CASTNET
2014 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 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. In 2014 80 sites at 78 distinct locations measure ground-level ozone concentrations.

As of January 2016, the network is comprised of approximately 94 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 Foster Wheeler 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.

The BLM sites are part of the Wyoming Air Resource Monitoring System (WARMS). The WARMS site configuration does not exactly match the other CASTNET sites with respect to sampling height, sensor specifications, and filter enclosure geometry.

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 2014

This report covers the CASTNET sites audited in 2014. Only those variables that were supported by the CASTNET program were audited. From February through December 2014, EEMS conducted field performance and systems audits at 37 monitoring sites at 37 separate locations. Ten of the sites audited operated a full complement of meteorological sensors. The locations, sponsor agency and dates of the audits along with states and EPA Regions are presented in Table 3-1.

Table 3-1. Site Audits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
SUM156	EPA/USFS	Sumatra	FL / R4	02/11/2014
IRL141	EPA/SJRWMD	Indian River Lagoon	FL / R4	02/13/2014
GAS153	EPA	Georgia Station	GA / R4	03/04/2014
SND152	EPA	Sand Mountain	AL / R4	03/05/2014
COW137	EPA/USFS	Coweeta	NC / R4	03/26/2014
ESP127	EPA	Edgar Evins St. Park	TN / R4	03/27/2014
SPD111	EPA	Speedwell	TN / R4	03/31/2014
PET427	NPS/EPA	Petrified Forest NP	AZ / R9	04/07/2014
GRC474	NPS/EPA	Grand Canyon NP	AZ / R9	04/08/2014
CHA467	NPS/EPA	Chiricahua NM	AZ / R9	04/23/2014
JOT403	NPS/EPA	Joshua Tree NM	CA / R9	04/28/2014
MEV405	NPS/EPA	Mesa Verde NP	CO / R8	05/05/2014
CAN407	NPS/EPA	Canyonlands NP	UT / R8	05/06/2014
GRB411	NPS	Great Basin NP	NV / R9	05/27/2014
DEN417	NPS/EPA	Denali NP	AK / R10	06/24/2014
DIN431	NPS	Dinosaur NM	UT / R8	07/15/2014
SAL133	EPA	Salamonie Reservoir	IN / R5	07/19/2014
FOR605	EPA	Fortification Creek	WY / R8	07/21/2014
ANA115	EPA	Ann Arbor	MI / R5	08/19/2014

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
HOX148	EPA	Hoxeyville	MI / R5	08/25/2014
UVL124	EPA	Unionville	MI / R5	08/26/2014
EGB181	EPA/Envir Canada	Egbert, Ontario	Ontario	08/28/2014
RED004	EPA	Red Lake Nation	MN / R5	09/04/2014
CTH110	EPA	Connecticut Hill	NY / R2	09/05/2014
MKG113	EPA	M. K. Goddard St. Park	PA / R3	09/20/2014
KEF112	EPA	Kane Experimental Forest	PA / R3	09/23/2014
PSU106	EPA	Penn State University	PA / R3	09/23/2014
ARE128	EPA	Arendtsville	PA / R3	09/25/2014
CAT175	EPA	Claryville	NY / R2	09/26/2014
HWF187	EPA	Huntington Wildlife Forest	NY / R2	09/30/2014
ACA416	NPS/EPA	Acadia NP	ME / R1	10/03/2014
HOW191	EPA	Howland AmeriFlux	ME / R1	10/06/2014
ASH135	EPA	Ashland	ME / R1	10/07/2014
PNF126	EPA	Cranberry	NC / R4	10/30/2014
ABT147	EPA	Abington	CT / R1	11/09/2014
BEL116	EPA	Beltsville	MD / R3	11/10/2014
WST109	EPA	Woodstock	NH / R1	11/10/2014

In addition to the sites listed in Table 3-1 that were visited for complete systems and performance audits, the 48 sites listed in Table 3-2 were visited to conduct NPAP Through-The-Probe (TTP) ozone Performance Evaluations (PE).

Table 3-2. Site Ozone PE Visits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
CAD150	EPA	Caddo Valley	AR / R6	02/25/2014
CHE185	EPA	Cherokee Nation	OK / R6	02/26/2014
CVL151	EPA	Coffeeville	MS / R4	02/28/2014
ALC188	EPA	Alabama-Coushatta	TX / R6	03/12/2014
BBE401	NPS/EPA	Big Bend NP	TX / R6	03/20/2014
PAL190	EPA	Palo Duro	TX / R6	03/25/2014
CDZ171	EPA	Cadiz	KY / R4	03/28/2014
MAC426	NPS	Mammoth Cave NP	KY / R4	03/28/2014
MCK131	EPA	Mackville	KY / R4	03/30/2014
MCK231	EPA	Mackville (precision site)	KY / R4	03/30/2014
CKT136	EPA	Crockett	KY / R4	03/31/2014
QAK172	EPA	Quaker City	OH / R5	04/08/2014
DCP114	EPA	Deer Creek St. Park	OH / R5	04/09/2014
OXF122	EPA	Oxford	OH / R5	04/10/2014
PIN414	NPS	Pinnacles NM	CA / R9	05/01/2014
YOS404	NPS	Yosemite NP	CA / R9	05/29/2014
SEK430	NPS	Sequoia NP - Ash Mountain	CA / R9	05/30/2014
LAV410	NPS	Lassen Volcanic NP	CA / R9	05/31/2014
SAN189	EPA	Santee Sioux	NE / R7	06/02/2014
PND165	EPA	Pinedale	WY / R8	07/16/2014
BAS601	EPA	Basin	WY / R8	07/17/2014
STK138	EPA	Stockton	IL / R5	07/21/2014
ALH157	EPA	Alhambra	IL / R5	07/22/2014
NEC602	EPA	Newcastle	WY / R8	07/22/2014
VIN140	EPA	Vincennes	IN / R5	07/23/2014
WNC429	NPS	Wind Cave NP	SD / R8	07/23/2014
ROM206	EPA	Rocky Mountain NP	CO / R8	08/16/2014

