CASTNET

2013 Annual Report

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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
CASTNET	Clean Air Status and Trends Network
DAS	data acquisition system
DC	direct current
deg	degree
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
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards
QAPP	Quality Assurance Project Plan
SOP	standard operating procedure
TEI	Thermo Environmental Instruments
USNO	United States Naval Observatory
V	volts
WRR	World Radiation Reference

1.0 Introduction

The Clean Air Status and Trends Network (CASTNET) is a national air monitoring program developed under mandate of the 1990 Clean Air Act Amendments. Each site in the network measures acidic gases and particles and other forms of atmospheric pollution using a continuous collection filter aggregated over a one week period. Hourly averages of surface ozone concentrations and selected meteorological variables are also measured.

Site measurements 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 effects 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, average historical deposition velocities are used to estimate dry deposition fluxes (Bowker et al 2011).

As of 2011, nearly all CASTNET ozone monitors adhere to the requirements of 40 CFR Part 58, and ozone concentration and quality assurance data are submitted to the Air Quality System (AQS) database. Currently 80 sites at 78 distinct locations measure ground-level ozone concentrations.

As of January 2014, the network is comprised of approximately 90 active rural sampling sites across the United States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), Environment Canada, Wyoming's Bureau of Land Management (BLM-WY), and several independent partners. AMEC E&C is responsible for operating the EPA and Environment Canada sponsored sites, and Air Resource Specialists, Inc. (ARS) is responsible for operating the NPS and Bureau of Land Management (BLM) sponsored sites. All sites collect filter samples for flux estimates.

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 evaluated parameters are consistent with the accuracy goals as defined in the CASTNET Quality Assurance Project Plan (QAPP). The parameter specific accuracy goals are presented in Table 2-1.

Due to budgetary necessity, the meteorological measurements were recently 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
Temperature	Accuracy	Comparison to 3 NIST measured baths (~ 0° C, ambient, ~ full-scale)	≤ ± 0.5° C
Delta Temperature	Accuracy	Comparison to temperature sensor at same test point	≤ ± 0.50° C

Sensor	Parameter	Audit Challenge	Acceptance Criteria
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	≤ ±10.0% of test gas concentration
DAS	Accuracy	Comparison with certified standard	≤ ± 0.003 VDC

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). Methods and procedures used are compliant with the National Performance Audit Program (NPAP).

Performance audits are conducted using standards that are certified as currently traceable to the National Institute of Standards and Technology (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 2013

This report covers the CASTNET sites audited in 2013. Only those variables that were supported by the CASTNET program were audited. From February through December 2013, EEMS conducted field performance and systems audits at 53 monitoring sites at 51 separate locations. Thirty-eight of the sites visited are sponsored by the EPA and fifteen sites are sponsored by the NPS. Initial audits were performed at BAS601, BUF603, NEC602 and SHE604 operated by BLM-WY. All but five of the 53 sites audited measured ozone. The small footprint sites, BUF603, NIC001, SHE604, UND002, and WFM105 do not have ozone analyzers. Nineteen of the sites audited operated a full complement of meteorological sensors and 48 of the sites operated only temperature sensors. The locations 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	2/13/2013
CAD150	EPA	Caddo Valley	AR / R6	2/14/2013
ALC188	EPA/Tribal	Alabama-Coushatta	TX / R6	2/15/2013
MAC426	NPS	Mammoth Cave NP	KY / R4	3/1/2013
CHE185	EPA/Tribal	Cherokee Nation	TX / R6	3/3/2013
CDZ171	EPA	Cadiz	KY / R4	3/5/2013
BBE401	NPS	Big Bend NP	TX / R6	3/6/2013
MCK131	EPA	Mackville	KY / R4	3/6/2013
MCK231	EPA	Mackville (precision site)	KY / R4	3/6/2013
PAL190	EPA	Palo Duro	TX / R6	3/7/2013
CKT136	EPA	Crockett	KY / R4	3/9/2013
PIN414	NPS	Pinnacles NM	CA / R9	4/11/2013
GRB411	NPS	Great Basin NP	NV / R9	4/16/2013
DCP114	EPA	Deer Creek St. Park	OH / R5	4/22/2013
SAN189	EPA/Tribal	Santee Sioux	NB / R7	4/25/2013
YOS404	NPS	Yosemite NP	CA / R9	5/1/2013

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
SEK430	NPS	Sequoia NP - Ash Mountain	CA / R9	5/3/2013
LAV410	NPS	Lassen Volcanic NP	CA / R9	5/7/2013
OXF122	EPA	Oxford	OH / R5	5/8/2013
QAK172	EPA	Quaker City	OH / R5	5/9/2013
PND165	EPA	Pinedale	WY / R8	5/12/2013
CNT169	EPA	Centennial	WY / R8	5/14/2013
YEL408	NPS	Yellowstone NP	WY / R8	6/6/2013
ROM206	EPA	Rocky Mountain NP	CO / R8	6/10/2013
ROM406	NPS	Rocky Mountain NP (NPS)	CO / R8	6/10/2013
GTH161	EPA	Gothic	CO / R8	6/12/2013
GLR468	NPS	Glacier NP	MT / R8	7/18/2013
BAS601	EPA/BLM	Basin	WY / R8	7/22/2013
SHE604	EPA/BLM	Sheridan	WY / R8	7/23/2013
BUF603	EPA/BLM	Buffalo	WY / R8	7/25/2013
NEC602	EPA/BLM	Newcastle	WY / R8	7/29/2013
BVL130	EPA	Bondville	IL / R5	7/31/2013
VIN140	EPA	Vincennes	IN / R5	8/23/2013
ALH157	EPA	Alhambra	IL / R5	8/24/2013
PRK134	EPA	Perkinstown	WI / R5	9/4/2013
VOY413	NPS	Voyageurs NP	MN / R5	9/5/2013
THR422	NPS	Theodore Roosevelt NP	ND / R8	9/9/2013
WNC429	NPS	Wind Cave NP	SD / R8	9/11/2013
STK138	EPA	Stockton	IL / R5	9/19/2013
WFM105	EPA	Whiteface Mountain	NY / R2	10/3/2013
NIC001	EPA	Nicks Lake	NY / R2	10/4/2013
UND002	EPA	Underhill	VT / R1	10/5/2013

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
WSP144	EPA	Washington Crossing St. Park	NJ / R2	10/24/2013
CDR119	EPA	Cedar Creek St. Park	WV / R3	10/29/2013
PAR107	EPA	Parsons	WV / R3	10/30/2013
BFT142	EPA	Beaufort	NC / R4	11/5/2013
GRS420	NPS	Great Smoky Mountains NP	TN / R4	11/5/2013
PED108	EPA	Prince Edward	VA / R3	11/6/2013
LRL117	EPA	Laurel Hill St. Park	PA / R3	11/8/2013
VPI120	EPA	Horton Station	VA / R3	11/9/2013
CND125	EPA	Candor	NC / R4	11/10/2013
SHN418	NPS	Shenandoah NP - Big Meadows	VA / R3	11/25/2013
BWR139	EPA	Blackwater NWR	MD / R3	12/3/2013

In addition to the sites listed in Table 3-1 that were visited for complete systems and performance audits, the 34 sites listed in Table 3-2 were visited to conduct NPAP Through-The-Probe (TTP) ozone 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	2/17/2013
IRL141	EPA/SJRWMD	Indian River Lagoon	FL / R4	2/20/2013
GAS153	EPA	Georgia Station	GA / R4	2/28/2013
SND152	EPA	Sand Mountain	AL / R4	2/28/2013
COW137	EPA	Coweeta	NC / R4	3/29/2013
ESP127	EPA	Edgar Evins St. Park	TN / R4	3/30/2013
SPD111	EPA	Speedwell	TN / R4	3/30/2013
CHA467	NPS	Chiricahua NM	AZ / R9	4/1/2013

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
PET427	NPS	Petrified Forest NP	AZ / R9	4/2/2013
GRC474	NPS	Grand Canyon NP	AZ / R9	4/4/2013
JOT403	NPS	Joshua Tree NM	CA / R9	4/8/2013
MEV405	NPS	Mesa Verde NP	CO / R8	4/18/2013
CAN407	NPS	Canyonlands NP	UT / R8	4/19/2013
KNZ184	EPA	Konza Prairie	KZ / R7	4/26/2013
PNF126	EPA	Cranberry	NC / R4	5/12/2013
MCK231	EPA	Mackville (precision site)	KY / R4	5/18/2013
DEN417	NPS	Denali NP	AK / R10	6/15/2013
MOR409	NPS	Mount Rainier NP	WA / R10	6/17/2013
HOX148	EPA	Hoxeyville	MI / R5	8/30/2013
UVL124	EPA	Unionville	MI / R5	8/30/2013
ANA115	EPA	Ann Arbor	MI / R5	9/17/2013
MKG113	EPA	M. K. Goddard St. Park	PA / R3	9/17/2013
KEF112	EPA	Kane Experimental Forest	PA / R3	9/20/2013
PSU106	EPA	Penn State University	PA / R3	9/24/2013
SAL133	EPA	Salamonie Reservoir	IN / R5	9/28/2013
CTH110	EPA	Connecticut Hill	NY / R2	10/14/2013
HWF187	EPA	Huntington Wildlife Forest	NY / R2	10/16/2013
WST109	EPA	Woodstock	NH / R1	10/17/2013
ASH135	EPA	Ashland	ME / R1	10/19/2013
HOW191	EPA	Howland AmeriFlux	ME / R1	10/20/2013
ACA416	NPS	Acadia NP	ME / R1	10/21/2013
ABT147	EPA	Abington	CT / R1	10/22/2013
BEL116	EPA	Beltsville	MD / R3	11/1/2013
ARE128	EPA	Arendtsville	PA / R3	11/7/2013

4.0 Performance and Audit Results

Table 4.1 summarizes the number of test failures by variable tested. All test results are those recorded from the site's primary logger.

