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0025	0.4587	0.999997	462	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Date Start	Time Start	Date End	Time End	File	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
03/20/17	5:15 PM	03/20/17	7:02 PM	c0320001.xls	1.0037	0.3798	0.9999985	461	-0.02
03/20/17	7:02 PM	03/20/17	8:49 PM	c0320002.xls	1.0010	0.5089	0.9999959	463	0.02
03/20/17	8:49 PM	03/20/17	10:49 PM	c0320003.xls	1.0017	0.4716	0.9999951	463	0.10
03/20/17	10:50 PM	03/21/17	12:33 AM	c0320004.xls	1.0015	0.5312	0.9999957	463	0.13
03/21/17	12:33 AM	03/21/17	2:20 AM	c0320005.xls	1.0025	0.4625	0.9999988	463	-0.17
03/21/17	2:20 AM	03/21/17	4:18 AM	c0320006.xls	1.0036	0.3849	0.9999971	461	-0.02
03/21/17	4:18 AM	03/21/17	6:02 AM	c0320007.xls	1.0032	0.4724	0.9999981	461	-0.03

Comments:

Instrument tested as found.
Ozone calibration factors at time of test: O3 BKG: -0.6 ppb O3 COEF: 1.020

Verification Expires on: **March 21, 2018**

Adam Zachary [signature] Date 03/2/2017

 SESDFORM-046-R0

Ozone Transfer Standard Verification Summary Report

U. S. Environmental Protection Agency
Region 4 Science and Ecosystem Support Division
Enforcement and Investigations Branch
Superfund and Air Section
980 College Station Rd.
Athens, GA 30605

	EPA Standard	GUEST Instrument
Agency:	EPA Region 4	EEMS
Contact:	Adam Zachary	Eric Hebert
Make:	NIST	TEI
Model:	SRP-10	49CPS
S/N:	10	517112167

SESD Project #: 17-0306 **Guest Test Status:** **PASS**
Test #: #1 "as found" **Guest Known Offset:** 0

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0056	0.0672	0.9999962	462	0
Upper Tolerance:	1.0300	3.0000			
LowerTolerance:	0.9700	-3.0000			

Date Start	Time Start	Date End	Time End	File	Slope	Intercept	R^2	Upper Range (ppb O_3)	Lower Range (ppb O_3)
03/20/17	5:15 PM	03/20/17	7:02 PM	c0320001.xls	1.0068	-0.0118	0.9999974	461	-0.02
03/20/17	7:02 PM	03/20/17	8:49 PM	c0320002.xls	1.0046	0.0834	0.9999936	463	0.02
03/20/17	8:49 PM	03/20/17	10:49 PM	c0320003.xls	1.0056	0.1286	0.9999983	463	0.10
03/20/17	10:50 PM	03/21/17	12:33 AM	c0320004.xls	1.0050	0.0747	0.9999968	463	0.13
03/21/17	12:33 AM	03/21/17	2:20 AM	c0320005.xls	1.0063	0.0405	0.9999943	463	-0.17
03/21/17	2:20 AM	03/21/17	4:18 AM	c0320006.xls	1.0048	0.1312	0.9999958	461	-0.02
03/21/17	4:18 AM	03/21/17	6:02 AM	c0320007.xls	1.0063	0.0238	0.9999972	461	-0.03

Comments:

Instrument tested as found.
Ozone calibration factors at time of test: O3 BKG: -0.2ppb O3 COEF: 1.015

Verification Expires on: **March 21, 2018**

Adam Zachary [signature] Date 03/21/2017

 SESDFORM-046-R0

Ozone Certification Records

TEI # 49CPS-70008-364			EEMS# 01110	Van 2		
EPA file	date	start time	slope	intercept	correlatioin	location
c0911002	11-Sep-17	14:57	1.00702	0.24225	1	R-7
c0911003	11-Sep-17	16:19	1.00881	-0.05789	1	R-7
c0911004	11-Sep-17	17:34	1.00822	-0.12224	1	R-7
c0911005	11-Sep-17	18:50	1.00810	-0.09644	1	R-7
c0911006	11-Sep-17	19:58	1.00773	-0.09255	1	R-7
c0911007	11-Sep-17	21:07	1.00802	-0.02126	1	R-7
c0911008	11-Sep-17	22:14	1.00824	-0.15698	1	R-7
c0911009	11-Sep-17	23:22	1.00795	-0.11083	1	R-7
		AVG =	**1.008011**	**-0.051993**	**1**	

