Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform

Quality Assurance Report

Project Quality Assurance

The project team implemented a comprehensive multi-step quality assurance (QA) process to ensure high quality air quality measurements were collected for robust data analysis. This was comprised of several components, including:

- Pre-and post-study verification and calibration checks, including flow checks,
- Primary ongoing zero and span checks,
- Comparisons of measured values between the Bercut station analyzers and mobile platform analyzers,
- Post-study assessment of AROMA check standard, and
- Assessment of data set completeness

The protocol was mostly consistent with the steps identified in the Standard Operating Procedure (SOP) submitted to the District. However, some of the quality control (QC) check frequencies were reduced to offset real-world challenges encountered during the study, and so that the volume of data collected during the campaign could be maximized. Some of these challenges included significant loss in the measurement campaign window due to adverse weather conditions and instrument issues. Additionally, the final community driving plan was significantly longer than the original plan (179-193 daily miles, as compared to original proposed mileage of 120-150 unique miles). Since the project had the desired objective of completing the entire driving route every day (where possible) for a consistent intercomparison of all community grid cells, the measurement team focused on maximizing data collection in lieu of achieving regulatory-level QA/QC that is typically reserved for regulatory monitoring. Furthermore, the collective multi-phase quantitative and qualitative reviews suggest that there was minimal drift in the mobile platform instruments.

Given that the project was focused on analyzing local pollution enhancements in community zones so statistically significant high pollution zones could be identified, the multi-phase review process provided overall confidence in the data quality for this type of analysis. Moreover, the use of local pollution enhancements will always be relative to the measurement baseline, leading to an analysis of relativity rather than absolutes. As such, the collective qualitative and quantitative approaches, along with the comprehensive bookended reviews in the 45-day study period, ensured that the study collected high quality data for the local pollution enhancement analysis.

Highlights

- The comprehensive data quality evaluation, including (1) pre- and post-study instrument evaluation, (2) daily checks, (3) weekly challenges, and (4) collocation comparison show that instruments performed well and the overall drift in instrument performance was limited.
- Moreover, given that the project focused on local enhancements, a dynamic background level was always subtracted from the measured concentrations.
- This performance review and data application provide confidence that the collected data was suitable for subsequent analysis.

Quality Assurance Process

With consideration to the QA practices described above, the overall validation of routine data relied on weight-of-evidence and compelling evidence approaches[1] for the evaluation of whether the measurements met the intended goals of the project. We have assessed the QA results using a weight-of-evidence approach and have concluded that although some specific elements of the project SOPs did not adhere to the intended frequency or target recovery of the calibration and zero checks, those QA deviations did not harm the attainment of the project goals stated in Section 2.1. In particular, this adjustment of the QA procedures is in accordance with standard mobile air monitoring practices which are designed to collect screening data rather than to ensure that data meet rigorous regulatory compliance standards.

Note that the supporting documentation for the summary data presented in this section is contained in Appendix.

Pre- and Post-Study Instrument Checks

Pre-field mobilization checks as well as post-study checks were conducted on all instruments, including flow checks on the Teledyne T640 and the Magee Aethalometer AE33. Documentation of

[1] Best Practices for Review and Validation of Ambient Air Monitoring Data, US EPA, EPA-454/B-21-007, August 2021.

these checks is included in Appendix, except for NO_2 and O_3, for which the documentation is unavailable.[2] Due to standard practice, all STI-owned instruments are checked for calibration prior to storage in advance of the next use, which constituted the pre-field check. Particulate-based instrument checks are contained in Table 2.

Primary Ongoing Quality Control Checks

Due to the previously noted challenges during the measurement campaign (e.g., weather conditions, instrument issues), QC checks did not entirely adhere to the U.S. Environmental Protection Agency's (EPA) Quality Assurance (QA) Handbook Volume II: Appendix D Validation Template[3] which outlines the Measurement Quality Objectives (MQOs) for all criteria pollutants. For gaseous criteria pollutants (CO, NO_2, and O_3), the U.S. EPA specifies that zero/span and one-point QC checks should be performed once every 14 days. Additionally, U.S. EPA also specifies the acceptance criteria (percent difference) that needs to be met when conducting regulatory monitoring. A brief table of U.S. EPA's MQOs for criteria pollutants is shown in Table 1.

Table 1. The relevant measurement quality objectives for criteria pollutants that were measured during the field campaign.

Parameter	Criteria	Frequency	Acceptance Criteria
Ozone (O_3)	1-point QC check	Every 14 days	< ±7.1% or < ±1.5 ppb, whichever is greater
Nitrogen dioxide (NO_2)	1-point QC check	Every 14 days	< ±15.1% or < ±1.5 ppb, whichever is greater
Carbon monoxide (CO)	1-point QC check	Every 14 days	< ±10.1%
$PM_{2.5}$	1-point flow rate verification	Every 30 days each separated by 14 days	< ±4.1% of transfer standard < ±5.1% of flow rate design value

Although the project SOP specified daily checks, the extenuating circumstances in the field did not allow that to be met to ensure that the project objectives of maximized data collection could be achieved. Table 2 shows the results of the QC checks that occurred during the mobile monitoring campaign. The record shows that all analyzers had multiple checks and zeros throughout the study after the initial pre-field check, including a mid-point and a final point.

[2] The initial NO_x analyzer was taken out of service for repair, so no post-testing check was necessary
[3] QA Handbook Volume II, Appendix D, Rev 1, US EPA, March, 2017

It should be noted that mobile air quality monitoring does not typically adhere to the same strict QA/QC criteria that is needed for regulatory monitoring because mobile monitoring data are frequently used to collect screening data while regulatory monitoring is used in policymaking, state implementation plans, and demonstrations of attainment of the National Ambient Air Quality Standards. Instead, in mobile air quality monitoring, it is typical to perform pre- and post-campaign QC checks to validate data. In this campaign, STI and other field staff attempted to adhere to U.S. EPA's MQOs as closely as possible but did not meet the frequency and/or acceptance criteria on one occasion for NO_2 (frequency criteria was not met between 3/8-3/30), on two occasions for O_3 (frequency criteria was not met between 3/5-3/30; acceptance criteria was not met on 3/4), on numerous occasions for CO which led to its invalidation for the entire campaign, and on one occasion for $PM_{2.5}$ (frequency not met).

It is noteworthy that the CO analyzer consistently had poor performance, as reflected in the relatively high deviations from the gas cylinder standard. It is believed that this is due to the combination of temperature instability in the van, the physical nature of the measurement method (e.g., gas filter correlation), and the effects of movement of the van. Background concentrations of CO were seen to be problematic as well. The net effect of all these issues hindered the ability to consistently assess QC checks. Ultimately, the QA system failed for the CO instrument, resulting in the invalidation of the entire CO dataset including mobile and stationary monitoring. Following the field campaign, no post-checks of the CO monitor occurred to verify the calibration due to the invalidation of the entire dataset.

Secondly, the original NO_x analyzer encountered challenges, with variable output and unstable internal parameters. The NO_x analyzer was replaced on March 7, 2023 with the District's newer instrument. This unit (the District's unit) proved useful and provided valid and consistent data during the period of its use in the mobile campaign. In March 2023, STI staff performed corrective actions and maintenance on its NO_x analyzer (STI's unit) including capillary cleaning and insertion of new parts. Following the conclusion of the mobile campaign, STI returned the District's NO_x analyzer and re-inserted its analyzer following maintenance to be used during stationary monitoring. It was determined that STI's NO_x analyzer performed poorly during the stationary measurements and it was subsequently sent to the manufacturer (Thermo Scientific™) who performed major maintenance on the instrument. Thus, the measurements taken using STI's NO_x analyzer during stationary monitoring were rendered to be of insufficient quality and were invalidated.

