2020 Clean Air Status and Trends Network Site Audit Program 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
BLM-WSO	Bureau of Land Management-Wyoming State Office
CASTNET	Clean Air Status and Trends Network
CFR	Code of Federal Regulation
CMAQ	Community Multi-scale Air Quality
DAS	data acquisition system
DC	direct current
DEP	Department of Environmental Protection
deg	degree
DQO	data quality objectives
DVM	digital voltmeter
ECCC	Environment and Climate Change Canada
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	global positioning system
k	kilo (1000)
km	kilometer
lpm	liters per minute
MLM	Multilayer Model
m/s	meters per second
mv	millivolt
NADP	National Atmospheric Deposition Program
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPAP	National Performance Audit Program
NPS	National Park Service
OAQPS	Office of Air Quality Planning and Standards
PE	Performance Evaluation
ppb	parts per billion
ppm	parts per million

PSD	Prevention of Significant Deterioration
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RH	relative humidity
RTD	Resistance Temperature Detector
SJRWMD	Saint John's Water Management District
SLAMS	State or Local Air Monitoring Stations
SOP	standard operating procedure
SRP	standard reference photometer
SSRF	Site Status Report Forms
STP	standard temperature and pressure
TEI	Thermo Environmental Instruments
TTP	Through The Probe
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USNO	United States Naval Observatory
V	volts
VDC	volts direct current
Wood	Wood Environment and Infrastructure Solutions
WRR	World Radiation Reference

1.0 Introduction

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

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

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

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

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

Currently 87 sites at 85 distinct locations measure ground-level ozone concentrations. Annual PE audit QA data are submitted to the Air Quality System (AQS) database.

As of December 2020, the network is comprised of 97 active rural sampling sites across the United States and Canada, cooperatively operated by the Environmental Protection Agency (EPA), the National Park Service (NPS), Bureau of Land Management – Wyoming State Office (BLM-WSO) and several independent partners. Wood Environment and Infrastructure Solutions (Wood) is responsible for operating the EPA sponsored sites and Air Resource Specialist, Inc. (ARS) is responsible for operating the NPS and BLM-WSO sponsored sites.

2.0 Project Objectives

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

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

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

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	$\leq \pm 10.0\%$ of input amount	
Relative Humidity	Accuracy	Compared to reference instrument or standard solution	≤±10.0%	
Solar Radiation	Accuracy	Compared to WRR traceable standard	$\leq \pm 10.0\%$ of daytime average	
Surface Wetness	Response	Distilled water spray mist	Positive response	
Surface Wetness	Sensitivity	1% decade resistance	N/A	
Shelter Temperature	Average Difference	Comparison to RTD at 3 observed points	2 °C	
TemperatureAccuracyComparison to 3 measured baths (~ 0° C, ambient, ~ full- scale) $\leq \pm 0.5^{\circ}$		$\leq \pm 0.5^{\circ} \mathrm{C}$		

Table 2-1. Performance Audit Challenge and Acceptance Criteria

Sensor	Parameter	Audit Challenge	Acceptance Criteria	
Delta Temperature	Accuracy	Comparison to temperature sensor at same test point	$\leq \pm 0.50^{\circ} \mathrm{C}$	
Wind Direction	Orientation Accuracy	Parallel to alignment rod/crossarm, or sighted to distant point	$\leq \pm 5^{\circ}$ 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	$\leq \pm 0.5$ mps below 5.0 mps input; $\leq \pm 5.0\%$ 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	$\leq \pm 5.0\%$ of designated rate	
	Slope		$0.9000 \le m \le 1.1000$	
	Intercept	Linear regression of multi- point test gas concentration as measured with a certified	-5.0 ppb ≤b ≤ 5.0 ppb	
Ozone	Correlation Coefficient	transfer standard	$0.9950 \le r$	
	Percent Difference	Comparison with Standard Concentration	Audit levels 3 through 10: $\leq \pm 15.1\%$ of test gas concentration Audit levels 1 and 2: $\leq \pm 1.5$ ppb actual difference or $\leq \pm 15.1\%$	
DAS	Accuracy	Comparison with certified standard	$\leq \pm 0.003 \text{ VDC}$	

The accuracy goals defined for ozone monitors in the CASTNET QAPP Table 4-12 are the same as those of 40 CFR, Part 58 Appendix A, for quality assurance for CASTNET site. To comply with Appendix A, the CASTNET audit program includes annual independent ozone PE. The EEMS

field scientists who conduct ozone PE maintain annual certification from the Office of Air Quality Planning and Standards (OAQPS) through the annual National Performance Audit Program (NPAP) training which EEMS attended in October 2019 (see end of Appendix for NPAP training certifications). EEMS personnel performed the Through-The-Probe (TTP) pollutant monitor audits following EPA's Quality Assurance Guidance Document – Method Compendium – Field Standard Operating Procedures (SOP) for the Federal PM_{2.5} Performance Evaluation Program and NPAP-TTP Audit Standard Operating Procedures (SOP). All procedures and guidance documents used to perform these audits can be found at the EPA OAQPS website: https://www3.epa.gov/ttn/amtic/npepga.html

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

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

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

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

- Site documentation (maintenance schedules, on-site SOPs, etc.) is current and log book records are complete.
- All maintenance and on-site SOPs are performed on schedule.
- Corrective actions are documented and appropriate for required maintenance/repair activity.
- Site operators demonstrate an adequate knowledge and ability to perform required site activities, including documentation and maintenance activities.

3.0 CASTNET Sites Visited in 2020

This report covers the CASTNET sites audited in 2020. Only those variables that were supported by the CASTNET program were audited. From February through December 2020, EEMS conducted PE and field systems audits at 34 monitoring sites. Meteorological sensors at one of the sites were also audited. The locations, sponsor agency and dates of the audits along with states and EPA Regions are presented in Table 3-1.

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
ABT147	EPA	Abington	CT / R1	9/28/2020
ANA115	EPA	Ann Arbor	MI / R5	10/7/2020
ARE128	EPA	Arendtsville	PA / R3	7/29/2020
ASH135	EPA	Ashland	ME / R1	9/27/2020
BEL116	EPA	Beltsville	MD / R3	9/22/2020
CAN407	NPS	Canyonlands NP	UT / R8	8/27/2020
CAT175	EPA	Claryville	NY / R2	10/20/2020
CAV436	NPS	Carlsbad Caverns	NM / R6	9/29/2020
CHA467	NPS	Chiricahua NM	AZ / R9	9/28/2020
COW137	EPA	Coweeta	NC / R4	5/30/2020
CTH110	EPA	Connecticut Hill	NY / R2	7/20/2020
DEN417	NPS	Denali NP	AK / R10	10/7/2020
DEV412	NPS	Death Valley NM	CA / R9	11/14/2020
DIN431	NPS	Dinosaur NM	UT / R8	8/28/2020
ESP127	EPA	Edgar Evans St. Park	TN / R4	10/16/2020
FOR605	EPA	Fortification Creek	WY / R8	6/3/2020
GAS153	EPA	Georgia Station	GA / R4	6/1/2020
GRB411	NPS	Great Basin NP	NV / R9	6/24/2020
GRC474	NPS	Grand Canyon NP	AZ / R9	9/25/2020
GRT434	NPS	Grand Teton NP	WY / R8	8/10/2020

 Table 3-1. Systems and Performance Site Audits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
HOX148	EPA	Hoxeyville	MI / R5	10/3/2020
HWF187	EPA	Huntington Wildlife Forest	NY / R2	7/13/2020
IRL141	EPA	Indian River Lagoon	FL / R4	5/22/2020
JOT403	NPS	Joshua Tree NM	CA / R9	11/13/2020
KEF112	EPA	Kane Experimental Forest	PA / R3	7/22/2020
MKG113	EPA	M. K. Goddard St. Park	PA / R3	7/21/2020
NPT006	EPA	Nez Perce Tribe	ID / R10	7/8/2020
PET427	NPS	Petrified Forest NP	AZ / R9	9/24/2020
PNF126	EPA	Cranberry	NC / R4	11/15/2020
PSU106	EPA	Penn State University	PA / R3	7/27/2020
RED004	EPA	Red Lake Nation	MN / R5	9/29/2020
SAL133	EPA	Salamonie Reservoir	IN / R5	11/4/2020
SND152	EPA	Sand Mountain	AL / R4	5/31/2020
SPD111	EPA	Speedwell	TN / R4	10/12/2020
SUM156	EPA	Sumatra	FL / R4	3/3/2020
UMA009	EPA	Umatilla Indian Reservation	WA / R10	11/23/2020
UVL124	EPA	Unionville	MI / R5	10/6/2020
WST109	EPA	Woodstock	NH / R1	9/25/2020

In addition to the sites listed in Table 3-1 that were visited for complete systems and performance audits, the 40 sites listed in Table 3-2 were visited to conduct TTP ozone and other pollutant gas PE.

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
ALC188	EPA	Alabama-Coushatta	TX / R6	2/17/2020
ALH157	EPA	Alhambra	IL / R5	12/7/2020
BAS601	EPA	Basin	WY / R8	6/2/2020
BBE401	NPS	Big Bend NP	TX / R6	2/19/2020
BFT142	EPA	Beaufort	NC /R4	12/16/2020
BVL130	EPA	Bondville	IL / R5	11/6/2020
BWR139	EPA	Blackwater NWR	MD / R3	11/15/2020
CAD150	EPA	Caddo Valley	AR / R6	8/22/2020
CDR119	EPA	Cedar Creek St. Park	WV / R3	11/13/2020
CDZ171	EPA	Cadiz	KY / R4	12/8/2020
CHC432	NPS	Chaco NHP	NM / R6	8/24/2020
CHE185	EPA	Cherokee Nation	OK / R6	8/21/2020
CKT136	EPA	Crockett	KY / R4	11/8/2020
CND125	EPA	Candor	NC / R4	12/12/2020
CNT169	EPA	Centennial	WY / R8	7/15/2020
CRM435	NPS	Craters of the Moon	ID / R10	7/6/2020
CVL151	EPA	Coffeeville	MS / R4	8/23/2020
DCP114	EPA	Deer Creek St. Park	OH / R5	8/29/2020
GLR468	NPS	Glacier NP	MT / R8	8/13/2020
GRS420	NPS	Great Smoky Mountains NP	TN / R4	10/14/2020
LRL117	EPA	Laurel Hill St. Park	PA / R3	6/17/2020
MAC426	NPS	Mammoth Cave NP	KY / R4	8/19/2020
MCK131	EPA	Mackville	KY / R4	11/7/2020

Table 3-2. Site Ozone PE Visits

Site ID	Sponsor Agency	Site Location	State and EPA Region	Audit dates
MCK231	EPA	Mackville (precision site)	KY / R4	11/7/2020
NEC602	EPA	Newcastle	WY / R8	6/3/2020
OXF122	EPA	Oxford	OH / R5	11/2/2020
PAL190	EPA	Palo Duro	TX / R6	2/20/2020
PAR107	EPA	Parsons	WV / R3	11/12/2020
PED108	EPA	Prince Edward	VA / R3	12/6/2020
PND165	EPA	Pinedale	WY / R8	8/8/2020
PRK134	EPA	Perkinstown	WI / R5	6/23/2020
QAK172	EPA	Quaker City	OH / R5	11/9/2020
SAN189	EPA	Santee Sioux	NE / R7	10/22/2020
SHN418	NPS	Shenandoah NP - Big Meadows	VA / R3	6/16/2020
STK138	EPA	Stockton	IL / R5	11/18/2020
VIN140	EPA	Vincennes	IN / R5	12/4/2020
VOY413	NPS	Voyageurs NP	MN / R5	9/30/2020
VPI120	EPA	Horton Station	VA / R3	11/10/2020
WSP144	EPA	Washington Crossing St. Park	NJ / R2	7/30/2020
YEL408	NPS	Yellowstone NP	WY / R8	8/11/2020

4.0 Performance Audit Results

This section provides the summarized performance evaluation (audit) results of each variable challenged at each station visited except for trace gas audit results. CASTNET operates trace gas monitors at several sites including three sites that are part of the NCORE Network (GRS420, MAC426, and BVL130). Performance evaluation audits of the CASTNET trace gas monitors were performed at BVL130, ROM206, PND165, HWF187, GRS420, MAC426, and PNF126 in 2020. Results of the NO_y, CO, and SO₂ monitor audits for those sites have been uploaded to the EPA AQS database and are not included in this report. All PE results for all monitors were within acceptance limits.

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

The errors presented in the tables in the following sections are reported as the difference of the measurement recorded by the DAS and the audit standard. Where appropriate, negative values indicate readings that were lower than the standard, and positive values indicate readings that were above the standard value. The results are 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. Errors for all parameters other than ozone appear to be random and without bias.

Ozone audit results in general indicate a slight negative bias which will be discussed in the following section.

Detailed reports of the field site audits, which contain all test points for each variable at each site, can be found in the Appendices of each of the 2020 Quarterly reports. The variable specific data forms included in Appendix A of each quarter's report contain the challenge input values, the output of the DAS, additional relevant information pertaining to the variable and equipment, and all available means of identification of the sensors and equipment for each site.

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

Variable Tested	Number of Tests	Number of tests Failed	% Failed
Ozone	74	2	2.7
Flow Rate	35	1	2.9
Shelter Temperature (average)	35	1	2.9
Wind Direction Orientation Average Error	1	0	0
Orientation Maximum Error	1	0	0
Wind Direction Linearity Average Error	1	0	0
Linearity Maximum Error	1	0	0
Wind Direction Starting Torque	1	0	0
Wind Speed Low Range Average Error	1	0	0
Low Range Maximum Error	1	0	0
Wind Speed High Range Average Error	1	0	0
High Range Maximum Error	1	0	0
Wind Speed Starting Torque	1	0	0
All Temperature Sensors	33	2	6.1
Relative Humidity	1	0	0
Solar Radiation	1	0	0
Precipitation	0	0	0
DAS Analog to Digital	32	0	0

Table 4-1. Performance Audit Results by Variable Tested

4.1 Ozone

Seventy-four ozone performance evaluation audits were performed in 2020. All ozone challenges were conducted to comply with the OAQPS NPAP-TTP Standard Operating Procedures (SOP) which can be found at <u>https://www.epa.gov/amtic/national-performance-audit-program-npap-gaseous-monitoring</u>. Each ozone monitor was challenged with ozone-free air and four up-scale concentrations. The ozone test gas concentrations were measured with a NIST-traceable photometer that was verified as a level 2 standard by USEPA. The results of the ozone audits were uploaded to the AQS database at the end of each quarter.

Results of all ozone audits performed are included in Table 4-2. Two monitors tested failed the annual PE with a level 2 test point difference above \pm 1.5 ppb. These monitors, UVL124 and PRK134 are highlighted in the table below. It was determined that the monitor at UVL124 required maintenance. The monitors at THR422, ACA416 and WNC429 are operated by state agencies.