TEI # 0517112167			EEMS# 01113	Van 1		
c0912009	12-Sep-17	12:57	1.00475	0.63362	1	R-7
c0912010	12-Sep-17	14:26	1.00431	0.56119	1	R-7
c0912011	12-Sep-17	15:41	1.00471	0.27233	1	R-7
c0912012	12-Sep-17	16:54	1.00611	0.12497	1	R-7
c0912013	12-Sep-17	18:09	1.00524	0.10027	1	R-7
c0912014	12-Sep-17	19:23	1.00550	0.27944	1	R-7
c0912015	12-Sep-17	20:40	1.00508	0.21464	1	R-7
c0912016	12-Sep-17	21:54	1.00459	0.44674	1	R-7
		AVG =	**1.005036**	**0.329150**	**1**	

Enter date in yellow highlighted cell next to "Date".

S/N = 0517112167

Enter new slope and intercept in yellow highlighted cells

	Date	**1/21/2016**
m_1	1/21/2016	0.996503
m_2	1/20/2016	0.99993
m_3	1/19/2016	1.00076
m_4	1/18/2016	0.99819
m_5	9/21/2015	1.02307
m_6	4/29/2015	1.02260
I_1	1/21/2016	-0.323250
I_2	1/20/2016	-0.41890
I_3	1/19/2016	-0.49351
I_4	1/18/2016	-0.27641
I_5	9/21/2015	-0.26399
I_6	4/29/2015	-0.20400
Average m	1/21/2016	1.00684
Avarage I	1/21/2016	-0.33001
$S_{m\,(\%)}$	1/21/2016	1.24
$S_{I\,(ppb)}$	1/21/2016	0.1
Test s_m	1/21/2016	PASS
Test s_I	1/21/2016	PASS

Enter date in yellow highlighted cell next to "Date".

S/N = 0517112167

Enter new slope and intercept in yellow highlighted cells

	Date	**1/22/2016**
m_1	1/22/2016	0.998195
m_2	1/21/2016	0.99650
m_3	1/20/2016	0.99993
m_4	1/19/2016	1.00076
m_5	1/18/2016	0.99819
m_6	9/21/2015	1.02307
I_1	1/22/2016	-0.384025
I_2	1/21/2016	-0.32325
I_3	1/20/2016	-0.41890
I_4	1/19/2016	-0.49351
I_5	1/18/2016	-0.27641
I_6	9/21/2015	-0.26399
Average m	1/22/2016	1.00278
Avarage I	1/22/2016	-0.36001
$S_{m\,(\%)}$	1/22/2016	1.00
$S_{I\,(ppb)}$	1/22/2016	0.1
Test s_m	1/22/2016	PASS
Test s_I	1/22/2016	PASS

Enter date in yellow highlighted cell next to "Date".

S/N = 0517112167

Enter new slope and intercept in yellow highlighted cells

	Date	**1/23/2016**
m_1	1/23/2016	0.999917
m_2	1/22/2016	0.99820
m_3	1/21/2016	0.99650
m_4	1/20/2016	0.99993
m_5	1/19/2016	1.00076
m_6	1/18/2016	0.99819
I_1	1/23/2016	-0.335463
I_2	1/22/2016	-0.38403
I_3	1/21/2016	-0.32325
I_4	1/20/2016	-0.41890
I_5	1/19/2016	-0.49351
I_6	1/18/2016	-0.27641
Average m	1/23/2016	0.99892
Avarage I	1/23/2016	-0.37193
$S_{m\,(\%)}$	1/23/2016	0.16
$S_{I\,(ppb)}$	1/23/2016	0.1
Test s_m	1/23/2016	PASS
Test s_I	1/23/2016	PASS

Enter date in yellow highlighted cell next to "Date".