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
ROM406	NPS	Rocky Mountain NP (NPS)	CO / R8	08/16/2014
GTH161	EPA	Gothic	CO / R8	08/21/2014
GLR468	NPS	Glacier NP	MT / R8	08/23/2014
CNT169	EPA	Centennial	WY / R8	08/23/2014
YEL408	NPS	Yellowstone NP	WY / R8	08/24/2014
THR422	NPS	Theodore Roosevelt NP	ND / R8	08/25/2014
VOY413	NPS	Voyageurs NP	MN / R5	09/08/2014
PRK134	EPA	Perkinstown	WI / R5	09/10/2014
LRL117	EPA	Laurel Hill St. Park	PA / R3	09/19/2014
BVL130	EPA	Bondville	IL / R5	09/20/2014
ANA115	EPA	Ann Arbor	MI / R5	09/24/2014
GRS420	NPS	Great Smoky Mountains NP	TN / R4	10/27/2014
PED108	EPA	Prince Edward	VA / R3	11/03/2014
BWR139	EPA	Blackwater NWR	MD / R3	11/13/2014
WSP144	EPA	Washington Crossing St. Park	NJ / R2	11/14/2014
VPI120	EPA	Horton Station	VA / R3	11/17/2014
SHN418	NPS/EPA	Shenandoah NP - Big Meadows	VA / R3	11/18/2014
PAR107	EPA/USFS	Parsons	WV / R3	11/19/2014
CDR119	EPA	Cedar Creek St. Park	WV / R3	11/21/2014
CND125	EPA	Candor	NC / R4	11/24/2014
BFT142	EPA	Beaufort	NC / R4	11/25/2014

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 2014 Quarterly report. The variable specific data forms included in Appendix A of each quarter's report contain the challenge input values, the output of the DAS, additional relevant information pertaining to the variable and equipment, and all available means of identification of the sensors and equipment for each site.

Table 4-1. Performance Audit Results by Variable Tested

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	81	1	1.2
Flow Rate	37	2	5.4
Shelter Temperature (average)	34	0	0.0
Wind Direction Orientation Average Error	10	0	0.0

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Orientation Maximum Error	10	2	20.0
Wind Direction Linearity Average Error	9	0	0.0
Linearity Maximum Error	9	1	11.1
Wind Direction Starting Torque	9	0	0.0
Wind Speed Low Range Average Error	10	0	0.0
Low Range Maximum Error	10	0	0.0
Wind Speed High Range Average Error	10	0	0.0
High Range Maximum Error	10	0	0.0
Wind Speed Starting Torque	10	1	10.0
Temperature	36	2	5.6
2 Meter Temperature	1	0	0.0
Relative Humidity	10	0	0.0
Solar Radiation	9	1	11.1
Precipitation	10	0	0.0
DAS Analog to Digital	33	0	0.0

4.1 Ozone

Eighty-one ozone analyzers were audited during 2014. The ozone analyzer at site ANA115 was audited twice due to a failure during the first audit. Each monitor was challenged with ozone-free air and four up-scale concentrations. The ozone test gas concentrations were generated and measured with a NIST-traceable photometer that was verified as a level 2 standard by USEPA.

Three sites (MEV405, GRB411, and ANA115) had at least one audit level test point above the 40 CFR part 58 annual PE acceptance criteria of +/- 10%. Only one monitor (site ANA115) exceeded the +/- 10% criteria for the average of all test points. The ANA115 monitor was repaired and re-audited. Results of all ozone audits performed are included in Table 4-2.

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 each quarter for those sites for which EEMS is authorized to upload QA data to AQS.

4.2 Flow Rate

The dry deposition filter pack sampling system flow rates at 36 sites were audited. A NIST-traceable dry-piston primary flow rate device was used for the tests. Two sites (FOR605 and ACA416) had audit results that were above 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 34 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.

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

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 ozone audits.