Site ID	Actual Difference for Level 2	Average (% diff) for Levels 3, 4 and 6	Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	EEMS Standard Number	Date
ABT147	0.06	-0.3	-0.4	0.99571	0.08449	1.00000	1114	9/28/2020
ALC188	-0.57	-1.6	-1.9	0.99031	-0.30602	1.00000	1110	2/17/2020
ALH157	-0.71	-1.6	-2.1	0.99253	-0.41390	0.99999	1110	12/7/2020
ANA115	0.26	2.1	2.2	1.02018	0.02164	1.00000	1115	10/7/2020
ARE128	-1.26	-3.8	-5.2	0.97883	-0.78681	0.99998	1114	7/29/2020
ASH135	-0.93	-2.5	-3.7	0.98793	-0.62522	0.99999	1114	9/27/2020
BAS601	-0.16	-0.3	-0.6	1.00369	-0.20488	0.99998	1110	6/2/2020
BBE401	-0.30	-0.1	-0.6	1.00051	-0.07487	0.99999	1110	2/19/2020
BEL116	0.32	0.0	0.9	0.98550	0.77873	0.99999	1115	9/22/2020
BFT142	-0.57	-1.1	-2.0	1.00390	-0.77559	1.00000	1114	12/16/2020
BVL130	-0.85	-4.2	-4.8	0.96538	-0.39174	1.00000	1114	11/6/2020
BWR139	-0.36	-1.5	-1.8	0.98884	-0.14904	1.00000	1114	11/15/2020
CAD150	0.65	-3.3	-3.8	0.94902	1.27959	0.99997	1115	8/22/2020
CAN407	-0.32	-1.8	-2.5	0.98565	-0.03337	0.99997	1110	8/27/2020
CAVE	0.94	1.3	3.4	0.98485	1.54690	0.99997	1110	9/29/2020
CDR119	-0.37	-1.9	-2.2	0.98394	-0.09674	1.00000	1114	11/13/2020

 Table 4-2.
 Performance Audit Results for Ozone

Site ID	Actual Difference for Level 2	Average (% diff) for Levels 3, 4 and 6	Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	EEMS Standard Number	Date
CDZ171	-0.02	-0.3	-0.7	0.99764	0.01650	0.99999	1110	12/8/2020
CHA467	-0.29	-1.1	-2.0	0.99093	-0.07257	0.99996	1110	9/28/2020
CHC432	0.08	-0.6	-0.7	0.99221	0.22496	1.00000	1110	8/24/2020
CHE185	-0.52	-5.0	-5.7	0.94897	0.11020	0.99997	1115	8/21/2020
CKT136	-0.66	-2.2	-2.8	0.98431	-0.25993	0.99999	1114	11/8/2020
CND125	-0.39	0.1	0.6	1.01001	-0.50766	1.00000	1114	12/12/2020
CNT169	-0.26	0.0	-0.4	0.99445	0.28335	0.99997	1110	7/15/2020
COW137	-1.46	-3.7	-5.6	0.98820	-1.43148	0.99999	1114	5/30/2020
CRM435	-0.57	-2.7	-2.8	0.97287	0.04425	0.99999	1110	7/6/2020
CTH110	-1.00	-5.4	-6.0	0.95439	-0.44109	1.00000	1114	7/20/2020
CVL151	0.44	1.2	1.9	0.99856	0.72172	0.99999	1115	8/23/2020
DCP114	0.18	0.3	0.5	0.99947	0.26606	0.99999	1114	8/29/2020
DEN417	0.55	0.0	1.0	0.98810	0.66287	0.99999	1110	10/7/2020
DEV412	-0.52	-2.0	-2.5	0.98540	-0.23248	1.00000	1110	11/14/2020
DIN431	-1.02	-2.0	-3.1	0.98984	-0.43922	0.99996	1110	8/28/2020
ESP127	-0.26	-2.9	-3.4	0.96253	0.43361	1.00000	1115	10/16/2020
GAS153	-1.34	-5.2	-7.0	0.96464	-0.73163	0.99997	1114	6/1/2020
GLR468	-1.42	-2.4	-4.5	0.99774	-0.83009	0.99984	1110	8/13/2020
GRB411	-1.10	-3.9	-5.0	0.97888	-0.67707	0.99986	1110	6/24/2020
GRC474	-0.56	-2.7	-2.9	0.97316	-0.01397	1.00000	1110	9/25/2020
GRS420	-0.29	-3.0	-3.3	0.97265	-0.03298	1.00000	1115	10/14/2020
GRT434	0.24	2.5	2.6	1.02367	0.11388	0.99999	1110	8/10/2020
HOX148	-0.12	-1.3	-1.4	0.98482	0.16381	1.00000	1115	10/3/2020
HWF187	-0.51	-1.5	-2.1	0.99352	-0.48948	1.00000	1114	7/13/2020
IRL141	-0.28	-0.1	-0.9	0.99475	0.20607	0.99996	1114	5/22/2020
JOT403	-0.01	-1.1	-1.5	0.98833	0.15462	0.99999	1110	11/13/2020
KEF112	-0.47	-2.5	-2.6	0.97185	0.24380	0.99998	1114	7/22/2020

Site ID	Actual Difference for Level 2	Average (% diff) for Levels 3, 4 and 6	Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	EEMS Standard Number	Date
LRL117	-0.56	-2.1	-2.5	0.98615	-0.35395	1.00000	1114	6/17/2020
MAC426	-0.22	-1.7	-1.8	0.98289	0.10760	0.99999	1114	8/19/2020
MCK131	-0.78	-3.4	-4.6	0.97873	-0.57646	0.99999	1114	11/7/2020
MCK231	-0.53	-1.5	-2.5	0.99707	-0.65291	1.00000	1114	11/7/2020
MKG113	-0.40	-1.2	-1.5	0.99187	-0.09786	0.99998	1114	7/21/2020
NEC602	-1.39	-2.9	-3.9	0.98551	-0.60777	0.99989	1110	6/3/2020
NPT006	-0.42	1.8	3.2	1.03208	-0.55726	0.99990	1110	7/8/2020
OXF122	-0.41	-0.9	-1.7	0.99756	-0.36609	1.00000	1114	11/2/2020
PAL190	-0.11	-1.0	-1.4	0.99309	-0.13399	0.99999	1110	2/20/2020
PAR107	-1.02	-2.9	-3.5	0.98329	-0.77807	1.00000	1114	11/12/2020
PED108	-0.38	-2.4	-2.5	0.97700	-0.03784	1.00000	1114	12/6/2020
PET427	-0.72	-1.9	-2.1	0.98244	-0.04845	0.99997	1110	9/24/2020
PND165	-1.48	-4.1	-5.2	0.97310	-0.76266	0.99997	1110	8/8/2020
PNF126	0.00	0.4	1.0	1.00058	0.08738	0.99999	1115	11/15/2020
PRK134	-2.00	-6.4	-7.9	0.96157	-1.39677	0.99999	1114	6/23/2020
PSU106	-0.68	-1.6	-2.2	0.99347	-0.54192	1.00000	1114	7/27/2020
QAK172	-0.63	-2.7	-3.0	0.97826	-0.27934	1.00000	1114	11/9/2020
SAL133	-0.45	-0.6	-1.0	0.99920	-0.32976	1.00000	1114	11/4/2020
SAN189	0.41	0.6	0.8	1.00548	0.03634	0.99999	1110	10/22/2020
SHN418	-0.66	-3.6	-3.8	0.96769	-0.13372	1.00000	1114	6/16/2020
SND152	0.29	1.0	2.3	0.99969	0.42217	0.99999	1114	5/31/2020
SPD111	-1.46	-3.2	-3.9	0.98127	-0.93412	0.99999	1115	10/12/2020
STK138	-0.57	-1.4	-2.4	0.99445	-0.39568	0.99999	1114	11/18/2020
SUM156	-0.33	1.2	2.9	1.03563	-1.04683	0.99997	1114	3/3/2020
UMA009	0.28	1.2	1.3	1.01124	0.04290	1.00000	1110	11/23/2020
UVL124	-3.53	-10.2	-14.1	0.95010	-2.66192	0.99997	1115	10/6/2020
VIN140	0.08	0.0	-0.3	1.00141	-0.00927	0.99999	1114	12/4/2020

Site ID	Actual Difference for Level 2	Average (% diff) for Levels 3, 4 and 6	Maximum (% diff) for Levels 3, 4 and 6	Ozone Slope	Ozone Intercept	Ozone Correlation	EEMS Standard Number	Date
VOY413	-0.43	-1.9	-2.4	0.98621	-0.03828	0.99994	1115	9/30/2020
VPI120	-0.84	-4.3	-5.0	0.96927	-0.54355	0.99998	1114	11/10/2020
WSP144	-0.88	-3.2	-4.2	0.97793	-0.48678	0.99999	1114	7/30/2020
WST109	-0.35	-0.3	-0.6	1.00016	-0.21124	1.00000	1114	9/25/2020
YEL408	-0.57	-2.0	-2.6	0.98725	-0.28452	0.99999	1110	8/11/2020
ZIO433	-1.11	-0.7	-1.6	1.01491	-1.38144	0.99999	1110	8/26/2020

4.1.1 Ozone Bias

EEMS is aware of the EPA *Technical Assistance Document* "<u>Transfer Standards for Calibration of</u> <u>Air Monitoring Analyzers for Ozone</u>" *October 2013* which can be found at the AMTIC website: <u>https://www.epa.gov/sites/default/files/2020-09/documents/ozonetransferstandardguidance.pdf</u>. EEMS is also aware of the document revisions that are currently in the review process prior to approval and publishing. The discussion below references the currently approved and published document.

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

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

Where:

 \overline{m} = average slope \overline{I} = average intercept

EEMS used this equation prior to 2017 with a rolling 6x6 average slope and intercept to correct level 2 standard photometer measurements back to the regional EPA level 1 standard reference photometer (SRP) for ozone PE audits. Since the technical assistance document also states that if any adjustments are made to the transfer standard a new 6x6 verification is required, EEMS did not adjust the physical settings (background and span) of the level 2 standards unless the photometer did not meet the criteria (+/- 3 %) comparison to the level 1 standard. Thereby only mathematical corrections were applied to the level 2 standard photometers.

Review of data prior to 2017 indicated that this procedure may have introduced a bias to the standard since the level 2 standards are only compared to the level 1 SRP two or three times per year. The rolling 6x6 slope and intercept averages may not have reflected the current relationship between the level 2 and the level 1 standards. This bias was observed in the data from the 2016 ozone PE audits.

In 2017, EEMS elected to deviate from the EPA Technical Assistance Document and began correcting the level 2 standard photometer using the most recent verification results rather than the rolling 6x6 results. All ozone audit standard measurements have been corrected back to the EPA level 1 standard using most recent slope and intercept relationship to the SRP since 2017.

The remainder of this section will focus on only Level 2 audit results available in AQS. Station monitor response to ozone-free (zero-air) audit gas are not available in AQS. Since EEMS frequently observes negative responses to zero-air from station monitors, it is likely that the lowest audit concentrations are impacted. Level 2 audit results provide the lowest concentration data with enough data points for a cursory comparison, therefore only level 2 audit data are compared.

Figures 4-1 presents annual PE ozone results for Level 2 concentrations performed by EEMS in 2020. As in previous years, the results indicate that there may be a negative bias. Data presented in previous year's reports indicate that the negative bias is not observed in results of PE performed at sites other than CASTNET. Those data are not presented in this report which will focus only on CASTNET PE and EEMS standards.



Figure 4-1. Ozone PE Actual Difference Level 2 Audits Performed by EEMS

Two sites (PRK134 and UVL124) were outside the acceptance criteria for level 2 audit points. Since the analyses presented in this report are intended to focus on systematic differences and not monitor maintenance issues, those two points have been removed from the following charts.

Previous analyses have pointed to differences in the zero-air generation systems used in the EEMS (and NPAP) mobile labs and the systems at the CASTNET sites. It is theorized that the reference air used in the mobile labs is dryer than the reference air used in the stations, and much dryer than the ambient air being sampled continuously by the monitors. It is theorized that the change from ambient air, to audit gas causes loss in the site sample train as the sample train conditions to the very dry audit gas, and therefore results in a negative audit bias. The data presented in this report further investigates that theory.

Since 2017 some CASTNET sites have been modified to include Nafion[™] dryers in the ozone sample train in an effort to address the moisture content of the ambient air. In theory the dryers should help reduce the sample train conditioning time when audit gas is introduced. To the best of our knowledge, data presented below presents audit results of sites with dryers compared to those without dryers. There may be more sites with dryers that we are not aware of. Figure 4-2 presents the level 2 audit results of all sites that do not have dryers.



Figure 4-2. Ozone PE Actual Difference Level 2 Audits Sites Without Dryers

Results indicate that there is a negative bias at sites that do not have dryers installed in the ozone sample train. Therefore, it should follow those sites with dryers should have no bias. Figure 4-3 presents sites audited using EEMS Van1 and Van2 at sites that have Nafion[™] dryers installed in the ozone sample train.

0.8

0.6

0.4

0.2

0

-0.2

-0.4

-0.6

ALC188

РРВ



ESP127

USEPA

Figure 4-3. Ozone PE Actual Difference Level 2 Audits Vans1 & 2 Sites With Dryers

Although the dataset is small, there appears to be no bias, or possibly a slight positive bias. However, the EEMS Van3 audit data (presented in Figure 4-4) do not seem to indicate the same result. Figure 4-4 indicates there is a negative bias at sites with and without dryers. Since more audits are performed using Van3, those results are driving the negative bias for the network. It is important to note that most sites audited with Van2 do not have dryers (western and NPS sites) which may mean that analysis using Van2 data may not directly compare to Van3 data.

● van1 ● van2

At this time there is still no clear cause for the negative bias observed. The Van3 data indicates that it may not be related to the moisture (or lack thereof) in the mobile lab zero air systems. This is reinforced by EEMS audit data from sites other than CASTNET (previously reported). EEMS will continue to investigate and report any findings.



Figure 4-4. Ozone PE Actual Difference Level 2 Audits Van3 Sites With & Without Dryers

4.2 Flow Rate

The controlled flow rate operated by the CASTNET filter pack system was audited at 35 sites in 2020. All flow rates are in standard temperature and pressure (at 25 °C) (STP). A NIST-traceable dry-piston primary flow rate device was used for the tests. The readings obtained from this primary standard are the STP flow rate observed, while the DAS flow rate was read from the on-site data logger. All but one (PET427) of the flow rate data accuracy results were found to be within the acceptance limits.

4.3 Shelter Temperature

At each site reporting ozone concentrations to AQS, the hourly average shelter temperature must be maintained between 20.0 to 30.0 degrees C or per manufacturers specifications if designated to a wider temperature range. Shelter temperature was audited at 35 of the sites visited. All but one (PET427) of the shelter temperature data accuracy results were found to be within the acceptance criterion of ± 2 °C. 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. A Resistance Temperature Detector (RTD) was used as the audit standard. Nearly all of the site sensors were observed to lag behind the audit sensor during the rapid changes in temperature inside the shelter as the air conditioning or heating cycled on and off. In most instances the shelter temperature sensors never reached the minimum or maximum temperature measured with the audit standard. 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)¹ the actual hourly averages may be lower or higher than those measured by the site sensors.

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

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)	Audit date
ABT147	0.19	0.5	1.49	1.50	0.89	9/28/2020
ANA115	0.71	0.89	1.50	1.50	0.00	10/7/2020
ARE128	0.45	0.7	1.55	1.50	-3.23	7/29/2020
ASH135	-0.13	-0.37	1.52	1.50	-1.32	9/27/2020
BEL116	1.18	1.72	1.53	1.50	-1.96	9/22/2020
CAN407	-0.03	0.79	3.03	3.00	-0.86	8/27/2020
CAVE	0.70	0.72				9/29/2020
CAT175			1.51	1.49	-1.04	10/20/2020
CHA467	0.86	1.49	2.99	3.01	0.74	9/28/2020
COW137	0.21	1.31	1.54	1.50	-2.60	5/30/2020
CTH110	0.03	0.1	1.53	1.50	-1.96	7/20/2020
DEN417	-0.28	-0.74	3.03	3.04	0.48	10/7/2020
DEV412	-0.02	-0.07				11/14/2020
DIN431	-0.48	-0.97	3.07	3.02	-1.57	8/28/2020
ESP127	0.59	0.82	1.51	1.50	-0.66	10/16/2020
FOR605			2.96	3.00	1.47	6/3/2020
GAS153	-0.10	0.85	1.51	1.50	-0.88	6/1/2020

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

¹ The revised acceptable operating temperature range for Thermo 49*i* monitor is 5 to 40 degrees C.

Site ID	Shelter Temp. Average Error (C)	Shelter Temp. Maximum Error (C)	STP Flow Rate Primary Standard (lpm)	STP Flow Rate Site DAS (lpm)	Flow Error (% diff)	Audit date
GRB411	0.57	0.87	3.00	3.02	0.59	6/24/2020
GRC474	0.59	1.68	3.06	3.00	-1.99	9/25/2020
GRT434	0.79	1.81				8/10/2020
HOX148	1.16	1.18	1.51	1.50	-0.88	10/3/2020
HWF187	-0.08	-0.39	1.50	1.51	0.89	7/13/2020
IRL141	0.16	0.3	1.53	1.50	-1.96	5/22/2020
JOT403	0.13	0.26	2.99	3.00	0.35	11/13/2020
KEF112	-0.39	-0.58	1.54	1.49	-3.03	7/22/2020
MKG113	-0.55	-0.71	1.54	1.49	-3.46	7/21/2020
NPT006	0.58	0.93	3.05	3.00	-1.46	7/8/2020
PET427	1.95	2.42	3.20	3.00	-6.19	9/24/2020
PNF126	0.61	1.1	1.57	1.50	-4.46	11/15/2020
PSU106	0.29	0.48	1.56	1.50	-3.85	7/27/2020
RED004			3.08	3.00	-2.81	9/29/2020
SAL133	0.31	0.6	1.50	1.50	0.00	11/4/2020
SND152	0.17	0.3	1.52	1.50	-1.32	5/31/2020
SPD111	1.43	1.67	1.57	1.50	-4.66	10/12/2020
SUM156	-0.01	-0.33	1.51	1.50	-0.88	3/3/2020
UMA009	-0.26	-0.34	3.02	3.00	-0.66	11/23/2020
UVL124	0.24	0.68	1.51	1.50	-0.66	10/6/2020
WST109	0.50	1.13	1.49	1.50	0.67	9/25/2020

4.4 Wind Speed

The wind speed sensors at one site equipped for meteorological measurements was audited. The wind speed data accuracy results at BEL116 were within the acceptance limits. The results of the wind speed performance audits are presented in Table 4-4.

4.4.1 Wind Speed Starting Threshold

The condition of the wind speed bearings 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 measurement criteria was applied. The QAPP states that field criteria are more stringent than DQO and established to maintain the system within DQO. Typically, field measurement criteria are set at approximately one-half the DQO. Therefore, 0.5 g-cm was used for the acceptance limit for audit purposes. This value is within the manufacturers' specifications for a properly maintained system.

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.

The results of the wind direction performance audits are presented in Table 4-4. The average errors for the sensor at BEL116 were within the acceptance limits for the linearity test and the orientation test.

4.5.1 Wind Direction Starting Threshold

The condition of the wind direction bearings were evaluated as part of the performance audits. The data acceptance criterion for wind direction bearing torque is not defined in the QAPP. However, *Appendix 1: CASTNET Field Standard Operating Procedures*, states that the wind direction bearing torque should be ≤ 10 g-cm for R. M. Young sensors. The manufacturer states that a properly maintained sensor will be accurate up to a starting threshold of 11 g-cm. To establish the wind direction bearing torque criterion for audit purposes the rational described in the QAPP measurement criteria 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. The sensor at BEL116 tested within acceptance limits for wind direction starting threshold. The test results are provided in Table 4-4.