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 are 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 2013 Quarterly report. The variable specific data forms included in the first Appendix 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. Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	80	1	1.3
Flow Rate	53	1	1.9
Shelter Temperature	48	16	33.3
Wind Direction Orientation Average Error	19	3	15.8

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Orientation Maximum Error	19	4	21.1
Wind Direction Linearity Average Error	17	1	5.9
Linearity Maximum Error	17	4	23.5
Wind Direction Starting Torque	17	1	5.9
Wind Speed Low Range Average Error	19	0	
Low Range Maximum Error	19	0	
Wind Speed High Range Average Error	19	0	
High Range Maximum Error	19	0	
Wind Speed Starting Torque	19	3	15.8
Temperature	50	3	6.0
2 Meter Temperature	5	0	
Relative Humidity	21	1	4.8
Solar Radiation	19	2	10.5
Precipitation	21	1	4.8
DAS Analog to Digital	44	0	

4.1 Ozone

Eighty ozone analyzers were audited during 2013. Each 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. One of the analyzers tested (site MCK231) failed the annual PE. As permitted by the PE SOP, the analyzer

was audited a second time following the repair by the site operator. The second PE was within acceptable limits, and both results are included in Table 4-2 with the results of all ozone audits.

All ozone challenges were conducted to comply with the OAQPS Standard Operating Procedures (SOP) which can be found at www.epa.gov/ttn/amtic/. The results of the ozone audits were uploaded to the AQS database at the end of 2013 for all CASTNET sites that reported ozone data to AQS in 2013.

In February of 2011 OAQPS issued a memorandum providing guidance for low-level audits of pollutant gases. The list of approved audit concentrations was expanded to 10 levels; therefore beginning in 2012 EEMS conducted ozone audits using levels from the new expanded list, and in lower concentration ranges. At least three consecutive audit levels were used.

4.2 Flow Rate

The dry deposition filter pack sampling system flow rates at 53 sites were audited. A NIST-traceable dry-piston primary flow rate device was used for the tests. One site was outside the acceptance criterion of ± 5.0%.

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 48 of the sites visited. 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 Resistive Temperature Detector (RTD) or a Thermocouple.

Most of the differences observed were due to the slow response of the site's shelter temperature sensors. Nearly all the site sensors lagged behind the audit sensor during the rapid changes in temperatures observed as the shelter air conditioning or shelter 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 1 degree C acceptance criterion. This criterion better follows the EPA OAQPS guidelines.

The results are summarized in Table 4-2. Flow rate and shelter temperature data are reported only for the sites that were visited for complete systems and performance audits. Ozone results are included for all site visits.

Table 4-2. Performance Audit Results for Ozone, Shelter Temperature, and Flow Rate

	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
CVL151	0.5	0.6	1.00458	-0.04842	0.99999	0.06	0.1	1.523	1.50	-1.56
CAD150	0.8	1	0.98806	0.40998	0.99997	0.07	0.14	1.531	1.50	-2.07
ALC188	0.8	1.1	1.01151	-0.34553	0.99998	0.43	0.93	1.548	1.49	-3.89
SUM156	1.7	2.4	0.98315	-0.12501	0.99995			1.536	1.50	-2.39
IRL141	0.8	1.1	1.00192	-0.84313	0.99996			1.517	1.50	-0.93
GAS153	1	1.8	1.01205	-0.25812	0.99998			1.544	1.50	-2.69
SND152	0.2	0.4	1.00643	-0.28276	0.99999			1.514	1.51	-0.26
MAC426	5.4	6.7	1.03139	1.44173	0.99999	0.98	1.4	1.487	1.50	0.84
CHE185	3.4	6.5	0.99014	2.2714	0.9999	0.58	0.82	1.521	1.50	-1.40
CDZ171	0.7	1.3	1.01314	-1.30738	0.99996	1.1	1.23	1.535	1.49	-3.04
BBE401	2	3.5	0.9826	2.099	0.99991	0.44	0.61	2.977	2.99	0.43
MCK131	0.5	1.2	1.016	-0.62386	0.99999	1.53	1.7	1.504	1.50	-0.24
MCK231	15.7	17.1	0.86335	-1.19057	0.99997	1.11	1.25	1.543	1.50	-2.89
PAL190	0.5	0.7	0.98874	0.6351	1	0.73	0.77	2.961	3.00	1.31
CKT136	1.5	2.4	0.99158	-0.26696	0.99999	0.42	0.42	1.519	1.50	-1.29
COW137	2.5	2.8	1.02623	-0.19778	0.99999					
ESP127	0.6	0.6	1.00977	-0.33906	0.99999					
SPD111	1	2.1	1.0111	-0.20253	0.99995					
CHA467	0.3	0.5	0.99085	0.45247	0.99999					
PET427	0.5	1.1	0.99254	0.63847	1					
GRC474	1.1	2.7	1.00765	-1.00446	1					
JOT403	2.1	4.3	0.95679	1.01348	0.99982					

	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
PIN414	1.1	1.7	0.98686	0.13471	0.99998	1.28	2.09	3.023	3.02	-0.10
GRB411	3.5	4.1	1.0428	-0.30416	0.99999					
MEV405	1.4	3.2	1.00093	-0.68617	0.99998					
CAN407	1.3	1.9	0.97307	0.93607	0.99997					
DCP114	1	2.6	0.993	0.92403	0.99999	0.11	0.12	1.525	1.50	-1.67
SAN189	3	3.6	0.95175	1.21042	0.99993	0.34	0.65	2.967	3.00	1.11
KNZ184						0.93	1.17	2.992	2.99	-0.08
YOS404	1.3	1.9	1.00354	-0.98519	0.99999	2.83	3.6	3.087	2.99	-3.24
SEK430	0.9	2.4	0.9873	0.82037	1	1.42	1.5	2.994	2.99	-0.14
LAV410	1	2.1	0.98219	1.20291	0.99999	1.27	1.68	2.966	3.00	1.12
OXF122	0.7	1.7	0.99852	0.14735	0.99992	0.45	0.52	1.499	1.50	-0.07
QAK172	0.8	1.3	0.99551	0.61213	0.99997	0.61	0.81	1.537	1.50	-2.49
PND165	4.1	4.4	0.9579	0.02026	0.99999	1.43	2.26	2.973	3.00	1.01
PNF126	6.6	7.5	1.06946	-0.38181	0.99993					
CNT169	3.5	4.1	0.95862	0.26392	0.99999	0.69	0.99	2.837	3.00	5.45
MCK231	2.7	5.4	0.97219	0.30066	0.9997					
YEL408	1.9	2.8	1.02906	-0.33928	0.99998	1.68	2.06	3.017	3.00	-0.46
ROM206	0.5	0.8	0.99603	0.31352	0.99998	0.52	0.54	2.977	3.00	0.78
ROM406	0.4	0.6	0.99341	0.32985	0.99999	2.58	4.47	2.999	3.01	0.32
GTH161	5.4	5.8	0.93953	0.44137	0.99997	0.47	1.11	2.937	3.00	2.11
DEN417	1.9	4.1	0.99826	1.06287	0.99998					
MOR409	3.5	5.3	0.9789	-0.66252	0.99992					
GLR468	2.5	3.3	1.02524	0.1505	0.99993	1.91	3.37	3.034	3.00	-1.14
BAS601	0.9	1.3	0.97762	0.89641	0.99997	1.57	2.23	3.250	3.22	-0.94
SHE604								3.071	3.18	3.38
BUF603								3.239	3.19	-1.45
NEC602	2	3.8	0.95697	0.97691	0.99991	0.2	0.3	3.230	3.29	1.82
BVL130	3.4	4.2	0.95159	0.75261	0.99999	0.36	0.47	1.553	1.51	-2.86
VIN140	4.6	6.1	1.04434	0.07624	0.99967	0.17	0.17	1.515	1.50	-1.00
ALH157	0.9	1.6	1.0176	-0.38879	0.99997	0.23	0.41	1.537	1.5	-2.44