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)
SUM156	-2.6	-4.0	0.98734	-0.66673	1	0.43	0.67	1.536	1.500	-2.39
IRL141	1.1	3.6	0.99726	0.41844	0.99988	0.83	1.01	1.517	1.503	-0.93
CAD150	2.1	2.4	1.02516	-0.20051	1					
CHE185	1.9	4.2	1.02487	-0.19321	0.99982					
CVL151	-0.6	-2.0	1.00749	-0.67428	0.99999					
GAS153	1.3	1.9	1.02217	-0.44253	1	0.09	0.10	1.544	1.503	-2.69
SND152	-0.5	-1.9	1.00529	-0.52037	0.99982	0.38	0.70	1.514	1.510	-0.26
ALC188	-1.7	-4.3	1.00006	-0.63109	0.99996					
BBE401	1.5	2.0	1.02051	-0.35549	0.99998					
PAL190	-1.6	-2.3	0.99016	-0.24018	0.99999					
COW137	2.1	2.8	1.01997	0.24297	0.99994	0.46	0.65	1.470	1.500	2.00
ESP127	0.4	0.8	0.99644	0.52675	0.99999	0.21	-0.31	1.503	1.510	0.44
CDZ171	-1.9	-3.5	0.99413	-0.51849	0.99995					
MAC426	1.1	1.7	1.01804	-0.31284	0.99998					
MCK131	1.2	2.6	1.00752	0.11721	0.99997					
MCK231	0.3	-1.2	1.01159	-0.35351	0.99998					
CKT136	-1.5	-2.2	0.99303	-0.34168	0.99999					
SPD111	1.7	2.5	1.00976	0.27889	0.99982	0.23	0.26	1.507	1.500	-0.44
PET427	5.0	7.2	1.01633	1.89013	1	0.89	-1.60	2.990	3.010	0.66
GRC474	-0.5	-3.2	1.0291	-1.89689	0.99999	0.35	-0.51	3.037	3.000	-1.22
QAK172	-1.1	-1.5	0.99571	-0.51311	0.99998					
DCP114	0.9	1.2	1.01025	-0.16701	0.99998					
OXF122	1.1	1.7	1.02714	-0.89517	0.99999					
CHA467	6.9	10.0	1.02891	2.25151	0.99999	0.30	0.53	2.997	2.996	-0.02
JOT403	-0.1	1.3	0.98081	1.06586	1	0.35	-0.49	3.060	3.000	-2.00
PIN414	0.7	0.9	1.0099	-0.21975	0.99999					
MEV405	-5.9	-10.4	0.9971	-2.66354	0.99983	1.76	-2.20	3.010	3.000	-0.33
CAN407	-2.0	-3.8	0.99581	-0.67417	0.99996	0.18	0.33	3.097	3.020	-2.54
GRB411	-7.8	-11.8	0.9826	-3.54543	0.99995	1.36	-3.28	3.053	2.980	-2.46

	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)
YOS404	1.8	3.1	1.03866	-1.0319	0.99999					
SEK430	-2.2	-3.9	0.99535	-0.73418	0.99997					
LAV410	-4.0	-5.4	0.97835	-0.93585	0.99999					
SAN189	1.8	1.9	1.01684	0.10424	0.99999					
DEN417	-1.1	-1.3	0.98709	0.093	1	0.45	0.62	2.970	3.000	1.00
DIN431	0.4	2.4	0.99366	0.33934	0.99996	0.23	-0.49	2.992	2.999	0.24
PND165	-2.1	-2.6	0.97661	0.15722	0.99998					
BAS601	-2.0	-2.9	0.96978	0.45325	0.99997					
SAL133	1.4	1.6	1.01925	-0.3512	0.99999	0.14	-0.31	1.483	1.500	1.11
FOR605								3.080	3.282	6.15
STK138	1.2	2.1	1.00334	0.41983	1					
ALH157	0.6	3.0	0.99162	0.55984	0.99994					
NEC602	-2.5	-3.5	0.96496	0.39273	0.99997					
VIN140	0.4	1.6	0.99454	0.3411	0.99998					
WNC429	-4.3	-4.8	0.95292	0.08442	0.99995					
ROM206	2.4	4.9	0.99749	1.26437	1					
ROM406	0.0	3.0	0.97262	1.35157	0.99999					
ANA115	-16.0	-17.9	0.80101	0.48989	0.99999	0.11	0.22	1.470	1.500	2.00
GTH161	-5.3	-6.3	0.95395	-0.665	0.99984					
CNT169	-3.9	-6.3	0.99274	-1.70626	1					
GLR468	-1.4	-1.7	0.98527	0.12602	0.99997					
YEL408	0.9	1.6	0.9947	0.81971	1					
HOX148	-0.3	2.2	0.97404	1.20525	0.99999	0.29	-0.60	1.500	1.490	-0.67
THR422	2.2	2.9	1.01485	0.46186	0.99998					
UVL124	0.8	2.2	0.99192	0.8064	1	0.34	0.50	1.490	1.500	0.67
EGB181						0.27	-0.36	1.523	1.487	-2.47
RED004								3.030	3.000	-1.00
CTH110	-1.4	-2.3	0.97108	0.71838	1	1.00	-1.07	1.497	1.500	0.22
VOY413	-0.8	-1.1	0.98467	0.485	0.99998					
PRK134	-3.1	-3.3	0.97063	-0.08659	1					

	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	0.9	2.0	0.99928	0.45197	0.99999					
BVL130	-2.0	-2.7	0.96651	0.76544	0.99999					
MKG113	0.2	0.6	1.00307	-0.04993	0.99998	0.21	0.47	1.510	1.500	-0.67
KEF112	3.5	8.0	1.00924	0.71974	0.99968	0.41	-1.06	1.520	1.497	-1.56
PSU106	-1.4	-2.5	0.99612	-0.5623	0.99986	0.14	-0.25	1.510	1.500	-0.67
ANA115	-1.6	-2.4	0.97366	2.22814	0.99999					
ARE128	-0.1	1.8	0.99159	0.17333	0.99995	0.51	0.65	1.500	1.503	0.22
CAT175								1.560	1.510	-3.31
HWF187	-3.2	-3.4	0.97152	-0.17924	1	0.29	-0.36	1.483	1.500	1.11
ACA416	2.9	3.4	1.02704	0.18362	0.99995	1.24	-2.27	1.590	1.490	-6.72
HOW191	-2.0	-2.5	0.98661	-0.31884	1	0.31	0.76	1.513	1.500	-0.89
ASH135	-2.7	-3.5	0.99168	-1.27949	0.99992	0.55	-0.87	1.530	1.500	-2.00
GRS420	-0.4	-0.8	0.99279	0.12506	0.99999					
PNF126	-0.2	0.8	0.98882	0.45144	1	0.51	-0.89	1.510	1.493	-1.12
PED108	-1.2	-1.3	0.98841	-0.05787	1					
ABT147	-0.3	-1.3	1.01003	-0.59769	0.99995	0.30	-0.38	1.493	1.497	0.22
BEL116	0.2	0.6	1.00369	-0.41489	0.99992	0.66	0.78	1.550	1.507	-2.88
WST109	0.2	0.6	1.00183	-0.02369	0.99998	0.77	1.45	1.490	1.500	0.67
BWR139	0.6	1.2	1.00631	-0.08494	0.99997					
WSP144	-0.9	-2.0	0.99369	0.05217	0.99998					
VPI120	0.2	1.2	0.99285	0.4212	1					
SHN418	2.6	5.0	1.00083	1.29253	1					
PAR107	-1.6	-1.8	0.99033	-0.42713	0.99999					
CDR119	-2.4	-3.5	0.98684	-0.57024	1					
CND125	-0.1	-0.2	0.99966	-0.05026	1					
BFT142	2.2	2.9	1.03135	-0.65714	0.99993					