Site ID		W	ind Direc	tion		Wind Speed				
	Orientation Error		Linearity Error		Starting	Low Rar	Low Range Error		High Range Error	
	Ave (deg)	Max (deg)	Ave (deg)	Max (deg)	Torque (g-cm)	Ave (m/s)	Max (m/s)	Ave (% diff)	Max (% diff)	Torque (g-cm)
BEL116	0.8	2	1	2	12	-0.04	-0.2	-0.001	-0.007	0.40

Table 4-4. Performance Audit Results for Wind Sensors

* 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. (NP = not performed)

4.6 Temperature and Two-Meter Temperature

The EPA sponsored site temperature measurement systems consist of a temperature sensor mounted on a tower approximately 9 meters above ground-level. Sites operated by the National Park Service have moved the temperature sensors to approximately two meters above the ground (2-meter temperature). The BLM-WSO has recently upgraded the temperature sensors at their sites to submersible RTD sensors.

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

A total of 33 temperature sensors were tested, and all but two (DEV412 and PET427) were found to be within the acceptance criterion. The average errors for all sensors are presented in Table 4-5.

4.6.1 Temperature Shield Blower Motors

All none of the temperature systems with sensor shield blower motors (forced-air aspiration) encountered during the site audits conducted during 2020 were found to be functioning.

4.7 **Relative Humidity**

The relative humidity system audited at BEL116 was tested with a combination of primary standard salt solutions, and a NIST-traceable transfer standard relative humidity probe. The results of the average and maximum errors throughout the measurement range of approximately 30% to 95% are presented in Table 4-5. The humidity sensor was within the acceptable limits.

As in previous years, operation of both temperature and humidity sensors with respect to natural or forced-air aspiration can vary between sites. At most EPA sponsored sites temperature and

humidity sensors are operating in naturally aspirated shields. At most NPS sponsored sites temperature and humidity sensors are operating in shields designed to be mechanically aspirated with forced-air blowers.

During humidity 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.

		9-meter	2-Meter	Relative	Humidity
Audit Date	Site ID	Temperature Ave. Error	Temperature Ave. Error	Range	0 - 100%
		(deg C)	(deg C)	Ave. Error	Max. Error
9/28/2020	ABT147	0.02			
10/7/2020	ANA115	0.07			
7/29/2020	ARE128	-0.13			
9/27/2020	ASH135	0.06			
9/22/2020	BEL116	0.16	0.22	1.6	1.9
8/27/2020	CAN407		0.19		
10/20/2020	CAT175	0.09			
9/29/2020	CAVE		-0.16		
9/28/2020	CHA467		0.42		
5/30/2020	COW137	-0.07			
7/20/2020	CTH110	-0.14			
10/7/2020	DEN417		-0.07		
11/14/2020	DEV412	1.17			
8/28/2020	DIN431		-0.07		
10/16/2020	ESP127	0.14	-		
6/3/2020	FOR605		0.02		
6/1/2020	GAS153	-0.01			
6/24/2020	GRB411		0.05		

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

Audit Date	Site ID	9-meter Temperature Ave. Error	2-Meter Temperature Ave. Error	Relative	9 Humidity 0 – 100%
		(deg C)	(deg C)	Ave. Error	Max. Error
				(%)	(%)
9/25/2020	GRC474		0.28		
8/10/2020	GRT434		0.37		
10/3/2020	HOX148	0.22			
7/13/2020	HWF187	-0.09			
5/22/2020	IRL141	-0.01			
11/13/2020	JOT403		-0.20		
7/22/2020	KEF112	-0.09			
7/21/2020	MKG113	-0.04			
7/8/2020	NPT006	-0.25			
9/24/2020	PET427		0.98		
11/15/2020	PNF126	0.19			
7/27/2020	PSU106	0.07			
9/29/2020	RED004	0.07			
11/4/2020	SAL133	0.09			
5/31/2020	SND152	-0.04			
10/12/2020	SPD111	0.10			
3/3/2020	SUM156	-0.05			
11/23/2020	UMA009	0.01			
10/6/2020	UVL124	0.14			
9/25/2020	WST109	-0.03			

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 or a model 8-48 were used as the audit standard system.

One site, BEL116, was tested. The site had daytime average results that were within the acceptance criterion. The results of the test are included in Table 4-6. The percent difference of the maximum single-hour average solar radiation value observed during the site audit is also reported in Table 4-6 although this criterion is not part of the CASTNET data quality indicators. The maximum value was also within $\pm 10\%$.

4.9 Precipitation

Data were not recovered from the site DAS during the only precipitation audit performed in 2020 at BEL116, and therefore the results are not reported.

Site ID		Solar Radiation Error							
	Daytime Ave. (% diff)	Std. Max. Value (w/m2)	Site Max. Observed (w/m2)	Max. Value (% diff)	Ave. Error (% diff)				
BELL	2.5	809	815	1.11					

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

4.10 Data Acquisition Systems (DAS)

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

4.10.1 Analog Test

The accuracy of each logger was tested on two different channels (if two channels were available to be used) with a NIST-traceable Fluke digital voltmeter. At the EPA sponsored sites the channels above analog channel 8 could not be tested since there were no empty channels available to test. All 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. All site data loggers were found to be set to the correct date and within ± 5 minutes per the acceptance criterion for time. However, most of the NPS clocks were found to be 1 to 3 minutes different than the standard, whereas the EPA sponsored site clocks were all within 2-3 seconds. The Campbell Scientific logger clocks at the EPA sites are synchronized with the internet, whereas the ESC loggers at the NPS sites are not. Only one site for BLM-WSO was visited for a systems audit and the logger time and date were not verified.

			Analog Test	Date	Time		
Audit Date	Site ID	Low	Channel	High	Channel	Correct	Error
Dure		Average	Maximum	Average	Maximum	(Y/N)	(minutes)
9/28/2020	ABT147	-0.0001	-0.0001			Y	0.02
10/7/2020	ANA115	0.0000	0.0000			Y	0.03
7/29/2020	ARE128	-0.0001	-0.0001			Y	0.00
9/27/2020	ASH135	0.0000	0.0001			Y	0.00
9/22/2020	BEL116	0.0000	-0.0001			Y	0.02
8/27/2020	CAN407	-0.0002	-0.0003			Y	0.67
9/29/2020	CAV436	0.0002	0.0005			Y	0.13
9/28/2020	CHA467			0.0002	0.0005	Y	0.18
5/30/2020	COW137	0.0000	-0.0002			Y	0.00
7/20/2020	CTH110	-0.0001	-0.0002			Y	0.00
10/7/2020	DEN417	-0.0002	-0.0005			Y	0.05
11/14/2020	DEV412			0.0000	-0.0004	Y	0.35
8/28/2020	DIN431	-0.0003	-0.0006			Y	0.27
10/16/2020	ESP127	-0.0001	-0.0002			Y	0.00
6/1/2020	GAS153	0.0000	-0.0001			Y	0.00
6/24/2020	GRB411			-0.0002	-0.0005	Y	1.38
9/25/2020	GRC474			0.0002	0.0004	Y	1.17
8/10/2020	GRT434			0.0001	0.0003	Y	0.83
10/3/2020	HOX148	0.0000	0.0001			Y	0.03
7/13/2020	HWF187	0.0000	-0.0001			Y	3.45
11/13/2020	JOT403			0.0003	0.0005	Y	1.08
7/22/2020	KEF112	0.0000	0.0001			Y	0.02
7/21/2020	MKG113	-0.0001	-0.0002			Y	0.00

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

Audit			Analog Test	Error (volt	ts)	Data	Time	
Audit Date	Site ID	Low Channel		High	Channel	Correct	Error	
Date		Average Maximum		Average	Maximum	(Y/N)	(minutes)	
9/24/2020	PET427			0.0003	0.0006	Y	0.22	
11/15/2020	PNF126	-0.0001	-0.0002			Y	0.50	
7/27/2020	PSU106	-0.0001	-0.0002			Y	0.00	
11/4/2020	SAL133	0.0000	0.0001			Y	0.00	
5/31/2020	SND152	0.0000	0.0001			Y	0.02	
10/12/2020	SPD111	-0.0002	-0.0004			Y	1.50	
3/3/2020	SUM156	-0.0001	-0.0002			Y	0.03	
10/6/2020	UVL124	0.0000	0.0001			Y	0.00	
9/25/2020	WST109	0.0002	0.0003			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.

The CASTNET siting criteria (particularly for gaseous pollutant monitors) have been revised since the previous annual report. There are some discrepancies in the revised QAPP regarding siting criteria. For the audits performed in 2020, EEMS used 10 meters as the minimum distance to roads as provided in the image below from the CASTNET QAPP as Table 2-1

Onsite Criteria (Distance to Sensor or Inlet)		
Criterion	Meteorology	Filter Pack and Gas Monitoring
Distance from Tree Dripline	50 m	≥ 10 m from dripline
Obstacles to wind	10x obstacle height	2x obstacle height above inlet
Inlet Clearance		Unrestricted airflow arc of 270 degrees
Secondary road (> 100 ADT*)	500 m	500 m
Secondary road (≤ 100 ADT)	200 m	200 m
Feedlot operations	500 m	500 m
Intensive agricultural operations (including aerial spraying)	500 m	500 m
Limited agricultural operations	200 m	200 m
Large parking lot	200 m	200 m
Small parking lot	100 m	100 m
Gas Monitoring) Traffic Volume Criteria		
Roadway Average Daily Traffic [*] (vehicles/day)	Minimum Distance O3 and Oxides of Nitrogen (meters)	Minimum Distance CO (meters)
≤ 1,000	10	
10,000	10	10
15,000	20	25
20,000	30	45
30,000		80
40,000	50	115
50,000		135
60,000		150 (maximum required)
70,000	100	
≥110,000	250	

Table 2-1. CASTNET Siting Criteria (Page 1 of 2)
The CASTNET QAPP is currently being revised to more closely follow 40 CFR Part 58 Appendix E. The audit program will incorporate those changes when they are implemented beginning with audits in 2021.

5.2 Sample Inlets

Based on the siting criteria information provided in the CASTNET QAPP, with consideration given to the siting criteria compromises described in the previous section, all but four sites (LAV410, YEL408, VOY413, and SUM156) visited in 2020 have ozone monitor sample trains that are sited properly and in accordance with the CASTNET QAPP. All ozone sample inlets are currently being evaluated with respect to obstructions above the inlet. The acceptance criterion requires that there should be no obstructions (including trees) within a 26.6 degree angle (object distance must be at least two times the height) above the ozone inlet. There are trees that violate the 26.6 degree sample inlet requirement at the four sites listed above.

The dry deposition filter packs are designed to sample from a height of 10 meters. Most of the filter pack sample lines are also Teflon. Inline filters are present in the sample trains to prevent moisture and particulates from damaging the flow rate controller. A few sites were configured with the dry deposition filter face below the edge of the rain shield enclosure. This may impact the size of the particles collected on the filter. The standard CASTNET configuration is the filter face must not extend below the edge of the enclosure.

5.3 Infrastructure

Sites continue to be improved by repairing the site shelters which had deteriorated throughout the years of operation. 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. Wi-Fi routers with improved internet service have been installed at most sites.

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 Wood and ARS field operations centers. In most 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.

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

5.5 Documentation

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 always 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.

6.1 Analog to Digital Convertor Tests

EEMS continues to test at least one channel on any DAS where a channel is available to test. However, the value of this test has diminished over the years of the audit program and it may be time to reevaluate the necessity of testing the analog conversion function of the DAS due to the following:

- 1. Most modern sensors and monitors have moved away from using analog signals and are currently using digital signals for data reporting. There are very few analog inputs being used on the site data loggers.
- 2. When each parameter is challenged with an audit standard the response of the sensor is recorded from the DAS. This will inherently account for both the error of the sensor and the error of the DAS.
- 3. Since replacing the DAS at the majority (all EPA sponsored) of the sites approximately 10 years ago, there have been no analog tests that have exceeded the acceptance criteria. Data are presented below (Figures 6-1 and 6-2) that indicate there have been no failures (± 0.003v) and 99.7% of the test results were ±0.002 or less since 2010.

Given the evolution of data acquisition systems, and the move towards using digital signals from the monitors and sensors, the inherent ability to account for DAS error during challenges, and the excellent audit results over the past 10 years, it is suggested that consideration be given to eliminating the analog test from the audit procedures.





Figure 6-2. Analog DAS Tests 2010 Through 2020



7.0 References

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

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.

Schwede, D., & Lear, G.C. (2014). A novel hybrid approach for estimating total deposition in the United States. Atmospheric Environment, 92, 207-220.

APPENDIX 1

Audit Standards Certifications

Ozone Transfer Standard Verification Summary Report



U. S. Environmental Protection Agency Region 4 Laboratory Services & Applied Science Division Quality Assurance and Program Services Branch Quality Assurance Section 980 College Station Rd. Athens, GA 30605

SESD Project #: Test #:	20-0157 # 1 "as found"	Agency: Contact: Make: Model: S/N: Guest Guest K	EPA Standard EPA Region 4 Keith Harris NIST SRP 10 Test Status: nown Offset:	GUEST Instrument NIST EEMS Thermo 49CPS 70008-364 PASS 0	EE Van	ms (01110	
	and "as left"		Level 2	Slope	Intercept	R ²	High O ₃	Lower O ₃
		A	verages:	1.0026	0.0359	0.9999989	422	0
		U	pper Tolerance:	1.0300	3.0000			
		L	owerTolerance:	0.9700	-3.0000			
							Upper Range	Lower Range
Cycle Start Da	ate / Time	Fil	e Name	Slope	Intercept	R ²	(ppb O ₃)	(ppb O ₃)
1/13/20 4:4	45 PM	Cal20	011300.xls	1.0016	-0.0459	0.9999980	422	0.00
1/13/20 6:	25 PM	Cal20	011301.xls	1.0020	0.0251	0.9999997	423	-0.05
1/13/20 8:	05 PM	Cal20	011302.xls	1.0021	0.0460	0.9999985	423	-0.01
1/13/20 9:4	45 PM	Cal20	011303.xls	1.0033	-0.0204	0.9999992	423	0.06
1/13/20 11:	:25 PM	Cal20	011304.xls	1.0033	0.0943	0.9999991	423	0.06
1/14/20 1:0	05 AM	Cal20	011400.xls	1.0026	0.1525	0.9999994	422	-0.06
1/14/20 2:4	45 AM	Cal20	011401.xls	1.0034	0.0001	0.9999986	421	0.04
Comments:	Instrument te	ested as foun	d.					
	Ozone calibra	ation factors	at time of test:	O3 BKG: 0.0	ppb O3 CC	EF: 1.018		

Verification Expires on: January 14, 2021 Date 01/14/20 Keith Harris

Page 1 of 1

Ozone Transfer Standard Verification Summary Report



U. S. Environmental Protection Agency Region 4 Laboratory Services & Applied Science Division Quality Assurance and Program Services Branch Quality Assurance Section 980 College Station Rd. Athens, GA 30605

SESD Project #: Test #:	20-0158 # 1 "as found"	Agency: Contact: Make: Model: S/N: Guest Guest K	EPA Standard EPA Region 4 Keith Harris NIST SRP 10 Test Status: nown Offset:	GUEST Instrument EEMS Eric Hebert Thermo 49i 1180030022 PASS 0	E	Ems Jan 3	01114	
	and "as left"		Level 2	Slope	Intercept	R ²	High O ₃	Lower O ₃
		L'	Averages:	0.9995	0.2901	0.999999	422	0.00
			owerTelerance:	1.0300	3.0000			
		E	oner relevance.	0.0700	-0.0000		Upper Range	Lower Range
Cycle Start D	ate / Time	Fil	e Name	Slope	Intercept	R ²	(ppb O ₃)	(ppb O ₃)
1/13/20 4:	45 PM	Cal20	011300.xls	0.9992	0.1478	0.9999982	422	0.00
1/13/20 6:	25 PM	Cal20	011301.xls	0.9987	0.2732	0.9999992	423	-0.05
1/13/20 8:	05 PM	Cal20	011302.xls	0.9993	0.2565	0.9999984	423	-0.01
1/13/20 9:	45 PM	Cal20	011303.xls	0.9999	0.2851	0.9999989	423	0.02
1/13/20 11	:25 PM	Cal20	011304.xls	0.9995	0.4050	0.9999991	423	0.06
1/14/20 1:	05 AM	Cal20	011400.xls	0.9996	0.3926	0.9999998	422	-0.06
1/14/20 2:	45 AM	Cal20	011401.xls	1.0001	0.2708	0.9999984	421	0.04
Comments:	Instrument te	sted as four	d.					
	Ozone calibra	ation factors	at time of test:	O3 BKG: - 0	4 ppb 03 (COEF: 0.990)	

Verification Expires on: January 14, 2021 Keith Harris 3 2 2 Date 01/14/120

Ozone Transfer Standard Verification Summary Report



U. S. Environmental Protection Agency Region 4 Laboratory Services & Applied Science Division Quality Assurance and Program Services Branch Quality Assurance Section 980 College Station Rd. Athens, GA 30605

Make: Model: S/N: 156 Guest Guest K	NIST SRP 10 Test Status:	Eric Hebert Thermo 49 iQps 1180930075 PASS 0	0	Van'l		
	Level 2	Slope	Intercept	R ²	High O ₃	Lower O ₃
LA CONTRACT	verages:	0.9949	0.3222	0.9999944	422	0
Ļ	Jpper Tolerance:	1.0300	3.0000			
L	.owerTolerance:	0.9700	-3.0000			
					Upper Range	Lower Range
ie Fil	le Name	Slope	Intercept	R ²	(ppb O ₃)	$(ppb O_3)$
Cal20)011300.xls	0.9988	0.0863	0.9999931	422	0.00
Cal20)011301.xls	0.9885	0.3766	0.9999991	423	-0.05
Cal20)011302.xls	0.9902	0.3919	0.9999979	423	-0.01
Cal20)011303.xls	0.9941	0.5503	0.9999843	423	0.02
Cal20)011304.xls	1.0007	0.0943	0.9999991	423	0.06
Cal20)011400.xls	1.0000	0.2294	0.9999891	422	-0.06
	e Fil Cal20 Cal20 Cal20 Cal20 Cal20 Cal20 Cal20 Cal20 Cal20 Cal20	e File Name Cal20011300.xls Cal20011301.xls Cal20011302.xls Cal20011303.xls Cal20011304.xls Cal20011304.xls Cal20011400.xls	e File Name Slope Cal20011300.xls 0.9988 Cal20011301.xls 0.9885 Cal20011302.xls 0.9902 Cal20011303.xls 0.9941 Cal20011304.xls 1.0007 Cal20011400.xls 1.0000	File Name Slope Intercept Cal20011300.xls 0.9885 0.3766 Cal20011302.xls 0.9902 0.3919 Cal20011303.xls 0.9941 0.5503 Cal20011304.xls 1.0007 0.0943 Cal20011400.xls 1.0000 0.2294	File Name Slope Intercept R ² Cal20011300.xls 0.9988 0.0863 0.9999931 Cal20011301.xls 0.9885 0.3766 0.9999991 Cal20011302.xls 0.9902 0.3919 0.9999979 Cal20011303.xls 0.9941 0.5503 0.9999943 Cal20011304.xls 1.0007 0.0943 0.9999991 Cal20011304.xls 1.0000 0.2294 0.9999891	File Name Slope Intercept R ² (ppb O ₃) Cal20011300.xls 0.9988 0.0863 0.9999931 422 Cal20011300.xls 0.9885 0.3766 0.9999991 423 Cal20011302.xls 0.9902 0.3919 0.9999979 423 Cal20011303.xls 0.9941 0.5503 0.9999843 423 Cal20011304.xls 1.0007 0.0943 0.9999991 423 Cal20011400.xls 1.0000 0.2294 0.9999891 422

Comments:

Prior to test one instrument was adjusted to more closely match the SRP.