In addition, as described in the memorandum in the Appendix, the AROMA instrument was originally calibrated at the Entanglement facility, but the checks performed in the field were performed using an expired gas cylinder standard, though done in a standard run basis, not using the internal calibration check routine. However, it was determined that the expired gas cylinder standard (for benzene) was still within its original specifications, so the field checks remained as valid checks. Other parameters were not checked in the expired gas cylinder standard, but based on the post deployment calibration check of the AROMA instrument, all other parameters passed (Appendix Attachment 4).

Table 2. Periodic Primary Zero and Span Checks

Date	Parameter	Std conc (ppmv)	Std flow (mL/min)	Diluent flow (mL/min)	Final conc (ppmv)	Target	Result	RSD	Bkg	Zero
3/3/2023	CO	14.74	99	9900	0.146	0.15	0.18	21%	0.23	0.4
3/4/2023		14.74	100	4800	0.301	0.301	0.39	26%	0.4	0.1
3/5/2023		14.74	300	10520	0.409	0.590	0.400	47%	-0.5	0
3/6/2023		14.74	100	2500	0.567	0.567	0.511	10%	0.231	0
3/22/2023		14.74	100	10000	0.146	0.146	0.131	11%	-0.455	0
3/30/2023		14.74	100	10000	0.146	0.146	0.160	9%	0.25	0
3/3/2023	NO_2	45.44	100	10000	0.450	100	98	4%		
3/5/2023		45.44	25	9993	0.113	0.113	0.114	1%		
3/6/2023		45.44	9.96	4430	0.102	0.102	0.102	0%		
		Instrument switch occurred (the District's instrument was inserted into the vehicle)								
3/7/2023		45.44	9.96	4430	0.102	0.102	0.105	3%		
3/8/2023						0.102	0.11	7%		
3/30/2023		45.44	9.96	4430	0.102	0.102	0.107	5%		
3/4/2023	O_3	Ozone Generator				100	109	8%		
3/5/2023						200	205	2%		

Date	Parameter	Std conc (ppmv)	Std flow (mL/min)	Diluent flow (mL/min)	Final conc (ppmv)	Target	Result	RSD	Bkg	Zero
3/30/2023						100	107	7%		
3/5/2023	Methane	3.027	2000	0.0000	3.027	3.027	3.3	8.6%	0	
3/30/2023		3.027	2000	0.0000	3.027	3.027	2.5	19.1%	0	
3/9/2023	CO_2	20500	100	10420	194.867	200	203	4.1%		
3/9/2023	Benzene	5.2	100	9900	0.052	0.052	0.05	3.9%	See Attachment 4.	
3/30/2023		5.2	10	1000	0.051	0.051	0.05	2.9%		

Table 3. Pre- and post-campaign flow rate verifications, temperature/pressure checks, and leak checks.

Date	Instrument	Parameter	Unit	Reference	Measurement	Absolute Difference	Percent Difference (%)
2/9/2023	T640	Temperature	°C	19.8	19.2	0.6	-
		Pressure	mmHg	768	766.6	1.4	-
		Leak Check	µg m^{-3}	0	0	0	-
		Flow	lpm	5.03	5.02	.01	-0.2
		PMT	N/A	10.9	10.8	0.1	-
8/24/2023	T640	Temperature	°C	23.8	24.2	0.6	-
		Pressure	mmHg	757.5	755.3	1.4	-
		Leak Check	µg m^{-3}	0	0	0	-
		Flow	lpm	4.97	4.96	.01	-0.2
		PMT	N/A	10.9	10.8	0.1	-
2/8/2023	AE33	Max Flow	lpm	>6.8	6.859	-	-
6/23/2023	AE33	Max Flow	lpm	>6.8	6.891	-	-

As previously mentioned, a post-calibration check was performed by Entanglement on the AROMA-VOC instrument using a different gas cylinder standard. The expired benzene calibration standard was re-analyzed after the end of the study by Entanglement against a new 5% NIST-traceable benzene calibration standard and was found to still be within specifications. Therefore, the in-field quality control checks performed while in standard RapidScan mode (e.g., not using the system cal check option) demonstrated the lack of drift and continuing performance under the original MQO goals. Note that no adjustments to the instrument response factor were made during the field operations. A separate discussion of the re-checks of the expired cylinder against a new calibration standard is contained in Appendix.

Secondary Ongoing Bercut Station to Mobile Platform Comparisons

On a daily basis, the output of the Bercut station analyzers was compared informally to the output of the mobile platform. Table 3 contains the documentation regarding the frequency of both the primary and secondary instrument evaluation criteria. This table shows that the informal semi-quantitative comparison of +/-20% of the Bercut station values was performed daily, with just a few exceptions. This table also includes when the primary quantitative checks were performed, as noted in Table 1.

Table 3. Daily and Periodic Primary and Secondary Instrument QC Checks

Date	Monitoring Day	$PM_{2.5}$	BC	NO_2	O_3	CO	AROMA
Pre-Test		*	*	*	*	*	*
2/16/2023	Yes	ON	ON	ON	ON	ON	
2/17/2023	Yes	ON	ON				
2/18/2023							
2/19/2023	Yes	ON	ON	ON	ON	ON	
2/20/2023	Yes	ON	ON	ON	ON	ON	
2/21/2023	Yes	ON	ON	ON	ON	ON	
2/22/2023	Yes	ON	ON	ON	ON	ON	
2/23/2023							
2/24/2023	Yes	ON	ON	ON	ON	ON	
2/25/2023	Yes	ON	ON	ON	ON	ON	
2/26/2023							
2/27/2023							
2/28/2023							
3/1/2023	Yes	ON		ON	ON	ON	
3/2/2023	Yes	ON	ON	ON	ON	ON	
3/3/2023	Yes			*		*	
3/4/2023	Yes	ON	ON	*	*	ON	
3/5/2023	Yes	ON	ON	ON	*	*	
3/6/2023						*	
3/7/2023	Yes	ON	ON	ON	ON	ON	
3/8/2023	Yes	ON	ON	ON	ON	ON	
3/9/2023	Yes	ON	ON	ON	ON	ON	*
3/10/2023							
3/11/2023							

Date	Monitoring Day	$PM_{2.5}$	BC	NO_2	O_3	CO	AROMA
3/12/2023							
3/13/2023							
3/14/2023							
3/15/2023							
3/16/2023	Yes	ON	ON	ON	ON	ON	
3/17/2023	Yes	ON	ON	ON	ON	ON	
3/18/2023							
3/19/2023							
3/20/2023							
3/21/2023							
3/22/2023						*	
3/23/2023							
3/24/2023							
3/25/2023	Yes	ON	ON	ON	ON	ON	
3/26/2023	Yes	ON	ON	ON	ON	ON	
3/27/2023							
3/28/2023							
3/29/2023							
3/30/2023	Yes	ON	ON	*	ON	*	*
Post-Test		*	*	*		N/A	*
*=Zero and Span Check; Yellow = Zero/cal checks							
ON = Bercut Station comparison							
Blank = Non-monitoring day							
N/A = Not performed due to malfunction							

As the table shows, the semi-quantitative comparison between the mobile and stationary Bercut platforms was performed regularly, confirming that the mobile platform instruments remained in stable operating mode.

Hourly Comparisons--Bercut Station and Mobile Platform

The project team evaluated the performance of NO_2, CO, $PM_{2.5}$, and BC instruments in the mobile monitoring platform by comparing hourly-aggregated measurements against measurements from Sacramento Metropolitan Air Quality Management District's (SMAQMD) Bercut station (AQS ID: 06-067-0015). These evaluations were conducted for all timeframes outside of normal mobile monitoring operations (i.e., 18:00-8:00). In the analysis, outliers outside the 99th percent confidence interval of the van measurements were removed.