	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
HOX148	1.9	2.7	0.96463	1.17379	0.99999					
UVL124	0.9	1.6	0.98832	0.60271	0.99996					
PRK134	1.7	3.1	0.96421	1.00502	0.99996	0.34	0.57	1.524	1.50	-1.58
VOY413	0.6	1.8	0.9897	0.73068	0.99998	1.84	2.79	3.029	2.99	-1.31
THR422	2.3	3.3	1.03488	-0.57521	0.99998	0.54	0.83	3.062	3.00	-2.07
WNC429	3.4	4.4	0.95048	0.71139	0.99999	0.9	1.46	3.030	3.00	-0.99
ANA115	2.4	2.8	0.97477	0.1818	0.99996					
MKG113	1	2.1	0.98679	-0.03352	0.99989					
STK138	3.3	3.6	0.96544	0.07959	1	0.73	1.12	1.526	1.50	-1.72
KEF112	0.7	1.1	1.0114	-0.29229	0.99999					
PSU106	2.3	3.6	1.03118	-0.2242	0.99989					
SAL133	0.6	1	0.98728	0.562	0.99999					
WFM105								3.048	3.00	-1.72
NIC001								2.970	3.00	0.98
UND002								3.061	3.02	-1.54
CTH110	1.6	1.8	1.01988	-0.29392	0.99999					
HWF187	2.6	3.9	0.98133	-0.37537	0.99999					
WST109	1.9	2.5	0.98852	-0.41715	0.99998					
ASH135	4.6	7	0.97158	-0.77854	0.99999					
HOW191	1.4	1.7	0.98713	-0.02481	0.99999					
ACA416	4.9	5.4	1.05331	-0.07432	0.99999					
ABT147	3.3	4.2	0.97501	-0.40433	1					
WSP144	4.4	8.9	0.99499	-2.02336	0.99986	1.36	1.41	1.552	1.50	-3.45
CDR119	2.1	3.4	0.99066	-0.43578	0.99984	0.58	1.16	1.514	1.49	-1.62
PAR107	0.7	1.2	1.00668	-0.0465	0.99992	0.33	0.49	1.500	1.50	-0.02
BEL116	1	2.6	0.998	0.4768	0.99998					
BFT142	2.3	5.4	1.00271	-1.02853	0.9999	0.22	0.47	1.474	1.50	1.71
GRS420	1.1	1.5	0.9769	0.86907	0.99999	1.42	1.66	3.088	3.01	-2.70
PED108	1.3	2.1	0.99401	-0.28334	1	0.36	0.58	1.535	1.49	-2.77
ARE128	0.8	1.9	1.02492	-1.07077	0.99992					

	Ozone average (% diff)	Ozone maximum (% diff)	Ozone slope	Ozone intercept	Ozone correlation	Shelter temp. average error (C)	Shelter temp. maximum error (C)	STP Flow observed (lpm)	Flow DAS (lpm)	Flow Error (% diff)
LRL117	1.6	2	0.98264	0.15412	0.99999	0.32	0.41	1.487	1.50	0.87
VPI120	2	2.3	0.97387	0.34143	1.00000	0.78	1.02	1.539	1.51	-1.90
CND125	0.5	1	0.98959	0.36844	0.99997	0.84	1.01	1.518	1.50	-1.18
SHN418	0.8	1.3	0.98262	0.95657	0.99995	1.28	2.02	1.509	1.50	-0.58
BWR139	1.5	2.6	0.99874	0.37322	0.99971	0.23	0.34	1.528	1.50	-1.86

4.4 Wind Speed

The wind speed sensors at 19 sites equipped for meteorological measurements were audited. All sites were found to be well within the acceptance limit. The results of the wind speed performance audits are presented in Table 4-3.

One site (BVL130) was found to have a wind speed sensor heater that was not functioning. Wind data quality may have been impacted at BVL130 during freezing temperatures due to the heater failure.

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings was 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 manufacture's specifications for a properly maintained system. Three sites were found to be outside 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 each of the 19 sensors tested, three sites were outside the acceptance criterion of ± 5 degrees. All but one of the sensors tested for average linearity, were within the acceptance limit. The results of the wind direction performance audits are presented in Table 4-3.

One site (BVL130) was found to have a wind direction sensor heater that was not functioning. Wind data quality may have been impacted at BVL130 during freezing temperatures due to the heater failure.

4.5.1 Wind Direction Starting Threshold

The condition of the wind direction bearings was 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. All but one of the wind direction starting thresholds was within acceptance limits. The test results are provided in Table 4-3.

Table 4-3. 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)	
MAC426	1.4	2	1.5	5	6	0.01	0.03	0.00	0.00	0.20
CHE185	0.5	2	1	3	22	0.12	-0.30	0.00	0.01	1.00
BBE401	1.8	3	0.8	2	10	0.01	0.03	0.00	0.00	0.25

	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	1.2	3	1	2	15	0.05	-0.20	0.00	0.00	0.35
PIN414	3.4	6	2.2	6	8	0.01	0.03	0.00	0.00	0.45
YOS404	10.8	13	1.5	4	8	0.02	0.02	0.01	-0.01	0.30
SEK430	2.8	5	1.8	3	14	0.07	-0.19	0.00	0.00	0.40
LAV410	3.2	5	2	4	8	0.01	0.03	0.00	0.00	0.30
YEL408	9.5	13	1.2	5	8	0.09	0.13	0.01	0.02	0.30
ROM406	9.7	13	10.8	43	14	0.05	-0.20	0.00	0.00	0.30
GLR468	1.5	3	1	2	12	0.05	-0.20	0.00	0.00	0.30
SHE604	2.2	3				0.13	-0.50	0.00	-0.01	0.80
BUF603	2.2	4				0.11	-0.45	0.01	0.01	0.90
BVL130	2.2	4	1.8	7	9	0.02	0.05	0.00	0.00	0.35
VOY413	1.8	4	2	7	9	0.01	0.02	0.01	0.01	0.45
THR422	1.5	3	1.5	5	9	0.00	0.01	0.00	0.00	0.35
WNC429	1	2	1.5	3	12	0.27	0.35	0.02	0.06	0.45
GRS420	1	4	1.8	5	11	0.09	0.20	0.01	0.01	0.50
SHN418	1.2	2	1.2	3	18	0.05	-0.20	0.00	0.00	0.40

* 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 site temperature measurement systems consist of a temperature sensor mounted at approximately 9 meters above ground-level on a tower. A few sites also utilized a second sensor to measure temperature at approximately two meters from the ground (2-meter temperature).

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 of the 50 sensors tested, three were outside the acceptance criterion. It should be noted that all three sensors were located at sites recently added to the CASTNET and operated by the BLM. 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.

Only five 2-meter temperature sensors were tested, and all were within criterion. The average errors for all sensors are presented in Table 4-4.

4.6.1 Temperature Shield Blower Motors

Three of the temperature sensor shield blower motors encountered (sites DCP114, VIN140, and SEK430) during the site audits conducted during 2013 were found to be non-functioning. All 2-meter temperature sensor shield blowers were functioning properly. It is likely that even though the temperature parameter at these sites was found to be within acceptance criteria, the data quality is impacted by the non-functioning blowers.

4.7 Relative Humidity

The relative humidity systems at the sites 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 4-4.

The relative humidity measurement being made at each of the 21 sites equipped with relative humidity sensors is provided by a sensor supplied by any one of three different manufactures. At EPA sponsored sites with R. M. Young equipment, humidity sensors are operating in naturally aspirated shields. At EPA sponsored sites with Climatronics equipment, humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers. One site (GRS420) was found to have a RH sensor in a shield designed to be aspirated with a blower which was not functioning. It is likely that relative humidity data quality at GRS420 was impacted during the time that the blower was not functioning.

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 results of the tests are included in Table 4-4.

Table 4-4. 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 (%)	Max. Error (%)
CVL151	0.16			
CAD150	0.08			
ALC188	0.31			
MAC426	0.31	0.33	10.67	27.4
CHE185	0.13	0.15	5.30	-8.1
CDZ171	0.13			
BBE401	0.16		1.90	2.5
MCK131	0.08			
MCK231	0.15			
PAL190	0.04	0.04	5.20	-9.1
CKT136	0.2			
PIN414	0.08		3.00	-4.2
DCP114	0.13			
SAN189	0.11			
KNZ184	0.17			
YOS404	0.05		2.87	4.3
SEK430	0.13		1.97	-2.9

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity	
			Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
LAV410	0.15		5.67	11.4
OXF122	0.44			
QAK172	0.17			
PND165	0.05			
CNT169	0.1			
YEL408	0.05		1.77	2.8
ROM206	0.08			
ROM406	0.1	0.11	1.93	-4.2
GTH161	0.13			
GLR468	0.09		2.33	-4.5
BAS601	2.09		2.13	-4.1
SHE604	2.1		3.07	-6.0
BUF603	0.5		2.50	4.1
NEC602	1.81		2.00	-4.9
BVL130	0.14	0.31	1.50	-2.0
VIN140	0.21			
ALH157	0.08			
PRK134	0.1			
VOY413	0.11		1.93	-2.0
THR422	0.04		1.67	2.7
WNC429	0.08		1.87	-3.9
STK138	0.07			
WSP144	0.07			
CDR119	0.12			
PAR107	0.12			
BFT142	0.07			

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity	
			Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
GRS420	0.13		5.20	8.6
PED108	0.01			
LRL117	0.06			
VPI120	0.23			
CND125	0.12			
SHN418	0.13		6.23	9.9
BWR139	0.09			

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.