Ozone calibration factors at time of test:

O3 BKG: 1.2 ppb O3 COEF: 0.998

Verification Expires on: January 14, 2021 Date 01/14/ Keith Harris

Date

2/14/2020 - - Calibration and verification of three RTD meters with most recent certification of EEMS RTD

	TMI Cert data	1/29/2020					RTD		RTD		RTD	
					At	Date	01230 / 012	31	01227 / 1		01228 / 2	
	TMI	EEM	IS		EEMS	2/14/2020	EEMS		EEMS		EEMS	
	STD	RTI	2		F	RTD	AER		van3		van1	
Cert #	A3483085	0122	<u>29</u>		01	1229						
			diff	corrected	raw	corrected	raw	corrected	raw	corrected	raw	corrected
	-25.00	-25.05	0.050	-25.026	0.08	0.10	0.11	0.09	0.21	0.08	-0.05	0.08
	0.00	0.01	-0.010	0.027	11.06	11.07	11.09	11.08	11.29	10.82	11.04	11.32
	100.00	100.02	-0.020	100.011	20.88	20.89	20.90	20.90	21.22	20.67	20.96	21.17
	150.00	150.01	-0.010	149.988	30.65	30.66	30.65	30.66	31.01	30.64	30.78	30.65
					39.36	39.37	39.35	39.37	39.83	39.39	39.59	39.39
					50.87	50.87	50.83	50.86	51.39	50.86	51.15	50.85
					25.25	25.26	25.26	25.26	25.60	25.27	25.35	25.27
			RTD (01229								
	2020 (correction: sl	ope=	1.00025954								
		in	tercept=	-0.0170992								
		corr= 1	1.0000000									
	a					slope =	0.998854		1.007968		1.008426	
	Ein Hel	ut	2/14/2020			intercept =	0.024392		0.129496		-0.12932	
						correlation =	1.0000		1.0000		1.0000	

4577 E NW 6TH S GAINESVILLE, FL 352-262-0802	STREET . 36209	P.O. Numb	er: EEMS 01222) Van-
Description: PSYC Manufacturer: AZ IN Model Number: AZ 87 Serial Number: 10325	CHROMETER W/ PROBE STRUMENTS 23 5187	Calibratic Calibratic Procedur Tempera Humidity	on Date: 01/29/202 01/202 0	0 GROTHERMOGR 2011
On-Site Calibration:		As Foun Calibrati	d Condition: IN TOLER on Results: IN TOLER	ANCE
1994 and TMI's Quality Man Results contained in this doe	cupies of ISO 9001 and aligned with its per ual, QM-1. cument relate only to the item calibrated.	rtinent requirements. This calibration Calibration due dates appearing on th	e certificate or label are determ	evant to laboratory nts of ANSI/NCSL Z540 ined by the client for
Results contained in this doe administrative purposes and This certificate shall not be r Measurements not currently	cipies of ISO 9001 and aligned with its per ual, QM-1. cument relate only to the item calibrated. I do not imply continued conformance to s reproduced, except in full, without the writt on TMI's Scope of Accreditation are ident	rtinent requirements. This calibration Calibration due dates appearing on th pecifications. en permission of Technical Maintenan ified with an asterisk.	e certificate or label are determine, Inc.	Ints of ANSI/NCSL Z540
Parallohs, meeting the print 1994 and TMI's Quality Man Results contained in this dor administrative purposes and This certificate shall not be r Measurements not currently WALLY GYNM	cipies of ISO 9001 and aligned with its perual, QM-1. cument relate only to the item calibrated. I do not imply continued conformance to s reproduced, except in full, without the writt on TMI's Scope of Accreditation are ident	rtinent requirements. This calibration Calibration due dates appearing on th pecifications. en permission of Technical Maintenan ified with an asterisk.	complies with all the requireme e certificate or label are determined ice, Inc.	Ints of ANSI/NCSL Z540
VALLY GYNN	cipies of ISO soof and aligned with its per- ual, QM-1. cument relate only to the item calibrated. I do not imply continued conformance to s reproduced, except in full, without the writt on TMI's Scope of Accreditation are ident with the source of the source of the source of the source N, BRANCH MANAGER Calibre	rtinent requirements. This calibration Calibration due dates appearing on th pecifications. en permission of Technical Maintenan ified with an asterisk. Scott (ration Standards	e certificate or label are determine.	Ints of ANSI/NCSL Z540
Asset Number 0710649	cipies of ISO 9001 and aligned with its per ual, QM-1. cument relate only to the item calibrated. I do not imply continued conformance to s reproduced, except in full, without the writt on TMI's Scope of Accreditation are ident with the writt on TMI's Scope of Accreditation are ident Manufacturer THUNDER SCIENTIFIC	rtinent requirements. This calibration Calibration due dates appearing on th pecifications. en permission of Technical Maintenan ified with an asterisk. Scott (ration Standards <u>Model Number</u> 2500ST	complies with all the requireme e certificate or label are determined ice, Inc. Chamberlain, QUALITY Date Calibrated 6/21/2019	Inter of laboratory inter of ANSI/NCSL Z540 ined by the client for MANAGER <u>Cal Due</u> 2/21/2020

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

Page 2 of 2

°F °F

°F

%RH

%RH

%RH

Unit ADJ/FAIL

As Left

49.3

69.3

89.2 31.1

49.0

73.9

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	
Temperature Accuracy	50.0	49.0	51.0	49.3	
Temperature Accuracy	70.0	69.0	71.0	69.3	
Temperature Accuracy	90.0	89.0	91.0	89.2	
Humidity Accuracy	33.0	30.0	36.0	31.1	
Humidity Accuracy	50.0	47.0	53.0	49.0	
Humidity Accuracy	75.0	72.0	78.0	73.9	

Certificate Number

A3483224

Issue Date: 01/29/20

EEMS OIZZZ Van - 1

m=	1.0173
b =	- 2,2459
F2 =	0,9999
	0 1/30/2020

TMI

Technical Maintenance, Inc.

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

4577 E NW 6TH GAINESVILLE, F	STREET 1 36209	P.O. Numbe	er:	
352-262-0802		ID Numb	er: (EEMS 0122	10/220
Description: THE	RMO HYGROMETER	Calibratio	n Date: 01/29	/2020
Manufacturer: ROT	RONIC	Calibratio	n Due: 01/29	A-HYGROTHERMOGE
Model Number: HYG	ROPALM		Rev: 2	2/22/2011
Serial Number: 4086	31 002/124431	Temperat	ture: 71	°F % RH
Technician: STE	VE TORRES	As Found	d Condition: IN TO	LERANCE
On-Site Calibration: Comments:		Calibrati	on Results: IN TC	DLERANCE
Limiting Attribute:				
Compliance are based on t TMI's Quality System is ac operations, meeting the pri 1994 and TMI's Quality Ma Results contained in this d administrative purposes are	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1.	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 tinent requirements. This calibration of Calibration due dates appearing on the pecifications	evel using a coverage fa measurement. 017 is written in a langua complies with all the requ	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for
Compliance are based on t TMI's Quality System is ac operations, meeting the pri 1994 and TMI's Quality Ma Results contained in this d administrative purposes ar This certificate shall not be Measurements not current	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1. ocument relate only to the item calibrated. ad do not imply continued conformance to s e reproduced, except in full, without the writt ly on TMI's Scope of Accreditation are ident	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 tinent requirements. This calibration of Calibration due dates appearing on the pecifications. en permission of Technical Maintenan- ified with an asterisk.	evel using a coverage fa measurement. 017 is written in a langua complies with all the requ e certificate or label are d ce, Inc.	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for
Compliance are based on to TMI's Quality System is ac operations, meeting the pri 1994 and TMI's Quality Ma Results contained in this d administrative purposes ar This certificate shall not be Measurements not current	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1. ocument relate only to the item calibrated. ad do not imply continued conformance to s a reproduced, except in full, without the writt ly on TMI's Scope of Accreditation are ident	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 tinent requirements. This calibration of Calibration due dates appearing on the pecifications. en permission of Technical Maintenan- ified with an asterisk.	evel using a coverage fa measurement. 017 is written in a langua complies with all the requ e certificate or label are d ce, Inc.	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for
TMI's Quality System is ac operations, meeting the pri 1994 and TMI's Quality Ma Results contained in this d administrative purposes ar This certificate shall not be Measurements not current	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1. occument relate only to the item calibrated. ad do not imply continued conformance to s e reproduced, except in full, without the writt ly on TMI's Scope of Accreditation are ident of the transformation of the transformation of the transformation IN, BRANCH MANAGER	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 tinent requirements. This calibration of Calibration due dates appearing on the pecifications. en permission of Technical Maintenan- ified with an asterisk.	evel using a coverage fa measurement. 017 is written in a langua complies with all the requ e certificate or label are d ce, Inc. wt Cham chamberlain, QUAL	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for
Results contained in this d administrative purposes are Measurements not current WALLY GYN	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1. ocument relate only to the item calibrated. ad do not imply continued conformance to s a reproduced, except in full, without the writt ly on TMI's Scope of Accreditation are ident with the additional of the item calibrated. IN, BRANCH MANAGER Calibre	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 the transmission of the transmission of transmis	evel using a coverage fa measurement. 017 is written in a langua complies with all the requ e certificate or label are d ce, Inc.	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for
Asset Number 0710649	expressed as expanded uncertainty values est results falling within specified limits with credited to ISO/IEC 17025:2017 and ANSI/ inciples of ISO 9001 and aligned with its per inual, QM-1. ocument relate only to the item calibrated. ad do not imply continued conformance to s a reproduced, except in full, without the writt ly on TMI's Scope of Accreditation are ident with the second score of the second score of the second IN, BRANCH MANAGER <u>Calibre</u> <u>Manufacturer</u> THUNDER SCIENTIFIC	at an approximately 95% confidence I no reduction by the uncertainty of the NCSL Z540-1-1994. ISO/IEC 17025:2 trinent requirements. This calibration of Calibration due dates appearing on the pecifications. en permission of Technical Maintenan- ified with an asterisk. Scott O ration Standards <u>Model Number</u> 2500ST	evel using a coverage fa measurement. D17 is written in a langua complies with all the requ e certificate or label are d ce, Inc. Chamberlain, QUAL Date Calibrate 6/21/2019	ctor of k=2. Statements of age relevant to laboratory irrements of ANSI/NCSL Z54 letermined by the client for LoLain LITY MANAGER d <u>Cal Due</u> 2/21/2020

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



Data Sheet

Temperature Accuracy
Temperature Accuracy
Temperature Accuracy
Humidity Accuracy
Humidity Accuracy
Humidity Accuracy

r

Certificate Number

A3483222 Issue Date: 01/29/20

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
ature Accuracy	15.0	14.6	15.4	14.9	14.9	С	
ature Accuracy	25.0	24.6	25.4	24.7	24.7	С	
ature Accuracy	35.0	34.6	35.4	34.8	34.8	С	
Accuracy	33.0	31.4	34.6	32.8	32.8	%	
Accuracy	50.0	48.4	51.6	49.9	49.9	%	
Accuracy	75.0	73.4	76.6	73.6	73.6	%	

EEMS# 01220/01225 Van-2

m=	0.9697
6 =	1.0302
r ^z =	Ø. 9999
	1/30/2020



Technical Maintenance, Inc.

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4577 E NW 6TH GAINESVILLE, F	STREET L 36209	P.O. Number:	\frown	Van
352-262-0802		ID Number:	EEMS 01223	
Description: PSY Manufacturer: AZ II Model Number: AZ 8 Serial Number: 1032 Technician: STE	CHROMETER W/ PROBE NSTRUMENTS 723 15189 VE TORRES	Calibration D Calibration D Procedure: Temperature Humidity: As Found C	ate: 01/29/2020 01/29/202 TMI-M-HY Rev: 2/22/ : 71 °F 36 % Ri ondition: IN TOLER	GROTHERMOGR 2011 H ANCE
On-Site Calibration: Comments:		Calibration	Results: IN TOLER	ANCE
Limiting Attribute:				
Results contained in this de	ocument relate only to the item calibrated.	Calibration due dates appearing on the cert	incate of label are determined	ined by the client for
Results contained in this di administrative purposes an This certificate shall not be Measurements not current	reproduced, except in full, without the write y on TMI's Scope of Accreditation are iden	Calibration due dates appearing on the cen pecifications. Ien permission of Technical Maintenance, Ir tified with an asterisk.		ined by the client for
Results contained in this de administrative purposes an This certificate shall not be Measurements not current	d do not imply continued conformance to s reproduced, except in full, without the writing on TMI's Scope of Accreditation are iden	Calibration due dates appearing on the cen pecifications. In permission of Technical Maintenance, Ir tified with an asterisk.	tt Chambe	hed by the client for
Results contained in this de administrative purposes an This certificate shall not be Measurements not current	ocument relate only to the item calibrated. Id do not imply continued conformance to s reproduced, except in full, without the writt y on TMI's Scope of Accreditation are iden	Calibration due dates appearing on the cen pecifications. ten permission of Technical Maintenance, Ir tified with an asterisk.	the chamber	hain MANAGER
Results contained in this di administrative purposes an This certificate shall not be Measurements not current	N, BRANCH MANAGER	Calibration due dates appearing on the cen pecifications. ten permission of Technical Maintenance, Ir tified with an asterisk. Scott Char ration Standards	nc. # Chambe mberlain, QUALITY	hained by the client for
Results contained in this di administrative purposes an This certificate shall not be Measurements not current WALLY GYN Asset Number 0710649	Deciment relate only to the item calibrated. In a do not imply continued conformance to so reproduced, except in full, without the write y on TMI's Scope of Accreditation are iden Without the write N, BRANCH MANAGER <u>Calib</u> <u>Manufacturer</u> THUNDER SCIENTIFIC	Calibration due dates appearing on the cen pecifications. ten permission of Technical Maintenance, Ir tified with an asterisk. Scott Char <u>ration Standards</u> <u>Model Number</u> 2500ST	nc. <i>H Chambe</i> mberlain, QUALITY <u>Date Calibrated</u> 6/21/2019	MANAGER <u>Cal Due</u> 2/21/2020

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Rev. 13 8/17/2018

Data Sheet

Page 2 of 2

Parameter

A3483225 Issue Date: 01/29/20

Certificate Number

Temperature Accuracy
Temperature Accuracy
Temperature Accuracy
Humidity Accuracy
Humidity Accuracy
Humidity Accuracy

Nomina	<u>Minimum</u>	Maximum	As Found	As Left	Unit ADJ/FAI	L
50.0	49.0	51.0	49.5	49.5	°F	
70.0	69.0	71.0	69.5	69.5	°F	
90.0	89.0	91.0	89.4	89.4	°F	
33.0	30.0	36.0	31.2	31.2	%RH	
50.0	47.0	53.0	49.0	49.0	%RH	
75.0	72.0	78.0	74.0	74.0	%RH	

EEMS	#	01223
	Var	- 3

m	11	1.0176
b	2	-2.1949
F2	11	0.9999
	Ð) 1/30/2020



Technical Maintenance, Inc.