Concentrations measured in the van were compared against monitoring data measured by regulatory monitors at the Bercut station. Across all pollutants, slopes ranged from 0.6-1.9. NO_2 concentrations (**Figure 1**) had a robust comparison against the regulatory monitor (slope = 1.1, r^2 = 0.75, p <0.01). CO concentration concentrations measured in the van were statistically significant when compared to the regulatory station (r^2 = 0.35, p <0.01) (**Figure 2**), but van instrument concentrations trended much lower than the stationary monitoring instrument (slope = 0.61). BC measurements (**Figure 13**) in the van measured higher than the stationary monitoring instrument (slope = 1.9, r^2 = 0.73, p <0.01), but this high slope was primarily driven by hourly measurements from February 19-20, 2023, and when BC measurements in the van were high (>3 µg m^{-3}). When these measurements are removed (not shown), the BC measurements compared very well against the SLAMS monitor (slope = 1.1, r^2 = 0.65, p <0.01). $PM_{2.5}$ performance was also within an acceptable range (slope = 1.0, r^2 = 0.76) when the hourly van measurements were compared against the hourly Federal Equivalence Method measurements from the Bercut site (**Figure 4**).

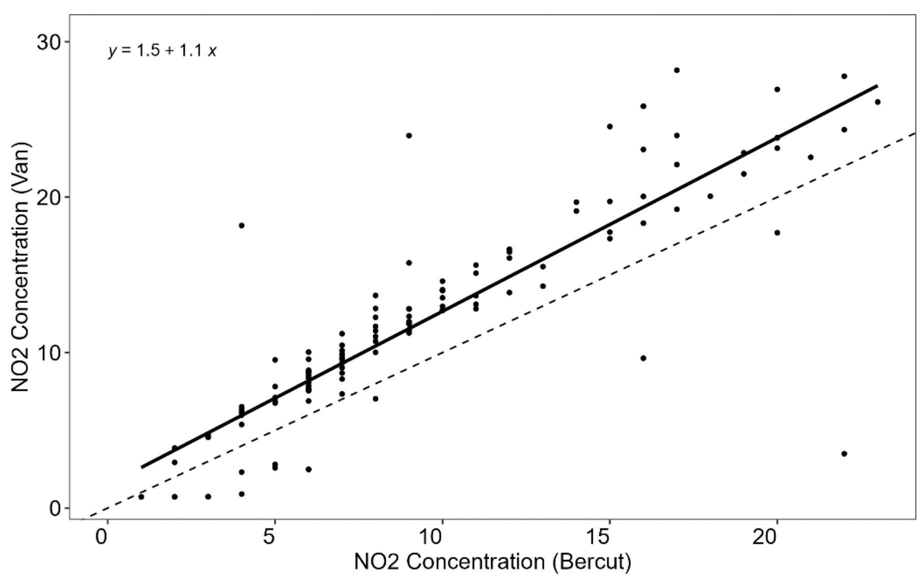


Figure 1. Overnight comparisons of hourly nitrogen dioxide (NO_2) concentrations (ppbv) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

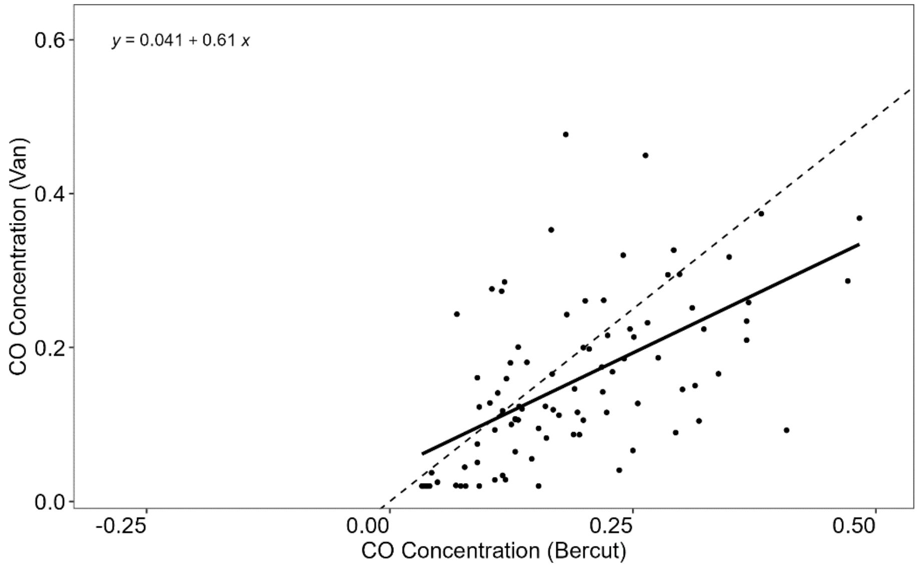


Figure 2. Overnight comparisons of hourly carbon monoxide (CO) concentrations (ppbv) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

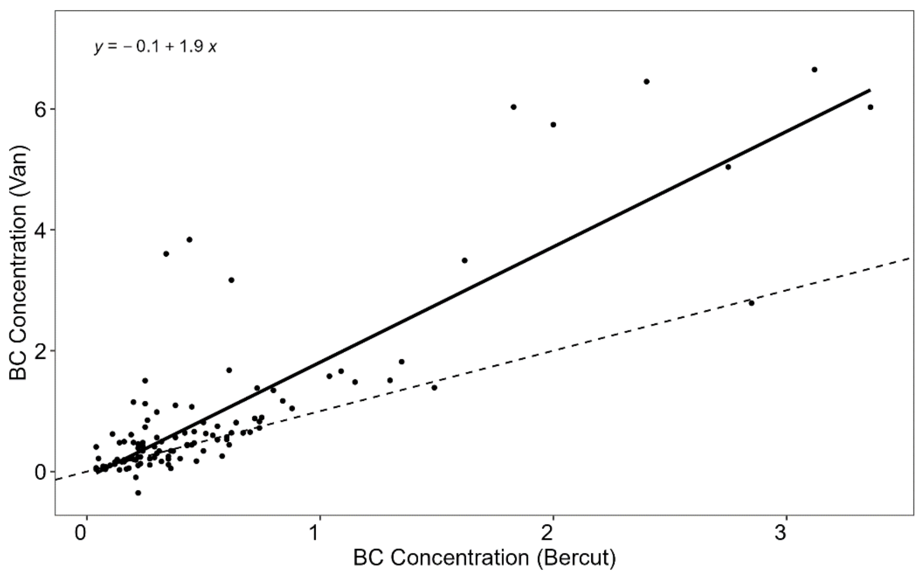


Figure 3. Overnight comparisons of hourly BC concentrations (µg m^{-3}) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

For the period between February 19-20, 2023, the CO analyzer in the mobile monitoring platform had a zero intercept that was set high (+0.4965). Comparisons to the Bercut station during the overnight periods were used to correct data during that timeframe.

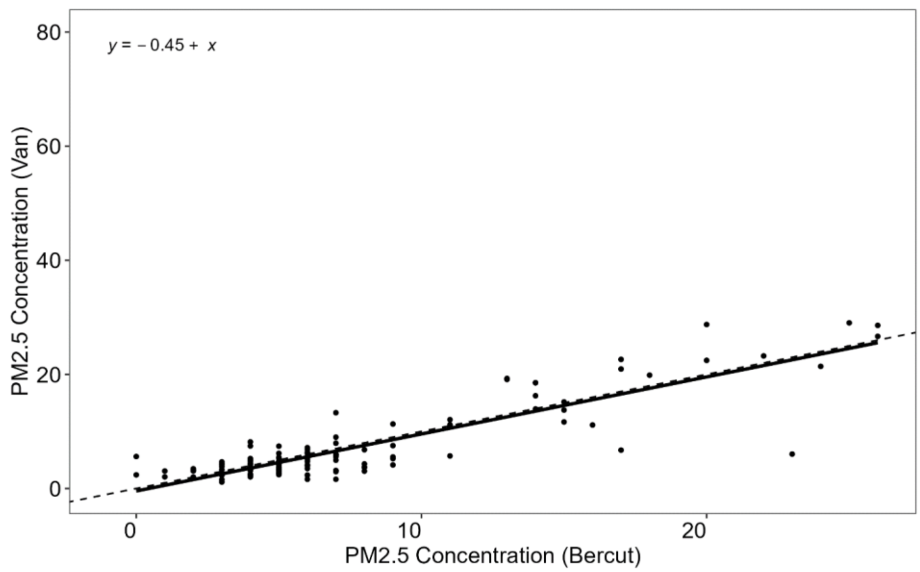


Figure 4. Overnight comparisons of hourly $PM_{2.5}$ concentrations (µg m^{-3}) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

As with the other analyzers, the comparison of the hourly mobile platform with the Bercut station analyzer showed that the data were stable and although not quantitatively in agreement - likely due to the placement of the inlets – the measurements from the van were confirmed to provide a consistent measurement result.