4.4 Wind Speed

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

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings were evaluated as part of the performance audits. The data acceptance criterion for wind speed bearing torque is not defined in the QAPP. However, ***Appendix 1: CASTNET Field Standard Operating Procedures***, states that the wind speed bearing torque should be ≤ 0.2 g-cm. To establish the wind speed bearing torque criterion for audit purposes the rational described in the QAPP for data quality objectives (DQO) was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically field criteria are set at approximately one-half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacture's specifications for a properly maintained system. One site (JOT403) was 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 ten sensors tested, all sites were within the acceptance criterion of ± 5 degrees for the average error. The results of the wind direction performance audits are presented in Table 4-3.

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 of the wind direction starting thresholds were 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)	
PET427	1.8	3	2.25	5	18	0.05	-0.20	0.00	0.00	0.35
GRC474	2.8	4	2	4	12	0.13	-0.30	0.01	-0.02	0.40
CHA467	4.8	6	2.5	7	11	0.11	0.15	0.01	0.02	0.35
JOT403	1.0	2	1.5	5	16.5	0.05	-0.20	0.00	0.00	0.50
MEV405	2.8	5	2	5	9	0.05	-0.12	0.00	-0.01	0.35
CAN407	1.8	3	1.75	4	9	0.05	0.14	0.01	0.01	0.30
GRB411	3.5	6	0.88	2.5	7	0.07	-0.10	0.00	-0.01	0.30
FOR605	3.5	5				0.07	-0.17	0.01	0.01	0.00
ACA416	2.6	5	1.5	3	10	0.17	-0.20	0.10	-0.39	0.30
BEL116	2.0	4	1	3	12	0.05	-0.20	0.00	0.00	0.35

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

4.6 Temperature and Two-Meter Temperature

The 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 36 sensors tested, two were outside the acceptance criterion. It should be noted that one sensor (FOR605) was located at a site 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 one 2-meter temperature sensor was tested, and was within criterion. The average errors for all sensors are presented in Table 4-4.

4.6.1 Temperature Shield Blower Motors

All of the temperature sensor shield blower motors encountered during the site audits conducted during 2014 were found to be functioning. The 2-meter temperature sensor shield blower was also functioning properly.

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.

As in previous years, operation of humidity sensors with respect to natural or forced-air aspiration can vary between sites. At most EPA sponsored sites humidity sensors are operating in naturally aspirated shields. At most NPS sponsored sites humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers. During audit tests with the primary standard salt solutions, the sensors were removed from the shields and placed in a temperature controlled enclosure. During audit tests with the transfer standard probe, the sensor and transfer were placed in the same ambient conditions. Therefore the audit tests do not account for differences in the operation of the sensors due to the different shield configurations.

The average errors of all sensor tests 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 (%)
SUM156	0.07			
IRL141	0.06			
GAS153	0.12			
SND152	0.24			
COW137	0.08			
ESP127	0.09			
SPD111	0.14			
PET427	0.24		1.31	1.75
GRC474	0.24		1.20	-2.6
CHA467	0.51		2.22	3.46
JOT403	0.12		2.83	-4.96
MEV405	0.37		1.42	2.22
CAN407	0.09		1.48	3.1
GRB411	0.07		3.47	4.7
DEN417	0.05			
DIN431	0.44			
SAL133	0.10			
FOR605	0.67		4.50	-6.5
ANA115	0.20			
HOX148	0.11			
UVL124	0.08			
EGB181	0.06			
CTH110	0.11			

Site	Temperature Ave. Error (deg C)	2 Meter Temperature Ave. Error (deg C)	Relative Humidity	
			Range 0 – 100%	
			Ave. Error (%)	Max. Error (%)
MKG113	0.09			
KEF112	0.18			
PSU106	0.17			
ARE128	0.19			
CAT175	0.06			
HWF187	0.14			
ACA416	0.17		1.30	-1.95
HOW191	0.05			
ASH135	0.02			
PNF126	0.28			
ABT147	0.12			
BEL116	0.09	0.16	1.74	2.25
WST109	0.14			

4.8 Solar Radiation

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

Nine sites were tested. One site had daytime average result that was 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

The ten 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 results are summarized in Tables 4-5. All results were within the acceptance criterion.

Of the eight tipping bucket heaters tested, one site (PET427) had a non-functioning heater.