S/N = 0517112167

Enter new slope and intercept in yellow highlighted cells

	Date	**1/28/2016**
m_1	1/28/2016	1.00770
m_2	1/23/2016	0.99992
m_3	1/22/2016	0.99820
m_4	1/21/2016	0.99650
m_5	1/20/2016	0.99993
m_6	1/19/2016	1.00076
I_1	1/28/2016	0.22470
I_2	1/23/2016	-0.33546
I_3	1/22/2016	-0.38403
I_4	1/21/2016	-0.32325
I_5	1/20/2016	-0.41890
I_6	1/19/2016	-0.49351
Average m	1/28/2016	1.00050
Avarage I	1/28/2016	-0.28841
$S_{m\,(\%)}$	1/28/2016	0.38
$S_{I\,(ppb)}$	1/28/2016	0.3
Test s_m	1/28/2016	PASS
Test s_I	1/28/2016	PASS

Enter date in yellow highlighted cell next to "Date".

S/N = 0517112167

Enter new slope and intercept in yellow highlighted cells

	Date	**9/14/2016**
m_1	9/14/2016	1.01342
m_2	1/28/2016	1.00770
m_3	1/23/2016	0.99992
m_4	1/22/2016	0.99820
m_5	1/21/2016	0.99650
m_6	1/20/2016	0.99993
I_1	9/14/2016	0.32479
I_2	1/28/2016	0.22470
I_3	1/23/2016	-0.33546
I_4	1/22/2016	-0.38403
I_5	1/21/2016	-0.32325
I_6	1/20/2016	-0.41890
Average m	9/14/2016	1.00261
Avarage I	9/14/2016	-0.15202
$S_{m\,(\%)}$	9/14/2016	0.65
$S_{I\,(ppb)}$	9/14/2016	0.3
Test s_m	9/14/2016	PASS
Test s_I	9/14/2016	PASS

Enter date in yellow highlighted cell next to "Date".

Enter new slope and intercept in yellow highlighted cells

	Date	**3/21/2017**
m_1	3/21/2017	1.00560
m_2	9/14/2016	1.01342
m_3	1/28/2016	1.00770
m_4	1/23/2016	0.99992
m_5	1/22/2016	0.99820
m_6	1/21/2016	0.99650
I_1	3/21/2017	0.06720
I_2	9/14/2016	0.32479
I_3	1/28/2016	0.22470
I_4	1/23/2016	-0.33546
I_5	1/22/2016	-0.38403
I_6	1/21/2016	-0.32325
Average m	3/21/2017	1.00356
Avarage I	3/21/2017	-0.07101
$S_{m\,(\%)}$	3/21/2017	0.65
$S_{I\,(ppb)}$	3/21/2017	0.3
Test s_m	3/21/2017	PASS
Test s_I	3/21/2017	PASS

Enter date in yellow highlighted cell next to "Date".

Enter new slope and intercept in yellow highlighted cells

	Date	**9/12/2017**
m_1	9/12/2017	1.005036
m_2	3/21/2017	1.00560
m_3	9/14/2016	1.01342
m_4	1/28/2016	1.00770
m_5	1/23/2016	0.99992
m_6	1/22/2016	0.99820
I_1	9/12/2017	0.329150
I_2	3/21/2017	0.06720
I_3	9/14/2016	0.32479
I_4	1/28/2016	0.22470
I_5	1/23/2016	-0.33546
I_6	1/22/2016	-0.38403
Average m	9/12/2017	1.00498
Avarage I	9/12/2017	0.03773
$S_{m\,(\%)}$	9/12/2017	0.55
$S_{I\,(ppb)}$	9/12/2017	0.3
Test s_m	9/12/2017	PASS
Test s_I	9/12/2017	PASS

Enter date in yellow highlighted cell next to "Date".

Enter new slope and intercept in yellow highlighted cells

	Date	
m_1		
m_2		
m_3		
m_4		
m_5		
m_6		
I_1		
I_2		
I_3		
I_4		
I_5		
I_6		
Average m		
Avarage I		
$S_{m\,(\%)}$		
$S_{I\,(ppb)}$		
Test s_m		
Test s_I		

$$\frac{1}{5}\left[\sum_{i=1}^{6}(m_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} m_i\right)^2\right]$$

$$\left[\sum_{i=1}^{6}(I_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} I_i\right)^2\right]$$

$$S_m = \frac{100}{\bar{m}}\sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(m_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} m_i\right)^2\right]}$$

$$S_I = \sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(I_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} I_i\right)^2\right]}$$

$$S_m = \frac{100}{\bar{m}}\sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(m_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} m_i\right)^2\right]}$$

$$S_I = \sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(I_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} I_i\right)^2\right]}$$