Nineteen sites were tested. Two sites had daytime average results that were outside the acceptance criterion. The results of the individual tests for each site are included in Table 4-5. The percent difference of the maximum single-hour average solar radiation value observed during each site audit is also reported in Table 4-5 although this criterion is not part of the CASTNET data quality indicators. Those values greater than ±10% are bold.

4.9 Precipitation

All sites audited used a tipping bucket rain gauge for the 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 rain gauge at one site, WNC429, was not functioning and therefore the test results are outside of the acceptable criterion. The results are summarized in Tables 4-5.

Of the seventeen tipping bucket heaters tested, five sites (GRS420, CHE185, SEK430, BBE401, and PIN414)) were found to be not functioning properly. Precipitation data quality may have been impacted at these sites during precipitation events that occurred near freezing temperatures.

Table 4-5. 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)	
MAC426	6.8	251	274	8.4	6.0
CHE185	1.41	781	794	1.6	2.0
BBE401	8.95	755	821	8.0	3.0
PAL190	1.52	742	749	0.9	1.0
PIN414	9.42	943	858	-9.9	2.0
YOS404	3.82	1018	969	-5.1	3.0
SEK430	1.73	913	893	-2.2	4.7
LAV410	9.72	359	400	**10.3**	3.0
YEL408	1.35	753	763	1.3	3.0
ROM406	3.05	1070	994	-7.6	0.0
GLR468	2.83	831	832	0.1	3.0
BAS601	0.95	799	800	0.1	0.0
SHE604	3.12	888	862	-3.0	7.1
BUF603	13.71	953	818	**-16.5**	3.3
NEC602	9.47	915	819	**-11.7**	5.0
BVL130					4.0
VOY413	1.9	684	684	0.0	2.0
THR422	5.99	757	708	-6.9	2.0
WNC429	8.37	769	717	-7.3	100.0
GRS420	10.53	514	553	7.1	2.0
SHN418					2.0

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 loggers as their only DAS. The results presented in table 4-6 include the tests performed on the primary logger at each site.

4.10.1 Analog Test

The accuracy of each primary logger was tested on two different channels (if two channels were available to be used) with a NIST-traceable Fluke digital voltmeter. At some of the EPA sponsored sites the channels above analog channel 8 could not be tested since there were no empty channels available to test. All data loggers were within 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 DAS were set to the correct date and within ±5 minutes per the acceptance criterion for time.

Table 4-6. Performance Audit Results for Data Acquisition Systems

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
CVL151	0.0003	0.0005			Y	0.00
CAD150	0.0005	-0.0007			Y	0.05
ALC188	0.0003	-0.0005			Y	0.00
MAC426	0.0000	0.0001	0.0000	0.0001	Y	0.45
CHE185	0.0010	0.0011			Y	0.03
CDZ171	0.0003	-0.0005			Y	0.00
BBE401	0.0000	0.0001	0.0000	0.0001	Y	0.02
MCK131	0.0004	-0.0006			Y	0.02
MCK231	0.0004	-0.0007			Y	0.00
PAL190	0.0000	0.0001			Y	0.00
CKT136	0.0004	-0.0006			Y	0.00
PIN414	0.0003	-0.0010	0.0000	0.0000	Y	0.67
DCP114	0.0003	-0.0006			Y	0.00
SAN189	0.0002	-0.0004			Y	0.00
KNZ184	0.0003	0.0005			Y	0.00

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
YOS404	0.0000	0.0001	0.0000	0.0000	Y	0.52
SEK430	0.0000	0.0000	0.0000	0.0001	Y	0.33
LAV410	0.0001	0.0003	0.0001	0.0003	Y	0.15
OXF122	0.0003	-0.0005			Y	0.02
QAK172	0.0003	-0.0005			Y	0.00
PND165	0.0000	0.0001			Y	0.08
CNT169	0.0000	0.0001			Y	0.00
YEL408	0.0000	0.0001	0.0003	-0.0009	Y	0.03
ROM206	0.0000	0.0001			Y	0.02
ROM406	0.0000	0.0001	0.0000	0.0001	Y	0.40
GTH161	0.0000	0.0001			Y	0.00
GLR468	0.0001	-0.0001	0.0000	0.0000	Y	0.72
BVL130	0.0000	0.0001			Y	0.02
VIN140	0.0004	-0.0006			Y	0.27
ALH157	0.0003	0.0006			Y	0.07
VOY413	0.0000	0.0001	0.0000	0.0000	Y	0.00
THR422	0.0000	0.0001	0.0000	0.0001	Y	0.03
STK138	0.0000	0.0000			Y	0.00
WSP144	0.0000	0.0000			Y	0.03
CDR119	0.0003	-0.0006			Y	0.02
PAR107	0.0003	-0.0006			Y	0.00
BFT142	0.0003	-0.0005			Y	0.00
GRS420	0.0000	0.0001	0.0001	0.0002	Y	0.73
PED108	0.0003	0.0005			Y	0.00
LRL117	0.0003	-0.0005			Y	0.00
VPI120	0.0004	-0.0006			Y	1.77

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
CND125	0.0003	-0.0005			Y	0.00
SHN418	0.0001	0.0003	0.0002	-0.0007	Y	0.00
BWR139	0.0001	0.0002			Y	0.00

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.

5.2 Sample Inlets

With consideration given to the siting criteria compromises described in the previous section, the sites visited this year have analyzer sample trains that are sited properly and in accordance with the CASTNET QAPP. 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, SD is operated by the State.

Estimated sample residence times have been calculated from the data obtained for sample train length, tubing diameter, and sample flow rates during the site audits. The results of those calculations and comments regarding ozone siting criteria, are included in Table 5-1. The requirements of 40 CFR Part 58 Appendix E are that sample inlets should not be located within 20 meters of trees.

Table 5-1. Ozone Inlet Siting and Sample Residence Time

Site	Residence Time (sec)	Inlet Comment	Site	Residence Time (sec)	Inlet Comment
ALC188	4.8		MCK231	5.9	
ALH157	5.9		NEC602	4.0	
BAS601	4.0		OXF122	5.9	
BBE401	4.8		PAL190	4.8	
BFT142	4.0		PAR107	4.8	
BVL130	4.8		PED108	7.1	
BWR139	4.8		PIN414	4.8	
CAD150	4.8		PND165	4.8	
CDR119	4.8	15 meters from trees	PRK134	5.9	
CDZ171	7.1		QAK172	5.9	
CHE185	23.8		ROM206	4.8	
CKT136	5.9		ROM406	4.8	
CND125	4.8		SAN189	6.3	
CNT169	4.8		SEK430	6.3	Trees within 10 meters
CVL151	4.8	17 meters	SHN418	5.9	
DCP114	4.8	Small trees within 10 meters	STK138	7.1	
GLR468	5.9		THR422	15.8	
GRS420	4.8		VIN140	7.1	
GTH161	4.8		VOY413	4.8	Trees within 5 meters
KNZ184	4.8		VPI120	7.1	
LAV410	4.0	< 10 meters	WNC429	1.2	
LRL117	4.8		WSP144	4.8	
MAC426	4.0		YEL408	4.8	10 to 15 meters from trees
MCK131	5.9		YOS404	4.0	

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.

Results of the evaluations will be included in future reports. It is anticipated that the new criteria will replace the evaluation of trees within 20 meters of the sample inlet.

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 contain 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.

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 degrading signal cables, was especially helpful. 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. Some of the site operators mentioned that the CASTNET features in the NPS "Monitor" are informative, helpful, and appreciated.

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. A few operators do not use the "chain-of-custody" label.

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; this recommendation was also included in the previous annual report.

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.