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)	
PET427	8.35	926	1008	8.1	1.8
GRC474	0.29	941	936	-0.5	4.0
CHA467	11.42	966	1079	**10.5**	2.0
JOT403	6.74	950	1017	6.6	8.0
MEV405	7.58	1002	1069	6.3	1.0
CAN407	7.84	1028	1114	7.7	6.0
GRB411	0.44	1034	1039	0.5	6.0
FOR605	2.29	868	853	-1.8	9.7
ACA416	2.56	647.3	635.6	-1.8	2.0
BEL116					4.0

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 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		
SUM156	0.0001	-0.0002			Y	0.02
IRL141	0.0000	-0.0002			Y	0.02
GAS153	0.0001	0.0001			Y	0.02
SND152	0.0001	-0.0003			Y	0.03
COW137	0.0001	-0.0001			Y	0.02
ESP127	0.0001	-0.0001			Y	0.00
SPD111	0.0001	-0.0003			Y	0.00
PET427	0.0002	0.0003	0.0004	0.0006	Y	1.33
GRC474	0.0003	0.0005	0.0001	0.0002	Y	1.83
CHA467	0.0001	0.0002	0.0020	0.0021	Y	1.23
JOT403	0.0002	0.0004	0.0002	0.0004	Y	1.67
MEV405	0.0002	0.0003	0.0001	0.0002	Y	1.10
CAN407	0.0001	0.0002	0.0009	0.0022	Y	0.67
GRB411	0.0001	-0.0002	0.0002	-0.0003	Y	2.38
DEN417	0.0001	0.0002	0.0002	0.0005	Y	1.17
DIN431	0.0002	0.0003			Y	1.25
SAL133	0.0001	-0.0002			Y	0.02
ANA115					Y	0.05
HOX148	0.0001	0.0001			Y	0.75
UVL124	0.0002	-0.0003			Y	0.02

Site	Analog Test Error (volts)				Date Correct (Y/N)	Time Error (minutes)
	Low Channel		High Channel			
	Average	Maximum	Average	Maximum		
EGB181	0.0002	0.0004			Y	1.33
CTH110	0.0003	0.0007			Y	0.05
MKG113	0.0001	-0.0001			Y	0.02
KEF112	0.0001	-0.0004			Y	0.00
PSU106	0.0001	-0.0002			Y	0.02
ARE128	0.0000	-0.0001			Y	0.02
HWF187	0.0002	0.0004			Y	0.25
ACA416	0.0000	0.0001	0.0003	-0.0006	Y	0.00
HOW191	0.0001	-0.0002			Y	0.00
ASH135	0.0001	-0.0002			Y	0.00
PNF126	0.0002	-0.0003			Y	0.00
ABT147	0.0001	0.0001			Y	0.00
BEL116	0.0002	-0.0004			Y	0.02
WST109	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 (South Dakota) is operated by the State.

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

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

5.3 Infrastructure

Sites continue to be improved by repairing the site shelters which had deteriorated throughout the years of operation. The installation and upgrade of the data loggers and 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.

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

Certificate Number
A1521764
Issue Date: 12/27/13

Certificate of Calibration

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

P.O. Number: HOLD
ID Number: 40062084/75299
EEMS # 01220

Description: HYGRO CLIP
Manufacturer: ROTRONIC
Model Number: HYGROCLIP
Serial Number: 40062084/75299
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments:

Calibration Date: 12/27/2013
Calibration Due: 12/27/2014
Procedure: TMI-M-HYGROTHERMOGRAPHS Rev: 2/22/2011
Temperature: 72 °F
Humidity: 42 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

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

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. 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/IEC 17025 and ANSI/NCSL Z540-1 by A2LA. ISO/IEC 17025 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.

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
9304027	THUNDER SCIENTIFIC	2500	6/11/2013	8/11/2014

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

Technical Maintenance, Inc. **INSTRUMENT DATA SHEET** **Rotronic HygroPalm**

Asset Numbers: 01220 & 40062084/75299 Customer: EE & MS
Date Tested: 12/27/2013

Parameter Tested	Nominal Value	Tolerance	Lower Limit	Upper Limit	As Found	Pass/Fail	As Left
Temperature Accuracy							
	19.12	±0.2 °C	18.92	19.32	19.00	PASS	AS FOUND
	22.3	±0.2 °C	22.1	22.5	22.2	PASS	AS FOUND
	24.6	±0.2 °C	24.4	24.8	24.5	PASS	AS FOUND
Humidity Accuracy							
	20	±1.5%	18.5	21.5	20.1	PASS	AS FOUND
	50	±1.5%	48.5	51.5	48.6	PASS	AS FOUND
	75	±1.5%	73.5	76.5	74.5	PASS	AS FOUND

Certificate Number
A1521787
Issue Date: 12/27/13

Certificate of Calibration

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

P.O. Number: HOLD
ID Number: 01225

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

Calibration Date: 12/27/2013
Calibration Due: 12/27/2014
Procedure: TMI-M-HYGROTHERMOGRAPHS Rev: 2/22/2011
Temperature: 72 °F
Humidity: 42 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

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

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. 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/IEC 17025 and ANSI/NCSLZ540-1 by A2LA. ISO/IEC 17025 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.