EEMS # 01113
6-day calibration
At EEMS 1/21/2016
offset = -0.2
span = 1.015

EEMS # 01113
6-day calibration
At EEMS 1/22/2016
offset = -0.2
span = 1.015

EEMS # 01113
6-day calibration
At EEMS 1/23/2016
offset = -0.2
span = 1.015

EEMS # 01113
Verification
At EPA R4 1/28/2016
offset = -0.2
span = 1.015

EEMS # 01113
Verification
At EPA R7 9/14/2016
offset = -0.2
span = 1.015

EEMS # 01113
Verification
At EPA R4 3/21/2017
offset = -0.2
span = 1.015

EEMS # 01113
Verification
At EPA R7 9/12/2017
offset = -0.2
span = 1.015

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 1/21/2016
S/N= 0517112175

m_1	1/21/2016	0.991499
m_2	1/20/2016	0.99565
m_3	1/19/2016	0.99975
m_4	1/18/2016	0.99722
m_5	1/7/2015	1.01540
m_6	1/3/2015	0.99307
I_1	1/21/2016	-0.844393
I_2	1/20/2016	-0.23545
I_3	1/19/2016	-0.73832
I_4	1/18/2016	-0.43380
I_5	1/7/2015	-0.09100
I_6	1/3/2015	0.13058
Average m	1/21/2016	0.99876
Avarage I	1/21/2016	-0.36873
$s_{m\ (\%)}$	1/21/2016	0.87
$s_{I\ (ppb)}$	1/21/2016	0.4
Test s_m	1/21/2016	PASS
Test s_I	1/21/2016	PASS

$$\frac{1}{5}\left[\sum_{i=1}^{6}(m_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} m_i\right)^2\right]$$

$$\left[\sum_{i=1}^{6}(I_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} I_i\right)^2\right]$$

EEMS 01111
6-day calibration
At EEMS **1/21/2016**
BKG = -0.6
COEF = 1.020

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 1/22/2016
S/N= 0517112175

m_1	1/22/2016	0.993072
m_2	1/21/2016	0.99150
m_3	1/20/2016	0.99565
m_4	1/19/2016	0.99975
m_5	1/18/2016	0.99722
m_6	1/7/2015	1.01540
I_1	1/22/2016	-0.398185
I_2	1/21/2016	-0.84439
I_3	1/20/2016	-0.23545
I_4	1/19/2016	-0.73832
I_5	1/18/2016	-0.43380
I_6	1/7/2015	-0.09100
Average m	1/22/2016	0.99876
Avarage I	1/22/2016	-0.45686
$s_{m\ (\%)}$	1/22/2016	0.87
$s_{I\ (ppb)}$	1/22/2016	0.3
Test s_m	1/22/2016	PASS
Test s_I	1/22/2016	PASS

EEMS 01111
6-day calibration
At EEMS **1/22/2016**
BKG = -0.6
COEF = 1.020

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 1/23/2016
S/N= 0517112175

m_1	1/23/2016	0.994291
m_2	1/22/2016	0.99307
m_3	1/21/2016	0.99150
m_4	1/20/2016	0.99565
m_5	1/19/2016	0.99975
m_6	1/18/2016	0.99722
I_1	1/23/2016	-0.686363
I_2	1/22/2016	-0.39819
I_3	1/21/2016	-0.84439
I_4	1/20/2016	-0.23545
I_5	1/19/2016	-0.73832
I_6	1/18/2016	-0.43380
Average m	1/23/2016	0.99525
Avarage I	1/23/2016	-0.55609
$s_{m\ (\%)}$	1/23/2016	0.30
$s_{I\ (ppb)}$	1/23/2016	0.2
Test s_m	1/23/2016	PASS
Test s_I	1/23/2016	PASS

$$S_m = \frac{100}{\bar{m}}\sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(m_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} m_i\right)^2\right]}$$

$$S_I = \sqrt{\frac{1}{5}\left[\sum_{i=1}^{6}(I_i)^2 - \frac{1}{6}\left(\sum_{i=1}^{6} I_i\right)^2\right]}$$