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

A3483055 Issue Date: 01/29/20	of Calibration Page 1
Der: ENVIRONMENTAL ENGINEERING & MEASUREMEN 4577 E NW 6TH STREET GAINESVILLE, FL 36209 352-262-0802	T SERVICES P.O. Number: ID Number: EEMS 01226
Description: DIGITAL STIK THERMOMETER Manufacturer: FLUKE Model Number: 1551A EX Serial Number: 2085085 Technician: STEVE TORRES On-Site Calibration: Comments:	Calibration Date: Calibration Due: Procedure: Procedure: Temperature: Humidity: As Found Condition: IN TOLERANCE Calibration Results: IN TOLERANCE
Limiting Attribute:	

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. 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;2017 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration complies with all the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

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

This certificate shall not be reproduced, except in full, without the written permission of Technical Maintenance, Inc.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

alle

WALLY GYNN, BRANCH MANAGER

Scott Chamberlain

Scott Chamberlain, QUALITY MANAGER

Calibra	ation Standards		
Manufacturer FLUKE	Model Number 5609-12-D	Date Calibrated 7/17/2019	<u>Cal Due</u> 7/17/2020
ADDITEL CORPORATION	ADT875PC-155	6/4/2019	6/4/2020
FLUKE/HART	1502A	11/5/2019	2/28/2020
	ADDITEL CORPORATION	Manufacturer Model Number FLUKE 5609-12-D ADDITEL CORPORATION ADT875PC-155 FLUKE/HART 1502A	Manufacturer FLUKEModel Number 5609-12-DDate Calibrated 7/17/2019ADDITEL CORPORATIONADT875PC-1556/4/2019FLUKE/HART1502A11/5/2019



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Certificate Number A3483055 Issue Date: 01/29/20

Certificate of Calibration

Data Sheet

Page 2 of 2

Parameter

Temperature Accuracy Temperature Accuracy Temperature Accuracy Temperature Accuracy

Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
-25.00	-25.05	-24.95	-25.04	-25.04	°C	
0.00	-0.05	0.05	-0.01	-0.01	°C	
100.00	99.95	100.05	100.00	100.00	°C	
150.00	149.95	150.05	150.00	150.00	°C	

EEMS # 01226 Van-2

m	Γ,	1,0001863
Ь	ι,	-0.022977
42	11	1-0000

1/30/2020



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Certificate Number A3483085 Issue Date: 01/29/20	of Calibration Page 1 of			
ner: ENVIRONMENTAL ENGINEERING & MEASUREME	ENT SERVICES EEMS			
4577 E NW 6TH STREET	P.O. Number:			
GAINESVILLE, FL 36209	Varia			
352-262-0802	ID Number EEMS 01229			
Description: DIGITAL STIK THERMOMETER	Calibration Date: 01/29/2020			
Manufacturer: FLUKE	Calibration Due: 01/29/2021			
Model Number: 1551A EX	Procedure: FLUKE 1551A EX,52A EX Rev: 11/1/2010			
Serial Number: 3275143	Temperature: 71 °F			
Technician: STEVE TORRES	Humidity: 36 % RH As Found Condition: IN TOLERANCE			
On-Site Calibration:	Calibration Results: IN TOLERANCE			

Limiting Attribute:

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. 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 17025:2017 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration complies with all the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

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

This certificate shall not be reproduced, except in full, without the written permission of Technical Maintenance, Inc.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

WALLY GYNN, BRANCH MANAGER

Scott Chambarlain

Scott Chamberlain, QUALITY MANAGER

	Calibra	ation Standards		
Asset Number 05535	Manufacturer FLUKE	Model Number 5609-12-D	Date Calibrated 7/17/2019	<u>Cal Due</u> 7/17/2020
660TL18010015	ADDITEL CORPORATION	ADT875PC-155	6/4/2019	6/4/2020
A88072	FLUKE/HART	1502A	11/5/2019	2/28/2020



Technical Maintenance, Inc.

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Page 2 of 2

Parameter

Issue Date: 01/29/20

Certificate Number

A3483085

Temperature Accuracy Temperature Accuracy Temperature Accuracy Temperature Accuracy

	Data Sheet					
Nominal	Minimum	Maximum	As Found	As Left	<u>Unit</u>	ADJ/FAIL
-25.00	-25.05	-24.95	-25.05	-25.05	°C	
0.00	-0.05	0.05	0.01	0.01	°C	
100.00	99.95	100.05	100.02	100.02	°C	
150.00	149.95	150.05	150.01	150.01	°C	
	Nominal -25.00 0.00 100.00 150.00	Nominal Minimum -25.00 -25.05 0.00 -0.05 100.00 99.95 150.00 149.95	Mominal Minimum Maximum -25.00 -25.05 -24.95 0.00 -0.05 0.05 100.00 99.95 100.05 150.00 149.95 150.05	Mominal Minimum Maximum As Found -25.00 -25.05 -24.95 -25.05 0.00 -0.05 0.05 0.01 100.00 99.95 100.05 100.02 150.00 149.95 150.05 150.01	NominalMinimumMaximumAs FoundAs Left-25.00-25.05-24.95-25.05-25.050.00-0.050.050.010.01100.0099.95100.05100.02100.02150.00149.95150.05150.01150.01	Mominal Minimum Maximum As Found As Left Unit -25.00 -25.05 -24.95 -25.05 -25.05 °C 0.00 -0.05 0.05 0.01 0.01 °C 100.00 99.95 100.05 100.02 100.02 °C 150.00 149.95 150.05 150.01 150.01 °C

EEMS # 01229 Van-2

m=	1.0002595
6=	-0.017099
r ² =	1.0000
Ø	1/30/2020



Technical Maintenance, Inc.

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lage lof 1



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 EEMS # -01245 ard

Calibration Certificate

		1	01246
Instrument:	Precision Spectral	Pyranometer, Model PSP, Serial Number 34341F3	Van 3
Procedure:	This pyranometer v procedures describe The Eppley Labora	was compared in Eppley's Integrating Hemisphere a ed in <i>ISO 9847 Section 5.3.1</i> and Technical Procedu atory, Inc.'s Quality Assurance Manual on Calibratic	ccording to are, TP01 of ons.
Transfer Standard:	Eppley Precision S	pectral Pyranometer, Model PSP, Serial Number 21	231F3
Results:	Sensitivity: Uncertainty: Resistance:	S = 9.31 μV / Wm ⁻² U ₉₅ = ±0.91% (95% confidence level, k=2) 699 Ω at 23°C	
Traceability:	This calibration is t comparisons with F which participated XII) at Davos, Swit the remarks section "AS FOUND / AS	traceable to the World Radiation Reference (WRR) Eppley's AHF standard self-calibrating cavity pyrhe in the Twelfth International Pyrheliometric Compar tzerland in September-October 2015. Unless otherw below or on the Sales Order, the results of this cali LEFT".	through liometers isons (IPC ise stated in bration are
Due Date:	Eppley recommend annual calibrations	ds a minimum calibration cycle of five (5) years I for highest measurement accuracy.	out encourages
Customer:	EEMS Gainesville, FL		
Signatures:	Dulta L. X In Charge of Test:	Minty Thomas Han	h
Eppley SO:	65601		
Date of Certificate	February 5, 2020		
Remarks:	Amplifier #10765 s	set with gain = 76.72 so that $1 \text{ V} = 1400 \text{ Wm}^{-2}$.	

Page 1 of 1



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

EEMS # 01247

Calibration Certificate

Instrument:	Black & White Py	ranometer, Model	8-48, Serial Number 23824	Van	2		
Procedure:	This pyranometer procedures describ The Eppley Labor	was compared in bed in <i>ISO 9847 S</i> ratory, Inc.'s Quali	Eppley's Integrating Hemisphere <i>fection 5.3.1</i> and Technical Proce ity Assurance Manual on Calibrat	according to dure, TP01 of tions.			
Transfer Standard:	Eppley Black & White Pyranometer, Model 8-48, Serial Number 14061						
Results:	Sensitivity: Uncertainty: Resistance:	$S = 8.83 \mu V$ U ₉₅ = ±0.91% 346 Ω at 23°C	/ Wm ⁻² (95% confidence level, k=2)				
	Date of Test:	February 4, 202	.0				
Traceability:	This calibration is comparisons with which participated XII) at Davos, Sw the remarks section "AS FOUND / AS	s traceable to the V Eppley's AHF sta d in the Twelfth In vitzerland in Septer on below or on the S LEFT".	Vorld Radiation Reference (WRR indard self-calibrating cavity pyrh ternational Pyrheliometric Comp mber-October 2015. Unless other Sales Order, the results of this ca	.) through neliometers arisons (IPC wise stated in alibration are			
Due Date:	Eppley recomment annual calibration	nds a minimum ca as for highest meas	alibration cycle of five (5) years surement accuracy.	but encourages			
Customer:	EEMS Gainesville, FL						
Signatures:	Dula L. In Charge of Test	Gunty	Reviewed by:	h			
Eppley SO:	65601						

Date of Certificate February 5, 2020

Remarks:

Page 1 of 1



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

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802 Serial Number: CA04013

Description: Anemometer Drive - 200 to 15000 RPM (Comprised of 18820A Control Unit and 18830A Motor Assembly)

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

27106D Output Frequency Hz (1)	Calculated RPM (2)	Indicated RPM (3)
50	300	300
450	2700	2700
850	5100	5100
1250	7500	7500
1700	10200	10200
2100	12600	12600
2500	15000	15000
	27106D Output Frequency Hz (1) 50 450 850 1250 1700 2100 2500	27106D Output Frequency Calculated Hz (1) RPM (2) 50 300 450 2700 850 5100 1250 7500 1700 10200 2100 12600 2500 15000

 Measured output frequency of YOUNG model 27106D standard anemometer attached to motor shaft.

(2) YOUNG model 27106D produces 10 pulsed per revolution of the anemometer shaft.

(3) Indicated on the Control Unit LCD.

* Indicates out of tolerance

As found Service / Repair Unit New Unit No calibration adjustments required As left EEMS # 01253 - controller 01254 - motor - low 01255 - motor - high 2/2/20 m=1 b=0 Traceable frequency meter used for calibration: Model: 34405A Serial Number: TW46290020 Date: 18 June 2020 Calibration Interval: One year EC Tested By : METEOROLOGICAL INSTRUMENTS Tel 231-946-3980 Fax 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com ISO 9001:2008 CERTIFIED



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

Page 1 of 1 Van 2 EEMS# 01261 & 01457

CERTIFICATE OF CALIBRATION AND TESTING

Model: 18802/18811 Serial Number: CA04353 Description: Anemometer Drive - 2 motors, 20 to 15,000 RPM (18802 comprised of 18820A Control Unit and 18830A Motor Assembly) (18811 comprised of 18820A Control Unit and 18831A Motor Assembly)

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

Nominal	27106D Output		
Motor RPM	Frequency	Calculated	Indicated
RPM	Hz (1)	RPM (2)	RPM (3)
18802	Clockwise and C	ounterclockwise rotation	verified.
300	50	300	300
2700	450	2700	2700
5100	850	5100	5100
7500	1250	7500	7500
10200	1700	10200	10200
12600	2100	12600	12600
15000	2500	15000	15000
18811	✓ Clockwise and C	ounterclockwise 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 output frequency of YOUNG model 27106D standard anemometer attached to motor shaft.

(2) YOUNG model 27106D produces 10 pulsed per revolution of the anemometer shaft.

(3) Indicated on the Control Unit LCD.

* Indicates out of tolerance.

New Unit

Service / Repair Unit
 No calibration adjustments required

As found As left

EC

Traceable frequency meter used for calibration: Model: 34405A

Serial Number: TW46290020

Date: 14 May 2020 Calibration Interval: One year

Tested By :

M E T E O R O L O G I C A L I N S T R U M E N T S Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com ISO 9001:2008 CERTIFIED

Pagel of 1

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18.	18	19		68
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Warren-Knight Instrument Company 2045 Bennett Road

Philadelphia, PA 19116 Phone: 215-464-9300; Fax: 215-464-9303

Web: http://www.warrenind.com

Calibra	ation Da	ta Record			and the second second	Temperatu	Temperature: 70 Humidity: 39%		
Custon	ner Nam	ie	F	FEXMS	Item Name	USHI	KATA		
Manuf	acturer		F		Model	5-2.	5		
Serial I	Number		1	1918.32	Calibration Date	3-7-	20		
Calibra	tion Fre	quency			Job Card Number	8-26	704		
Custon	ner Refe	rence Num	iber		Date of Certificat	ion 3-2-	20)		
Measure	ment Stan	dards	~						
Theodo	lite Wild	T-3 S/N 18	801 Calib	ration 01/17/2020 Du	e 01/17/2021 NIST Nur	nber 738/229329-83	738/223398		
Optical	Wedge	(&E 71-702	0 S/N 516	7 Calibration; 01/16/20	019 Due 01/16/2024, N	IST Number 731/244	084-89 731/221	617	
Initial Re	port					Direction	Tojecance	Compass Needle Error	
Vanes						(Degree)	(Minute)	(Minute)	
Pivot in	line with	h Circle/Sigh	nts	D Pass	s 🗆 Fail	0	+/- 30		
Needle						45	+/- 30		
Pivot Sh	harpness			D Pass	Fail	90	+/- 30		
Straight	tness (+/	-15 Minutes	5)	D Pass	Fail	135	+/- 30		
Balance	•			Pass	; 🗌 Fail	150	+/- 30		
Lifter Fu	unction			Pass	Fail	225	+/- 30		
Azimuth	Ring					270	+/- 30		
Control	Knob Fu	Inction		Pass	Fail	315	+/- 30		
Pinion (Gear			D Pass	; 🗆 Fall				
Gradua	tion Clar	ity		Pass	Fail				
Gradua	tion less	than 1 minu	ite in any	position Pass	; 🗋 Fail				
Level Bub	ble								
Bubble	in Level			Pass	Fail				
Physica	I Conditio	on		Pass	🗌 Fail				
Pass/Rep	air/Replac	e Destature	0						
Pass	N/A	Replace	Repair		- Managetter				
2				Needle D Sharpen	i 🗆 Magnetize				
				Cap with Jewel					
H				Pivot 🗆 Snarpen					
	E			Level C Remount					
				North Sight		1			
				North Sight Block					
				South Sight Block					
				South Signt Block					
E				Varie Spring					
1			П	Control Kooh Assen	shiv				
Ē			П	Coupr Glass	ion i				
			Ē	Cover Glass Gasket					
		Π	Π	Clamp Screw					
				Pinion Gear		- 0.01			
			D	Compass Ring					
Final Rep	ort								
Vanes						Direction	Tolerance (Minute)	Compass Neeple Error (Minute)	
Pivot in	line with	Circle/Sich	ts	P Pace	D Fail	0	+/- 30	(30	
Needle	THIR WILL	circle/sign	123	1 20 1 033	Lever 1 Mill	45	+/- 30	1230	
Pivot Sh	arnness			D Pass	🗆 Fail	90	+/- 30	130	
Straight	nere (1)	15 Minuter	1	12/000	T Fail	135	+/- 30	230	
aslass	11035 [+/	TO MULTURES	1	La Phase	T Fall	180	+/- 30	GED	
Dalance	in attract			Let ass		225	+/- 30	1 270	
utter FL	inction			Lar Pass		220	4/ 20	220	
Azimuth	Rung	a attent		1 mh	TI sail	315	+(-30	30	
Lontrol	Knob Fu	nction		E Pass			1.20	1 120	
Pinion (rear			Le Pass					
Graduat	tion Clar	itγ		LO Pass					
Gradual	tion less	than 1 minu	ite in any	position Pass				1	
Rubble	in Leval			12 phere	E Fail				
Physics	Conditie	nn	1	P Pace	E Fail				
Certificati	Ion	1	1)	1					
	Del	al. 1	an	Orm			1 1 .	N	
6.1	and the second s	The second second		01		-14.4	11.11	211121	

