Sistema de Monitoreo Atmosférico de la Ciudad de México

Ambient Air Quality Monitoring Audit Report

Submitted to:
Dirección General de Gestión de la Calidad del Aire
Secretaría del Medio Ambiente
Ciudad de México

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December 2017

Sistema de Monitoreo Atmosférico de la Ciudad de México

Air Quality Monitoring Site Audit Report

Submitted to:

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Conducted on:

18-22 December 2017

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EXECUTIVE SUMMARY

Tersum A'res and EPA Systems, LLC were contracted by the Environmental Secretariat of the Government of the Federal District (*Secretaría del Medio Ambiente del Gobierno del Distrito Federal* (GDF)) to support the GDF in conducting Technical Systems and Performance (TS&P) audits of selected stations within the Mexico City ambient air monitoring network. EPA Systems has been performing these audits since 2009. Prior to EPA Systems, these audits were performed in 2003 and 2005 by the US EPA Office of Air Quality Planning and Standards (OAQPS) with follow-up audits conducted by GDF auditors. Prior to this, audits were performed as an adjunct to a research program in Mexico City by the US EPA Office of Research and Development (ORD).

This report details the results of the TS&P audits conducted between 18 and 22 December 2017 on nine of the GDF ambient systems plus the main laboratory's reference analyzers. The audits were performed using an independent Protocol 1 calibration standard and an Environics Model 6103 calibrator and API Model 701 clean air source. The performance audit consisted of challenging each nitrogen oxides (NO_x), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3) analyzer at four to five upscale data values plus zero. In addition, the nitrogen dioxide (NO_2) converter efficiency for each NO_x analyzer was tested using a gas-phase titration approach using three different NO concentrations and three different ozone concentrations. This test is designed to create difference NO_2 concentrations by setting the O_3 and NO concentrations to yield approximately the same NO value (approximately 100 ppb).

The systems audit showed that GDF has an effective system for station operation and calibration. These operational protocols include:

- The instrument diagnostic information collected during each multipoint calibration is checked during each site visit;
- Technicians call the main laboratory each time work is done on the instruments so there is a record at the site and at the main laboratory;
- Control charts of all zero, span, and precision check sample data from each instrument calibration is kept and reviewed prior to each site visit;
- Each operator has access to 1-minute data for each site parameter and calibration point;
- Each station is configured in the same manner with ozone analyzer on top and CO analyzer on bottom. The sample lines to the manifold are also configured similarly. This makes it easier to work on and service the analyzers.
- A master list of maintenance and calibration activities (along with frequency and dates of activities) is posted in each shelter so that the operators know what activities are needed during each site visit; and

- Standard Operating Procedures (SOPs) are available for many of the instruments, however the new Thermo analyzers do not have updated SOPs, the automatic verification of the analyzers is not properly described in the old version of the SOPs and there are no SOPs for the TEOM 1405DFs.

A review of the site log books showed the logs were signed and dated and that all activities during each site visit as well as arrival and departure times were recorded.

The sites were all very clean and well-kept and the site instrumentation was neatly plumbed and wired making maintenance and servicing of the instrumentation much easier. The operators the auditor had the opportunity to meet and interact with demonstrated a strong commitment to performing quality work and expressed a lot of pride with the jobs they did.

There were several changes to the network between the last audit and 2017 audit. All the continuous monitoring sites are now equipped with either API 701 or Thermo 146i dynamic dilution calibrators and API 700 clean air sources. The calibration equipment is configured with timers that turn on to remotely perform instrument calibrations every 6th day. These every 6th day calibration include zero, span, precision check sample and two GPT points. These calibrations are performed through the zero and span ports on the analyzers and not through the sample ports. On a monthly basis, a zero, span, and precision check calibrations are performed manually through the sample ports with multi-point calibrations and three-point GPTs being performed on a quarterly basis.

The auditor noted one minor issue with the calibration frequency and that was associated with performing manual, through the sample port calibrations, monthly instead of bi-weekly. This would only have a potential to impact data quality if the sample valve developed a leak allowing site air to be monitored instead of ambient air. It is also a slight deviation from US EPA guidance.

The audit data showed that all the instruments are operating well within specification and the slight procedural deviation noted would only impact data if a sample valve malfunctions. With the existing site protocols all required calibration information is being captured at levels above those required by US EPA. Because manual “through the system” zero, span, and precision check calibrations are performed monthly, any issues with the system performance (e.g., sample valve failure) will always be caught within less than 30 days.

Overall, the performance audit demonstrated that the sites were extremely well run and were collecting valid and defensible data. Of the 40 criteria monitoring instruments audited, none of the analyzers had instrument responses that were outside of the audit objective acceptance criterion for gaseous pollutants. The audit objective criteria is 15% mean absolute percent difference and no more than 15% relative percent difference for each concentration level of each pollutant analyzer. For all sites and pollutants, the mean instrument response was less than ±5%. Figures ES-1 through ES-4 show the average audit responses at the ten sites for each of the four criteria pollutant analyzers.

In addition to conducting performance audits of the criteria pollutant monitors, a flow rate check of each particulate matter sampler was conducted. As it is critical that the samplers maintain proper flow through the sampling heads (which fractionate the particulate in the various size fractions) to ensure that the heads provide the proper particulate matter cut-points. All sites with either TEOM 1405DFs or the one site with a beta gauge, flow rate audits indicated that all sites were operating properly.

Based on the 10 sites audited, the audit demonstrated that the SIMAT monitoring network has a good QA/QC system in place to operate the network and that performance-wise, the instrumentation is operating well within acceptable limits.