EEMS 01111
6-day calibration
At EEMS **1/23/2016**
BKG = -0.6
COEF = 1.020

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 1/29/2016
S/N 0517112175

m_1	1/29/2016	1.00100
m_2	1/23/2016	0.99429
m_3	1/22/2016	0.99307
m_4	1/21/2016	0.99150
m_5	1/20/2016	0.99565
m_6	1/19/2016	0.99975
I_1	1/29/2016	0.25770
I_2	1/23/2016	-0.68636
I_3	1/22/2016	-0.39819
I_4	1/21/2016	-0.84439
I_5	1/20/2016	-0.23545
I_6	1/19/2016	-0.73832
Average m	1/29/2016	0.99588
Avarage I	1/29/2016	-0.44084
$s_{m\ (\%)}$	1/29/2016	0.38
$s_{I\ (ppb)}$	1/29/2016	0.4
Test s_m	1/29/2016	PASS
Test s_I	1/29/2016	PASS

EEMS 01111
Verification
At EPA R-4 **1/29/2016**
BKG = -0.6
COEF = 1.020

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 2/8/2017
S/N 0517112175

m_1	2/8/2017	1.008785
m_2	1/29/2016	1.00100
m_3	1/23/2016	0.99429
m_4	1/22/2016	0.99307
m_5	1/21/2016	0.99150
m_6	1/20/2016	0.99565
I_1	2/8/2017	0.363823
I_2	1/29/2016	0.25770
I_3	1/23/2016	-0.68636
I_4	1/22/2016	-0.39819
I_5	1/21/2016	-0.84439
I_6	1/20/2016	-0.23545
Average m	2/8/2017	0.99738
Avarage I	2/8/2017	-0.25715
$s_{m\ (\%)}$	2/8/2017	0.65
$s_{I\ (ppb)}$	2/8/2017	0.5
Test s_m	2/8/2017	PASS
Test s_I	2/8/2017	PASS

EEMS 01111
Verification
At EEMS **2/8/2017**
BKG = -0.6
COEF = 1.020

Enter date in yellow highlighted cell next to "Date". Place cursor next to m_1 and type ctrl+a.
Enter new slope and intercept in yellow highlighted cell:

Date 3/21/2017
S/N= 0517112175

m_1	3/21/2017	1.002500
m_2	2/8/2017	1.00879
m_3	1/29/2016	1.00100
m_4	1/23/2016	0.99429
m_5	1/22/2016	0.99307
m_6	1/21/2016	0.99150
I_1	3/21/2017	0.458700
I_2	2/8/2017	0.36382
I_3	1/29/2016	0.25770
I_4	1/23/2016	-0.68636
I_5	1/22/2016	-0.39819
I_6	1/21/2016	-0.84439
Average m	3/21/2017	0.99852
Avarage I	3/21/2017	-0.14145
$s_{m\ (\%)}$	3/21/2017	0.67
$s_{I\ (ppb)}$	3/21/2017	0.6
Test s_m	3/21/2017	PASS
Test s_I	3/21/2017	PASS

$$S_m = \frac{100}{\bar{m}}\sqrt{\ldots}$$

$$S_I = \sqrt{\frac{1}{5}\ldots}$$

EEMS 01111
6-day calibration
At EPA R4 **3/21/2017**
BKG = -0.6
COEF = 1.020

Airgas
an Air Liquide company

Airgas Specialty Gases
Airgas USA, LLC
630 United Drive
Durham, NC 27713
Airgas.com

CERTIFICATE OF ANALYSIS

Grade of Product: EPA Protocol

Part Number:	E04NI99E80A00KC	Reference Number:	122-400963914-1A
Cylinder Number:	JB03523	Cylinder Volume:	83.4 CF
Laboratory:	124 - Durham (SAP) - NC	Cylinder Pressure:	1750 PSIG
PGVP Number:	B22017	Valve Outlet:	660
Gas Code:	CO,NO,NOX,SO2,BALN	Certification Date:	Sep 06, 2017

Expiration Date: Sep 06, 2020

Certification performed in accordance with "EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards (May 2012)" document EPA 600/R-12/531, using the assay procedures listed. Analytical Methodology does not require correction for analytical interference. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.