Van 1

Doc templates 2/wk-40-1360 survey compass calibration record

lage 1 of 1

EEMS # 01265 Van 2

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

Calibra	tion Dat	a Record					Temperature: 10 Humidity: 34 10			
Custom	her Name	e	1	56×14	5	Item Name	USHI	USHIKATA		
Manufa	acturer					Model	5-25			
Serial N	lumber			19003	7	Calibration Date	13-2-	20	6	
Calibra	tion Freq	luency	-			Job Card Number	5-26	703	1	
Custom	ner Refer	ence Numl	per			Date of Certification	3-7-2	.0 /		
Measurer	ment Stand	ards						20/222200		
Theodo	lite Wild	T-3 S/N 188	01 Calib	pration 01/17/2	2020 Due 0	1/17/2021 NIST Nomber	738/229329-83 7	38/223398		
Optical	Wedge K	&E 71-7020	S/N 516	7 Calibration; 0	1/16/2019	3 Due 01/16/2024, NIST I	Number 731/2440	84-89 /31/22161/		
Initial Rep	port						Direction	Tolerance	Compass Needle Error	
Vanes							(Degree)	(Minute)	(Minute)	
Pivot in	line with	Circle/Sight	ts		Pass [Fail	0	+/- 30		
Needle							45	+/- 30		
Pivot Sh	arpness				Pass [] Fail	90	+/- 30		
Straight	ness (+/-	15 Minutes	ľ.		Pass [] Fail	135	+/- 30		
Balance					Pass D] Fail	180	+/- 30		
ifter Fr	Inction				Pass [] Fail	225	+/- 30		
Azimush s	Ring						270	+/- 30		
Control	Knoh Fur	nction			Pass [] Fail	315	+/- 30		
Dinion G	Sear				Pass F] Fail	-	and a second	Record and the second	
Graduat	tion Clarit	NV .			Pass [] Fail		111		
Graduation less than 1 minute in any position			Pass I] Fail						
evel Buh	ble	and a marite	is many	Provinsell						
Bubble i	in Level				Pass D] Fail				
Physical	Conditio	n			Pass [] Fail				
Pass/Repi	air/Replace									
Pass	N/A	Replace	Repair	-						
				Needle 🗆	Sharpen t	Magnetize				
				Cap with Je	wel					
				Pivot 🗆 Sha	arpen					
				Level 🗆 Re	mount					
				North Sight	_					
				North Sight	Block					
				South Sight						
				South Sight	Block					
				Vane Spring	3					
				Drive						
				Control Kno	b Assemb	Y				
				Cover Glass						
				Cover Glass	Gasket					
				Clamp Screy	W					
				Pinion Gear						
				Compass Ri	ng					
Final Rep	ort						Direction	Toletance	Compass Needle Error	
vanes					1		(Degree)	(Minute)	(Minute)	
Pivot in	line with	Circle/Sight	ts		Pass [] Fail	0	+/- 30	5.30	
Veedle					1		45	+/- 30	\$20	
Pivot Sh	arpness				Pass [Fall	90	+/- 30	30	
Straight	ness (+/-	15 Minutes)		Pass [] Fail	135	+/- 30	530	
Balance	1				Pass [] Fail	180	+/- 30	\$30	
lifter Fr	inction				D Pass I] Fail	225	+/- 30	630	
Azimuth	Ring						270	+/- 30	5.70	
Control	Knhh Eu	oction			12 Pass 1	Fail	315	+/- 30	530	
Dinion	Sear	in com			the pace I	T Fail				
Gradue	tion Class	tu l			M Pace I] Fail				
Gradual	tion lass	than 1 minu	to in one	position	TA Pace T	T Fail				
SUDE TO	aon less l	man i minu	ice istenty	position	Mar 1 033 L	2 · en				
Bubble	in Level			_	D Pass [Fail				
Physica	Conditio	n	1		Pass [Fail				
Certificat	ion	1 /1	1	- 15				1		
10	rep	, Tao	lon	si				All M		
			V			John Maga Duality	Assurance	In n	44	

Doc templates 2/wk-40-1360 survey compass calibration record

Page lof 1

Philadelphia, Phone: 215-4	PA 19116 64-9300; F	ax: 215-4	64-9303	L	Jan =	3	
Web: http://ww	ww.warrenii	nd.com				700	1. 29 dy
Calibration Data Rec	ord	220	110	I tam Nama	1 emperature	LATA	numiany: 3/ 10
Lustomer Name		EF K/	P	Model	1.5 12	Ann	
Serial Number		1995	78	Calibration Date	3-2	7A	
Calibration Frequenc	v	1151	10	Job Card Number	15-22	170%	
Customer Reference	Number			Date of Certification	3-2-1	20)	
Measurement Standards	1				12		
Theodolite Wild T-3 S/	N 18801 Cali	bration 01/1	7/2020 Due	01/17/2021 NIST Number	738/229329-83	7 38/223 398	
Optical Wedge K&E 71	-7020 S/N 51	67 Calibration	n; 01/16/201	19 Due 01/16/2024, NIST N	lumber 731/2440	084-89 731/22161	/
Vanes					Direction	Tolerance	Compass Needie Erro
Volies	The second second		10-		(Degree)	(Minute)	(Minute)
Pivot in line with Circle	/Sights		LI Pass	LI Fail	45	+/-30	
Needle Divot Sharanass			D Pace	D Fail	90	+/- 30	
Straightness (+/ 1E Mil	nutes)		C Pass	Fail	135	+/- 30	
Balance	10(03)		D Pass	D Fail	180	+/- 30	
Lifter Function			D Pass	Fail	225	+/- 30	
Azimuth Ring			- 1035		270	+/- 30	1
Control Knob Function			D Pass	🗋 Fail	315	- +/- 30	
Pinion Gear			Pass	🗌 Fail			
Graduation Clarity			Pass	🗆 Fail			
Graduation less than 1	minute in an	y position	D Pass	🗌 Fail			
Level Bubble			Date	C Fail			
Physical Condition			Pace	🗌 Fail			
Pass/Repair/Replace			1 - 1 033				
Pass N/A Repl	ace Repair						
		Needle	⊇ Sharpen	Magnetize			
		Cap with	Jewel				
		Pivot D	Sharpen				
		Level D	Remount				
		North Si	ght Block				
		North Sig	ant BIOCK				
		South Sie	tht Block				
		Vane Spr	ning				
		Drive					
		Control	Knob Assemb	ply:			
		Cover Gl	325				
		Cover GI	ass Gasket				
		Pinion G	Par				
		Compass	Ring				
Final Report		d second sec					
Vanes			/		(Degree)	(Minute)	Compass Needle Error (Minute)
Pivot in line with Circle	/Sights		Pass	🗆 Fail	0	+/- 30	230
Needle			. 1/2		45	+/- 30	530
Pivot Sharpness			Pass Pass	🗆 Fail	90	+/- 30	530
Straightness (+/-15 Min	nutes)		D Pass	🗆 Fail	135	+/- 30	5.30
Balance			Pass	🗆 Fail	180	+/- 30	130
Lifter Function			Pass	L Fail	225	+/- 30	130
Azimuth Ring			TEL		270	+/- 30	2217
Control Knob Function			the Pass		212	77-30	170
Pinion Gear			W Pass				
Graduation Clarity	minuto In an	nosition	TP Pass				
Graduation less than 1	minute in an	y position	1 mass				
Bubble in Level			Pass	🗋 Fail			
Physical Condition	1 .		Pass	🗋 Fall			
Certification	1.1.					4	9
tought	allog	ze				A. A. M	

Doc templates 2/wk-40-1360 survey compass calibration record

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Issue Date: 02/04/20		
Customer: ENVIRONMENTAL ENGINEERING & MEASUREMENT 4577 E NW 6TH STREET GAINESVILLE, FL 36209 352-262-0802	SERVICES P.O. Number: ID Number: 013	EEMS 10 Van-1
	Catibration Date:	02/04/2020
Description. DIGITAL MOLTIMETER	Calibration Due:	02/04/2021
Manufacturer: FLUKE	Procedure:	METCAL FLUKE 187
Model Number: 187	r rooddire.	Rev: 6/15/2015
Serial Number: 86590148	Temperature:	73 °F
	Humidity:	40 % RH
Technician: KENNETH PEEK	As Found Conditi	on:IN TOLERANCE
On-Site Calibration:	Calibration Result	ts: IN TOLERANCE
Comments:		

Limiting Attribute:

Certificate Number

A3488979

This instrument has been calibrated using standards traceable to the SI units through the National Institute of Standards and Technology (NIST) or other National Metrological Institute (NMI). The method of calibration is direct comparison to a known standard, derived from natural physical constants, ratio measurements or compared to consensus standards.

Reported uncertainties are expressed as expanded uncertainty values at an approximately 95% confidence level using a coverage factor of k=2. 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 17025:2017 and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is written in a language relevant to laboratory operations, meeting the principles of ISO 9001 and aligned with its pertinent requirements. This calibration complies with all the requirements of ANSI/NCSL Z540-1-1994 and TMI's Quality Manual, QM-1.

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

This certificate shall not be reproduced, except in full, without the written permission of Technical Maintenance, Inc.

Measurements not currently on TMI's Scope of Accreditation are identified with an asterisk.

WALLY GYNN, BRANCH MANAGER

Srott Chambalain

Scott Chamberlain, QUALITY MANAGER

	Calibra	tion Standarus		
Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
7040208	FLUKE	5520A	5/2/2019	5/2/2020



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

Page 1 of 5

Certificate Number A3479890 ssue Date: 01/28/20

Certificate of Calibration

Page 1 of

15500 Date. 01/20/20	
Customer: ENVIRONMENTAL ENGINEERING & MEASUREME	ENT SERVICES Van - 2
4577 E NW 6TH STREET	P.O. Number:
GAINESVILLE EL 36209	
052 062 0802	ID Number FEMS 01212
352-262-0602	
Description: DIGITAL MULTIMETER	Calibration Date: 01/28/2020
Manufacturer: FLUKE	Calibration Due: 01/28/2021
Model Number: 287	Procedure: METCAL FLUKE 287 Rev: 6/15/2015
Serial Number: 95740243	Temperature: 73 °F
	Humidity: 39 % RH
Technician: KENNETH PEER	As Found Condition: IN TOLERANCE
On-Site Calibration:	Calibration Results: IN TOLERANCE
Limiting Attribute:	
This instrument has been calibrated using standards traceable to the SI Metrological Institute (NMI). The method of calibration is direct comparis compared to consensus standards.	units through the National Institute of Standards and Technology (NIST) or other National son to a known standard, derived from natural physical constants, ratio measurements or
Reported uncertainties are expressed as expanded uncertainty values a compliance are based on test results falling within specified limits with n	at an approximately 95% confidence level using a coverage factor of k=2. Statements of to reduction by the uncertainty of the measurement.
TMI's Quality System is accredited to ISO/IEC 17025:2017 and ANSI/NO operations, meeting the principles of ISO 9001 and aligned with its pertir 1994 and TMI's Quality Manual, QM-1.	CSL Z540-1-1994. ISO/IEC 17025:2017 is written in a language relevant to laboratory inent requirements. This calibration complies with all the requirements of ANSI/NCSL Z540-1
Results contained in this document relate only to the item calibrated. Ca administrative purposes and do not imply continued conformance to spe	alibration due dates appearing on the certificate or label are determined by the client for ecifications.
This certificate shall not be reproduced, except in full, without the written	n permission of Technical Maintenance, Inc.
Measurements not currently on TMI's Scope of Accreditation are identified	ied with an asterisk.
and the	Scott Chambarlan
WALLY GYNN, BRANCH MANAGER	Scott Chamberlain, QUALITY MANAGER
Calibration	Standards

Asset Number	Manufacturer	Model Number	Date Calibrated	Cal Due
7040208	FLUKE	5520A	5/2/2019	5/2/2020



Technical Maintenance, Inc.

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Certificate Number A3479886 Issue Date: 01/28/20

Certificate of Calibration

omer: ENVIRONMENTAL	ENGINEERING & MEASURE	MENT SERVICES	V	an-3
4577 E NW 6TH S	TREET	P.O. Number:		
GAINESVILLE, FL	36209		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
352-262-0802		ID Number:	EEMS 01311	
Description: DIGITA	AL MULTIMETER	Calibration D	ate: 01/28/2020	
Manufacturer: FLUKE		Calibration D	ue: 01/28/2021	1
Model Number: 287		Procedure:	METCAL F	LUKE 287
Sarial Number: 05740	125	Temperature	73 °F	.015
Senai Number: 95740	155	Humidity:	39 % RH	1
Technician: KENN	ETH PEER	As Found C	ondition:IN TOLER	ANCE
On-Site Calibration:	1	Calibration	Results: IN TOLER	ANCE
compared to consensus stan	dards.			
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accre operations, meeting the princ 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re-	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the write and the state of the sta	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL Z540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com Calibration due dates appearing on the ce specifications.	I using a coverage factor of asurement. is written in a language rel plies with all the requireme rtificate or label are determ	f k=2. Statements of evant to laboratory nts of ANSI/NCSL Z54 ined by the client for
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accre operations, meeting the princ 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re Measurements not currently	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the writh on TMI's Scope of Accreditation are ide	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL Z540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com Calibration due dates appearing on the ce specifications. itten permission of Technical Maintenance, I ntified with an asterisk.	I using a coverage factor of asurement. is written in a language rel plies with all the requireme rtificate or label are determ Inc.	f k=2. Statements of evant to laboratory nts of ANSI/NCSL 254 ined by the client for
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accre- operations, meeting the prince 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re- Measurements not currently	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the writh on TMI's Scope of Accreditation are ide	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL 2540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com Calibration due dates appearing on the ce specifications. itten permission of Technical Maintenance, I ntified with an asterisk.	I using a coverage factor of asurement. is written in a language rel plies with all the requirement rtificate or label are determ Inc.	f k=2. Statements of evant to laboratory nts of ANSI/NCSL 254 ined by the client for
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accrr operations, meeting the princ 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re Measurements not currently	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the write on TMI's Scope of Accreditation are ide U.BRANCH MANAGER	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL Z540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com . Calibration due dates appearing on the ce specifications. itten permission of Technical Maintenance, I ntified with an asterisk.	I using a coverage factor of asurement. is written in a language rel plies with all the requireme rtificate or label are determ Inc.	f k=2. Statements of evant to laboratory nts of ANSI/NCSL Z52 ined by the client for
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accrr operations, meeting the princ 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re Measurements not currently WALLY GYNN	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the write on TMI's Scope of Accreditation are ide I, BRANCH MANAGER Calibrati	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL Z540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com . Calibration due dates appearing on the ce specifications. itten permission of Technical Maintenance, I ntified with an asterisk. Scott Char on Standards	I using a coverage factor of asurement. is written in a language rel plies with all the requirement ntificate or label are determ Inc.	f k=2. Statements of evant to laboratory nts of ANSI/NCSL 254 ined by the client for
compared to consensus stan Reported uncertainties are ex- compliance are based on tes TMI's Quality System is accrr 1994 and TMI's Quality Manu Results contained in this doc administrative purposes and This certificate shall not be re Measurements not currently WALLY GYNN Asset Number	dards. xpressed as expanded uncertainty value it results falling within specified limits with edited to ISO/IEC 17025:2017 and ANS ciples of ISO 9001 and aligned with its p ual, QM-1. cument relate only to the item calibrated. do not imply continued conformance to eproduced, except in full, without the wri- on TMI's Scope of Accreditation are ide I, BRANCH MANAGER <u>Calibrati</u> <u>Manufacturer</u>	es at an approximately 95% confidence leve th no reduction by the uncertainty of the mea I/NCSL Z540-1-1994. ISO/IEC 17025:2017 ertinent requirements. This calibration com . Calibration due dates appearing on the ce specifications. itten permission of Technical Maintenance, I ntified with an asterisk. Scott Char <u>on Standards</u> <u>Model Number</u>	I using a coverage factor of asurement. is written in a language rel plies with all the requireme rtificate or label are determ inc. 	(k=2. Statements of evant to laboratory nts of ANSI/NCSL Z54 ined by the client for MANAGER <u>Cal Due</u>



Technical Maintenance, Inc.

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

		REMEINT SERVICES		
4577 E NW 6TH ST	REET	P.O. Number:	-	
GAINESVILLE, FL	36209	1)
352-262-0802		ID Number:	EEMS 01414	-
Description: PRIMA	RY FLOW CALIBRATOR	Calibration Da	ate: 02/16/202	0
Manufacturer: MESA L	ABORATORIES INC	Calibration D	ie: 02/16/202	1
Model Number: DEFEN	DER 530+ H	Procedure:	TB 9-6680)-293-40 2013
Serial Number: 159956		Temperature	70 °F	2015
		Humidity:	49 % R	н
Technician: KYLEF	10111	As Found Co	ndition: IN TOLER	ANCE
On-Site Calibration:		Calibration F	esults: IN TOLER	ANCE
Limiting Attribute:	prated using standards traceable to he method of calibration is direct co ards.	the SI units through the National Institute of Star mparison to a known standard, derived from na	idards and Technology (N ural physical constants, r	NIST) or other Natic atio measurements
Limiting Attribute: This instrument has been calib Metrological Institute (NMI). The compared to consensus standi Reported uncertainties are exp compliance are based on test in TMI's Quality System is accreated operations, meeting the princip 1994 and TMI's Quality Manual Results contained in this docur administrative purposes and do This certificate shall not be rep	prated using standards traceable to the method of calibration is direct co ards. pressed as expanded uncertainty va results falling within specified limits dited to ISO/IEC 17025:2017 and Al oles of ISO 9001 and aligned with it il, QM-1. ment relate only to the item calibrate o not imply continued conformance produced, except in full, without the	the SI units through the National Institute of Star mparison to a known standard, derived from na lues at an approximately 95% confidence level with no reduction by the uncertainty of the meas NSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is s pertinent requirements. This calibration comp ed. Calibration due dates appearing on the cert to specifications. written permission of Technical Maintenance, In	idards and Technology () ural physical constants, r using a coverage factor of urement. written in a language rel ies with all the requireme ficate or label are determ	VIST) or other Natio atio measurements f k=2. Statements of levant to laboratory nts of ANSI/NCSL ; ined by the client fo
Limiting Attribute:	prated using standards traceable to the method of calibration is direct co ards. pressed as expanded uncertainty va results falling within specified limits dited to ISO/IEC 17025:2017 and Al ples of ISO 9001 and aligned with it al, QM-1. ment relate only to the item calibrate o not imply continued conformance produced, except in full, without the in TMI's Scope of Accreditation are i	the SI units through the National Institute of Star mparison to a known standard, derived from na lues at an approximately 95% confidence level with no reduction by the uncertainty of the meas NSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 i s pertinent requirements. This calibration comp ed. Calibration due dates appearing on the cert to specifications. written permission of Technical Maintenance, In dentified with an asterisk.	Idards and Technology (N ural physical constants, r using a coverage factor of urement. written in a language rel ies with all the requireme ficate or label are determ	NIST) or other Natic atio measurements f k=2. Statements of evant to laboratory nts of ANSI/NCSL ; ined by the client fo
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Technical Maintenance, Inc.