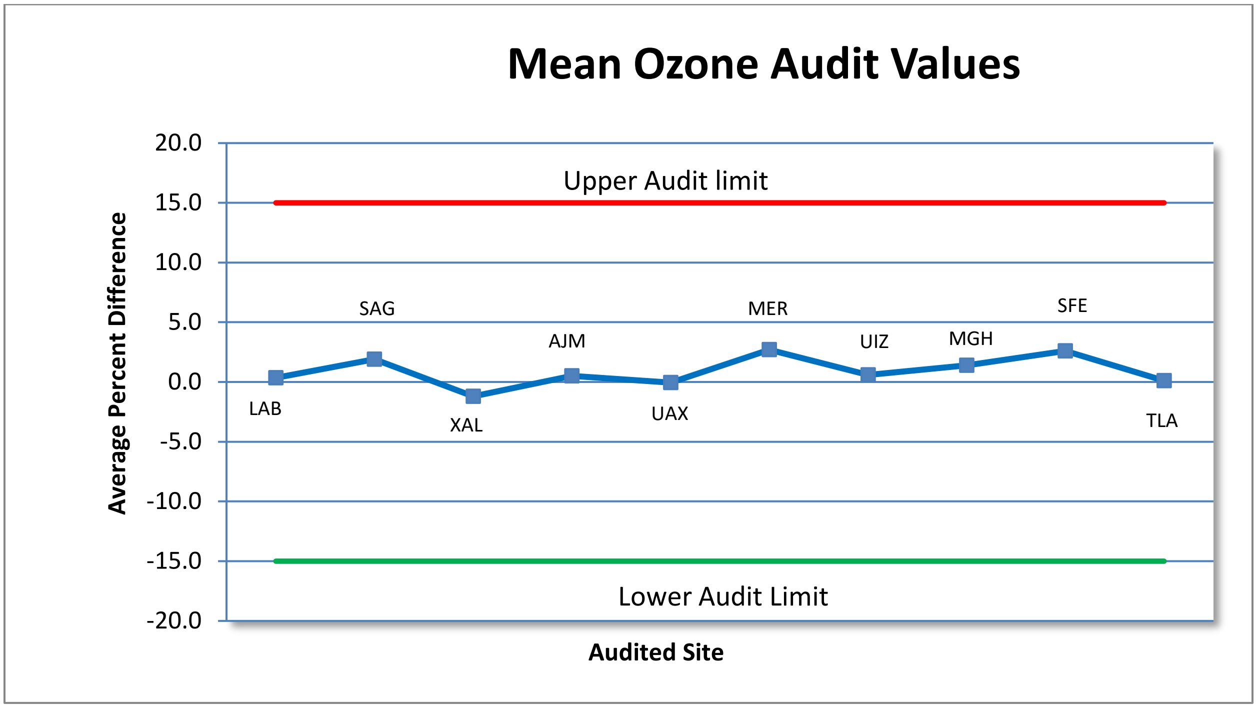


Figure ES- 1. Summary of Average Ozone Audit Results

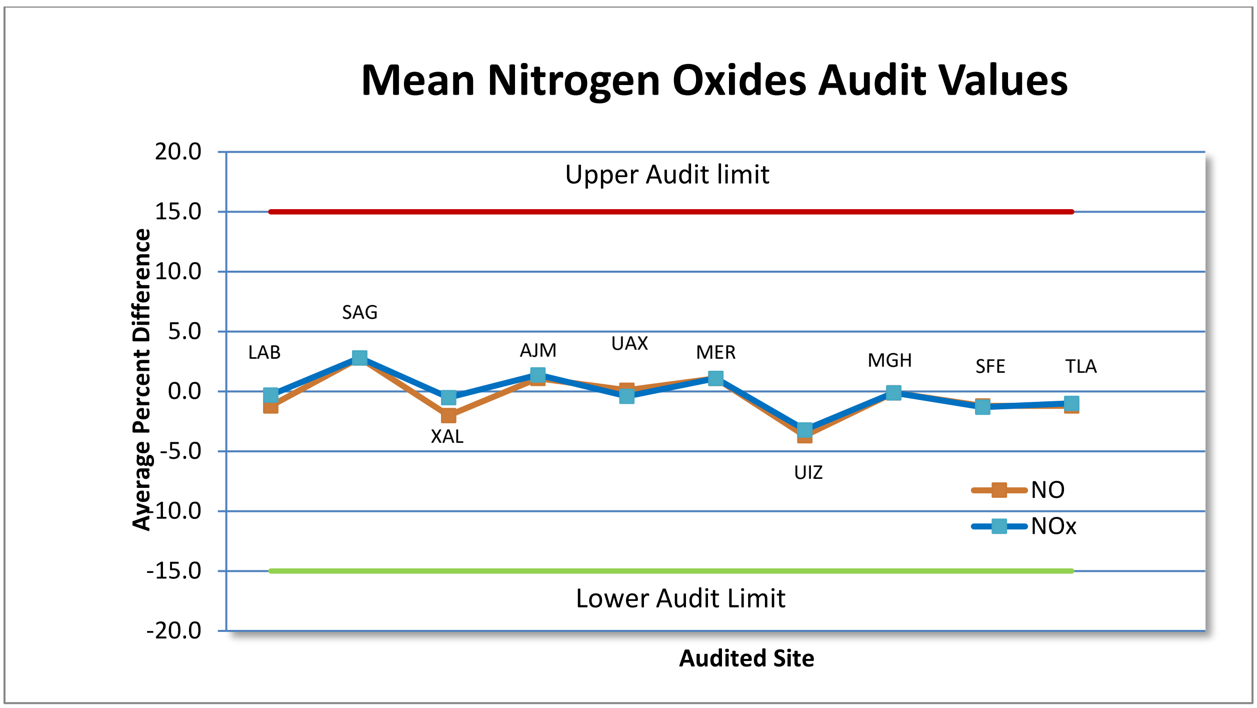


Figure ES- 2. Summary of Average Nitrogen Oxides Audit Results

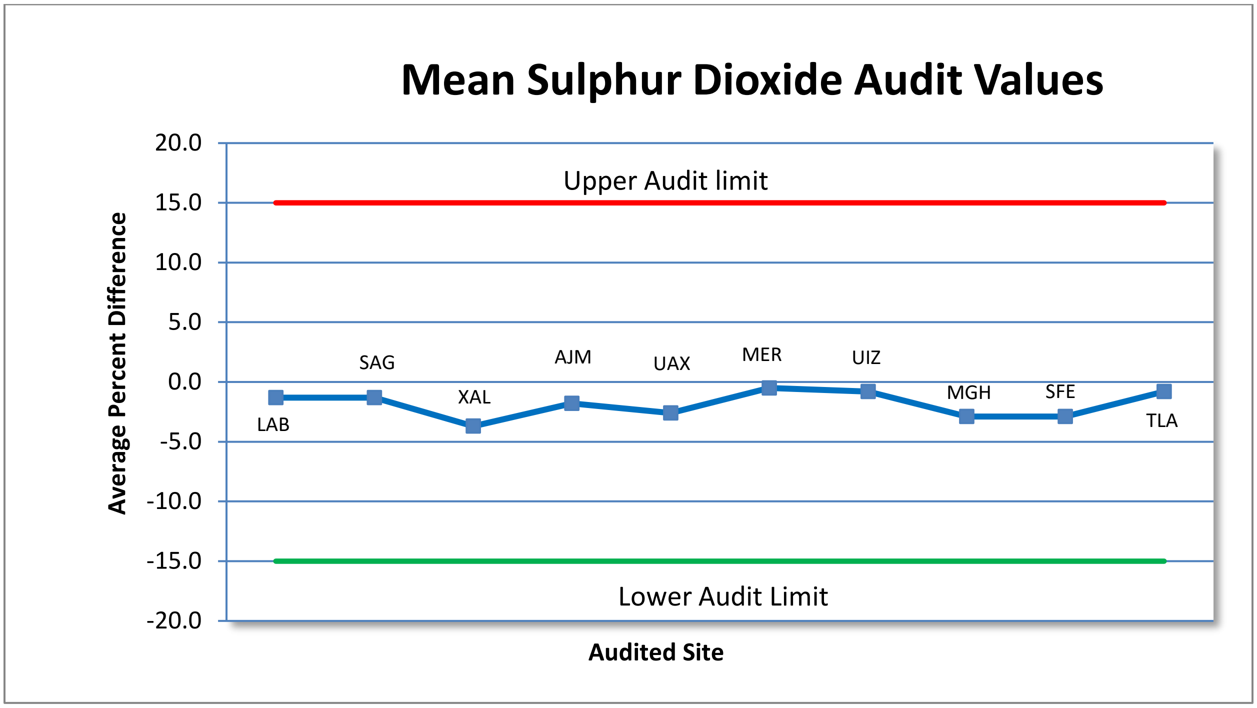


Figure ES- 3. Summary of Average Sulphur Dioxide Audit Results

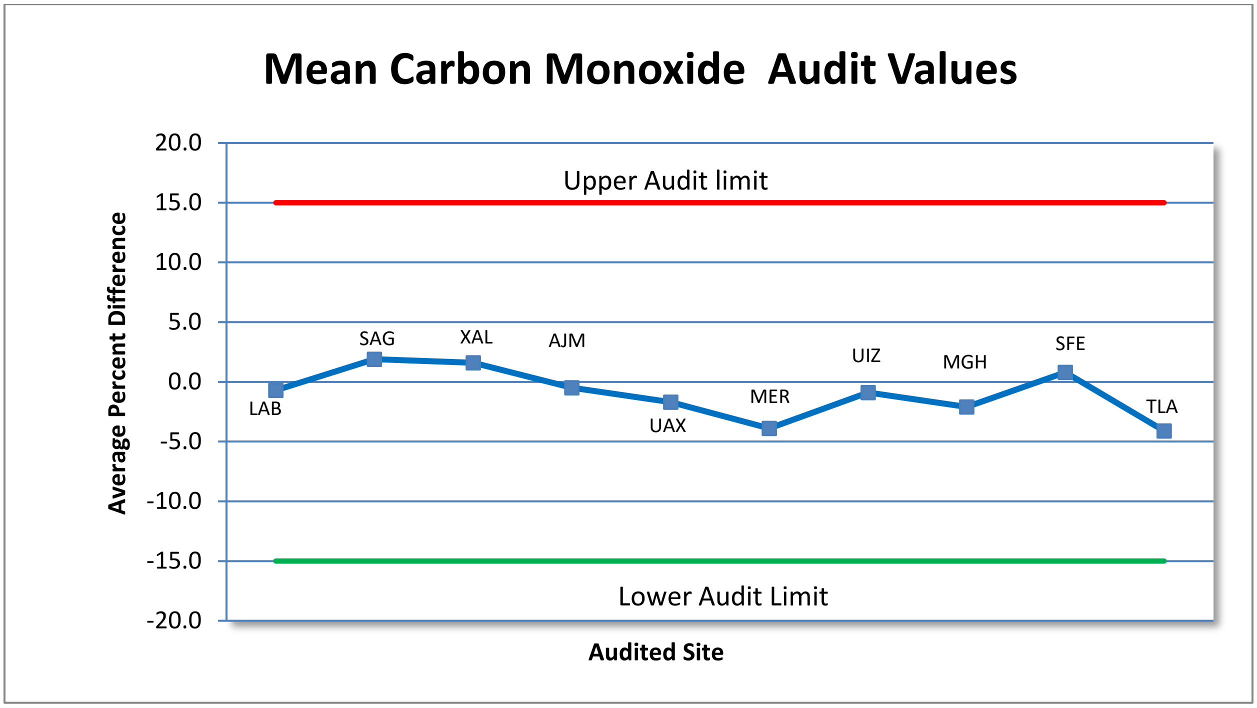


Figure ES- 4. Summary of Average Carbon Monoxide Audit Results

1.0 INTRODUCTION

This report details the Technical Systems and Performance (TS&P) audit conducted on ten (10) ambient air monitoring sites operated by Ciudad de Mexico. At the time of the audit the Mexico City Atmospheric Monitoring System (Sistema de Monitoreo Atmosférico de la Ciudad de México, SIMAT) operates a total of 32 automated stations for criteria gases and PM in and around Mexico City. The audit was conducted 18 – 22 December 2017 and was designed to determine the operational state of the individual criteria monitors (performance audit) as well as evaluate the systems and procedures used to calibrate and operate the network. Some monitoring stations also have manual particulate monitoring and meteorological monitoring, but these parameters were not part of the audit.