Do Not Use This Cylinder below 100 psig, i.e. 0.7 megapascals.

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty	Assay Dates
NOX	15.15 PPM	15.22 PPM	G1	+/- 1.4% NIST Traceable	08/30/2017, 09/06/2017
NITRIC OXIDE	15.15 PPM	14.96 PPM	G1	+/- 1.4% NIST Traceable	08/30/2017, 09/06/2017
SULFUR DIOXIDE	15.72 PPM	16.21 PPM	G1	+/- 1.2% NIST Traceable	08/30/2017, 09/06/2017
CARBON MONOXIDE	510.0 PPM	513.1 PPM	G1	+/- 0.7% NIST Traceable	08/30/2017
NITROGEN	Balance				

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Uncertainty	Expiration Date
NTRM	15061037	CC442704	18.12 PPM NITRIC OXIDE/NITROGEN	+/- 1.2%	Nov 11, 2018
PRM	12367	APEX1099237	10.00 PPM NITROGEN DIOXIDE/AIR	+/- 1.5%	May 29, 2016
GMIS	1114201603	CC506722	4.965 PPM NITROGEN DIOXIDE/NITROGEN	+/- 2.0%	Nov 14, 2019
SRM	96-K-004	CAL015233	49.66 PPM SULFUR DIOXIDE/NITROGEN	+/- 1.0%	Mar 22, 2019
GMIS	124542142108	CC415491	15.04 PPM SULFUR DIOXIDE/NITROGEN	+/- 1.1%	Jun 03, 2020
NTRM	12062411	CC214643	487.1 PPM CARBON MONOXIDE/NITROGEN	+/- 0.6%	Jun 22, 2018

The SRM, PRM or RGM noted above is only in reference to the GMIS used in the assay and not part of the analysis.

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700 AHR0801333 CO	FTIR	Aug 24, 2017
Nicolet 6700 AHR0801333 NO	FTIR	Aug 24, 2017
Nicolet 6700 AHR0801333 NO2	FTIR	Aug 24, 2017
Nicolet 6700 AHR0801333 SO2	FTIR	Aug 24, 2017

Triad Data Available Upon Request

Approved for Release

SCOTT-MARRIN, INC. PGVP Vendor ID: H12013
6531 Box Springs Blvd • Riverside, CA 92507-0725
Phone: +1(951)653-6780 • Fax: +1(951)653-2430 • www.scottmarrin.com

Report Of Analysis
EPA Protocol Gas Mixtures

TO: EEMS01
Environmental, Engineering & Measurement Svcs Inc
1128 NW 39th Drive
Gainesville, FL 32605
(352) 262-0802

REPORT NO: 69075-01
REPORT DATE: March 13, 2017
CUSTOMER PO NO: E HEBERT

CYLINDER SIZE: 50A (52 std cu ft)
CYLINDER PRESSURE: 2000 psig
CYLINDER NUMBER: **JB03389**

COMPONENT	CONCENTRATION (v/v) ± EPA UNCERTAINTY	REFERENCE STANDARD		ANALYZER MAKE, MODEL, S/N, DETECTION		REPLICATE ANALYSIS DATA	
Carbon monoxide	506 ± 2 ppm	GMIS	SRM 1680b	Carle Insts Model 8000		3/3/2017	3/13/2017
			Samp#: 2-I-23	Serial # 8249		505 ppm	506 ppm
		Cyl#: CC323	Cyl#: CAL015763	Methanation/FID		505 ppm	506 ppm
		588 ± 2 ppm	496.7 ± 1.6 ppmv	Gas Chromatography		505 ppm	507 ppm
		Exp: 10/7/2024	Exp: 2/20/2017	LAST CAL DATE: 3/7/2017	x̄ :	505 ppm	506 ppm
Nitric oxide	14.91 ± 0.16 ppm	GMIS	SRM 2629a	TECO Model 42C		3/3/2017	3/10/2017
NOx	14.91 ppm		Samp#: 50-G-90	Serial # 57458-333		14.92 ppm	14.96 ppm
Nitrogen dioxide	< 0.15 ppm	Cyl#: CC28468	Cyl#: FF31693	Continuous		14.93 ppm	14.90 ppm
		20.34 ± 0.21 ppm	18.96 ± 0.19 ppm	Chemiluminescence		14.86 ppm	14.92 ppm
		Exp: 12/20/2019	Exp: 6/30/2017	LAST CAL DATE: 3/7/2017	x̄ :	14.90 ppm	14.93 ppm
Sulfur dioxide	15.26 ± 0.22 ppm	GMIS	SRM 1689	Bovar/W Res Model 922M		3/3/2017	3/10/2017
			Samp#: 98-A-33	Serial # 9228379-1		15.28 ppm	15.23 ppm
		Cyl#: CA03167	Cyl#: FF40537	Continuous		15.24 ppm	15.30 ppm
		10.22 ± 0.11 ppm	4.813 ± 0.05 ppm	UV Photometry		15.29 ppm	15.18 ppm
		Exp: 10/7/2020	Exp: 1/8/2017	LAST CAL DATE: 2/20/2017	x̄ :	15.27 ppm	15.24 ppm
O2-free Nitrogen	Balance						