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

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:	Mike Crowe	Eric Hebert
Make:	NIST	~~TEI~~ Thermo
Model:	SRP-10	49C
S/N:	10	49C-73104-373
Guest Test Status:		**PASS**
Guest Known Offset:		0

SESD Project #: 13-0152
Test #: 1

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0243	-0.2652	0.9999985	477	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)
12/17/12	11:46 AM	12/17/12	1:29 PM	c1217001.xls	1.0229	-0.2923	0.9999990	475	-0.11
12/17/12	1:30 PM	12/17/12	3:13 PM	c1217002.xls	1.0238	-0.3578	0.9999989	477	-0.06
12/17/12	3:13 PM	12/17/12	4:56 PM	c1217003.xls	1.0244	-0.2108	0.9999983	477	-0.13
12/17/12	4:56 PM	12/17/12	6:39 PM	c1217004.xls	1.0241	-0.2658	0.9999985	477	-0.02
12/17/12	6:39 PM	12/17/12	8:22 PM	c1217005.xls	1.0243	-0.1719	0.9999981	477	0.07
12/17/12	8:22 PM	12/17/12	10:05 PM	c1217006.xls	1.0253	-0.2540	0.9999989	477	-0.10
12/17/12	10:05 PM	12/17/12	11:48 PM	c1217007.xls	1.0254	-0.3036	0.9999976	478	0.05

Comments: Instrument within tolerance.
No adjustments made.
Ozone calibration factors at time of test: O3 BKG = 0.2 ppb O3 COEF = 1.027

Verification Expires on: **December 17, 2013**

Mike Crowe _____ Date 12-19-12

EEMS # 01100

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:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP-10	49CPS
S/N:	10	49CPS-70008-364
Guest Test Status:		PASS
Guest Known Offset:		0

SESD Project #: 13-0153
Test #: 1

Level 2	Slope	Intercept	R^2	High O_3	Lower O
Averages:	1.0032	0.0315	0.9999957	484	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)
12/18/12	2:06 PM	12/18/12	3:48 PM	c1218001.xls	1.0011	-0.2100	0.9999974	482	-0.27
12/18/12	3:48 PM	12/18/12	5:31 PM	c1218002.xls	0.9999	-0.0072	0.9999960	484	0.29
12/18/12	5:31 PM	12/18/12	7:15 PM	c1218003.xls	1.0011	0.0190	0.9999936	483	-0.17
12/18/12	7:15 PM	12/18/12	8:58 PM	c1218004.xls	1.0006	0.2832	0.9999960	484	-0.21
12/18/12	8:58 PM	12/18/12	10:40 PM	c1218005.xls	1.0050	-0.0538	0.9999994	484	0.13
12/18/12	10:40 PM	12/19/12	12:23 AM	c1218006.xls	1.0067	0.1154	0.9999903	484	-0.21
12/19/12	12:23 AM	12/19/12	2:07 AM	c1218007.xls	1.0081	0.0738	0.9999975	485	-0.26

Comments: Instrument within tolerance.
No adjustments made.
Ozone calibration factors at time of test: O3 BKG = 0.0 ppb O3 COEF = 1.035

Verification Expires on: **December 19, 2013**

Mike Crowe Date 12-19-12

EEMS# 01110

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:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP-10	49CPS
S/N:	10	517112175
Guest Test Status:		**PASS**
Guest Known Offset:		0

SESD Project #: 13-0151
Test #: 1

Level 2	Slope	Intercept	R^2	High O_3	Lower
Averages:	1.0204	0.1794	0.9999986	477	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)	Lowe Rang (ppb O
12/17/12	11:46 AM	12/17/12	1:29 PM	c1217001.xls	1.0185	0.0420	0.9999984	475	-0.11
12/17/12	1:30 PM	12/17/12	3:13 PM	c1217002.xls	1.0200	0.0365	0.9999991	477	-0.06
12/17/12	3:13 PM	12/17/12	4:56 PM	c1217003.xls	1.0207	0.1060	0.9999986	477	-0.13
12/17/12	4:56 PM	12/17/12	6:39 PM	c1217004.xls	1.0205	0.1856	0.9999986	477	-0.02
12/17/12	6:39 PM	12/17/12	8:22 PM	c1217005.xls	1.0203	0.3054	0.9999984	477	0.07
12/17/12	8:22 PM	12/17/12	10:05 PM	c1217006.xls	1.0210	0.3312	0.9999990	477	-0.10
12/17/12	10:05 PM	12/17/12	11:48 PM	c1217007.xls	1.0214	0.2488	0.9999981	478	0.05

Comments: Instrument within tolerance.
No adjustments made.
Ozone calibration factors at time of test: O3 BKG = -0.5 ppb O3 COEF = 1.026

Verification Expires on: **December 17, 2013**

Mike Crowe Date 12-19-12

EEMS # 01111

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:	Mike Crowe	Eric Hebert
Make:	NIST	Thermo
Model:	SRP-10	49c analyzer
S/N:	10	49C-73104-373
Guest Test Status:		PASS
Guest Known Offset:		0

SESD Project #: 13-0324
Test #: 1

Level 2	Slope	Intercept	R^2	High O_3	Lower O_3
Averages:	1.0118	-0.2469	0.9999973	481	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)
04/01/13	5:11 PM	04/01/13	6:54 PM	c0401001.xls	1.0106	-0.1983	0.9999984	478	0.10
04/01/13	6:54 PM	04/01/13	8:36 PM	c0401002.xls	1.0118	-0.2266	0.9999971	480	-0.23
04/01/13	8:37 PM	04/01/13	10:19 PM	c0401003.xls	1.0113	-0.1144	0.9999977	481	-0.41
04/01/13	10:19 PM	04/02/13	12:01 AM	c0401004.xls	1.0113	-0.1640	0.9999978	482	-0.15
04/02/13	12:01 AM	04/02/13	1:47 AM	c0401005.xls	1.0127	-0.3806	0.9999959	482	0.20
04/02/13	1:48 AM	04/02/13	3:30 AM	c0401006.xls	1.0126	-0.2933	0.9999979	482	0.07
04/02/13	3:30 AM	04/02/13	5:12 AM	c0401007.xls	1.0122	-0.3514	0.9999963	482	0.45

Comments: Instrument oscillating by approximately 2 ppb when switching between cells.
Changed averaging time from 10 sec. to 60 seconds. Doing so alleviated the issue.
Intrument within tolerance.
Ozone calibration factors at time of test 1: O3 BKG = 0.2 ppb O3 COEF = 1.016

Verification Expires on: **April 2, 2014**

Mike Crowe Mike Crowe Date 4/3/13

Ozone Certifiction Records

EPA file	date	start time	slope	intercept	correlatioin	location
c0217008	17-Feb-09	12:01	1.01323	0.06364	1	R-7
c0217007	17-Feb-09	10:56	1.01279	0.23014	1	R-7
C0217006	17-Feb-09	9:52	1.01158	0.0047	1	R-7
C0212004	12-Feb-09	16:31	1.00906	-0.27196	1	R-7
C0213008	13-Feb-09	11:42	1.01345	-0.1985	1	R-7
		AVG =	**1.012022**	**-0.034396**	**1**	

EEMS Thermo 49-CPS 0517115175

EPA file	date	start time	slope	intercept	correlatioin	location
c0930002	30-Sep-13	13:30	1.00488	0.21264	1	R-7
c0930003	30-Sep-13	14:39	1.00502	0.25051	1	R-7
c0930004	30-Sep-13	16:02	1.00448	0.36422	1	R-7
c0930005	30-Sep-13	17:41	1.00482	0.37669	1	R-7
c0930006	30-Sep-13	18:49	1.00569	0.21213	1	R-7
c0930007	30-Sep-13	19:55	1.00569	0.17804	1	R-7
c0930008	30-Sep-13	21:01	1.00570	0.29168	1	R-7
c0930009	30-Sep-13	22:06	1.00575	0.18324	1	R-7
		AVG =	**1.005254**	**0.25864**	**1**	

NVLAP Lab Code 200661

Bios
Driving a Higher Standard in Flow Measurement℠

Calibration Certificate

Certificate No.	5015962	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	DryCal Nexus NS		1128 NW 39th Drive
Serial No.	103471		Gainesville, FL 32605
Cal. Date	6/13/2012		USA

All calibrations are performed in accordance with ISO 17025 at Bios International Corporation, 10 Park Place, Butler, NJ, 07405, 800-663-4977, an ISO 17025:2005 – accredited laboratory through NVLAP. 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.

Temperature and pressure are tested in accordance with Bios International Corporation PR06-02.
Expanded uncertainty of measurement: temperature ±0.035°C and pressure ±8Pa at two times coverage.

As Received Calibration Data

Technician Brian Roberts

Lab. Pressure 751 mmHg
Lab. Temperature 22.8 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	Condition
24.5°C	22.8°C	1.7°C	±0.6°C	Out of Tolerance
753mmHg	751mmHg	2mmHg	±1.8mmHg	Out of Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
Precision Thermometer	305460	8/15/2011	8/14/2012
Precision Barometer	2981392	6/4/2012	6/4/2013

Bios

Driving a Higher Standard in Flow Measurement℠

As Shipped Calibration Data

Certificate No. 5015962
Technician Brian Roberts

Lab. Pressure 751 mmHg
Lab. Temperature 22.5 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	Condition
22.5°C	22.5°C	-	±0.6°C	In Tolerance
751mmHg	751mmHg	-	±1.8mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
Precision Thermometer	305460	8/15/2011	8/14/2012
Precision Barometer	2981392	6/4/2012	6/4/2013

DryCal Nexus Temperature and Pressure Certification
The Drycal DCLite is a true primary volumetric flow standard. Temperature and pressure corrections are applied by the Nexus NS to obtain standardized flow readings. The temperature and pressure transducers are calibrated against NIST traceable standards.