1.1 MEXICO CITY METROPOLITAN AREA

The Mexico City Metropolitan Area (MCMA) lies in an elevated basin at an altitude of 2,240 meter above mean sea level (amsl), near the center of the country (19º25' N latitude, 99º10' W longitude). The floor of the basin is confined on three sides by mountain ridges with a broad opening to the north and narrowed gap to the south-southwest. The surrounding peaks attain an elevation of nearly 4,000-meter asml. The metropolitan area is located on the southwest side of the basin and covers about 1500 km^2. The MCMA includes the 16 “delegaciones” within the Federal District and clusters of municipalities (municipios) including 37 in the State of Mexico. Mexico City (DF) is the country capital and is home to the national political institutions, the greatest concentration of economic investments and most of the country's industrial and financial infrastructure. MCMA has over 22 million inhabitants.

1.2 SECRETARÍA DEL MEDIO AMBIENTE DEL GOBIERNO DEL DISTRITO FEDERAL

The Secretariat of the Environment of Mexico City Government (Secretaría del Medio Ambiente del Gobierno de la Ciudad de México) is responsible for environmental policies and programs, including implementing local and federal laws, in Mexico City. Since 1993, the Secretariat of the Environment has been the primary organization responsible for ambient air monitoring in the Mexico City Metropolitan Area and operates the Mexico City Atmospheric Monitoring System (Sistema de Monitoreo Atmosférico, SIMAT) for this purpose.

The Atmospheric Monitoring System consists of 43 monitoring stations, a support laboratory, an environmental information center, and an information technology support center. Monitoring is further segregated into an Automatic Ambient Air Monitoring Network (Red Automática de Monitoreo Atmosférico, RAMA), a Manual Particulate Monitoring Network, an Atmospheric Deposition Network, and a Meteorological Network. With the support of the environmental information center and the information technology support center, monitoring data are transferred daily and hourly into the Metropolitan Area Air Quality Index (Índice Metropolitano de la Calidad del Aire, IMECA). The IMECA is widely distributed to public and private sector organizations in the Mexico City area to assist in making public health decisions.

Currently the SIMAT network consist of 32 automated stations (O_3, NO_X, SO_2, CO, PM_{10} and $PM_{2.5}$), 10 manual stations (TSP, PM_{10}, $PM_{2.5}$ and heavy metals), 26 meteorological stations (RH, T, WDR, WSP, P and UV radiation) and 16 atmospheric deposition stations (wet and dry atmospheric deposition).

The audit was performed at 9 of the 32 automatic station sites operated as part of the SIMAT network. In addition, as part of the audit, the reference analyzers of the SIMAT laboratory were audited. A summary of the audit schedule along with the parameters audited is summarized in Table 1-1 below. Table 1-2 shows the make, model, and serial number (S/N) of each audited gas-phase analyzer at the 10 sites. A map showing the location of the 10 sites is presented in Figure 1-1. Site descriptions for the 10 sites are presented below in Section 1.3.

Table 1-1. Summary of Site Parameters

Site Name	Initials	Date Audited	Parameters Audited
SIMAT Laboratory	LAB	22/12/2017	O_3, NO_x, SO_2, CO
San Agustín	SAG	18/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
Xalostoc	XAL	18/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
Ajusco Medio	AJM	19/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
UAM Xochimilco	UAX	19/12/2017	O_3, NO_x, SO_2, CO, Beta Flows
Merced	MER	20/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
UAM Iztapalapa	UIZ	20/12/2017	O_3, NO_x, SO_2, CO
Miguel Hidalgo	MGH	21/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
Santa Fe	SFE	21/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows
Tlalnepantla	TLA	22/12/2017	O_3, NO_x, SO_2, CO, TEOM Flows

Table 1-2. Summary of Analyzer Make, Model, and Serial Number at Each Site

Site	Analyte	Analyzer Make	Analyzer Model	Analyzer S/N
LAB	O_3	API	400A	888
	NO_X	API	200A	2356
	SO_2	API	100A	1707
	CO	API	300	1781
SAG	O_3	API	400E	1202
	NO_X	API	200E	1630
	SO_2	API	100	494
	CO	API	300	1163
	TEOM	Thermo	1405DF	1405A211341010
XAL	O_3	API	T400	78
	NO_X	API	T200	69
	SO_2	API	100E	1359
	CO	API	T300	1146
	TEOM	Thermo	1405DF	1405A204750905
AJM	O_3	API	400E	1210
	NO_X	Thermo	42i	1403660574
	SO_2	Thermo	43i	1403660608
	CO	Thermo	48i	1403660606
	TEOM	Thermo	1405DF	1405A226131310
UAX	O_3	Thermo	49i	1034445708
	NO_X	API	200E	1610
	SO_2	Thermo	43i	1034445694
	CO	Thermo	48i	1034440605
	Beta Gauge	Thermo	FH62C-14	E1261
MER	O_3	API	400E	1200
	NO_X	API	200E	1595
	SO_2	API	T100	72
	CO	API	T300	1147
	TEOM	Thermo	1405DF	1405A204740904
UIZ	O_3	API	400E	1214
	NO_X	API	T200	72
	SO_2	API	100E	1352
	CO	API	T300	1567
	TEOM	Thermo	1405DF	Out for Maintenance
MGH	O_3	Thermo	49i	1403660579
	NO_X	Thermo	42i	1403660575
	SO_2	Thermo	43i	1403660609
	CO	Thermo	48i	1034445705
	TEOM	Thermo	1405DF	1405A226091310
SFE	O_3	API	400E	1213
	NO_X	Thermo	42i	1034445700
	SO_2	Thermo	43i	1403660610
	CO	API	300	1162
	TEOM	Thermo	1405DF	1405A211351010
TLA	O_3	API	400E	1199
	NO_X	API	T200	73
	SO_2	API	T100	70
	CO	API	T300	1148
	TEOM	Thermo	1405DF	1405A204730904

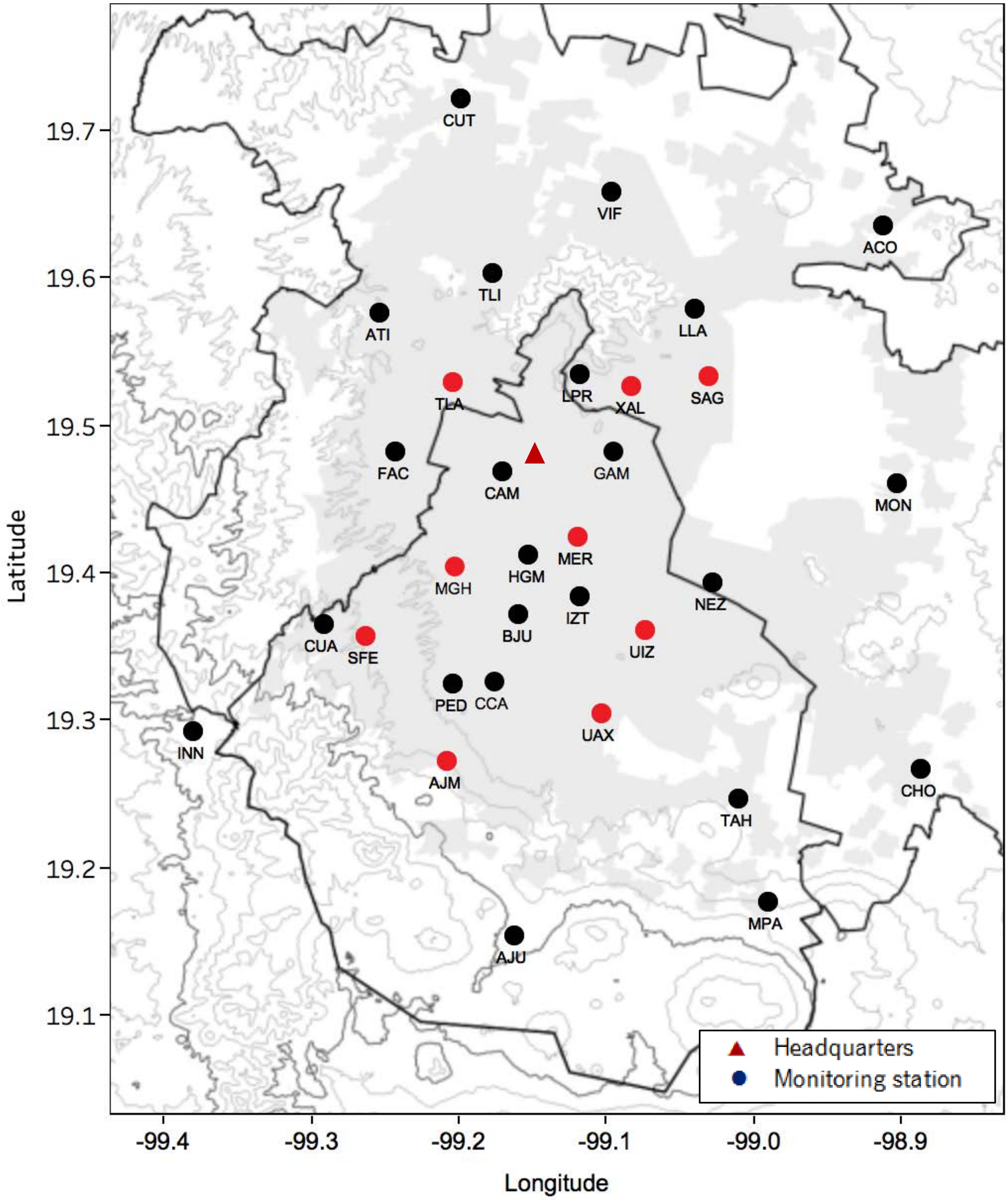


Figure 1-1. Map of the Air Quality Monitoring Network During 2017, Audited Sites Highlighted in Red.