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
9304027	THUNDER SCIENTIFIC	2500	6/11/2013	8/11/2014

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 & 45656048/124432 Customer: EE & MS
Date Tested: 12/27/13

Parameter Tested	Nominal Value	Tolerance	Lower Limit	Upper Limit	As Found	Pass/Fail	As Left	Pass/Fail
Temperature Accuracy	63.26 °F	± 0.4 °F	62.86 °F	63.66 °F	63.1 °F	Pass	As Found	Pass
	69.36 °F	± 0.4 °F	68.96 °F	69.76 °F	69.1 °F	Pass	As Found	Pass
	78.80 °F	± 0.4 °F	78.40 °F	79.20 °F	78.5 °F	Pass	As Found	Pass
Humidity Accuracy	33.00 %	± .5%+1.5% of rdg	32.00 %	34.00 %	33.8 %	Pass	As Found	Pass
	50.00 %	± .5%+1.5% of rdg	48.75 %	51.25 %	48.9 %	Pass	As Found	Pass
	70.00 %	± .5%+1.5% of rdg	68.45 %	71.55 %	68.7 %	Pass	As Found	Pass

Certificate Number
A1521806
Issue Date: 12/27/13

Certificate of Calibration

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

P.O. Number: HOLD
ID Number: 01231
and 01230

Description: TEMPERATURE PROBE
Manufacturer: UNKNOWN
Model Number: SP034-39
Serial Number: 01H0060
Technician: STEVE TORRES
On-Site Calibration: ☐
Comments:

Calibration Date: 12/27/2013
Calibration Due: 12/27/2014
Procedure: NA 17-20ST-132
Rev: 11/1/2011
Temperature: 72 °F
Humidity: 42 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

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

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. 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/IEC 17025 and ANSI/NCSL Z540-1 by A2LA. ISO/IEC 17025 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.

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
30946	FLUKE	5616	5/11/2013	9/9/2014
A06118	HART SCIENTIFIC	9103	11/7/2013	1/23/2015
A88072	FLUKE	1502A	8/20/2013	5/14/2014

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: 01230 & 01231 Customer: EE & MS
Date Tested: 12/27/13

Parameter Tested	Nominal Value In °C	Tolerance ±.13 °C	Lower Limit	Upper Limit	As Found	Pass/Fail	As Left
Temperature Accuracy							
	0.006	0.130	-0.124	0.136	0.01	PASS	AS FOUND
	10.061	0.130	9.931	10.191	9.94	PASS	AS FOUND
	20.120	0.130	19.990	20.250	20.04	PASS	AS FOUND
	29.941	0.130	29.811	30.071	30.00	PASS	AS FOUND
	40.028	0.130	39.898	40.158	40.02	PASS	AS FOUND
	49.928	0.130	49.798	50.058	49.93	PASS	AS FOUND

Certificate Number
A1522190
Issue Date: 12/30/13

Certificate of Calibration

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

P.O. Number: HOLD
ID Number: 01310

Description:	DIGITAL MULTIMETER	Calibration Date:	12/28/2013
Manufacturer:	FLUKE	Calibration Due:	12/28/2014
Model Number:	187	Procedure:	METCAL FLUKE 187 Rev: 8/30/2012
Serial Number:	86590148	Temperature:	72 °F
Technician:	RENN BANE	Humidity:	42 % 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/IEC 17025 and ANSI/NCSL Z540-1 by A2LA. ISO/IEC 17025 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.

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
7040208	FLUKE	5520A	11/30/2012	12/30/2013

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
A1522191
Issue Date: 12/30/13

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
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740135
Technician: RENN BANE
On-Site Calibration: ☐
Comments:

Calibration Date: 12/28/2013
Calibration Due: 12/28/2014
Procedure: METCAL FLUKE 287
Rev: 8/30/2012
Temperature: 72 °F
Humidity: 42 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

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

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. 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/IEC 17025 and ANSI/NCSL Z540-1 by A2LA. ISO/IEC 17025 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.

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
7040208	FLUKE	5520A	11/30/2012	12/30/2013

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
A1522192
Issue Date: 12/30/13

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
Manufacturer: FLUKE
Model Number: 287
Serial Number: 95740243
Technician: RENN BANE
On-Site Calibration: ☐
Comments:

Calibration Date: 12/28/2013
Calibration Due: 12/28/2014
Procedure: METCAL FLUKE 287
Rev: 8/30/2012
Temperature: 72 °F
Humidity: 42 % RH
As Found Condition: IN TOLERANCE
Calibration Results: IN TOLERANCE

Limiting Attribute:

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

Reported uncertainties and "test uncertainty ratios" (TUR's) are expressed as expanded uncertainty values at approximately 95% confidence level using a coverage factor of K=2. 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
7040208	FLUKE	5520A	11/30/2012	12/30/2013

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

MesaLabs

NVLAP
NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5031777	**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	1/8/2014		USA

All calibrations are performed in accordance with ISO 17025 at 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 Lilianna Malinowska

Lab. Pressure 737 mmHg
Lab. Temperature 22.5 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
499.94 sccm	500.35 sccm	-0.08%	1.00%	In Tolerance
5001.1 sccm	5000.7 sccm	0.01%	1.00%	In Tolerance
29954 sccm	30032.5 sccm	-0.26%	1.00%	In Tolerance
21.9 °C	22.5 °C	-0.6°C	±0.8°C	In Tolerance
751 mmHg	737 mmHg	14 mmHg	±3.5mmHg	Out of Tolerance

Mesa Laboratoires Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	103521	6/12/2013	6/12/2014
Precision Thermometer	300907	4/30/2013	4/30/2014
Precision Barometer	2981392	6/12/2013	6/12/2014

EEMS #01416

MesaLabs

NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5031774	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	Definer 220 High Flow		1128 NW 39th Drive
Serial No.	131818		Gainesville, FL 32605
Cal. Date	1/8/2014		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 Lilianna Malinowska