Data Completeness

Table 4 details overall data completeness for each parameter during mobile monitoring. Data collected during stationary monitoring were excluded from the completeness calculation. In general, data completeness was satisfactory, and all but two parameters achieved a valid data percentage greater than 85%. Alkanes had the highest percentage of valid data (98.92%), and CO had the lowest percentage of valid data (46.72%). Because the "IJ" QC flag was determined based on driving speed, the percentage of data flagged as "IJ" was mostly consistent across all parameters. Notable issues encountered throughout data collection that affected overall data completeness are outlined below.

- The Thermo 48i CO analyzer experienced calibration and drift issues throughout data collection, leading to a higher abundance of data missing and flagged as "AN" relative to other parameters. Ultimately, all
- BC has a higher total data count because all other data collected at a 1-sec temporal resolution (CO, NO_2, ozone, $PM_{2.5}$, and PM_{10}) were aggregated to a 1-min and 1-hr temporal resolution by the datalogger on 2/16 and 2/17, and thus were unusable for subsequent

analysis. The 1-sec BC data collected during these days were manually extracted from the Magee AE33 Aethalometer.

- Many diene data points were flagged as "AN" throughout mobile monitoring due to a high number of negative values below the negative MDL (Figure 5).

Table 4. Data completeness during the mobile monitoring data collection period.

Parameter	Total Count[a]	Missing Count (%)[b]	AN Count (%)[c]	MD Count (%)[c]	IJ Count (%)[c]	AM Count (%)[c]	Valid Count (%)[d]
Carbon Monoxide	407,119	64,017 (15.72%)	343,102 (84.28%)	71,171 (17.48%)	4,687 (1.15%)	0 (0.00%)	0 (0%)
Nitrogen Dioxide	407,119	55,843 (13.72%)	8 (0.00%)	16,056 (3.94%)	11,490 (2.82%)	0 (0.00%)	351,268 (86.28%)
Ozone	407,119	55,843 (13.72%)	321 (0.08%)	332 (0.08%)	11,737 (2.88%)	0 (0.00%)	350,955 (86.20%)
$PM_{2.5}$	407,119	55,843 (13.72%)	0 (0.00%)	0 (0.00%)	11,789 (2.90%	40 (0.01%)	351,236 (86.27%)
PM_{10}	407,119	55,843 (13.72%)	0 (0.00%)	0 (0.00%)	11,789 (2.90%	40 (0.01%)	351,236 (86.27%)
Alkanes	71,676	432 (0.60%)	345 (0.48%)	0 (0.00%)	1,956 (2.73%)	0 (0.00%)	70,899 (98.92%)
Aromatics	71,676	911 (1.27%)	2,293 (3.20%)	8 (0.01%)	1,908 (2.66%)	0 (0.00%)	68,472 (95.53%)
Black Carbon	447,801	0 (0.00%)	66,577 (14.87%)	0 (0.00%)	11,789 (2.63%)	0 (0.00%)	381,224 (85.13%)
Dienes	71,676	353 (0.49%)	21,465 (29.95%)	2,941 (4.10%)	1,198 (1.67%)	0 (0.00%)	49,858 (69.56%)
Carbon Dioxide	71,676	6,002 (8.37%)	0 (0.00%)	0 (0.00%)	1,834 (2.56%	0 (0.00%)	65,674 (91.63%)
Methane	71,676	8,214 (11.46%)	0 (0.00%)	0 (0.00%)	1,671 (2.33%)	0 (0.00%)	63,462 (88.54%)

[a] Total data count was calculated by counting the number of data points collected during the daily mobile monitoring period.
[b] Missing data count was calculated by counting the number of data points collected during the daily mobile monitoring period in which the concentration was missing (I.e., null).
[c] Flagged data counts were calculated by counting the number of data points collected during the daily mobile monitoring period that were flagged as "AN", "MD", "IJ", or "AM".
[d] Valid data counts were calculated by subtracting the number of data points flagged as "AN" or "AM" and the number of missing data points from the total data count.

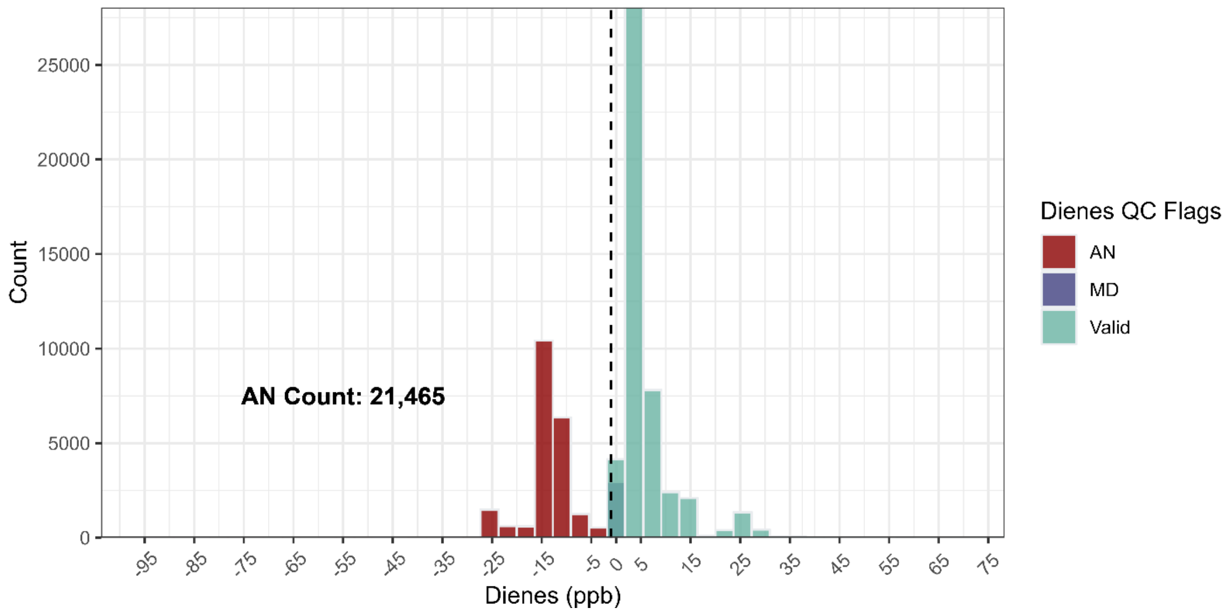


Figure 5. Raw diene concentrations collected during the mobile monitoring data collection period color coded by QC flags. Note: data flagged as "Valid" include data not flagged or flagged as "IJ".

Data Evaluation

An overall assessment of the data collected was performed using two concepts from within EPA QA guidance:[4] 1) Compelling evidence, and 2) weight of evidence. The former is related to the question of whether a set of data can be accepted to meet the specific QC check specifications using other information. Secondly, the weight-of-evidence approach is used for assessing whether a data set can be used for regulatory decisions.