1.3 Site Information

Site: SIMAT Laboratory

Address:

Avenida Sur de los Cien Metros s/n, Colonia Nueva Vallejo, Delegación Gustavo A. Madero, Distrito Federal, CP 07750.

Geographic Location:

19º29’1.34’’ N latitude, 99º08’50.12’’ W longitude.

Description:

This is the headquarters of the Sistema de Monitoreo Amosférico de la Ciudad de México and houses some of the network’s reference analyzers. These units are not typically used to monitor ambient air but rather are used to do comparisons to field analyzers.

Site: San Agustín (SAG)

Address:

Santa Rita S/N esquina Sur 90, Colonia Nuevo Paseo de San Agustín, Municipio de Ecatepec de Morelos, Estado de México, C.P. 55130

Geographic Location:

19°53’29.40 ’’ N latitude, 99°03’03.08’’ W Longitude

Description:

This station is situated on the roof of a two-story community healthcare center (Centro de salud comunitario) in a generally residential neighborhood. The neighborhood is generally small side streets with no major roadways or rail lines in direct proximity to the site. Sample inlet is approximately 12 – 14 meters above ground level.

Site: Xalostoc (XAL)

Address:

Vía Morelos km 12.5, entre López Rayón y Av. Benito Juárez, Colonia Xalostoc, Municipio Ecatepec de Morelos, Estado de México, CP 54190.

Geographic Location:

19º31’33.58’’ N latitude, 99º04’56.64’’ W longitude.

Description:

This station is in an industrial/commercial/residential area, it is housed in a shed on the top of the fourth floor of a Regional Hospital. There is a major avenue near the station with heavy traffic. Sample inlet is 30 m above ground level.

Site: Ajusco Medio (AJM)

Address:

Encinos # 41, col. Miguel Hidalgo 4ta sección, Tlalpan, C.P. 14250

Geographic Location:

19° 16´ 19.49´´ N latitude, 99° 12´ 27.28´´ W longitude.

Description:

This station is located on the fourth-floor roof of a new hospital. The instruments are housed in an Ekto Shelter with sample inlet approximately 25 m above ground level. The "green" roof is covered in plant material to absorb rain fall, minimize runoff, and reduce heat buildup. This site is also equipped with a digital camera system that captures city-wide photo every 10 minutes for haze evaluation.

Site: UAM Xochimilco (UAX)

Address:

Universidad Autónoma Metropolitana, Campus Xochimilco, Edificio H. Calzada del Hueso No. 1100, Colonia Villa Quietud, Delegación Coyoacán, Distrito Federal, CP 04960.

Geographic Location:

19º18'16.00'' N latitude, 99º06'13.20'' W longitude.

Description:

This station is located on the fourth-floor roof of the science building at Universidad Autónoma Metropolitana Campus Xochimilco. The system was housed in a concrete building. The university is situated in a gated residential area with no major streets adjacent to the station. The sample inlet is approximately 20 m above ground level.

Site: Merced (MER)

Address:

Avenida Congreso de la Unión esquina con Stand de Tiro s/n, Colonia Merced Balbuena, Delegación Venustiano Carranza, Distrito Federal, CP 15860.

Geographic Location:

19º25'28.60'' N latitude, 99º07'10.54'' W longitude.

Description:

This station is near the downtown of Mexico City in a shed on the third-floor roof of a junior high school. The streets around the station are wide and heavily traveled. There is an elevated Metro railway to the west. Sample Inlet is 17 m above ground level.

Site: UAM Iztapala (UIZ)

Address:

Universidad Autónoma Metropolitana Campus Iztapalapa, Edificio T. Av. San Rafael Atlixco No. 186, Colonia La Vicentina, Delegación Iztapalapa, Distrito Federal, CP 09340.

Geographic Location:

19º21'38.86'' N latitude, 99º04'25.97'' W longitude.

Description:

This station is located on the top of the third-floor building at Universidad Autónoma Metropolitana Campus Iztapalapa and housed in an Ekto Shelter. There are no major streets adjacent to the station. Sample inlet is approximately 18 m above ground level.

Site: Miguel Hidalgo (MGH)

Address:

Doctor Balmis No. 148, Colonia Doctores, Delegación Cuauhtémoc, C.P. 06726, Ciudad de México

Geographic Location:

19°41’13.91’’, N latitude, 99º15’12.44’’ W longitude

Description:

This site is located on the roof of a community center with early childhood development and other programs in a residential neighborhood. The equipment is mounted in an Ekto shelter on the roof of the center.

Site: Santa Fe (SFE)

Address:

Francisco J. Serrano S/N entre Av. Tamaulipas y Av. Santa Fe, Colonia Prados de la Montaña, Delegación Álvaro Obregón, C.P. 05616, Ciudad de México

Geographic Location:

19°35’76.72’’, N latitude, 99º26’31.55’’ W longitude

Description:

This site is located at a city Park, “Parque Prados de la Montaña". This site is a city park but is located in a new, upscale and growing part of Mexico City. This site is an old landfill that has been closed but is under landfill gas recovery with wells and gas lines crisscrossing the property.

Site: Tlalnepantla (TLA)

Address:

Glorieta de Atlacumulco. Avenida Toluca s/n, Glorieta Atlacomulco, Colonia Tlalnemex, Municipio de Tlalnepantla de Baz, Estado de México, CP 54070.

Geographic Location:

19º31’44.68’’ N latitude, 99º12’16.55’’ W longitude.

Description:

This station is located in a shed on the top of a 2-meter platform in the northwest of the city in the municipality of Tlalnepantla, Estado de México. This site is located at a municipal water facility in a generally residential neighborhood. There are no major streets adjacent to this site. This site is downwind from a major industrial area located north of the site. Sample Inlet is approximately 6.8 m above ground level.

1.4 BACKGROUND

This section provides background on the organizations involved with this audit.

1.4.1 Secretaría del Medio Ambiente del Gobierno del Distrito Federal (GDF)

The Secretariat of the Environment of the Mexico City Government (*Secretaría del Medio Ambiente del Gobierno de la Ciudad de México*) is responsible for environmental policies and programs, including implementing local and federal laws, in the Mexico City metropolitan area (Mexico City and adjoined municipalities in the State of Mexico). The Mexico City Government (formely Federal District Government, GDF) became the primary organization responsible for ambient air monitoring in the Mexico City area in 1993 when the Automatic Ambient Air Monitoring Network (RAMA) was transferred to the GDF.

Prior to the early 1970's, air quality monitoring in Mexico City was part of the Normalized Pan American Sampling Network (*Red Panamericana de Muestreo Normalizado*). In 1971, Mexico passed the "Law for Preventing and Controlling Environmental Contamination", (*Ley para Prevenir y Controlar la Contaminación Ambiental*). In 1972 the Sub-secretary for Environmental Improvement (Subsecretaría de Mejoramiento del Ambiente) was created under the Secretary of Health. These events led to the creation of a 48 station National monitoring network, with 22 of these stations being in the Mexico City air basin. Currently the Mexico City Atmospheric Monitoring System (SIMAT) consists of 41 monitoring stations, a support laboratory, an environmental information center, and an information technology support center. Monitoring is further segregated into an Automatic Monitoring Network (RAMA), a Manual Particulate Monitoring Network, an Atmospheric Deposition Network, and a Meteorological Network. With the support of the environmental information center and the information technology support center, monitoring data are translated daily and hourly into the Metropolitan Area Air Quality Index (*Índice Metropolitano de la Calidad del Aire* (IMECA). The IMECA is widely distributed to public and private sector organizations in the Mexico City area to assist in making public health decisions.

1.4.2 Secretariat of the Environment and Natural Resources (SEMARNAT)

The Secretariat of the Environment and Natural Resources (*Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT)) is the primary federal agency responsible for environmental protection in the Country of Mexico. The Sub-secretary of Environmental Protection Management (*Subsecretaría de Gestión para la Protección Ambiental*) is the SEMARNAT organizational unit primarily responsible for environmental quality. However, the National

Institute of Ecology and Climate Change (*Instituto Nacional de Ecología y Cambio Climático*, INECC) provides technical and research support for environmental issues (including monitoring).