Lab. Pressure 737 mmHg
Lab. Temperature 22.5 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
501.64 sccm	500.35 sccm	0.26%	1.00%	In Tolerance
5016.7 sccm	5000.7 sccm	0.32%	1.00%	In Tolerance
30058 sccm	30032.5 sccm	0.08%	1.00%	In Tolerance
21.8 °C	22.5 °C	-0.7°C	±0.8°C	In Tolerance
751 mmHg	737 mmHg	14 mmHg	±3.5mmHg	Out of Tolerance

Mesa Laboratoires Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-44	103521	6/12/2013	6/12/2014
Precision Thermometer	300907	4/30/2013	4/30/2014
Precision Barometer	2981392	6/12/2013	6/12/2014

EEMS# 01417

MesaLabs

NVLAP®
NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5031775
Product	Definer 220 Low Flow
Serial No.	120910
Cal. Date	1/8/2014

Sold to: Environmental Engineering & Measurement Services, Inc - Gainesville
1128 NW 39th Drive
Gainesville, FL 32605
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 Lilianna Malinowska

Lab. Pressure 736 mmHg
Lab. Temperature 22.9 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
30.371 sccm	30.1385 sccm	0.77%	1.00%	In Tolerance
100.38 sccm	100.52 sccm	-0.14%	1.00%	In Tolerance
499.47 sccm	501.87 sccm	-0.48%	1.00%	In Tolerance
21.9 °C	22.9 °C	-1°C	±0.8°C	Out of Tolerance
752 mmHg	736 mmHg	16 mmHg	±3.5mmHg	Out of Tolerance

Mesa Laboratoires Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML-800-10	103743	3/18/2013	3/18/2014
Precision Thermometer	300907	4/30/2013	4/30/2014
Precision Barometer	2981392	6/12/2013	6/12/2014

EEMS # 01415

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

PACKING LIST

The Eppley Laboratory, Inc.
12 Sheffield Ave.,P.O. Box 419
Newport, RI 02840-0419
Phone # 401-847-1020 Fed. ID No. 05-0136490

S.O. No. 63990

1/7/2014

Name / Address

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

Ship To

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

P.O... Verbal Ship Date 1/21/2014 Ship Via UPS Ground

Ordered	Shipped

Recalibration of Model PSP # 34341F3 w/Shield & Cable

Reset Amplifier # 10765

Set Gain so 1V = ~~1396~~ 1400 $W m^{-2}$

$\frac{1400}{1396} \times S = V_{full}$

$S = 9.41 \times 10^{-6}$ $V/W m^{-2}$

$V_{full} = 13174$ $NV = 0.01374$

$Gain = \frac{1V}{V_{full}} = 75.91$

Made in USA

Total

Terms Credit Card

FOB Newport, RI USA

Date

1/8/2014 - - **Calibration and verification of three RTD meters with most recent certification of EEMS RTD**

TMI Data -- 12/27/2013

	TMI STD	EEMS RTD 01230 / 01231	
cert date=	11/7/2013		
	0.006	0.01	-0.004
	10.061	9.94	0.121
	20.120	20.04	0.080
	29.941	30.00	-0.059
	40.028	40.02	0.008
	49.928	49.93	-0.002

RTD 01230/01231

2014 correction: slope= 1.0013315

intercept= -0.0573053

0.9999948

At EEMS	**Date 1/8/2014** RTD 01230 / 01231 raw	corrected	**RTD 01226** EEMS raw	corrected	**RTD 01227** EEMS SEG raw	corrected	**RTD 01228** EEMS EOH raw	corrected
	0.06	0.12	0.04	0.11	-0.05	0.10	-0.13	0.10
	12.53	12.57	12.50	12.56	12.43	12.55	12.38	12.55
	19.75	19.78	19.73	19.78	19.67	19.76	19.63	19.76
	25.22	25.24	25.20	25.25	25.19	25.27	25.17	25.27
	30.99	31.01	31.01	31.05	31.03	31.06	31.01	31.09
	41.50	41.56	41.52	41.55	41.51	41.54	41.52	41.54
	52.83	52.89	52.85	52.87	52.85	52.85	52.88	52.85
slope =			**1.00095**		**1.002883**		**1.004956**	
intercept =			**-0.06956**		**-0.15155**		**-0.23009**	
correlation =			**1.0000**		**1.0000**		**1.0000**	

MesaLabs

NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5031778	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	DryCal Nexus NS		1128 NW 39th Drive
Serial No.	103471		Gainesville, FL 32605
Cal. Date	1/15/2014		USA

All calibrations are performed in accordance with ISO 17025 at 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.

Temperature and pressure are tested in accordance with Mesa Laboratories 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 752 mmHg
Lab. Temperature 21.7 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	Condition
21°C	21.7°C	-0.6°C	±0.6°C	Out of Tolerance
749mmHg	752mmHg	-3mmHg	±1.8mmHg	Out of Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
Precision Thermometer	305460	8/27/2013	8/27/2014
Precision Barometer	2981392	6/12/2013	6/12/2014

EEMS# 01420

MesaLabs

NVLAP Lab Code 200661

Calibration Certificate

Certificate No.	5031776	**Sold to:**	Environmental Engineering & Measurement Services, Inc - Gainesville
Product	DryCal DC-Lite Medium High		1128 NW 39th Drive
Serial No.	103424		Gainesville, FL 32605
Cal. Date	1/7/2014		USA

All calibrations are performed in accordance with ISO 17025 at 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 Procedure PR05-02 or PR01-10 using high-purity nitrogen or filtered laboratory air.