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Page 2 of 2

ANSI/NCSL Z540-1-1994

Data Sheet

Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
5.0000	4.9500	5.0500	5.0123	5.0123	slm	
10.000	9.900	10.100	10.038	10.038	slm	
15.000	14.850	15.150	15.045	15.045	slm	
20.000	19.800	20.200	20.064	20.064	sim	
25.000	24.750	25.250	25.082	25.082	slm	
30.000	29.700	30.300	30.109	30,109	sim	

EEMS# 01414

m=	1.0036251	
6 -	-0.00507	(L Pm)
rt =	0.99999	
Ø	2/25/2020	



Certificate Number

A3506546

Issue Date: 02/16/20

Parameter

Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy

Technical Maintenance, Inc.

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Rev. 13 8/17/2018

4577 E NW 6TH ST		CEMENT DERVICED		C
	TREET	P.O. Number:		
GAINESVILLE, FL	36209)
352-262-0802		ID Number	EEMS 01416	
Description: PRIMA	RY FLOW CALIBRATOR	Calibration	Date: (05/06/202	0)
Manufacturer: BIOS II	NTERNATIONAL CORP.	Calibration	Due: 05/06/202	1
Andel Number: DEEIN	ER 220-H	Procedure:	TB 9-6680)-293-40
Nodel Number, DEI IN	A	-	Rev: 2/20/	2013
Serial Number: 122974	4	Humidity	e: 70 °F 49 %R	н
Fechnician: SEAN	LEWIS	As Found	Condition: IN TOLER	ANCE
On-Site Calibration:]	Calibration	Results: IN TOLER	RANCE
Comments: Standard (Conditions of 14.7 psia / 25	°C		
imiting Attribute:				
This instrument has been cali	ibrated using standards traceable to t	he SI units through the National Institute of S	tandards and Technology (I	NIST) or other Natio
		mpanson to a known standard, derived from	natural physical constants, r	atio measurements
compared to consensus stand Reported uncertainties are ex compliance are based on test	dards. pressed as expanded uncertainty va t results falling within specified limits	lues at an approximately 95% confidence lev	natural physical constants, r el using a coverage factor o rasurement.	atio measurements
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compared to consensus stand Reported uncertainties are ex- compliance are based on test fMI's Quality System is accre- operations, meeting the princi 1994 and TMI's Quality Manua Results contained in this docu administrative purposes and of This certificate shall not be re Measurements not currently of WALLY GYNN, <u>Asset Number</u> FL2146 FL7536	dards. corressed as expanded uncertainty values results falling within specified limits edited to ISO/IEC 17025:2017 and AN iples of ISO 9001 and aligned with its ial, QM-1. ument relate only to the item calibrate do not imply continued conformance eproduced, except in full, without the value on TMI's Scope of Accreditation are in Manufacturer FLUKE FLUKE	Iues at an approximately 95% confidence lev with no reduction by the uncertainty of the me NSI/NCSL Z540-1-1994. ISO/IEC 17025:201 s pertinent requirements. This calibration cor ed. Calibration due dates appearing on the c to specifications. written permission of Technical Maintenance, dentified with an asterisk. <u>Model Number MOLBOX1+A700-A</u> 3E4-VCR-V-Q	natural physical constants, r el using a coverage factor o pasurement. 7 is written in a language rei nplies with all the requireme ertificate or label are determ Inc. March Chambe amberlain, QUALITY <u>Date Calibrated</u> 7/3/2018 6/22/2018	to measurements f k=2. Statements levant to laboratory ints of ANSI/NCSL ined by the client for MANAGER <u>Cal Due</u> 7/3/2020 6/22/2020



Technical Maintenance, Inc.

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Data Sheet

Page 2 of 2

Parameter

Issue Date: 05/06/20

Certificate Number

A3598861

Flow Measurement Accuracy Flow Measurement Accuracy

As Found As Left Unit ADJ/FAIL Minimum Maximum Nominal 0.5005 0.4955 0.5055 0.4983 0.4983 slm 6.061 6.009 6.009 slm 5.941 6.001 11.879 12.119 12.030 12,030 sim 11.999 18,180 18.021 18.021 slm 18,000 17.820 24.031 24.007 23.767 24.247 24.031 slm 30.002 29.702 30.302 29.945 29.945 slm

$$m = 0.9988443$$

$$b = 0.021567 \quad (SIPm)$$

$$F^2 = 0.99999$$

Use Raw (un corrected) Readings (GD) 5/15/20

ANSI/NCSL Z540-1-1994

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Rev. 13 8/17/2018

	T.O. Number.)
-262-0802	ID Number: E	EMS 01417	
otion: PRIMARY FLOW CALIBRATOR	Calibration Date	: 02/16/202	0
acturer: BIOS INTERNATIONAL CORP.	Calibration Due:	02/16/202	1
Number: DEFINER 220-H	Procedure:	TB 9-6680	2013
Number: 131818	Temperature:	70 °F	2010
	Humidity:	49 % R	н
Sian: KYLE HUITT	As Found Cond	dition: OUT OF 1	OLERANCE
e Calibration:	Calibration Res	sults: LIMITED	CALIBRATION
ents: Sensor Factor received at 1.000. Adjusted to 0.9	980. Unit calibrated to a Stand	lard Temperature	e of 25°C.
a Attribute: UNIT IS NOT CALIBRATED GREATER T	HAN 25 SLPM.		_
ality System is accredited to ISO/IEC 17025:2017 and ANSI/NCSL 25 is, meeting the principles of ISO 9001 and aligned with its pertinent re I TMI's Quality Manual, QM-1. contained in this document relate only to the item calibrated. Calibratia ative purposes and do not imply continued conformance to specificati ificate shall not be reproduced, except in full, without the written perm ments not currently on TMI's Scope of Accreditation are identified with	540-1-1994. ISO/IEC 17025:2017 is wire equirements. This calibration complies on due dates appearing on the certifica- ions. ission of Technical Maintenance, Inc. n an asterisk.	itten in a language re with all the requireme te or label are determ	evant to laboratory nts of ANSI/NCSL 25 ined by the client for
The second secon	Siot	Chambe	nat
WALLY GYNN, BRANCH MANAGER	Scott Chamb	erlain, QUALITY	MANAGER
Calibration	Standards		
	Andel Number Da	te Calibrated	
t Number Manufacturer M L2146 FLUKE MC	DLBOX1+A700-A	7/3/2018	<u>Cal Due</u> 7/3/2020
ality System is accredited to ISO/IEC 17025:2017 is, meeting the principles of ISO 9001 and aligned I TMI's Quality Manual, QM-1. contained in this document relate only to the item crative purposes and do not imply continued conformificate shall not be reproduced, except in full, witho ments not currently on TMI's Scope of Accreditatio	and ANSI/NCSL Z with its pertinent re alibrated. Calibrati nance to specificat ut the written perm n are identified with	and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is wr with its pertinent requirements. This calibration complies alibrated. Calibration due dates appearing on the certifica nance to specifications. ut the written permission of Technical Maintenance, Inc. n are identified with an asterisk.	and ANSI/NCSL Z540-1-1994. ISO/IEC 17025:2017 is written in a language rel with its pertinent requirements. This calibration complies with all the requirement alibrated. Calibration due dates appearing on the certificate or label are determ nance to specifications. ut the written permission of Technical Maintenance, Inc. n are identified with an asterisk.

Certificate Number A3508402 Issue Date: 02/17/20

Certificate of Calibration

Data Sheet

Page 2 of 2

Parameter

Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy Flow Accuracy

Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
5.0000	4.9500	5.0500	5.0790	4.9720	sim	А
10.000	9.900	10.100	10.171	9.951	slm	A
15.000	14.850	15.150	15.326	14.992	sim	A
20.000	19.800	20.200	20.568	20.083	sim	A
25.000	24.750	25.250	25.533	24.914	sim	A
30.000	29.700	30,300	24.448	24.467	slm	L

EEMS # 01417

m =	1.00032	
5 =	-0.0224	(Lpm)
r2 =	0.99997	

a 2/25/20



Technical Maintenance, Inc.

Rev. 13 8/17/2018

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er: ENVIRONMENTAL	ENGINEERING & MEASU	REMENT SERVICES		
4577 E NW 6TH ST	TREET	P.O. Number:		
GAINESVILLE, FL	36209	(
352-262-0802		ID Number	: EEMS 01421)
Description: PRIMA	RY FLOW CALIBRATOR	Calibration I	Date: 02/16/202	20
Manufacturer: MESA	LABORATORIES INC	Calibration I	Due: 02/16/202	21
Model Number: DEFIN	ER 220-H	Procedure:	TB 9-6680	0-293-40
Serial Number: 14861		Temperatur	Rev: 2/20/	/2013
		Humidity:	49 % R	H
rechnician: KYLE	HUIT	As Found C	Condition: IN TOLER	RANCE
On-Site Calibration:		Calibration	Results: IN TOLER	RANCE
0	1		10580	
Comments: Sensor Fa	ctor received at 1.000. Unit	calibrated to a Standard Temperatu	ure of 25°C.	
Comments: Sensor Fa	ctor received at 1.000. Unit	the SI units through the National Institute of St	ure of 25°C.	NIST) or other Nationa
Comments: Sensor Far Limiting Attribute: This instrument has been calil Metrological Institute (NMI). T compared to consensus stand Reported uncertainties are ex compliance are based on test TMI's Quality System is accre- portations, modified the action	ctor received at 1.000. Unit	calibrated to a Standard Temperatulation of Standard Temperatulation of Standard Temperatulation of Standard, derived from national institute of Standard, derived from national standard, der	tandards and Technology (I hatural physical constants, i el using a coverage factor o rasurement. 7 is written in a language re	NIST) or other Nationa ratio measurements or of k=2. Statements of levant to laboratory
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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 of Calibration

Page 2 of 2

Data Sheet

Parameter	Nominal	Minimum	Maximum	As Found	As Left	Unit	ADJ/FAIL
Flow Accuracy	5.0000	4.9500	5.0500	5.0190	5.0190	sim	
Flow Accuracy	10.000	9.900	10.100	10.026	10.026	sim	
Flow Accuracy	15.000	14.850	15.150	15.040	15.040	slm	
Flow Accuracy	20.000	19.800	20.200	20.095	20.095	sim	
Flow Accuracy	25.000	24.750	25.250	25.106	25.106	slm	
Flow Accuracy	30.000	29.700	30.300	30.135	30,135	sim	

EEMS # 01421

m = 1.0050 b = -0.01733 (Lpm) $r^2 = 0.99999$

Q) 2/25/2020



Certificate Number

A3506549 Issue Date: 02/16/20

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 OF ANALYSIS

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

Van 2

Grade of Product: EPA Protocol

Part Number: Cylinder Number: Laboratory: PGVP Number: Gas Code:

an Air Liquide company

E02AI99E60A003C JB03172 124 - Durham (SAP) - NC B22020 CO,BALA63

Cylinder Volume: Cylinder Pressure: Valve Outlet: Certification Date: Expiration Date: Feb 06, 2028

Reference Number: 122-401714441-1 63.2 CF 2436 PSIG 590 Feb 06, 2020

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

		E	to Not Use This Cylinder below 10	00 psig, i.e. 0.7 megapas	cals.	
Compor	nent	Requested Concentration	ANALYTICAL Actual Concentration	Protocol Method	Total Relative Uncertainty	Assay Dates
CARBON AIR	MONOXIDE	50.00 PPM Balance	51.12 PPM	G1	+/- 0.6% NIST Traceable	02/06/2020
Туре	Lot ID	Cylinder No	CALIBRATION Concentration	STANDARDS	Uncertainty	Expiration Date
NTRM	09010213	KAL004779	98.48 PPM CARBON MO	NOXIDE/NITROGEN	+/- 0.5%	Oct 16, 2024
Instrum	ent/Make/Mode	il.	ANALYTICAL F Analytical Principle	EQUIPMENT	Last Multipoint Calib	ration
Horiba VI	A510 CO 1G46EA	407	Nondispersive Infrared (NE	DIR)	Jan 31, 2020	

Triad Data Available Upon Request PERMANENT NOTES:-NA-

NOTES:RAN TV01202020-B

S/N JB03172

Van 2 High Co



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Page 1 of 122-401714441-1

AITGAS, Air Liquide company				Airgas 525 No Tooele Airgas.o	USA, LLC orth Industrial Loop Road , UT 84074
CE	RTIFICAT	E OF ANA	LYSIS	1	1 2
Gr	ade of Prod	uct: EPA P	rotocol	L	ranc
art Number: ylinder Number: aboratory: GVP Number:	E02AI99E60A001C JB03465 COC 124 - Tooele (SAP) - B72019 CO BALA) F C - UT C V	Reference Number: Cylinder Volume: Cylinder Pressure: /alve Outlet: Certification Date:	153-401569729-1 63.2 CF 2436 PSIG 590 Aug 23, 2019	
Certification performed 600/R-12/531, using the uncertainty as stated below	Exp in accordance with "EPA Trate assay procedures listed. An with a confidence level of 95	iration Date: Au aceability Protocol for Assa alytical Methodology does 5%. There are no significan	ay and Certification of Gased not require correction for an nt impurities which affect the	us Calibration Standards (M alytical interference. This cy use of this calibration mixtu	flay 2012)" document EPA /linder has a total analytical ire. All concentrations are on a
Certification performed 600/R-12/531, using the uncertainty as stated below	Exp in accordance with "EPA Tri- assay procedures listed. An with a confidence level of 9: Do Requested Concentration	iration Date: Au aceability Protocol for Assa halytical Methodology does 5%. There are no significan volume/volume basis Not Use This Cylinder belo ANALYTIC Actuai	ay and Certification of Gaseo not require correction for an nt impurities which affect the s unless otherwise noted. ow 100 psig, i.e. 0.7 megapa CAL RESULTS Protocol Method	us Calibration Standards (N alytical interference. This cy use of this calibration mixtu scals. Total Relative	Aay 2012)" document EPA /linder has a total analytical ire. All concentrations are on a Assay Dates
Certification performed 600/R-12/531, using the uncertainty as stated below Component CARBON MONOXIDE AIR	Exp in accordance with "EPA Tri- assay procedures listed. An with a confidence level of 9: Do Requested Concentration 9.000 PPM Balance	iration Date: Au aceability Protocol for Asse halytical Methodology does 5%. There are no significan volume/volume basis Not Use This Cylinder belo ANALYTIC Actuai Concentration 9.049 PPM	ay and Certification of Gaseo not require correction for an nt impurities which affect the s unless otherwise noted. ow 100 psig, i.e. 0.7 megapa CAL RESULTS Protocol Method G1	ous Calibration Standards (N alytical interference. This cy use of this calibration mixtu scals. Total Relative Uncertainty +/- 0.7% NIST Tracea	May 2012)" document EPA vlinder has a total analytical irre. All concentrations are on a Assay Dates able 08/23/2019
Certification performed 600/R-12/531, using the uncertainty as stated below Component CARBON MONOXIDE AIR Type Lot ID	Exp I in accordance with "EPA Tra- e assay procedures listed. An with a confidence level of 9! Do Requested Concentration 9.000 PPM Balance Cylinder No	iration Date: Au aceability Protocol for Asse halytical Methodology does 5%. There are no significan volume/volume basis Not Use This Cylinder belo AnALYTIC Actuai Concentration 9.049 PPM CALIBRATIO Concentration	ay and Certification of Gaseo not require correction for an nt impurities which affect the s unless otherwise noted. ow 100 psig, i.e. 0.7 megapa CAL RESULTS Protocol Method G1	us Calibration Standards (N alytical interference. This cy use of this calibration mixtu scals. Total Relative Uncertainty +/- 0.7% NIST Tracea	May 2012)" document EPA vlinder has a total analytical ure. All concentrations are on a Assay Dates able 08/23/2019 Expiration Date
Certification performed 600/R-12/531, using the uncertainty as stated below Component CARBON MONOXIDE AIR Type Lot ID NTRM 08011130	Exp I in accordance with "EPA Tr. a assay procedures listed. An with a confidence level of 9: Do Requested Concentration 9.000 PPM Balance Cylinder No KAL004049	iration Date: Au aceability Protocol for Assa halytical Methodology does 5%. There are no significar volume/volume basis Not Use This Cylinder belo Antuai Concentration 9.049 PPM CALIBRATIO Concentration 9.855 PPM CARBON	ay and Certification of Gaseo in the require correction for an int impurities which affect the s unless otherwise noted. ow 100 psig, i.e. 0.7 megapa CAL RESULTS Protocol Method G1 ON STANDARDS	us Calibration Standards (M alytical interference. This cy use of this calibration mixtu scals. Total Relative Uncertainty +/- 0.7% NIST Tracea Uncertainty N 0.5%	Aay 2012)" document EPA /linder has a total analytical ire. All concentrations are on a Assay Dates able 08/23/2019 Expiration Date Jun 05, 2024
Certification performed 600/R-12/531, using the uncertainty as stated below Component CARBON MONOXIDE AIR Type Lot ID NTRM 08011130 Instrument/Make/Mod	Exp I in accordance with "EPA Tr. e assay procedures listed. An with a confidence level of 9 Do Requested Concentration 9.000 PPM Balance Cylinder No KAL004049	iration Date: Au aceability Protocol for Asse- halytical Methodology does 5%. There are no significar volume/volume basis Not Use This Cylinder belo AnALYTIC Actual Concentration 9.049 PPM CALIBRATIO Concentration 9.855 PPM CARBON ANALYTICA Analytical Print	Ig 23, 2027 ay and Certification of Gased not require correction for an nt impurities which affect the s unless otherwise noted. ow 100 psig, i.e. 0.7 megapa CAL RESULTS Protocol Method G1 ON STANDARDS MONOXIDE/NITROGEN L EQUIPMENT ciple	us Calibration Standards (M alytical interference. This cy use of this calibration mixtu scals. Total Relative Uncertainty +/- 0.7% NIST Tracea Uncertainty N 0.5% Last Multipoint Cal	Aay 2012)" document EPA /linder has a total analytical ire. All concentrations are on a Assay Dates able 08/23/2019 Expiration Date Jun 05, 2024