Prior to the 2009 air monitoring audit by EPA Systems, the United States Environmental Protection Agency (US EPA) performed the Mexico City ambient air monitoring network audits as requested by the Environmental Secretariat of the Government of the Federal District (*Secretaría del Medio Ambiente del Gobierno del Distrito Federal*, GDF) and the Pan American Health Organization (PAHO). The physical audits were performed by the US EPA Office of Air Quality Planning and Standards (OAQPS) and were conducted in 2003 and 2005. Prior to this, audits were performed as an adjunct to a research program in Mexico City by the US EPA Office of Research and Development (ORD). No additional audits by any organization within US EPA have been performed since 2005.

2.0 DESCRIPTION OF AUDIT METHODOLOGY

Performance audits are intended to independently evaluate the performance of an organization's monitoring equipment, calibration equipment, standards, and all operating, calibration, maintenance, quality assurance, and quality control procedures. Performance audits involve independent audit equipment, an independent auditor, and independent gas standards to challenge the instrumentation. Gaseous pollutant audits were accomplished by challenging the instruments through the instrument's sample inlet. The acceptance criterion for gaseous pollutants is 15% mean absolute difference and 15% for each concentration level of each pollutant analyzer. Monitors that exceed this criterion require corrective action. Also evaluated are the instruments response to individual audit concentrations, instrument linearity based on multiple standards (measured as slope and intercept and R^2), and zero checks.

Technical System Audits (TSAs) and Management System Reviews (MSRs) are reviews intended to evaluate how well the established quality system is working. TSAs are used to verify that appropriate technical and quality control procedures have been established and are being followed. For air monitoring organizations, some areas which are audited include:

- Written procedures;
- Documentation;
- Monitoring network design;
- Site appropriateness/siting requirements;
- Instrument operation;
- Laboratory procedures;
- Sample/data custody;
- Data handling systems;
- Data processing and calculation;
- Quality control; and
- Performance audit system.

Management System Reviews (MSRs) are evaluations of how effectively the QA program is working. These audits evaluate the overall quality system but may not effectively identify technical defects with the system. Possible elements of a MSR include the evaluation of:

- Organizational structure;
- Quality policy;
- Quality manager empowerment and effectiveness;

- Quality documentation;
- Corrective actions;
- Training and qualifications of staff;
- Commitment to quality by management and staff; and
- Overall effectiveness of the quality system.

The technical systems audit addressed several of the issues outlined above.

2.1 Performance Audit Procedures

The station performance audits were performed using an Environics Model 6103 (S/N 4880) calibrator and an API Model 701 air source. An EPA Protocol 1 calibration standard manufactured by Airgas Specialty Gases of Holland, Ohio was used to make individual dilution concentrations for the NO_x, SO_2 and CO analyzers. Ozone concentrations were produced by the Environics calibrator using the on-board ozone generator and certified photometer.

Prior to the audit, the calibrator was sent to Ozone Solutions, in Hull, Iowa to calibrate and certify the ozone photometer in the Environics. Ozone photometer certification is shown in Appendix A.

Table 2-1 presents the concentrations of the individual criteria pollutant analytes (NO, SO_2, CO) in the Protocol One gas standard. A copy of the gas certification is provided in Appendix A. The cylinder gas concentrations are certified valid for 96 months from manufacture. The ozone concentrations were generated by the Environics 6103 (S/N 4880) based on the ozone certification performed by Ozone Solutions in November 2017. Acceptable ranges for primary standards are a slope of between 0.970 and to 1.030 and a range of intercepts of ±1 – 3 ppb. The Environics ozone output was adjusted to have a slope of 1.0000 and an intercept of 0.0 ppb. Ozone primary standards need to be recertified every 12 months.

Table 2-1. Summary of Gas Standard Concentrations

Gas Standard	Cylinder Number	Concentration (ppm)	Certification Date	Expiration Date
SO_2	CC502682	55.04	8/11/2017	8/11/2025
NO		55.75		
CO		5498		

During the audit, each instrument was challenged with at least five different gas concentrations (four to five upscale points plus zero). In addition, a three-point gas-phase titration (GPT) was performed on each NO_x analyzer to test the NO_2 conversion efficiency. The GPT was performed by first creating a stable NO concentration and adding ozone at a concentration approximately 100 ppb lower than the NO concentration so that adjusted NO concentrations were between 80 and 120 ppb. This was done at three different ozone and NO concentrations to calculate the NO_2 converter efficiency.

To determine when the instrument readings were stable, the auditor used the STABIL function in each API analyzer to determine when the instrument reading was stable and could be recorded. A value at or below 2 ppb was used for O_3, NO_x, and SO_2 and a reading of 2 ppm was used for CO analyzers. This typically took 5 to 7 minutes for a stable reading to be obtained. For other instruments that didn't have this function the audit waited until the readings appeared stable and were no longer changing.

Because of site logistics, site security, and shortage of open space, most of the air quality stations in the Mexico City network are located on the roofs of governmental buildings, such as clinics, hospitals, schools, or universities. Each of the field sites and the main laboratory reference site were equipped with air quality monitors for nitrogen oxides (NO_x), sulphur dioxide (SO_2), ozone (O_3), and carbon monoxide (CO). In addition, the field sites were equipped with a particulate matter (PM) monitoring instrument. The PM monitors were typically Thermo Model 1405-DF FDMS combined PM_{10} / $PM_{2.5}$ samplers which measure $PM_{2.5}$ and PM_{10} simultaneously however, one site was configured with single inlet Beta Gauge based PM_{10} monitor. Many of the sites also had manual PM_{10} and $PM_{2.5}$ samplers along with meteorological sensors for wind speed and wind direction, ambient temperature, and solar radiation, however the audit scope only included the criteria pollutants and automated PM monitors and did not include these additional parameters, so they were not audited.

Other elements of the TSA and MSR audits included evaluating the physical condition of each site, site record keeping, operator knowledge and training, and overall operating procedures that can impact the data quality. All the sites audited were configured with zero air sources, dynamic dilution calibrators, and individual gas standards. The Mexico City operations staff conducts a series of calibrations at each site. These calibrations include:

- Automatic zero, span, gas-phase titration (GPT), and precision point checks;
- Monthly manual zero, span and precision check, and
- Manual multipoint calibration and GPT.

Table 2-2 summarizes the calibration frequency and calibration levels currently being implemented at the field sites.

SIMAT has established a strong preventative maintenance and cleaning schedule. This includes some of the following:

- Cleaning the sample manifolds monthly;
- Cleaning each PM_{10} sample head monthly;
- Changing instrument filters every 4-6 weeks (or more frequently if needed);
- Checking instrument flow rates monthly;

- Changing TEOM bypass filters every 6 months;
- Performing major equipment maintenance, including K_o check on every TEOM annually.

During the audit, the stations were found to be very clean, manifolds were free of dirt and dust, and the PM_{10} sample heads were in excellent condition and very clean. The network maintains extra PM_{10} sample heads so every month the sample heads are swapped so a very thorough cleaning and lubrication of the sample head can be performed at the laboratory under controlled conditions. Since the heads are completely disassembled and cleaned and threaded parts lubricated, this keeps the heads in better condition and allows them to last much longer and perform better. This should certainly be considered a “best practice” beyond what many networks do.

Table 2-2. Summary of SIMAT Calibration Type, Frequency, and Acceptance Criteria

Calibration Type	Frequency	Concentration Levels	Criteria
Automatic Zero, Precision check, Span Check, and GPT	Every 6th day	**Level 1** – 450 ppb for NO and SO_2, 400 ppb O_3, and 45 ppm for CO **Level 2** – 100 ppb NO and SO_2, 50 ppb O_3, and 10 ppm for CO **Level 3 -** Zero[1] **Level 4 –** GPT, two levels 450 ppb NO with 350 ppb O_3 200 ppb NO with 100 ppb O_3	**Level 1/2 –** If instrument response is more than ±5% from standard values the analyzer is adjusted **Level 3 –** Zero ±3 ppb for O_3 Zero ±5 ppb for NO, SO_2 Zero ±0.5 ppm for CO **Level 4 –** Converter Efficiency Greater than 96% or converter should be replaced
Manual Zero, Precision check, Span Check, and GPT	Monthly	**Level 1** – 450 ppb for NO, SO_2, 400 ppb O_3, and 40 ppm for CO **Level 2** – 100 ppb NO and, SO_2, 50 ppb O_3, and 10 ppm for CO **Level 3 -** Zero **Level 4 –** GPT, two levels 450 ppb NO with 350 ppb O_3 200 ppb NO with 100 ppb O_3	**Level 1/2 –** If instrument response is more than ±5% from standard values the analyzer is adjusted **Level 3 –** Zero ±3 ppb for O_3 Zero ±5 ppb for NO, SO_2 Zero ±0.5 ppm for CO **Level 4 –** Converter Efficiency Greater than 96% or converter should be replaced
Manual Gas Phase Titration (GPT)	During Each Multipoint Calibration	**Level 1** 450 ppb NO with 350 ppb O_3 **Level 2** 300 ppb NO with 200 ppb O_3 Level 3 200 ppb NO with 100 ppb O_3	Converter Efficiency Greater than 96% or converter should be replaced
Multipoint Calibration performed through instrument's sample port	Quarterly	**Level 1** 450 ppb for NO, SO_2, 400 ppb O_3, and 45 ppm for CO **Level 2** 300 ppb for NO, SO_2, O_3 and 30 ppm for CO **Level 3** 200 ppb for NO, SO_2, O_3 and 20 ppm for CO **Level 4** 100 ppb for NO and SO_2, 50 ppb O_3 and 10 ppm for CO **Level 5** zero	If instrument response is more than ± 3% from standard values analyzer is re-calibrated

[1] In practice the network does not allow negative zero's as the data logger reports values of less than 0 as zero instead of the actual negative value.