CERTIFICATION DATE: March 10, 2017 **EPA EXPIRATION DATE:** March 11, 2020

ppm = µmole/mole **% = mole-%** **x̄ = EPA weighted mean**

The above analyses were performed in accordance with Procedure G1 of the EPA Traceability Protocol, Report Number EPA600/R-12/531, dated May 2012.

The above analyses should not be used if the cylinder pressure is less than 100 psig.

ANALYST: M.J.Monson **APPROVED:** J. T. Marrin

The only liability of this company for gas which fails to comply with this analysis shall be replacement or reanalysis thereof by the company without extra cost.

FINAL SUMMARY AUDIT REPORT CO BASED
EEMS Van-2

Site Name: EPA Region 7

Audit Date: 9/12/2017

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Absolute Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero						
Audit Level 6					N/A	
Audit Level 5					N/A	
Audit Level 4					N/A	
Audit Level 1					N/A	
Post Zero						
Carbon Monoxide						
Pre Zero	-0.0088	0.000		0.0088	Pass	
CO Audit level 6	8.0395	7.960	-1.0	-0.0795	Pass	
CO Audit level 5	4.1930	4.166	-0.6	-0.0270	Pass	
CO Audit level 4	2.7243	2.720	-0.2	-0.0043	Pass	
CO Audit level 3					N/A	
CO Audit level 2					N/A	
Post Zero	-0.0433	-0.012		0.0313	Pass	
Oxides of Nitrogen						
Pre Zero	-0.0003	0.0000		0.0003	Pass	
NO Audit Point #1	0.2369	0.2370	0.0	0.0001	Pass	
NO Audit Point #2	0.1236	0.1228	-0.6	-0.0008	Pass	
NO Audit Point #3	0.0803	0.0796	-0.9	-0.0007	Pass	
NO Audit Point #4					N/A	
NO Audit Point #5					N/A	
Post Zero	-0.0013	-0.0002		0.0011	Pass	
Pre Zero	-0.0003	0.0000		0.0003	Pass	
NOx Audit Point #1	0.2369	0.2371	0.1	0.0002	Pass	
NOx Audit Point #2	0.1236	0.1228	-0.6	-0.0008	Pass	
NOx Audit Point #3	0.0803	0.0791	-1.5	-0.0012	Pass	
NOx Audit Point #4					N/A	
NOx Audit Point #5					N/A	
Post Zero	-0.0013	-0.0004		0.0009	Pass	
Pre Zero	0.0000	0.0000		0.0000		
NO2 Audit level 7	0.1292	0.1281	-0.9	-0.0011	Pass	
NO2 Audit level 6	0.0631	0.0622	-1.4	-0.0009	Pass	
NO2 Audit level 5	0.0427	0.0417	-2.3	-0.0010	Pass	
NO2 Audit level 1					N/A	
Post Zero	0.0000	-0.0003		-0.0003	Pass	
Converter Efficiency NO2 level 5	99.4%				Pass	
Converter Efficiency NO2 level 4	97.1%				Pass	
Converter Efficiency NO2 level 2	99.3%				Pass	
Converter Efficiency NO2 level 1					N/A	
Sulfur Dioxide						
Pre Zero	-0.0003	0.0000		0.0003	Pass	
SO2 Audit level 8	0.2425	0.2418	-0.3	-0.0007	Pass	
SO2 Audit level 7	0.1265	0.1265	0.0	0.0000	Pass	
SO2 Audit level 6	0.0822	0.0822	-0.1	0.0000	Pass	
SO2 Audit level 3					N/A	
SO2 Audit level 1					N/A	
Post Zero	-0.0013	0.0001		0.0014	Pass	