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BLEND BOTTLE VAN 2

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

CERTIFICATE OF ANALYSIS Grade of Product: EPA Protocol

Part Number: Cylinder Number: Laboratory: PGVP Number: Gas Code:

E04NI99E60A001C JB03448 124 - Durham (SAP) - NC B22020 CO,NO,NOX,SO2,BALN

Reference Number: 122-401714440-1A Cylinder Volume: Cylinder Pressure: Valve Outlet: Certification Date: Expiration Date: Feb 25, 2023

62.2 CF 2437 PSIG 660 Feb 25, 2020

Feb 05, 2020

Feb 05, 2020

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

			ANALYTI	CAL RESUL	LTS		
Compo	nent	Requested Concentration	Actual Concentration	Protocol Method	Total Rela Uncertair	ative ity	Assay Dates
NOX NITRIC C SULFUR CARBON NITROGI	DXIDE DIOXIDE MONOXIDE EN	15.00 PPM 14.95 PPM G1 XIDE 15.00 PPM 14.95 PPM G1 DIOXIDE 15.00 PPM 14.88 PPM G1 DIOXIDE 15.00 PPM 14.88 PPM G1 MONOXIDE 3000 PPM 2996 PPM G1 N Balance S1 S1		+/- 1.4% NIST Traceable +/- 1.4% NIST Traceable +/- 0.9% NIST Traceable +/- 1.0% NIST Traceable		02/18/2020, 02/25/202 02/18/2020, 02/25/202 02/18/2020, 02/25/202 02/18/2020, 02/25/202 02/18/2020	
Туре	Lot ID	Cylinder No	CALIBRATIC Concentration	ON STAND	ARDS	Uncertainty	Expiration Date
NTRM PRM GMIS NTRM NTRM The SRM,	12010216 PRM 124206889114 14010338 08012224 PRM or RGM noted a	AAL073584 D562879 CC322698 ND48595 KAL004602 above is only in reference	10.04 PPM NITRI 10.01 PPM NITRI 4.432 PPM NITRI 49.08 PPM SULF 2466 PPM CARB to the GMIS used in the a	IC OXIDE/NITRO OGEN DIOXIDE// OGEN DIOXIDE// UR DIOXIDE/NIT ON MONOXIDE// Issay and not part of	GEN AIR NITROGEN ROGEN NITROGEN f the analysis.	+/- 1.0% +/- 1.9% +/- 2.0% +/- 0.9% +/- 0.5%	Oct 16, 2022 Aug 17, 2018 Aug 15, 2021 Apr 17, 2024 May 09, 2024
Instrum	ent/Make/Mode	r	ANALYTICA Analytical Princ	L EQUIPM	IENT Last	t Multipoint Calib	pration
Nicolet 67 Nicolet 67	700 AHR0801549 (700 AHR0801549 (FTIR		Feb	05, 2020	

Triad Data Available Upon Request

PERMANENT NOTES:-NA-

Nicolet 6700 AHR0801549 NO

Nicolet 6700 AHR0801549 SO2



FTIR

FTIR

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Airgas USA, LLC 525 North Industrial Loop Road Tooele, UT 84074 Airgas.com

CERTIFICATE OF ANALYSIS Grade of Product: EPA Protocol

Van 2

Part Number: Cylinder Number: Laboratory: PGVP Number: Gas Code:

E02AI99E60A000C JB03450 COC 124 - Tooele (SAP) - UT B72019 CO, BALA

Reference Number: 153-401569730-1 Cylinder Volume: Cylinder Pressure: Valve Outlet: Certification Date: Expiration Date: Aug 23, 2027

63.2 CF 2436 PSIG 590 Aug 23, 2019

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

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

Compor	nent	Requested Concentration	ANALYTICAI Actual Concentration	L RESULTS Protocol Method	Total Relative Uncertainty	Assay Dates
CARBON AIR	MONOXIDE	4.000 PPM Balance	3.998 PPM	G1	+/- 1.1% NIST Traceab	le 08/23/2019
Туре	Lot ID	Cylinder No	CALIBRATION Concentration	STANDARDS	Uncertainty	Expiration Date
NTRM	08011130	KAL004049	9.855 PPM CARBON MC	NOXIDE/NITROGEN	0.5%	Jun 05, 2024
Instrum	ent/Make/Mode	el	ANALYTICAL I Analytical Princip	EQUIPMENT le	Last Multipoint Calib	oration
Thermo 4	8i-TLE 11636400	31 CO	CO NDIR (Mason)		Aug 19, 2019	

Triad Data Available Upon Request

PERMANENT NOTES:-NA-



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Page 1 of 153-401569730-1

EPA Protocol Gas Verification Program Date of Assay: 26-Feb-19 **Cylinder under Test:** Scott Marrin **JB03450 Pollutant Gas: Carbon Monoxide** Balance Gas: Air **Cylinder Pressure After Assay:** 850 psig Assayed CO Concentration = 9.384 Vendor Certified CO Concentration = 9.440 % bias = -0.60% 95% uncertainty of analysis = 0.07% **Reference Gas: SRM 1681b** FF20781 Expiration Date: 26-Sep-21

Analytical Facility: EPA Region 7 Ambient Air Standards Laboratory, Kansas City, KS

T. Bui/ L. Sena Analyst:

EPA Protocol Gas Verification Program Date of Assay: 26-Feb-19 **Cylinder under Test:** Scott Marrin JB03465 **Pollutant Gas: Carbon Monoxide** Balance Gas: Air **Cylinder Pressure After Assay:** 525 psig Assayed CO Concentration = 4.509 Vendor Certified CO Concentration = 4.490 % bias = 0.42% 95% uncertainty of analysis = 0.27% Reference Gas: SRM 1680b

Expiration Date:	CAL018075 20-Sep-21
Analyst:	T. Bui/ L. Sena
Analytical Facility:	EPA Region 7 Ambient Air Standards Laboratory,

Kansas City, KS

EPA Proto	col Gas Verif	ication Program
Date of Assay:	5-Mar-19	
Cylinder under Tes	it:	Scott Marrin JB03443
Pollutant Gas:		Carbon Monoxide
Balance Gas:		Air
Cylinder Pressure	After Assay:	1450 psig
Assayed CO Conce	entration =	0.521
Vendor Certified C	O Concentration =	0.502
	% bias =	3.77%
95% uncertainty of	analysis =	0.80%
Reference Gas:	SRM 1680b CAL018075	
Expiration Date:	20-Sep-21	
Analyst:	T. Bui/ L. Sena	
Analytical Facility:	EPA Region 7 Ambie Kansas City, KS	nt Air Standards Laboratory,

EPA Proto	col Gas Verifi	cation Program
Date of Assay:	27-Feb-19	
Cylinder under Tes	st:	Scott Marrin JB03389
Pollutant Gas: Balance Gas: Cylinder Pressure	After Assay:	Carbon Monoxide Nitrogen 1325 psig
Assayed CO Conce	entration =	504.8
Vendor Certified C	O Concentration =	506.0
·	% bias =	-0.24%
95% uncertainty of	f analysis =	0.21%
Reference Gas:	SRM 1680b CAL018075	
Expiration Date:	20-Sep-21	
Analyst:	T. Bui/ L. Sena	
Analytical Facility:	EPA Region 7 Ambier	nt Air Standards Laboratory,

Kansas City, KS

EPA Protocol Gas Verification Program

Date of Assay: 1-Mar-19

Cylinder under Test:

Scott Marrin JB03389

Pollutant Gas: Balance Gas: Cylinder Pressure After Assay: Sulfur Dioxide Nitrogen 1350 psig

Assayed SO2 Concentration =	15.22
Vendor Certified SO2 Concentration =	15.26
% bias =	-0.27%
95% uncertainty of analysis =	0.23%

Reference Gas:	SRM 1693a
	CAL015195
Expiration Date:	22-Mar-19
Analyst:	T. Bui/L. Sena
Analytical Facility:	EPA Region 7 Ambient Air Standards Laboratory, Kansas City, KS

EPA Protocol Gas Verification Program

Date of Assay:	6-Mar-19	
Cylinder under Te	st:	Scott Marrin JB03389
Pollutant Gas: Balance Gas: Cylinder Pressure	After Assay:	Nitric Oxide Nitrogen 1325 psig
Assayed NO Conc	entration =	15.06
Vendor Certified N	IO Concentration =	14.91
	% bias =	0.98%
95% Uncertainty o	f Analysis =	0.38%
Assayed NOx Con	centration =	15.05
Vendor Certified N	Ox Concentration =	14.91
	% bias =	0.91%
95% Uncertainty o	f Analysis =	0.41%
Reference Gas:	SRM 1683b CAL018181 25 Mar 19	
Analyst	T Ruill Sona	
Analytical Facility:	EPA Region 7 Ambier Kansas City, KS	nt Air Standards Laboratory,

FINAL SUMMARY AUDIT REPORT CO BASED EEMS Van-3

Site Name: EPA R-7

Actual NPAP Lab Response Station Response Percent Parameter Difference Pass/Fail Warning (ppm) Difference (ppm) (ppm) Ozone Pre Zero Audit Level 6 N/A Audit Level 4 N/A Audit Level 3 N/A Audit Level 2 N/A Post Zero Carbon Monoxide Pre Zero -0.0046 -0.012 -0.00769 Pass CO Audit level 4 2.5450 2.521 -1.0 -0.02453 Pass CO Audit level 4 1.5369 1.514 -1.5 -0.02343 Pass CO Audit level 3 0.5969 0.587 -1.7 -0.01037 Pass CO Audit level 2 0.1307 0.123 -6.2 -0.00816 Pass CO Audit level 1 0.0402 0.030 -25.4 -0.01021 Pass Post Zero -0.0083 -0.009 -0.00077 Pass Oxides of Nitrogen -0.00013 -0.00020 Pre Zero -0.00007 Pass NO Audit Point #1 0.07420 0.07440 0.3 0.00020 Pass 0.04481 0.04490 NO Audit Point #2 0.2 0.00009 Pass NO Audit Point #3 0.01740 0.01750 0.6 0.00010 Pass NO Audit Point #4 0.00381 0.00390 2.4 0.00009 Pass NO Audit Point #5 0.00117 0.00120 2.6 0.00003 Pass Post Zero -0.00024 -0.00020 0.00004 Pass Pre Zero -0.00014 -0.00020 -0.00006 Pass NOx Audit Point #1 0.07549 0.07420 -1.7 -0.00129 Pass NOx Audit Point #2 0.04559 0.04470 -2.0 -0.00089 Pass NOx Audit Point #3 0.01740 0.01770 -1.7 -0.00030 Pass NOx Audit Point #4 0.00388 0.00380 -2.1 -0.00008 Pass NOx Audit Point #5 -7.6 0.00119 0.00110 -0.00009 Pass Post Zero -0.00025 -0.00020 0.00005 Pass Pre Zero 0.00000 0.00010 0.00010 Pass NO2 Audit level 5 0.04659 0.04570 -1.9 -0.00089 Pass NO2 Audit level 4 0.01775 0.01710 -3.7 -0.00065 Pass NO2 Audit level 2 0.00409 0.00380 -7.1 -0.00029 Pass NO2 Audit level 1 0.00157 0.00130 -17.2 -0.00027 Pass Post Zero 0.00000 -0.00010 -0.00010 Pass Pass Converter Efficiency NO2 level 5 100.9% Converter Efficiency NO2 level 4 101.8% Pass Converter Efficiency NO2 level 2 102.7% Pass Converter Efficiency NO2 level 1 93.2% Fail Converter Efficiency calculated by OAQPS QA Guidance Doc 2.3 February 2002 = 100.7% Pass Sulfur Dioxide Pre Zero -0.00014 0.00008 0.00022 Pass SO2 Audit level 6 0.07688 0.07709 0.3 0.00021 Pass SO2 Audit level 5 0.04643 0.04694 0.00051 1.1 Pass SO2 Audit level 4 0.01849 0.00046 0.01803 2.6 Pass SO2 Audit level 2 0.00395 0.00372 -5.8 -0.00023 Pass SO2 Audit level 1 0.00121 0.00140 15.7 0.00019 Pass Post Zero -0.00025 0.00012 0.00037 Pass

Audit Date: 11/30/2020

FINAL SUMMARY AUDIT REPORT CO BASED EEMS Van-2

Site Name: EPA Region 7					Audit Date:	11/30/2020
Parameter	NPAP Lab Response (ppm)	Station Response (ppm)	Percent Difference	Actual Difference (ppm)	Pass/Fail	Warning
Ozone						
Pre Zero						
Audit Level 6					N/A	
Audit Level 5					N/A	
Audit Level 4					N/A	
Audit Level 3 Post Zero					N/A	
Carbon Monoxide						
Pre Zero	0.0017	-0.018		-0.0193	Pass	
CO Audit level 6	12 8589	12 954	0.7	0.0946	Pass	
CO Audit level 6	8 9173	8 994	0.9	0.0340	Pass	
CO Audit level 5	3 5806	3 616	1.0	0.0354	Pass	
CO Audit level 3	0 7868	0 793	0.8	0.0062	Pass	
CO Audit level 2	011 000	01100	010		N/A	
Post Zero	-0.0017	-0.008		-0.0061	Pass	
Oxides of Nitrogen						
Pre Zero	0.0000	-0.0001		-0.0001	Pass	
NO Audit Point #1	0.0642	0.0639	-0.5	-0.0003	Pass	
NO Audit Point #2	0.0445	0.0444	-0.2	-0.0001	Pass	
NO Audit Point #3	0.0179	0.0175	-2.2	-0.0004	Pass	
NO Audit Point #4	0.0039	0.0037	-5.1	-0.0002	Pass	
NO Audit Point #5					N/A	
Post Zero	0	-0.0002		-0.0002	Pass	
Pre Zero	0 0000	-0.0001		-0.0001	Pass	
NOx Audit Point #1	0.0642	0.0637	-0.8	-0.0005	Pass	
NOx Audit Point #2	0.0042	0.0441	-0.9	-0.0004	Pass	
NOx Audit Point #3	0.0179	0.0174	-2.8	-0.0005	Pass	
NOx Audit Point #4	0.0039	0.0036	-7.7	-0.0003	Pass	
NOx Audit Point #5	0.0000	0.0000	7.7	0.0000	N/A	
Post Zero	0.0000	-0.0002		-0.0002	Pass	
1 00(2010	0.0000	0.0002		0.0002	1 455	
Pre Zero	0.0000	0.0000		0.0000	Pass	
NO2 Audit level 5	0.0441	0.0442	0.2	0.0001	Pass	
NO2 Audit level 4	0.0208	0.0207	-0.5	-0.0001	Pass	
NO2 Audit level 3	0.0057	0.0056	-1.8	-0.0001	Pass	
NO2 Audit level 1	0.0025	0.0024	-4.0	-0.0001	Pass	
Post Zero	0.0000	0.0000		0.0000	Pass	
Converter Efficiency NO2 level 7	100.9%				Pass	
Converter Efficiency NO2 level 6	101.0%				Pass	
Converter Efficiency NO2 level 5	100.0%				Pass	
Converter Efficiency NO2 level 4	100.0%				Pass	
Converter Efficiency calculated b	y OAQPS QA Guidance	Doc 2.3 February 20	02 =	101.0%	Pass	
Sultur Dioxide	0.0000	0.0000		0.0000	Dest	
	0.0000	0.0002	0.7	0.0002	Pass	
	0.0639	0.0644	0.7	0.0005	Pass	
	0.0443	0.0448	1.2	0.0005	Pass	
	0.0178	0.0180	1.1	0.0002	Pass	
	0.0039	0.0037	-5.4	-0.0002	Pass	
SUZ AUGILIEVEL T	0.0000	0.0000		0.0000	N/A	
FUSI 2010	0.0000	0.0002		0.0002	Pass	



Field Scientist Certification

<u>Eric Hebert</u>

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

Office of Air Quality Planning and Standards Research Triangle Park, NC Course Dates: October 2-4, 2019

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



Field Scientist Certification

<u>Korey Devins</u>

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

Office of Air Quality Planning and Standards Research Triangle Park, NC Course Dates: October 2-4, 2019

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



Field Scientist Certification

Martin Valvur

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

Office of Air Quality Planning and Standards Research Triangle Park, NC Course Dates: October 2-4, 2019

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