3.0 INDIVIDUAL SITE AUDIT RESULTS

This section describes the audit results for each of the nine field sites plus the main laboratory. During the audit, audit data were recorded into a formatted Excel spreadsheet that calculated percent difference from each known concentration value. In addition, each site was reviewed to check that the systems met general siting and operational specifications. This check assessed the overall site conditions including preventative maintenance, documentation, and overall system operation. In general, the audits followed US EPA guidelines for ambient air monitoring systems found in the following documents:

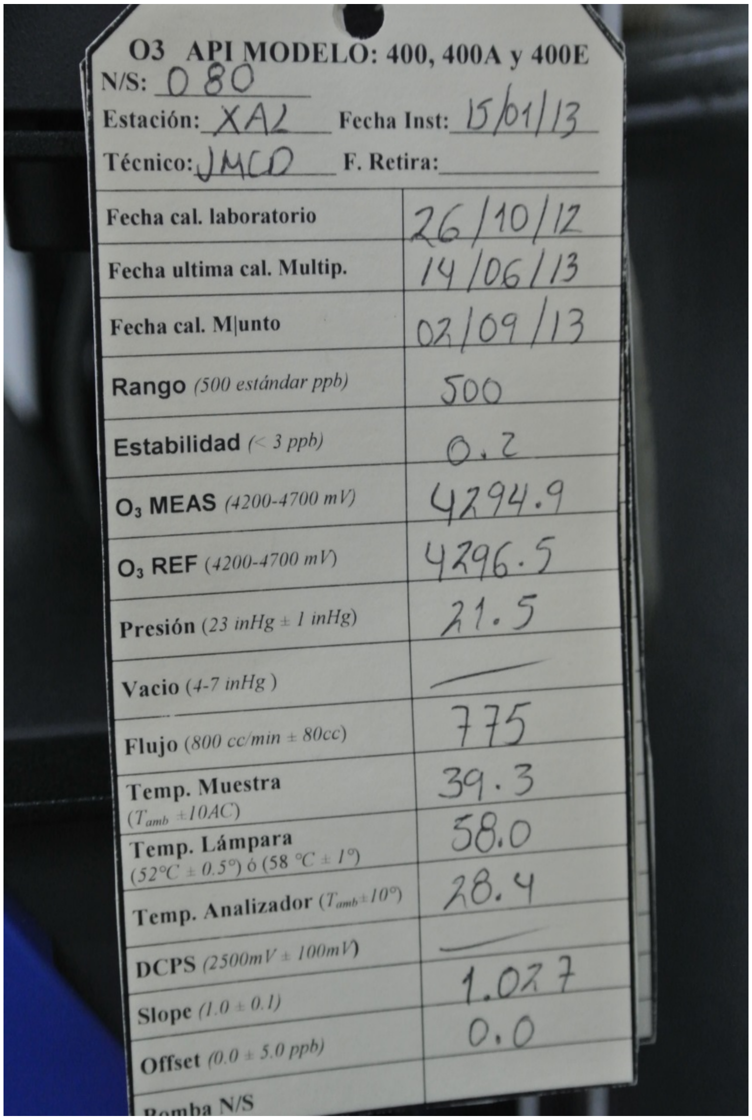
- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Part 1, Ambient Air Quality Monitoring Program System Development, EPA-454/B-13-003, May 2013.
- Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide to Environmental Quality Assurances, EPA/600/R-94/038a, April 1994.

3.1 General Observations

All sites were very well maintained, the plumbing and electrical wiring were well designed and consequently easy to work on, and finally, the shelters were quite clean. The glass sampling manifolds were found to be free of dirt and debris indicating that they were regularly cleaned and maintained. PM10 sample heads were also very clean and well maintained. Standard protocols specify that each glass manifold and PM_{10} sample head is cleaned monthly as part of the network's preventative maintenance regime described above in Section 2.

There were many "best practices" that the network uses to help ensure quality. There are Standard Operating Procedures (SOPs) for most of the analyzers, however with manpower limitations SOPs have not kept up with changing procedures and new analyzers. During each quarterly multipoint calibration, instrument diagnostics information and instrument performance parameters are recorded for each instrument and written on a heavy paper tag that is affixed to each analyzer. A photograph of one of these tags is shown in Figure 3-1. Each time an operator goes to a site to perform calibrations or other maintenance activities, the current operational parameters are reviewed based on the values listed on each instruments performance tag. Any significant changes from the values on the tag may be indicative of a possible instrument malfunction or degraded performance. As this information is typically available (depending on how long an individual instrument has been at a site) for a given instrument for at least one year if not longer, these tags allow an operator to very quickly determine if the current instrument performance has degraded (such as PMT voltage) since last multipoint calibration.

Figure 3-1. Photo of Instrument Information Tag



A review of the site operator logs showed that the operators were very good at documenting their on-site activities. Entries were written in ink, cross-outs were properly done, entries were signed and dated, and the time in and out documented. Figure 3-2 shows a photo of a typical logbook entry.

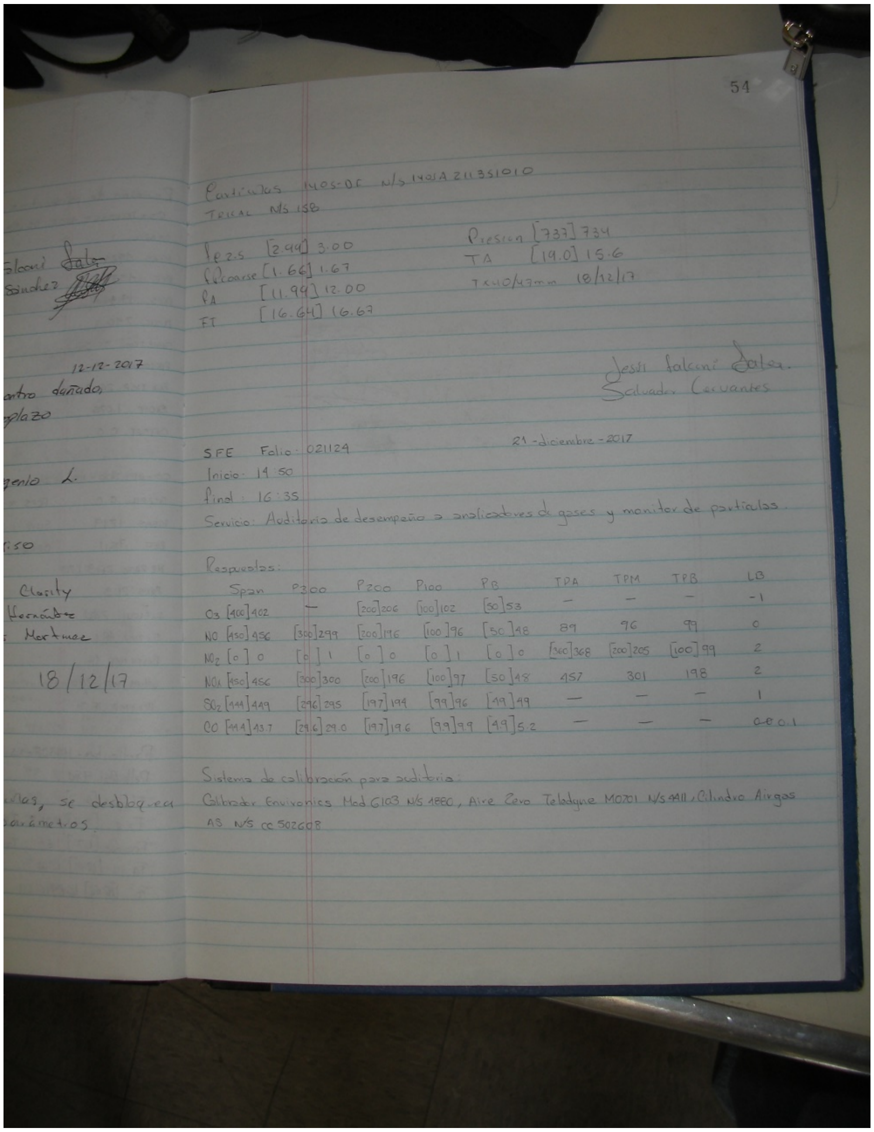
Operator logs are needed to reproduce data or determine the extent and rationale for any system downtime. It needs to be noted that site operators call the main laboratory each time they arrive or leave a site, so this information is documented in the main laboratory logs as well as the site logs.