Using the compelling evidence approach, it was determined that while there was an absence of the originally-specified daily data checks, the data should be deemed valid based on the acceptable QC checks that met EPA Appendix D Validation template criteria, the robust correlations with corresponding parameters from the Bercut monitoring station. While the data set was not intended for a specific regulatory action, it was intended to assist in directing other resources (e.g., additional confirmatory monitoring) for determining the local enhancements above background in communities.

Overall, therefore, these assessments provide support for the conclusion that the data set as constituted meets the objectives of the program.

[4] Best Practices for Review and Validation of Ambient Air Monitoring Data, US EPA, EPA-454/B-21-007, August 2021.

Appendix

1. Pre-test Certification for CO Analyzer
2. Pre- and post-test Certification for T640 Analyzer
3. Pre- and post-test Certification for Aethalometer
4. Calibration Report for AROMA

CleanAir

CleanAir Instrument Rental
500 W. Wood Street
Palatine, IL 60067-4975
800-553-5511
www.cleanair.com

Proof of Performance - Page 1 of 2

Instrument:	Teco 48iTLE CO Monitor	Tech Name:	Philip Grajek
Asset No:	210152	Date Generated:	2/6/23

Instrument Parameters

Calibration Range:	0-2 ppm	AGC:	198694 Hz
Averaging Time:	120 Sec.	Multi Point #1:	1.01302
BKG:	0.000	Multi Point #2:	0.21535
COEF:	.995	Multi Point #3:	-0.4598
Bias:	-107 V	Gain:	105
Internal Temperature:	41.0 °C	Voltage Output:	0-10 V
Chamber Temp:	48.1 °C	Current Output:	4-20 mA
Chamber Pressure:	718.9 mmHg	Connector Number 0-10V:	209637
Sample Gas Flow Rate:	.480 L/m	Connector Number 4-20mA	207989
S/R Ratio:	1.163079		

Calibration Results

CH	Step No.	Cylinder ID	Constituent	Target ppm	AVG ppm	Error %
1	1	3377686Y-1021	CO	0.00	0.01	0.25
1	2	SG9108677-1020	CO	1.60	1.57	1.29
1	3	SG9108677-1020	CO	1.00	0.98	0.97
1	4	SG9108677-1020	CO	0.40	0.39	0.64
1	5	3377686Y-1021	CO	0.00	0.00	0.23

Signature: [signature] Date: 12-6-23

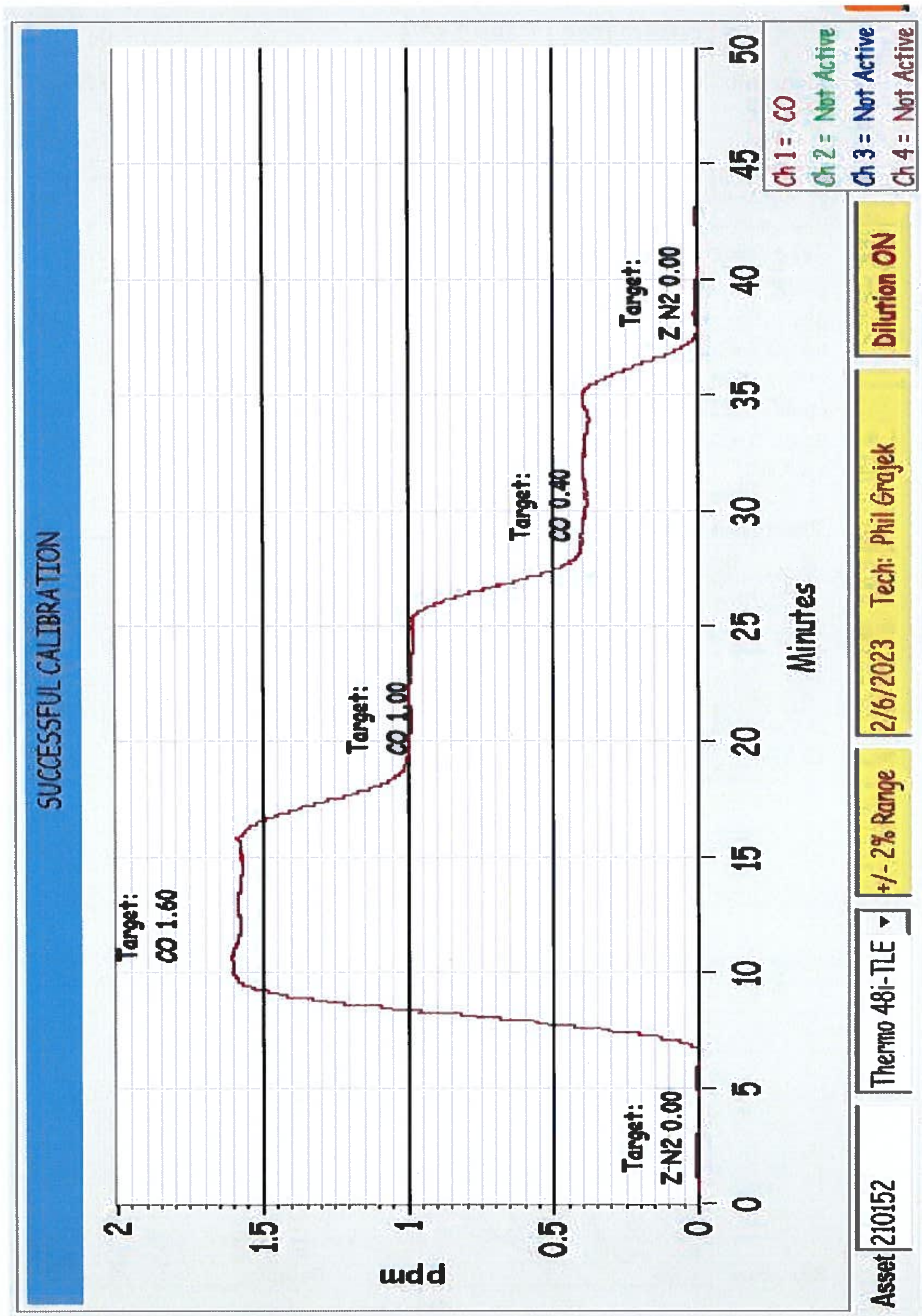
Printed On: 2/6/23

CleanAir.

Proof of Performance - Page 2 of 2

Instrument:	Teco 48iTLE CO Monitor	Tech Name:	Philip Grajek
Asset No:	210152	Date Generated:	2/6/23

Calibration Graph



Instrument	
Tester:	TJJ
Date:	2/9/2023
Make:	Teledyne
Model:	T640
Serial Num:	616

Note: If adjusted values are n/a, it means it passed the test and required no adjustments

Referance	
Make:	BGI Inc
Model:	tetraCal
Serial Num:	300
Cal Date:	n/a

Temperature:		
degrees C	As Found	Adjusted
Ref:	19.8	n/a
Meas:	19.2	n/a
Diff:	0.6	n/a

Allowed: +/- 2 C

Pressure:		
mmHg	As Found	Adjusted
Ref:	768	n/a
Meas:	766.56	n/a
Diff:	1.44	n/a

Allowed: +/- 10 mmHg

Leak Check:	PM10/PM2.5	
ug/cm3	As Found	Adjusted
Exp:	0/0	n/a
Meas:	0/0	n/a

Allowed: <0.2 ug/cm3

Flow:		
LPM	As Found	Adjusted
Ref:	5.03	n/a
Meas:	5.02	n/a
% Diff:	-0.198807	n/a

Allowed: 5% diff

PMT:		
n/a	As Found	Adjusted
Ref:	10.9	n/a
Meas:	10.8	n/a
Diff:	0.1	n/a
Setting (V):	1527	n/a