Calibration Notes

Bios is an ISO 17025-accredited metrology laboratory. Calibration Certificates for gauges and instruments used for calibration are available upon request. Rigorous analyses of our laboratory standards' uncertainties have been performed, in accordance with The Guide to the Expression of Uncertainty in Measurement (the GUM), assuring their traceable accuracy.

Technician Notes: _____

David W. Wilson, Chief Metrologist

Bios International • 10 Park Place Butler, NJ 07405 • 800.663.4977 • www.biosint.com

MesaLabs

NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5021821	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	Definer 220 High Flow		1128 NW 39th Drive
Serial No.	122974		Gainesville, FL 32605
Cal. Date	1/8/2013		USA

All calibrations are performed in accordance with ISO 17025 at Bios International, a division of Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, 800-663-4977, an ISO 17025:2005 – accredited laboratory through NVLAP. 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.

All units tested in accordance with our test number PR18-13 using high-purity nitrogen or filtered laboratory air.

As Received Calibration Data

Technician Jacquella Shives

Lab. Pressure 750 mmHg
Lab. Temperature 22.3 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
505.72 sccm	502.535 sccm	0.63%	1.00%	In Tolerance
5019.8 sccm	5006.35 sccm	0.27%	1.00%	In Tolerance
30163 sccm	30127.5 sccm	0.12%	1.00%	In Tolerance
22.3 °C	22.3 °C	0°C	±0.8°C	In Tolerance
750 mmHg	750 mmHg	0 mmHg	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	11/16/2012	11/16/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

EEMS# 01416

MesaLabs

NVLAP Lab Code 200661

As Shipped Calibration Data

Certificate No. 5021821
Technician Jacquella Shives

Lab. Pressure 760 mmHg
Lab. Temperature 22.4 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
503.09 sccm	501.285 sccm	0.36%	1.00%	In Tolerance
5012.2 sccm	5008.95 sccm	0.06%	1.00%	In Tolerance
30153 sccm	30150.5 sccm	0.01%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	±0.8°C	In Tolerance
760 mmHg	760 mmHg	-	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	11/16/2012	11/16/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

Calibration Notes

Bios is an ISO 17025-accredited metrology laboratory. Each Bios primary gas flow standard is dynamically verified by comparing it to one of our laboratory standards, which is a Proven DryCal® Technology volumetric piston prover of much higher accuracy (±0.25 % or less) but of similar operating principles. For this purpose, a flow generator of ±0.10 % or less stability is used. Our laboratory standards are qualified by direct measurement of their dimensions (diameter, length and time) using NIST-traceable precision gauges and instruments, such as depth micrometers and laser micrometers. Calibration Certificates for these gauges and instruments are available upon request. Rigorous analyses of our laboratory standards' uncertainties have been performed, in accordance with The Guide to the Expression of Uncertainty in Measurement (the GUM), assuring their traceable accuracy.
Flow readings in sccm performed at STP of 21.1°C and 760 mmHg.

Technician Notes: _____

220 - High
EEMS #
01416

DWWil

David W. Wilson, Chief Metrologist

1/8/2013

MesaLabs

NVLAP®
NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5021819	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	Definer 220 Low Flow		1128 NW 39th Drive
Serial No.	120910		Gainesville, FL 32605
Cal. Date	1/3/2013		USA

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All units tested in accordance with our test number PR18-13 using high-purity nitrogen or filtered laboratory air.

As Received Calibration Data

Technician Jacquella Shives

Lab. Pressure 752 mmHg
Lab. Temperature 22.5 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
30.180 sccm	30.2065 sccm	-0.09%	1.00%	In Tolerance
102.16 sccm	102.13 sccm	0.03%	1.00%	In Tolerance
504.8 sccm	502.485 sccm	0.46%	1.00%	In Tolerance
21.9 °C	22.5 °C	-0.6°C	±0.8°C	In Tolerance
751 mmHg	752 mmHg	-1 mmHg	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	103743	3/21/2012	3/21/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

EEMS # 01415

MesaLabs

NVLAP®
NVLAP Lab Code 200661

As Shipped Calibration Data

Certificate No. 5021819
Technician Jacquella Shives

Lab. Pressure 756 mmHg
Lab. Temperature 22.2 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
30.228 sccm	30.228 sccm	0%	1.00%	In Tolerance
101.03 sccm	100.785 sccm	0.24%	1.00%	In Tolerance
501.11 sccm	501.475 sccm	-0.07%	1.00%	In Tolerance
21.9 °C	21.9 °C	-	±0.8°C	In Tolerance
756 mmHg	756 mmHg	-	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	103743	3/21/2012	3/21/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

Calibration Notes

Bios is an ISO 17025-accredited metrology laboratory. Each Bios primary gas flow standard is dynamically verified by comparing it to one of our laboratory standards, which is a Proven DryCal® Technology volumetric piston prover of much higher accuracy (±0.25 % or less) but of similar operating principles. For this purpose, a flow generator of ±0.10 % or less stability is used. Our laboratory standards are qualified by direct measurement of their dimensions (diameter, length and time) using NIST-traceable precision gauges and instruments, such as depth micrometers and laser micrometers. Calibration Certificates for these gauges and instruments are available upon request. Rigorous analyses of our laboratory standards' uncertainties have been performed, in accordance with The Guide to the Expression of Uncertainty in Measurement (the GUM), assuring their traceable accuracy.
Flow readings in sccm performed at STP of 21.1°C and 760 mmHg.

Technician Notes: _____

EEMS # 01415

David W. Wilson, Chief Metrologist

MesaLabs

NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5021821	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	Definer 220 High Flow		1128 NW 39th Drive
Serial No.	122974		Gainesville, FL 32605
Cal. Date	1/8/2013		USA

All calibrations are performed in accordance with ISO 17025 at Bios International, a division of Mesa Laboratories, Inc., 10 Park Place, Butler, NJ, 07405, 800-663-4977, an ISO 17025:2005 – accredited laboratory through NVLAP. 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.

All units tested in accordance with our test number PR18-13 using high-purity nitrogen or filtered laboratory air.

As Received Calibration Data

Technician Jacquella Shives

Lab. Pressure 750 mmHg
Lab. Temperature 22.3 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
505.72 sccm	502.535 sccm	0.63%	1.00%	In Tolerance
5019.8 sccm	5006.35 sccm	0.27%	1.00%	In Tolerance
30163 sccm	30127.5 sccm	0.12%	1.00%	In Tolerance
22.3 °C	22.3 °C	0°C	±0.8°C	In Tolerance
750 mmHg	750 mmHg	0 mmHg	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	11/16/2012	11/16/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

EEMS# 01416

MesaLabs

NVLAP®
NVLAP Lab Code 200661

As Shipped Calibration Data

Certificate No. 5021821
Technician Jacquella Shives

Lab. Pressure 760 mmHg
Lab. Temperature 22.4 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Shipped
503.09 sccm	501.285 sccm	0.36%	1.00%	In Tolerance
5012.2 sccm	5008.95 sccm	0.06%	1.00%	In Tolerance
30153 sccm	30150.5 sccm	0.01%	1.00%	In Tolerance
22.4 °C	22.4 °C	-	±0.8°C	In Tolerance
760 mmHg	760 mmHg	-	±3.5mmHg	In Tolerance

Bios International Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	101897	11/16/2012	11/16/2013
Precision Thermometer	305460	8/20/2012	8/20/2013
Precision Barometer	2981392	6/4/2012	6/4/2013

Calibration Notes

Bios is an ISO 17025-accredited metrology laboratory. Each Bios primary gas flow standard is dynamically verified by comparing it to one of our laboratory standards, which is a Proven DryCal® Technology volumetric piston prover of much higher accuracy (±0.25 % or less) but of similar operating principles. For this purpose, a flow generator of ±0.10 % or less stability is used. Our laboratory standards are qualified by direct measurement of their dimensions (diameter, length and time) using NIST-traceable precision gauges and instruments, such as depth micrometers and laser micrometers. Calibration Certificates for these gauges and instruments are available upon request. Rigorous analyses of our laboratory standards' uncertainties have been performed, in accordance with The Guide to the Expression of Uncertainty in Measurement (the GUM), assuring their traceable accuracy.
Flow readings in sccm performed at STP of 21.1°C and 760 mmHg.

Technician Notes: _____

EEMS # 01416

David W. Wilson, Chief Metrologist

INNOCAL®
INNOVATIVE CALIBRATION SOLUTIONS
625 East Bunker Court
Vernon Hills, Illinois 60061
PH: 866-466-6225
Fax: 847-327-2993
www.innocalsolutions.com

NIST Traceable
Calibration Report

REPORT NUMBER
332326

Reference Number: **277938**
PO Number: **ERIC HEBERT0102**

EEMS
1128 NW 39th Dr
Gainsville, FL 32605 United States

Manufacturer:	Extech Instruments	**Calibration Date:**	01/12/2013
Model Number:	407907	**Calibration Due Date:**	01/12/2014
Description:	Temperature RTD, Handheld Thermometer	**Condition As Found:**	Initial Calibration
Asset Number:	CP100701	**Condition As Left:**	In Tolerance, No adjustment
Serial Number:	H232734		
Procedure:	DS Extech Instrument Co. 407907		

Remarks:
NIST-traceable calibration performed on the unit referenced above in accordance with customer requirements, published specifications and the lab's standard operating procedures. No adjustments were made to the unit.