Another best practice noted at each site included control charting of the zero and span and precision check data for each analyzer at the site. These data were kept at each site, so the operator could quickly see if an analyzer's performance was different from previous results or if an analyzer's performance was slowly changing. Another best practice which simplifies maintenance and operation is ensuring that the equipment orientation is exactly the same at each site. Each site has the instruments arranged from top to bottom in the following order, ozone, nitrogen oxides, sulphur dioxide, and carbon monoxide. This same orientation is also used on the manifold so one knows immediately by looking at the manifold configuration which sample line goes to which analyzer.

Overall, the nine ambient stations plus the laboratory reference analyzers appeared to be very well operated, the operators appear to be well trained, were very knowledgeable about QA/QC procedures and, clearly cared about the quality of their work.

All the continuous monitoring sites were equipped with equipment necessary to performed automated calibrations. This included either API T700 or Thermo 146i dynamic dilution calibrators and API 701 clean air sources. The systems are configured to perform calibrations through each instrument's zero and span ports. A timer is used to turn the air source and calibrator on and off and perform an automated calibration every 6th day. This calibration has now replaced the previously manual calibrations performed bi-weekly on each analyzer through the sample ports.

Figure 3-2. Photo of Site Log Book Entries



US EPA guidance requires that instrument zeros and spans be performed on a weekly basis (either manually or automatically). In addition, to weekly zero/span calibration, bi-weekly precision checks are required. This three-point calibration (zero, span, and a point 16% – 20% of span) must be through the instrument's sample line and "*as much of the sample system as practical*". Finally, a quarterly multi-point calibration and GPT must be performed.

The changes made since the last audit (and detailed in Table 2-2 above) provide good information on the status of instrument operation. Performing the precision check point with each automated calibration as well as the addition of GPT points is a good practice, however it must be noted that these calibrations are through the zero/span ports on the instrument and not through the instrument's sample port. US EPA requires bi-weekly precision checks through the sample port to ensure there are no leaks or problems with the sample system. Issues that would not be detected with a calibration through the zero/span ports.

The US EPA allows zero's and span's to be performed automatically through the zero/span ports but all other calibrations (Level One's or Precision checks, multipoint calibrations, and GPTs) must be performed using the sample ports. The US EPA "*Quality Assurance Handbook for Air Pollution Measurement Systems*, *Volume II Ambient Air Quality Monitoring Program* (May 2013) states in Appendix F:

> *"The integration of DAS, solenoid switches, and MFC into an automated configuration can bring an additional level of complexity to the monitoring station. Operators must be aware that this additional complexity can create situations where leaks can occur. For instance, if a solenoid switch fails to open, then the inlet flow of an analyzer may not be switched back to the ambient manifold, but instead will be sampling interior room air. When the calibrations occur, the instrument will span correctly, but will not return to ambient air sampling. In this case, the data collected must be invalidated. These problems are usually not discovered until there is an external "Through-the Probe" audit, but by then extensive data could be lost. It is recommended that the operator remove the calibration line from the calibration manifold on a routine basis and challenge the sampling system from the inlet probe. This test will discover any leak or switching problems within the entire sampling system."*

This is to ensure that if a leak develops in the sample valve, then this leak will be found and repaired quickly. Otherwise a large bias may result from a leaking sample valve, but the calibrations still appear correct based on the zero/span port calibrations.

While the changes made since the last audit are substantial and very good practice, the auditor would still like to see manual, through the sample port calibration checks every 2 weeks instead of monthly.

Most new networks today are switching to a CARB octopus sample manifold which easily allows all calibrations to be performed automatically through the entire sample system and eliminates the need for zero/span ports on the instruments. This manifold relies on a low internal air volume and the instruments own sample pumps to keep the manifold and sample inlet purged. Because of its low sample volume, there is no need for a blower system as with regular manifold systems. The use of the CARB octopus can easily reduce the costs associated with a new sample system by eliminating the requirement for zero/span ports and valves, the need for extensive tubing and fittings for the zero and span standards and reduces the costs of the manifold system itself by approximately 2/3rds. A photo of a CARB octopus sample manifold is shown in Figure 3-3.

Figure 3-3. Photo of a CARB Octopus Sample Manifold

While the audit results solidly demonstrate that the analyzers are performing well within acceptable limits, these small deviations from US EPA guidance leave open the potential to not capture possible future instrument problems in a timely manner.

Further discussions and audit results from each of the individual sites are presented in the sections presented below.

3.2 SIMAT AIR MONITORING LABORATORY (LAB) SITE

The air monitoring laboratory maintains a series of analyzers used as reference instruments and are not used in the field to monitor air quality. The audit results showed that all the parameters were well within the audit objective of ± 15% with average percent differences being {O_3 (0.34%), NO (-1.2%), NO_x (-0.3%), SO_2 (-1.0%), CO (-0.7%)}. In addition, the GPT showed a NO_2 converter efficiency of 100.0%. Audit results for each of the analyzers at this site are shown in Tables 3-1 to 3-5. Photos of the laboratory instrumentation are shown in Figure 3-4.

Table 3-1. Summary of Ozone (O_3) Audit Results, LAB Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	0.0023	---	***Slope:***	0.9755
0.0470	0.0491	4.5%	***Intercept:***	0.0027
0.0980	0.0976	-0.4%	***Correlation:***	0.9999
0.2050	0.2033	-0.8%		
0.4090	0.4014	-1.9%		
	Average	**0.34 %**		

[1] Objective ±15%

Table 3-2. Summary of Nitrogen Oxides (NO_x) Audit Results, LAB Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NOx	NO
0.0000	0.0012	0.0007	---	---	***Slope:***	1.0273	1.0187
0.0494	0.0481	0.0473	-2.6%	-4.2%	***Intercept:***	-0.0028	-0.0028
0.0996	0.0970	0.0961	-2.6%	-3.5%	***Correlation:***	0.9999	0.9999
0.1994	0.1987	0.1973	-0.3%	-1.0%			
0.2992	0.3033	0.3024	1.4%	1.1%			
0.4492	0.4615	0.4563	2.7%	1.6%			
		Average	**-0.3%**	**-1.2%**			

[1] Objective ±15%

Table 3-3. Summary of Nitrogen Oxides (NO_x) GPT Results, LAB Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0005	---	---	***Slope:***	1.0374
0.0920	0.0959	4.2%	0.092	***Intercept:***	-0.0004
0.1940	0.1973	1.7%	0.193	***Correlation:***	0.9999
0.3430	0.3572	4.1%	0.345	***Converter Efficiency[1]***	**100.0%**

[1] Acceptance Criteria >96%

Table 3-4. Summary of Sulphur Dioxide (SO_2) Audit Results, LAB Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0013	---	***Slope:***	0.9915
0.0487	0.0490	0.6%	***Intercept:***	0.0000
0.0983	0.0962	-2.1%	***Correlation:***	1.0000
0.1969	0.1936	-1.7%		
0.2954	0.2925	-1.0%		
0.4435	0.4408	-0.6%		
	Average	-1.0%		

[1] Objective ±15%

Table 3-5. Summary of Carbon Monoxide (CO) Audit Results, LAB Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.0	---	***Slope:***	0.9927
4.87	5.0	2.7%	***Intercept:***	-0.0619
9.82	9.7	-1.2%	***Correlation:***	0.9999
19.66	19.1	-2.9%		
29.51	29.0	-1.7%		
44.30	44.2	-0.2%		
	Average	-0.7%		

[1] Objective ±15%

Figure 3-4. Front and Back View of the SIMAT Laboratory Reference Analyzers

3.3 San Agustín (SAG) Site

The SAG site is located on the roof of a healthcare clinic with monitoring equipment housed inside of an Ekto shelter. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (1.9%), NO (2.8%), NO_x (2.8%), SO_2 (-0.4%), CO (1.9%)}. In addition, the GPT showed a NO_2 converter efficiency of 100.9%. Audit results for each of the analyzers at this site are shown in Tables 3-6 to 3-10. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$, as well as barometric pressure were within specification. Flow rate audit data are shown in Table 3-11. Photo of the site are shown in Figure 3-5.