Allowed: +/- 0.5

Taylor Jones
2/9/2023

Instrument	[illegible]
Tester:	TJJ
Date:	8/24/23
Make:	Teledyne
Model:	T640
Serial Num:	616

Note: If adjusted values are n/a it means it passed the test and required no adjustments

Referance	
Make:	BGI
Model:	tetraCal
Serial Num:	300
Cal Date:	n/a

Temperature:		
degrees C	As Found	Adjusted
Ref:	23.8	n/a
Meas:	24.2	n/a
Diff:	0.4	n/a

Allowed: +/- 2 C

Pressure:		
mmHg	As Found	Adjusted
Ref:	757.5	n/a
Meas:	755.3	n/a
Diff:	2.2	n/a

Allowed: +/- 10 mmHg

Leak Check:	PM10/PM2.5	
ug/cm3	As Found	Adjusted
Exp:	0	n/a
Meas:	0	n/a

Allowed: <0.2 ug/cm3

Flow:		
LPM	As Found	Adjusted
Ref:	4.97	n/a
Meas:	4.96	n/a
% Diff:	0.01	n/a

Allowed: 5% diff

PMT:		
n/a	As Found	Adjusted
Ref:	10.9	n/a
Meas:	10.8	n/a
Diff:	0.1	n/a
Setting (V):	1527	n/a

Allowed: +/- 0.5

Taylor Jones

[signature]

8/24/23

SERVICE ACTIVATION RECORD Aethalometer™ AE33	Serial number: AE33-S02-00045 Operater: STI Calibration flowmeter: **Tetracal SN:** 300	Aerosol

Backup				Checkmark
Backup CF card				X
Save original setup file *(rename to AE_setup.exe and save to root of service USB stick)*				X
Upload basic settings from the USB				X

AE33 System electrical conformity check				
PARAMETER	**VALUE**	**MEASURED**	**CONFORMITY**	**REM.**
PC	5 ± 0.1 V	4.942	✓	
12V	12 ± 0.1 V	12.02		
5	5 ± 0.1 V	4.989		
24V_LD	24 ± 0.25 V	23.94		
5V_LD	5 ± 0.1 V	4.986		
5V_DE	5 ± 0.1 V	4.968		
BAT_CLK	3.3 ± 0.2 V	3.422		
LED check (interconnection board)			Checkmark: ✓	

AE33 System check	Value	Checkmark
Check serial numbers	SN= AE33-S02-0004	✓
Latest Bootloader check	/	✓
Latest Firmware check	/	✓
Latest Software check	/	✓
Check for possible free instrument upgrades;	/	✓
Floating spot sealing plate (FSSP); up to S05		X
Led driver board (ver. 907 or higher); up to S07		X
Full metal Orifice; up to S03		✓
Change fuses: F4 (1,25A) , F1 (2,5A)		✓
Set the clock (UTP plugged in, NTP=on + GMT)	/	✓
Port check:	LAN	✓
	USB	✓
	RS232	✓

Tape sensor calibration/check	Value	Checkmark
Tape sensor calibration		✓
Tape sensor left RAW data (<40)		✓
Tape sensor right RAW data (<40)		✓
Manual TA – measure the length of TA (34 ± 2 mm)	L_{TA}= 35.77	✓
TA adjust (%)	8	✓
TA left with small tape sensor calibration disk & spool plate installed (0 ± 10)	-10	✓

Flow calibration/oriffice adjustment	Value	Checkmark
Flow sensor calibration (calibration pad)	/	✓
Solenoid 2 = ON, Flow=5l Δmax=20 (calibration pad)	Raw∑= 584 Raw1= 599	✓ Δmax=15
Solenoid 2 = OFF Measure flow F set=5l (calibration pad)	Fin= 5030 mlpm Fout= 4094 mlpm F∑= 5016 mlpm	✓
MAX FLOW (> 6.8 lpm) (calibration pad)	Fmax= 7131 mlpm	✓
Insert tape	/	✓
MAX FLOW (> 6.8 lpm)	Fmax= 6859 lpm	✓
Measure Fin(tape)=4.90l +/- 0,15l;	Fin(tape)= 4,92	✓
Set the orifice (tape) (F∑=5000; F1=3800 +/-100)	F∑= 5016 F1= 3736	✓

System verification	Value	Checkmark
ND filter test done (in case of optics parts replacement clear reference ND test)	/	✓
Leakage test done	/	✓ 24 %
Flow check done	/	✓
Stability test done (DBCI $_{(BCs1/CH6)}$ <450)	/	✓
Clean air test done (DBCI$_{(BCs1/CH6)}$ <550)	/	✓

Final check	Checkmark
Upload original setup file from the USB (add comments to Service report)	✓
Enter TA adjust (%)	✓
Check the clock (after restarting the instrument, without UTP cable)	✓
Stickers (Serial numbers, warnings, guide roller sticker, Windows CE)	✓
Check snap-grip hose clamps (2x)	✓
Vinyl cover caps (2x)	✓

Remarks: All good

replaced air filter, replace orface w/ new adjustable, full metal one.

Engineer: Taylor Jones ***SIGNATURE:*** [signature] ***DATE:*** 2/8/23

SERVICE ACTIVATION RECORD Aethalometer™ AE33	Serial number: AE33-S00-0004S Operater: STI Calibration flowmeter: **Tetracal SN:** 300	Aerosol

Backup		Checkmark
Backup CF card		✓
Save original setup file *(rename to AE_setup.exe and save to root of service USB stick)*		✓
Upload basic settings from the USB		✓

AE33 System electrical conformity check

PARAMETER	VALUE	MEASURED	CONFORMITY	REM.
PC	5 ± 0.1 V	4.91	✓	
12V	12 ± 0.1 V	12.04		
5	5 ± 0.1 V	4.98		
24V_LD	24 ± 0.25 V	23.95		
5V_LD	5 ± 0.1 V	4.98		
5V_DE	5 ± 0.1 V	4.97		
BAT_CLK	3.3 ± 0.2 V	3.41		
LED check (interconnection board)			Checkmark: ✓	

AE33 System check	Value	Checkmark
Check serial numbers	SN= AE33-S00-0004S	✓
Latest Bootloader check	/f	✓
Latest Firmware check	/	✓
Latest Software check	/	✓
Check for possible free instrument upgrades;	/	✓
Floating spot sealing plate (FSSP); up to S05		X
Full metal Orifice; up to S03		X
Change fuses: F4 (1,25A) , F1 (2,5A)		✓
Set the clock (UTP plugged in, NTP=on + GMT)	/	✓
Port check:	LAN	✓
	USB	✓
	RS232	✓

Tape sensor calibration/check	Value	Checkmark
Tape sensor calibration		✓
Tape sensor left RAW data (<40)		✓
Tape sensor right RAW data (<40)		✓
Manual TA – measure the length of TA (34 ± 2 mm)	L_{TA}= 33.24	✓
TA adjust (%)	-7%	✓
TA left with small tape sensor calibration disk & spool plate installed (0 ± 10)	-5	✓

Flow calibration/oriffice adjustment	Value	Checkmark
Flow sensor calibration (calibration pad)	/	✓
Solenoid 2 = ON, Flow=5l Δmax=20 (calibration pad)	RawΣ= 582 Raw1= 596	✓
Solenoid 2 = OFF Measure flow F set=5l (calibration pad)	Fin= 5020 mlpm Fout= 3829 mlpm FΣ= 5012 mlpm	✓
MAX FLOW (calibration pad)	Fmax= 6891 mlpm	✓
Insert tape	/	✓
MAX FLOW (tape)	Fmax= 6809 mlpm	✓
Measure Fin(tape)=4.90l +/- 0,15l;	Fin(tape)= 4.910 LPM	✓
Set the orifice (tape) (FΣ=5000; F1=3800 +/-100)	FΣ= 5012 F1= 3854	✓

System verification	Value	Checkmark
ND filter test done (in case of optics parts replacement clear reference ND test)	/	✓
Leakage test done	/	✓
Flow check done	/	✓
Stability test done (DBCI $_{(BCs1/CH6)}$ <450)	/	✓
Clean air test done (DBCI $_{(BCs1/CH6)}$ <550)	/	✓

Final check	Checkmark
Upload original setup file from the USB (add comments to Service report)	✓
Enter TA adjust (%)	✓
Check the clock (after restarting the instrument, without UTP cable)	✓
Stickers (Serial numbers, warnings, guide roller sticker, Windows CE)	✓
Check snap-grip hose clamps (2x)	✓
Vinyl cover caps (2x)	✓

Remarks: Standard maintenance and 2-day test performed.