FINAL SUMMARY AUDIT REPORT CO BASED
EEMS Van-2

Site Name: EPA R-7

Audit Date: 9/13/2017

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Absolute Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero						
Audit Level 6					N/A	
Audit Level 5					N/A	
Audit Level 4					N/A	
Audit Level 1					N/A	
Post Zero						
Carbon Monoxide						
Pre Zero	-0.0058	-0.008		-0.0017	Pass	
CO Audit level 4	2.7013	2.733	1.2	0.0317	Pass	
CO Audit level 4	1.4891	1.516	1.8	0.0264	Pass	
CO Audit level 3	0.4429	0.462	4.2	0.0188	Pass	
CO Audit level 2	0.0915	0.111	20.8	0.0190	Pass	
CO Audit level 1	0.0144	0.039	168.8	0.0243	Pass	
Post Zero	-0.0296	-0.065		-0.0354	Pass	
Oxides of Nitrogen						
Pre Zero	-0.0002	0.0003		0.0005	Pass	
NO Audit Point #1	0.0796	0.0812	2.0	0.0016	Pass	
NO Audit Point #2	0.0439	0.0449	2.3	0.0010	Pass	
NO Audit Point #3	0.0130	0.0132	1.5	0.0002	Pass	
NO Audit Point #4	0.0027	0.0025	-7.4	-0.0002	Pass	
NO Audit Point #5	0.0004				N/A	
Post Zero	-0.0009	-0.0007		0.0002	Pass	
Pre Zero	-0.0002	0.0003		0.0005	Pass	
NOx Audit Point #1	0.0796	0.0808	1.5	0.0012	Pass	
NOx Audit Point #2	0.0439	0.0451	2.7	0.0012	Pass	
NOx Audit Point #3	0.0130	0.0136	4.6	0.0006	Pass	
NOx Audit Point #4	0.0027	0.0028	3.7	0.0001	Pass	
NOx Audit Point #5	0.0004				N/A	
Post Zero	-0.0009	-0.0007		0.0002	Pass	
Pre Zero	0.0000	0.0002		0.0002		
NO2 Audit level 5	0.0382	0.0387	1.3	0.0005	Pass	
NO2 Audit level 4	0.0172	0.0173	0.7	0.0001	Pass	
NO2 Audit level 2	0.0031	0.0034	11.5	0.0004	Pass	
NO2 Audit level 1					N/A	
Post Zero	0.0000	-0.0001		-0.0001	Pass	
Converter Efficiency NO2 level 5	100.3%				Pass	
Converter Efficiency NO2 level 4	97.7%				Pass	
Converter Efficiency NO2 level 2	96.8%				Pass	Warning
Converter Efficiency NO2 level 1					N/A	
Sulfur Dioxide						
Pre Zero	-0.0002	0.0003		0.0005	Pass	
SO2 Audit level 6	0.0815	0.0805	-1.3	-0.0011	Pass	
SO2 Audit level 5	0.0449	0.0447	-0.5	-0.0002	Pass	
SO2 Audit level 4	0.0134	0.0128	-4.9	-0.0007	Pass	
SO2 Audit level 1	0.0028	0.0030	6.1	0.0002	Pass	
SO2 Audit level 1	0.0004	0.0011	170.0	0.0007	Pass	
Post Zero	-0.0009	-0.0005		0.0004	Pass	

Field Scientist Certification

Eric Hebert

Has satisfactorily completed
The US Environmental Protection Agency's
"National Performance Audit Program (NPAP)
Field Scientist Re-certification Course"

Office of Air Quality Planning and Standards
Research Triangle Park, NC
Course Dates: April 13-14, 2017

Gregory W. Noah
NPAP National Coordinator
USEPA, OAQPS, AAMG

Field Scientist Certification

Martin Valvur

Has satisfactorily completed
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Gregory W. Noah
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