Standards Utilized

Asset No.	Manufacturer	Model No.	Description	Cal. Date	Due Date
CPM126	Fluke Corporation	5520A-SC1100/PQ	Calibrator, Multi-Function Calibrator	10/20/2012	10/20/2013

Calibration Data

FUNCTION TESTED	Nominal Value	As Found	Out of Tol	As Left	Out of Tol	CALIBRATION TOLERANCE
RTD Temperature	-199.500 °C	-199.60		Same		-199.899 to -199.101 °C [EMU 0.013 °C][TUR 31:1]
"	-100.000 °C	-100.16		Same		-100.300 to -99.700 °C [EMU 0.0080 °C][TUR 37:1]
"	0.000 °C	-0.03		Same		-0.200 to 0.200 °C [EMU 0.0031 °C][TUR 65:1]
"	200.000 °C	200.12		Same		199.600 to 200.400 °C [EMU 0.013 °C][TUR 31:1]
"	500.000 °C	500.6		Same		499.300 to 500.700 °C [EMU 0.054 °C][TUR 13:1]
"	800.000 °C	800.7		Same		799.000 to 801.000 °C [EMU 0.18 °C][TUR 5.6:1]

EEMS #
01227

SEG

Temperature: 19° C
Humidity: 49% RH
Rpt. No.: 332326

Calibration Performed By:			Quality Reviewer:	
Panich, Eduard B	Metrologist	847-327-5322	Pietronicco, Mike	1/14/2013
Name	Title	Phone	Name	Date

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NIST Traceable
Calibration Report

REPORT NUMBER
332327

Reference Number: **277938**
PO Number: **ERIC HEBERT0102**

EEMS
1128 NW 39th Dr
Gainsville, FL 32605 United States

Manufacturer:	Extech Instruments	**Calibration Date:**	01/12/2013
Model Number:	407907	**Calibration Due Date:**	01/12/2014
Description:	Temperature RTD, Handheld Thermometer	**Condition As Found:**	Initial Calibration
Asset Number:	CP100702	**Condition As Left:**	In Tolerance, No adjustment
Serial Number:	H232679		
Procedure:	DS Extech Instrument Co. 407907		

Remarks:
NIST-traceable calibration performed on the unit referenced above in accordance with customer requirements, published specifications and the lab's standard operating procedures. No adjustments were made to the unit.

Standards Utilized

Asset No.	Manufacturer	Model No.	Description	Cal. Date	Due Date
CPM126	Fluke Corporation	5520A-SC1100/PQ	Calibrator, Multi-Function Calibrator	10/20/2012	10/20/2013

Calibration Data

FUNCTION TESTED	Nominal Value	As Found	Out of Tol	As Left	Out of Tol	CALIBRATION TOLERANCE
RTD Temperature	-199.500 °C	-199.68		Same		-199.899 to -199.101 °C [EMU 0.013 °C][TUR 31:1]
"	-100.000 °C	-100.23		Same		-100.300 to -99.700 °C [EMU 0.0080 °C][TUR 37:1]
"	0.000 °C	-0.07		Same		-0.200 to 0.200 °C [EMU 0.0031 °C][TUR 65:1]
"	200.000 °C	200.04		Same		199.600 to 200.400 °C [EMU 0.013 °C][TUR 31:1]
"	500.000 °C	500.6		Same		499.300 to 500.700 °C [EMU 0.054 °C][TUR 13:1]
"	800.000 °C	800.8		Same		799.000 to 801.000 °C [EMU 0.18 °C][TUR 5.6:1]

EEMS # 01228 EOH

Temperature: 19° C
Humidity: 49% RH
Rpt. No.: 332327

Calibration Performed By:			Quality Reviewer:	
Panich, Eduard B	Metrologist	847-327-5322	Pietronicco, Mike	1/14/2013
Name	Title	Phone	Name	Date

INSTRUMENT DATA SHEET

Serial/Asset Number: 01230 Customer: EE & MS
Date Tested: 01/29/13

Parameter Tested	Nominal Value In °C	Tolerance ±.13 °C	Lower Limit	Upper Limit	As Found	Pass/Fail	As Left
Temperature Accuracy							
	0.002	0.130	-0.128	0.132	0.01	PASS	AS FOUND
	9.986	0.130	9.856	10.116	9.99	PASS	AS FOUND
	19.991	0.130	19.861	20.121	20.00	PASS	AS FOUND
	29.995	0.130	29.865	30.125	30.00	PASS	AS FOUND
	39.996	0.130	39.866	40.126	40.00	PASS	AS FOUND
	50.032	0.130	49.902	50.162	50.02	PASS	AS FOUND

RTD 01230 / 01231

EOH

2/3/2013

Slope = 0.9997029

int = 0.0104287

r^2 = 1.000000

Certificate Number
A1290305
Issue Date: 01/27/13

Certificate of Calibration

Customer: EE & MS
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number: HOLD

ID Number: 01311

Description:	TRUE RMS MULTIMETER	Calibration Date:	1/26/2013
Manufacturer:	FLUKE	Calibration Due:	1/26/2014
Model Number:	287	Procedure:	METCAL FLUKE 287 Rev: 8/30/2012
Serial Number:	95740135	Temperature:	70 °F
Technician:	TONY ROGERS	Humidity:	49 % RH
On-Site Calibration: ☐		**As Found Condition:**	**IN TOLERANCE**
Comments:		**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. Either the measurement standard TUR to the item being calibrated is 4:1 or measurement uncertainties are reported. 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 17025 and ANSI/NCSL Z540-1 by A2LA. ISO17025 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.

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

JACK SHULER, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
2184901	FLUKE	5522A-SC1100	10/5/2012	10/5/2013

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
A1290306
Issue Date: 01/27/13

Certificate of Calibration

Customer: EE & MS
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number: HOLD

ID Number: 01312

Description:	TRUE RMS MULTIMETER	Calibration Date:	1/26/2013
Manufacturer:	FLUKE	Calibration Due:	1/26/2014
Model Number:	287	Procedure:	METCAL FLUKE 287 Rev: 8/30/2012
Serial Number:	95740243	Temperature:	70 °F
Technician:	TONY ROGERS	Humidity:	49 % RH
		As Found Condition:	**IN TOLERANCE**
On-Site Calibration: ☐		**Calibration Results:**	**IN TOLERANCE**
Comments:			

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. Either the measurement standard TUR to the item being calibrated is 4:1 or measurement uncertainties are reported. 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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FRANK BAHMANN, BRANCH MANAGER

JACK SHULER, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
2184901	FLUKE	5522A-SC1100	10/5/2012	10/5/2013

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
A1290308
Issue Date: 01/27/13

Certificate of Calibration

Customer: EE & MS
1128 NW 39TH DRIVE
GAINESVILLE, FL 32605
FEDEX

P.O. Number: HOLD

ID Number: 01310

Description:	TRUE RMS MULTIMETER	Calibration Date:	1/27/2013
Manufacturer:	FLUKE	Calibration Due:	1/27/2014
Model Number:	187	Procedure:	METCAL FLUKE 187 Rev: 8/30/2012
Serial Number:	86590148	Temperature:	70 °F
Technician:	TONY ROGERS	Humidity:	49 % RH
		As Found Condition:	**IN TOLERANCE**
On-Site Calibration: ☐		**Calibration Results:**	**IN TOLERANCE**
Comments:			

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. Either the measurement standard TUR to the item being calibrated is 4:1 or measurement uncertainties are reported. 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

JACK SHULER, QUALITY MANAGER

Calibration Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
2184901	FLUKE	5522A-SC1100	10/5/2012	10/5/2013

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

INSTRUMENT DATA SHEET

Asset Number: 01225 Customer: EE & MS
Date Tested: 01/29/13

Parameter Tested	Nominal Value	Tolerance	Lower Limit	Upper Limit	As Found	Pass/Fail	As Left	Pass/Fail	Meas Unc
Temperature Accuracy	60.89 °F	± 0.4 °F	60.49 °F	61.29 °F	61.2 °F	Pass	As Found	Pass	0.198 °F
	71.75 °F	± 0.4 °F	71.35 °F	72.15 °F	71.8 °F	Pass	As Found	Pass	0.198 °F
	79.36 °F	± 0.4 °F	78.96 °F	79.76 °F	79.7 °F	Pass	As Found	Pass	0.198 °F
Humidity Accuracy	33.00 %	± .5%+1.5% of rdg	32.00 %	33.00 %	33.0 %	Pass	As Found	Pass	0.7 %
	50.00 %	± .5%+1.5% of rdg	48.75 %	51.25 %	51.0 %	Pass	As Found	Pass	0.7 %
	70.00 %	± .5%+1.5% of rdg	68.50 %	71.50 %	68.6 %	Pass	As Found	Pass	0.7 %

EEMS# 01225

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

Certificate of Calibration and Testing

Test Unit:		
Model:	18802	Serial Number: CA04013
Description:	Anemometer Drive - 200 to 15,000 Rpm	
	- Comprised of Models 18820A Control Unit & 18830A Motor Assembly	

R.M. Young Company certifies that the above equipment has been inspected and calibrated using standards whose accuracies are traceable to the National Institute of Standards and Technologies (NIST).