Engineer: Alex Boenig **SIGNATURE:** Alex B **DATE:** 6/23/23

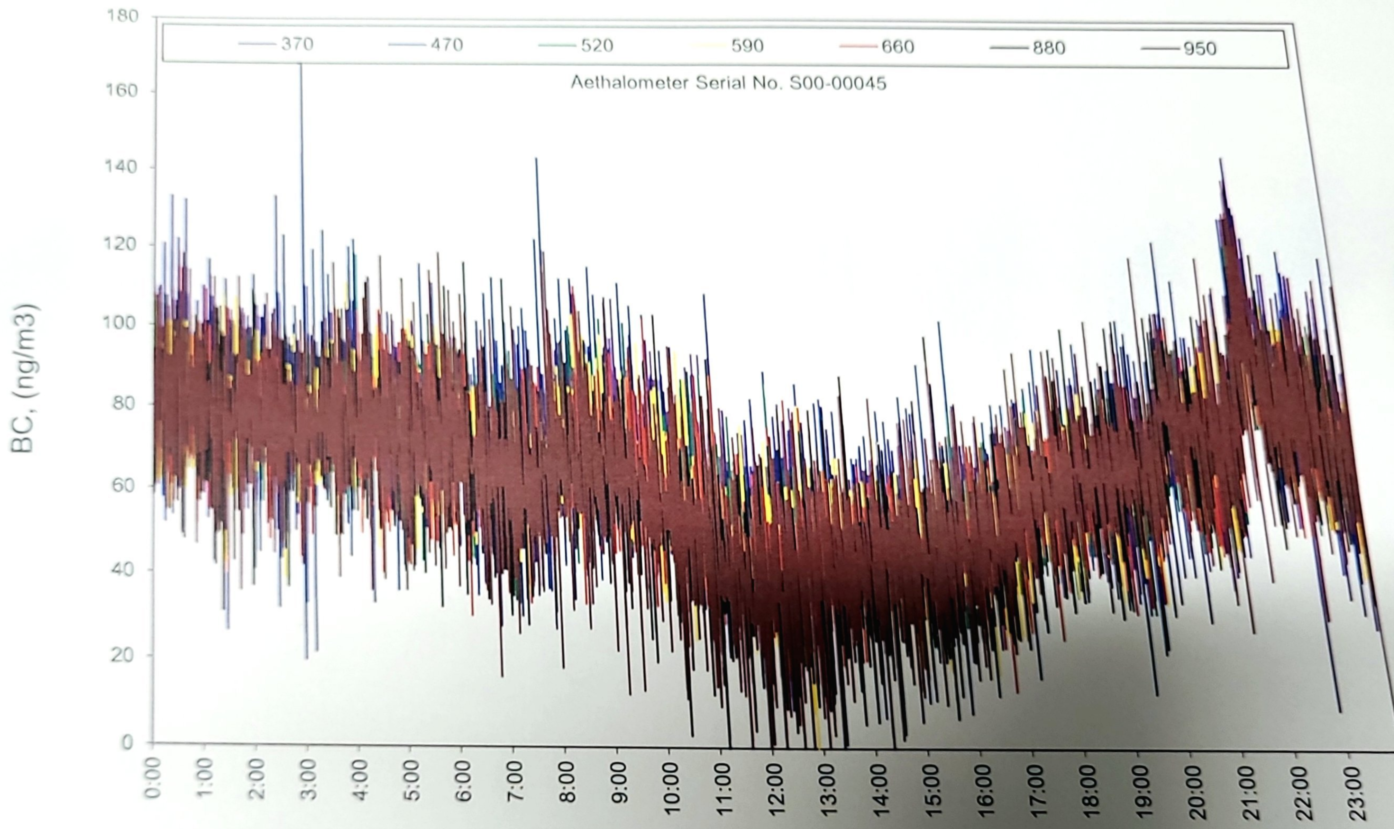
MAGEE SCIENTIFIC COMPANY

AETHALOMETER DATA PROCESSING

PRELIMINARY RESULTS - NOT FOR UNAUTHORIZED DISTRIBUTION

MAGEE SCIENTIFIC

AE33 Aethalometer Data : STI Lab



Saturday 24-Jun-23

Prepared 1:20 PM 6/26/2023 Filename: AE33 Parser and Analysis v.7 (display only).xlsx

Instrument Calibration Report

Date Prepared: August 18, 2023

Entanglement Technologies, Inc.

1192 Cherry Avenue,
San Bruno, CA 94066
650.204.7875

Summary

This report summarizes the calibration report for the AROMA analyzer for speciated analysis.

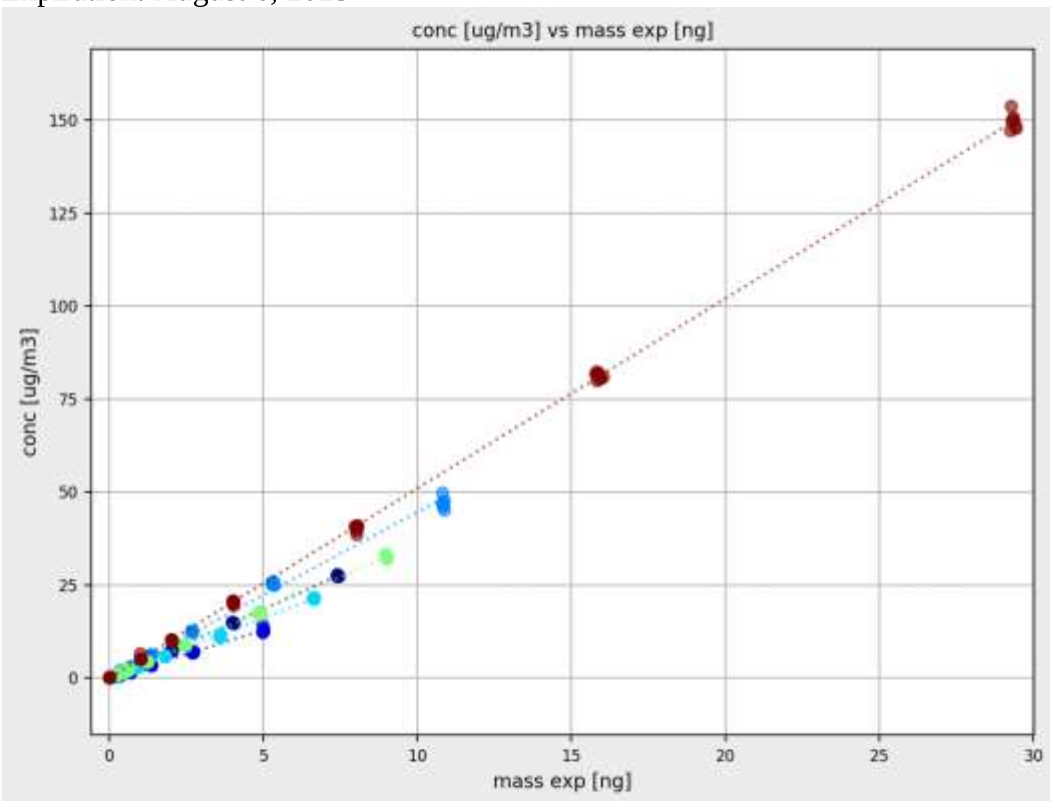
- The instrument received a full calibration on October 10, 2022 against a certified standard. This calibration was performed onsite in the European Commission's Joint Research Center
- Prior to deployment the instrument passed Continuing Calibration Verification on a known good standard (December 22, 2022)
- Insufficient gas remained in this standard for the deployment, however and expired standard was available. The concentrations in the expired standard were compared against the remains of the unexpired standard. The instrument response was updated to report the values contained in the expired standard for field QC Purposes.
- No Field Continuing Calibration Verification measurements were performed during the deployment.
- Upon completion of the field test, the instrument was re-validated against a new 5% certified standard. A secondary validation was performed with a Sonoma standard (benzene only).
- Reported data was reported using the calibration referenced the new certified standard.