As Received Calibration Data

Technician Lilianna Malinowska

Lab. Pressure 755 mmHg
Lab. Temperature 22.7 °C

Instrument Reading	Lab Standard Reading	Deviation	Allowable Deviation	As Received
193.7ccm	200.45ccm	-3.37%	1.00%	Out of Tolerance
5005ccm	5000.5ccm	0.09%	1.00%	In Tolerance
17000ccm	17008.5ccm	-0.05%	1.00%	In Tolerance

Mesa Laboratories Standards Used

Description	Standard Serial Number	Calibration Date	Calibration Due Date
ML_500_10	113779	1/2/2013	4/23/2014
ML_500_44	110104	5/17/2013	5/17/2014

CERTIFICATE OF CALIBRATION AND TESTING

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

MODEL: **18802 / 18811** SERIAL NUMBER: CA04013

(18802 Comprised of Models 18820A Control Unit & 18830A Motor Assembly)
(18811 Comprised of Models 18820A Control Unit & 18831A Motor Assembly) EEMS #01253

Nominal Motor RPM	27106D Output Frequency (Hz) - (1)	Calculated Rpm (1)	Indicated Rpm (2)
18802		-	☒ CW / CCW rotation verified
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10,200	1700	10200	10200
12,600	2100	12600	12600
15,000	2500	15000	15000
18811		-	☒ CW / CCW rotation verified
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

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

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

Traceable frequency meter used in calibration Model: DP5740 SN: 4863

Date of inspection 16 JAN 2014
Inspection Interval One Year

Tested By EC

CERTIFICATE OF CALIBRATION AND TESTING

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

MODEL: **18802 / 18811** SERIAL NUMBER: CA02777
(18802 Comprised of Models 18820A Control Unit & 18830A Motor Assembly)
(18811 Comprised of Models 18820A Control Unit & 18831A Motor Assembly) EEMS #01260

Nominal Motor RPM	27106D Output Frequency (Hz) - (1)	Calculated Rpm (1)	Indicated Rpm (2)
18802		-	☒ CW / CCW rotation verified
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10,200	1700	10200	10200
12,600	2100	12600	12600
15,000	2500	15000	15000
18811		-	☒ CW / CCW rotation verified
30.0	5	30.0	30.0
150.0	25	150.0	150.0
300.0	50	300.0	300.0
450.0	75	450.0	450.0
600.0	100	600.0	600.0
750.0	125	750.0	750.0
990.0	165	990.0	990.0

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

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

Traceable frequency meter used in calibration Model: DP5740 SN: 4863

Date of inspection 16 JAN 2014
Inspection Interval One Year

Tested By EC

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

Warren-Knight Instrument Company
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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

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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

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

Project:	Bios NEXUS EEMS # 01420/01410 Certification	Flow Rate Standard:	**BIOS Definer 220-H**
Project #:		EEMS #	**01416**
Contact Name:		Certification Date:	**1/8/2014**
Contact Phone #:		Certification #:	**5031777**
Contact Address:			

environmental, engineering & measurement services

1/22/2014 -- Flow rates are corrected to STP of one atmosphere and 25.0 degrees C. were plumbed together in series, in that order.
All tests were conducted with dry air. 146C, Nexus #1420, Definer 220-H

UNADJUSTED: **BIOS Nexus, EEMS # 01420**

Flow Rate Standard--Definer 220-H

Unadjusted	
Slope =	**1.008459**
Intercept =	**0.013579**
Correl =	**0.99997**

	Temp deg C	Press mmHg
Definer	20.5	761
NEXUS	20.0	764

SL/m: standard liters per minute

Definer 220-H	146C	NEXUS / DC-LITE		
STP	Target	Actual	Diff	% Diff
SL/m	Flow	SL/m		
X	SL/m	Y	Y - X	(Y - X)/X
1.035	1.25	1.066	0.031	3.0%
1.513	1.75	1.538	0.025	1.6%
2.00	2.25	2.02	0.021	1.1%
2.47	2.75	2.50	0.032	1.3%
2.94	3.25	2.98	0.036	1.2%
3.42	3.75	3.47	0.050	1.5%

Average Error (SL/m) = 0.032

NEXUS / DC_LITE Corrected Values (using slope and intercept)		
SL/m	Diff	% Diff
1.044	0.009	0.8%
1.511	-0.002	-0.1%
1.987	-0.009	-0.5%
2.465	-0.003	-0.1%
2.940	-0.002	-0.1%
3.429	0.008	0.2%

Average Error (SL 0.000

Raw Readings (Each set for 10 reading sets)

Target	Definer	Nexus
1.25	1.033	1.065
	1.034	1.059
	1.037	1.069
	1.035	1.069
		1.068
1.75	1.508	1.530
	1.514	1.535
	1.518	1.546
		1.540
2.25	1.993	2.010
	2.001	2.018
	1.995	2.011
	1.997	2.022
		2.027
2.75	2.469	2.498
	2.473	2.511
	2.460	2.499
	2.468	2.491
		2.497
3.25	2.941	2.980
	2.941	2.972
	2.951	2.986
	2.937	2.977
		2.978
3.75	3.423	3.476
	3.422	3.463
	3.423	3.459
	3.417	3.464
		3.494

Confirmation			
Test at 1.75 set point using			
NEXUS / DC-LITE only (Y)		Definer only (X)	
R1	R2	R1	R2
1.630	1.626	1.5904	1.5905
Average	1.628	Average	1.5905
Nexus corrected Value	1.6009		
Diff from Definer value (X)	0.66%		
Test at 3.25 set point using			
NEXUS / DC-LITE only (Y)		Definer only (X)	
R1	R2	R1	R2
3.085	3.084	3.0650	3.0467
Average	3.085	Average	3.0559
Nexus corrected Value	3.0452		
Diff from Definer value (X)	-0.35%		