Nominal Motor Rpm	27106D Output Frequency Hz (1)	Calculated Rpm (2)	Indicated Rpm (3)
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10,200	1700	10200	10200
12,600	2100	12600	12600
15,000	2500	15000	15000
☒ Clockwise and Counterclockwise rotation verified			

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

*Indicates out of tolerance

Traceable frequency meter used in calibration BK 1823

Date of inspection 4-26-13

Tested By [signature]

FINAL SUMMARY AUDIT REPORT
AUDIT AGENCY

Site Name: EPA-R7 Audit Date: 9/30/2013

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Pass/Fail	Warning
Ozone					
Ozone Audit level 5*				N/A	
Ozone Audit level 4*				N/A	
Ozone Audit level 3*				N/A	
Ozone Audit level 2*				N/A	
Ozone Audit level 1*				N/A	
Carbon Monoxide					
CO Audit Level 7	18.288	18.280	0.0	Pass	
CO Audit Level 5	6.794	6.840	0.7	Pass	
CO Audit Level 3	0.702	0.677	-3.6	Pass	
Oxides of Nitrogen					
NO Audit Point 4	0.184			N/A	
NO Audit Point 3				N/A	
NO Audit Point 2	0.068			N/A	
NO Audit Point 1	0.016			N/A	
NOx Audit Point 4	0.184			N/A	
NOx Audit Point 3				N/A	
NOx Audit Point 2	0.068			N/A	
NOx Audit Point 1	0.016			N/A	
NO2 Audit Level 8				N/A	
NO2 Audit Level 7				N/A	
NO2 Audit Level 6				N/A	
Converter Efficiency NO2 Audit Level 8				N/A	
Converter Efficiency NO2 Audit Level 7				N/A	
Converter Efficiency NO2 Audit Level 6				N/A	
Sulfur Dioxide					
SO2 Audit Level 7	0.1883	0.1839	-2.3	Pass	
SO2 Audit Level 6	0.0699	0.0687	-1.7	Pass	
SO2 Audit Level 4	0.0168	0.0167	-0.9	Pass	

FINAL SUMMARY AUDIT REPORT
AUDIT AGENCY

Site Name: EPA-R7 Audit Date: 9/30/2013

Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Pass/Fail	Warning
Ozone					
Ozone Audit level 5*	0.000			N/A	
Ozone Audit level 4*	0.000			N/A	
Ozone Audit level 3*	0.000			N/A	
Ozone Audit level 2*	0.000			N/A	
Ozone Audit level 1*	0.000			N/A	
Carbon Monoxide					
CO Audit Level 9	17.3			N/A	
CO Audit Level 7	7.3			N/A	
CO Audit Level 5				N/A	
Oxides of Nitrogen					
NO Audit Point 1	0.1740	0.1783	2.5	Pass	
NO Audit Point 2	0.0940	0.0951	1.2	Pass	
NO Audit Point 3	0.0740	0.0741	0.1	Pass	
NO Audit Point				N/A	
NOx Audit Point 1	0.1740	0.1780	2.3	Pass	
NOx Audit Point 2	0.0940	0.0950	1.1	Pass	
NOx Audit Point 3	0.0740	0.0741	0.1	Pass	
NOx Audit Point				N/A	
NO2 Audit Level 6	0.0620	0.0629	1.5	Pass	
NO2 Audit Level 5	0.0420	0.0426	1.4	Pass	
NO2 Audit Level 5	0.0210	0.0211	0.5	Pass	
Converter Efficiency NO2 Audit Level 6	97.4%			Pass	
Converter Efficiency NO2 Audit Level 5	102.7%			Pass	
Converter Efficiency NO2 Audit Level 5	99.5%			Pass	
Sulfur Dioxide					
SO2 Audit Level 4	0.178			N/A	
SO2 Audit Level 5	0.075			N/A	
SO2 Audit Level 6				N/A	

SiteReport - Site EEMS MOBILE
Report : TimeBeginning

	EPPLEY	LICOR / RMY		
Date&Time	SR-STD	PY48645	DIFFERENCE	PERCENT
	W/M2	W/M2	W/M2	DIFFERENCE
14/06/2014 20:25	NoData	NoData		
14/06/2014 20:26	559.1	561.8	2.7	0.5%
14/06/2014 20:27	561.9	565.1	3.2	0.6%
14/06/2014 22:28	851.6	862	10.4	1.2%
14/06/2014 22:29	853.7	866	12.3	1.4%
14/06/2014 22:30	854.2	867.7	13.5	1.6%
14/06/2014 22:31	851.2	866	14.8	1.7%
14/06/2014 22:32	849.5	863.7	14.2	1.7%
14/06/2014 22:33	848.2	863.4	15.2	1.8%
14/06/2014 22:34	846.1	861.7	15.6	1.8%
14/06/2014 22:35	846.2	862.4	16.2	1.9%
14/06/2014 22:36	846	862.6	16.6	2.0%
14/06/2014 22:37	847.4	864.2	16.8	2.0%
14/06/2014 22:38	849.9	867.3	17.4	2.0%
14/06/2014 22:39	852.7	869.4	16.7	2.0%
14/06/2014 22:40	861.4	878	16.6	1.9%
14/06/2014 22:41	867.4	881.9	14.5	1.7%
14/06/2014 22:42	871.3	885.4	14.1	1.6%
14/06/2014 22:43	874.9	888.7	13.8	1.6%
14/06/2014 22:44	877.5	892	14.5	1.7%
14/06/2014 22:45	877.5	891.5	14	1.6%
14/06/2014 22:46	878	892.4	14.4	1.6%
14/06/2014 22:47	879.6	894.4	14.8	1.7%
14/06/2014 22:48	881.5	896.1	14.6	1.7%
14/06/2014 22:49	881.9	895.2	13.3	1.5%
14/06/2014 22:50	880.4	892.3	11.9	1.4%
14/06/2014 22:51	881.9	893.1	11.2	1.3%
14/06/2014 22:52	880.9	893.1	12.2	1.4%
14/06/2014 22:53	882.4	893.6	11.2	1.3%
14/06/2014 22:54	884.5	895.8	11.3	1.3%
14/06/2014 22:55	884.7	896.5	11.8	1.3%
14/06/2014 22:56	884.6	896.5	11.9	1.3%
14/06/2014 22:57	884.6	896	11.4	1.3%
14/06/2014 22:58	886.7	897.3	10.6	1.2%
14/06/2014 22:59	886.8	896.7	9.9	1.1%
average 830 to 890 w/m2	**861.0**	**873.0**	**12.0**	1.4%

slope	1.02678
intercept	-16.91
	0.9983868

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

EEMS # 01272

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:	EE & MS
Purchase Order #:	
Instrument:	S-25 Tracon Surveying Compass
Serial Number:	191832
Quantity:	1
Calibration Due:	1/2015

John Noga, Quality Control

January 30, 2014

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 05/08/13 Due 05/08/14 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-2020 S/N 5167 Calibration 02/27/09 Due 02/27/14 731/244084-89

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

EEMS
~~190034~~ #01270

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:	EE & MS
Purchase Order #:	
Instrument:	S-25 Tracon Surveying Compass
Serial Number:	190034
Quantity:	1
Calibration Due:	1/2015

John Noga, Quality Control

January 30, 2014

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 05/08/13 Due 05/08/14 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-2020 S/N 5167 Calibration 02/27/09 Due 02/27/14 731/244084-89

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

EEMS # 01265

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:	EE & MS
Purchase Order #:	
Instrument:	S-25 Tracon Surveying Compass
Serial Number:	190037
Quantity:	1
Calibration Due:	1/2015

John Noga, Quality Control

January 30, 2014

Measurement Standards
Theodolite Wild T-3 S/N 18801 Calibration 05/08/13 Due 05/08/14 NIST Number 738/229329-83 738/223398
Optical Wedge K&E 71-2020 S/N 5167 Calibration 02/27/09 Due 02/27/14 731/244084-89

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:** **$S = 9.41\ \mu V / Wm^{-2}$** Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2) Resistance: 699 Ω at 23°C
	Date of Test: January 8, 2014
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 Eleventh International Pyrheliometric Comparisons (IPC XI) at Davos, Switzerland in September-October 2010. 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. Hinty / M. VIEIRA — In Charge of Test:

Thomas D. Kuk — Reviewed by:

Eppley SO 63990

Date of Certificate January 9, 2014

Remarks:

EEMS #
01245