Anthony Miller August 22, 2023

1192 Cherry Avenue, San Bruno, CA 94066 Phone: (650) 204-7875 / Fax: (650) 204-7857

Initial Calibration.

Date: October 10, 2022
Reference Number: 160-401863505-1
Expiration: August 6, 2023



All $r^2 > 0.99$.

	Coeff [arb]	R^2	Outlier Criteria
Butadiene	0.70	1.0	Pass
cisDCE	0.69	1.0	Pass
Isoprene	0.66	1.0	Pass
Trichloroethylene	0.67	1.0	Pass
Benzene	0.72	1.0	Pass
Toluene	0.68	1.0	Pass
Ethyl_benzene	0.64	1.0	Pass
Xylenes	0.65	1.0	Pass

1192 Cherry Avenue, San Bruno, CA 94066 Phone: (650) 204-7875 / Fax: (650) 204-7857

Pre-Deployment Continuing Calibration Verification

Date: December 22, 2022
Reference Number: HCL-004 SET 1
Expiration: Jan 6, 2023

	Result [ppbv]	Standard	RPD	Threshold	Result
Butadiene	11.127	10.0	11%	30%	PASS
cisDCE	9.9032	10.0	-1%	30%	PASS
Isoprene	10.172	10.0	2%	30%	PASS
Trichloroethylene	9.9427	10.0	-1%	30%	PASS
Benzene	10.173	10.0	2%	30%	PASS
Toluene	10.078	10.0	1%	30%	PASS
Ethyl_benzene	9.8593	10.0	-1%	30%	PASS
Xylenes	31.051	30.0	4%	30%	PASS

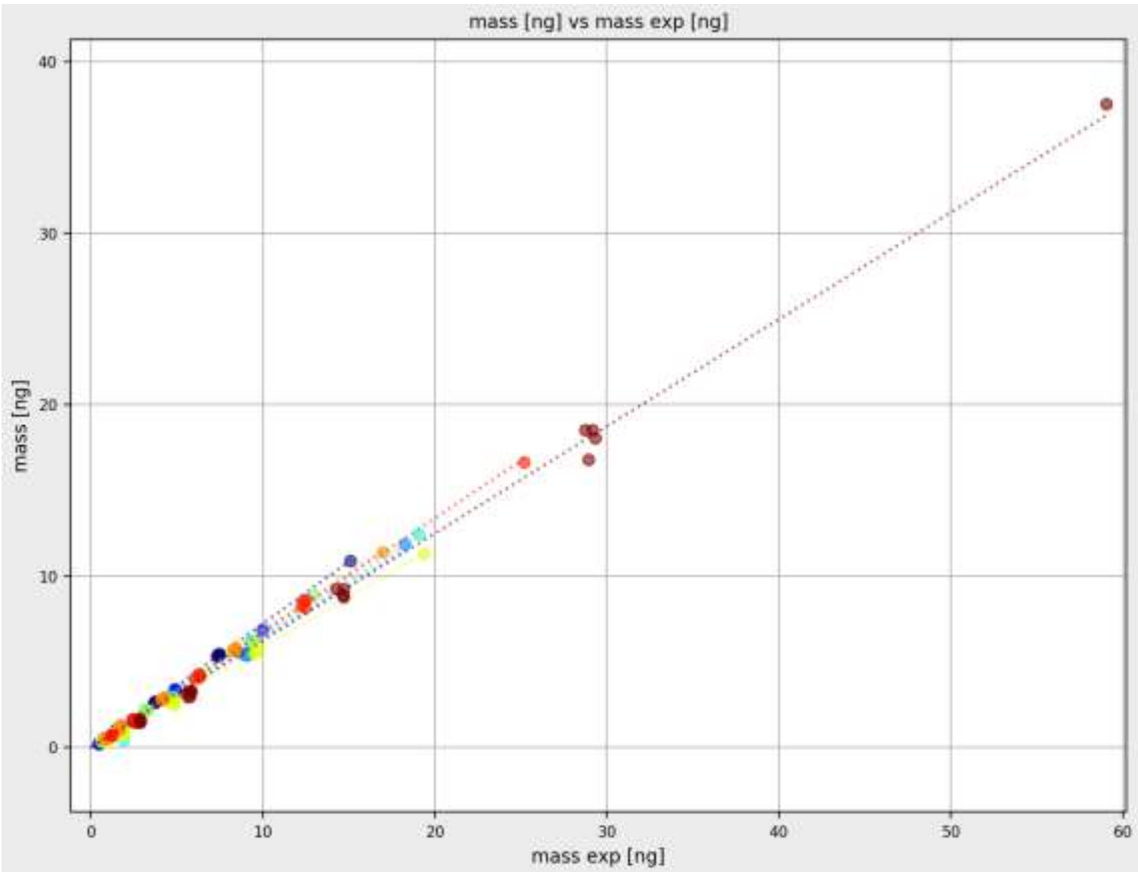
Expired Cal Cylinder: December 22, 2022
Reference Number HCL -003 SET 1
Expiration: Dec 3, 2021

	Result [ppbv]	Cal Target	Adjustment
Butadiene	8.784	10.0	-12%
cisDCE	6.692	10.0	-33%
Isoprene	5.078	10.0	-49%
Trichloroethylene	7.057	10.0	-29%
Benzene	6.57	10.0	-34%
Toluene	6.581	10.0	-34%
Ethyl_benzene	6.971	10.0	-30%
Xylenes	16.786	30.0	-44%

1192 Cherry Avenue, San Bruno, CA 94066 Phone: (650) 204-7875 / Fax: (650) 204-7857

Post Deployment Calibration

Date: April 18, 2023
Reference Number: CC524059
Expiration: April 8 2024



All $r^2 > 0.99$. Difference is expected vs measured mass reflects recalibration coefficients applied in final analysis.

	Coeff [arb]	R^2	Outlier Criteria
Butadiene	0.69	1.0	Pass
cisDCE	0.62	1.0	Pass
Isoprene	0.67	1.0	Pass
Trichloroethylene	0.68	1.0	Pass
Benzene	0.71	1.0	Pass
Toluene	0.67	1.0	Pass
Ethyl_benzene	0.65	1.0	Pass
Xylenes	0.63	1.0	Pass

1192 Cherry Avenue, San Bruno, CA 94066 Phone: (650) 204-7875 / Fax: (650) 204-7857

Post Deployment Sonoma Standard Validation

	Result [ppbv]	Cal Target	RPD
Benzene	50.1	50.0	0.2%

An expired Sonoma Benzene standard was evaluated on the analyzer at the conclusion of the deployment. This standard was used for Rapidscan calibration checks. The standard, despite expiration, matched the AROMA analysis results.

1192 Cherry Avenue, San Bruno, CA 94066 Phone: (650) 204-7875 / Fax: (650) 204-7857