Table 3-6. Summary of Ozone (O_3) Audit Results, SAG Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	0.0003	---	***Slope:***	0.9996
0.0500	0.0524	4.8%	***Intercept:***	0.0015
0.1020	0.1043	2.3%	***Correlation:***	1.0000
0.2040	0.2048	0.4%		
0.4020	0.4033	0.3%		
	Average	1.9%		

[1] Objective ±15%

Table 3-7. Summary of Nitrogen Oxides (NO_x) Audit Results, SAG Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0022	-0.0002	---	---	***Slope:***	1.0294	1.0345
0.0495	0.0511	0.0510	3.3%	3.1%	***Intercept:***	0.0004	-0.0010
0.0994	0.1012	0.1018	1.9%	2.5%	***Correlation:***	1.0000	1.0000
0.1995	0.2050	0.2021	2.8%	1.3%			
0.2996	0.3083	0.3099	2.9%	3.4%			
0.4496	0.4642	0.4649	3.2%	3.4%			
		Average	2.8%	2.8%			

[1] Objective ±15%

Table 3-8. Summary of Nitrogen Oxides (NO_x) GPT Results, SAG Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0024	---	---	***Slope:***	0.9800
0.0940	0.1013	7.8%	0.095	***Intercept:***	0.0022
0.2000	0.2064	3.2%	0.201	***Correlation:***	1.0000
0.3570	0.3733	4.6%	0.361	***Converter Efficiency[1]***	**100.9%**

[1] **Acceptance Criteria >96%**

Table 3-9. Summary of Sulphur Dioxide (SO_2) Audit Results, SAG Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0030	---	***Slope:***	0.9773
0.0488	0.0500	2.4%	***Intercept:***	0.0027
0.0981	0.0970	-1.1%	***Correlation:***	1.0000
0.1969	0.1960	-0.5%		
0.2958	0.2940	-0.6%		
0.4439	0.4350	-2.0%		
	Average	-0.4%		

[1] **Objective ±15%**

Table 3-10. Summary of Carbon Monoxide (CO) Audit Results, SAG Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	-0.1	---	***Slope:***	1.0145
4.88	5.1	4.6%	***Intercept:***	-0.0328
9.80	10.0	2.1%	***Correlation:***	1.0000
19.67	19.7	0.2%		
29.55	29.8	0.9%		
44.34	45.1	1.7%		
	Average	1.9%		

[1] Objective ±15%

Table 3-11. TEOM Flow Rate and Barometric Pressure Audit Results, SAG Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	1.15%	0.4%	-0.8%	Pass
PM_{coarse}	0.33	0.0%	-0.3%	Pass
$PM_{2.5}$	1.77	0.0%	-1.7%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	**Site Sensor Reading (atm)**	**Site Sensor Reading (mmHg)**	**Measurement Error (mm Hg) [1]**	**Pass / Fail**
586.0	0.764	580.64	-5.4	Pass

[1] Acceptance criteria ± 10 mm Hg

Figure 3-5. Photo of the SAG Site Shelter

3.4 XALOSTOC (XAL) SITE

This station is in an industrial/commercial/residential area. The equipment is housed in a small shelter on the fourth-floor roof of a Regional Hospital. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (-1.2%), NO (-2.0%), NO_x (-0.5%), SO_2 (-3.7%), CO (1.6%)}. In addition, the GPT showed a NO_2 converter efficiency of 98.2%. Audit results for each of the analyzers at this site are shown in Tables 3-12 to 3-16. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Flow rate audit data for the TEOM are shown in Table 3-17. Photo of the site is shown in Figure 3-6.

Table 3-12. Summary of Ozone (O_3) Audit Results, XAL Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	0.0010	---	**Slope:**	0.9640
0.0460	0.0470	2.2%	**Intercept:**	0.0020
0.1040	0.1020	-1.9%	**Correlation:**	1.0000
0.2010	0.1970	-2.0%		
0.3990	0.3860	-3.3%		
	Average	-1.2%		

[1] Objective ±15%

Table 3-13. Summary of Nitrogen Oxides (NO_x) Audit Results, XAL Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0031	0.0019	---	---	**Slope:**	0.9845	0.9914
0.0493	0.0504	0.0480	2.3%	-2.6%	**Intercept:**	0.0016	-0.0007
0.0994	0.0980	0.0958	-1.4%	-3.6%	**Correlation:**	1.0000	0.9999
0.1994	0.1977	0.1951	-0.8%	-2.1%			
0.2996	0.2949	0.2966	-1.6%	-1.0%			
0.4496	0.4457	0.4461	-0.9%	-0.8%			
			-0.5%	-2.0%			

[1] Objective ±15%

Table 3-14. Summary of Nitrogen Oxides (NO_x) GPT Results, XAL Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0012	---	---	*Slope:*	0.9646
0.0910	0.0900	-1.1%	0.089	*Intercept:*	0.0016
0.1910	0.1856	-2.8%	0.189	*Correlation:*	1.0000
0.3400	0.3295	-3.1%	0.333	*Converter Efficiency*	**98.2%**

Table 3-15. Summary of Sulphur Dioxide (SO_2) Audit Results, XAL Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0007	---	***Slope:***	0.9688
0.0486	0.0465	-4.4%	***Intercept:***	-0.0003
0.0981	0.0935	-4.7%	***Correlation:***	1.0000
0.1968	0.1903	-3.3%		
0.2958	0.2866	-3.1%		
0.4439	0.4297	-3.2%		
	Average	-3.7%		

[1] Objective ±15%

Table 3-16. Summary of Carbon Monoxide (CO) Audit Results, XAL Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.2	---	***Slope:***	1.0093
4.86	4.9	0.8%	***Intercept:***	0.1487
9.80	10.0	2.1%	***Correlation:***	0.9999
19.66	20.0	1.7%		
29.55	30.3	2.6%		
44.34	44.7	0.8%		
	Average	1.6%		

[1] Objective ±15%

Table 3-17. TEOM Flow Rate and Barometric Pressure Audit Results, XAL Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	1.71%	-0.1%	-1.8%	Pass
PM_{coarse}	2.40	-0.3%	-2.7%	Pass
$PM_{2.5}$	4.24	0.0%	-4.1%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	**Site Sensor Reading (atm)**	**Site Sensor Reading (mmHg)**	**Measurement Error (mm Hg) [1]**	**Pass / Fail**
581.5	0.762	579.12	-2.4	Pass

[1] Acceptance criteria ± 10 mm Hg

Figure 3-6. Photo of the XAL Site Shelter

3.5 Ajusco Medio (AJM) Site

This station is located on the fourth-floor roof of a new city hospital. The instruments are housed in an Ekto Shelter with sample inlet approximately 25 m above ground level. The "green" roof is covered in plant material to absorb rain fall, minimize runoff, and reduce heat buildup. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (0.5%), NO (1.1%), NO_x (1.4%), SO_2 (-1.8%), CO (-0.5%)}. In addition, the GPT showed a NO_2 converter efficiency of 98.8%. Audit results for each of the analyzers at this site are shown in Tables 3-18 to 3-22. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Flow rate audit data for the TEOM are shown in Table 3-23. Photos of the site are shown in Figures 3-7 and 3-8.

Table 3-18. Summary of Ozone (O_3) Audit Results, AJM Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0002	---	**Slope:**	1.0186
0.0480	0.0452	-5.8%	**Intercept:**	-0.0006
0.1000	0.1048	4.8%	**Correlation:**	0.9999
0.2010	0.2037	1.3%		
0.3990	0.4056	1.7%		
	Average	0.5%		

[1] Objective ±15%

Table 3-19. Summary of Nitrogen Oxides (NO_x) Audit Results, AJM Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0009	0.0001	---	---	**Slope:**	1.0124	1.0138
0.0495	0.0509	0.0506	2.8%	2.2%	**Intercept:**	0.0002	-0.0005
0.0997	0.1008	0.1004	1.1%	0.7%	**Correlation:**	1.0000	1.0000
0.1994	0.2008	0.2001	0.7%	0.4%			
0.2996	0.3028	0.3021	1.1%	0.8%			
0.4500	0.4568	0.4571	1.5%	1.6%			
		Average	1.4%	1.1%			

[1] Objective ±15%

Table 3-20. Summary of Nitrogen Oxides (NO_x) GPT Results, AJM Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0008	---	---	*Slope:*	1.0023
0.1000	0.1001	0.1%	0.098	*Intercept:*	0.0008
0.2030	0.2060	1.5%	0.202	*Correlation:*	1.0000
0.3630	0.3640	0.3%	0.359	*Converter Efficiency*	**98.8%**

Table 3-21. Summary of Sulphur Dioxide (SO_2) Audit Results, AJM Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0011	---	***Slope:***	0.9887
0.0489	0.0480	-1.8%	***Intercept:***	-0.0005
0.0984	0.0956	-2.9%	***Correlation:***	1.0000
0.1968	0.1931	-1.9%		
0.2958	0.2910	-1.6%		
0.4443	0.4400	-1.0%		
	Average	-1.8%		

[1] **Objective ±15%**

Table 3-22. Summary of Carbon Monoxide (CO) Audit Results, AJM Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.2	---	***Slope:***	0.9967
4.88	4.9	0.5%	***Intercept:***	0.0408
9.83	9.6	-2.1%	***Correlation:***	1.0000
19.66	19.5	-0.8%		
29.55	29.6	0.2%		
44.38	44.3	-0.2%		
	Average	-0.5%		

[1] Objective ±15%

Table 3-23. TEOM Flow Rate and Barometric Pressure Audit Results, XAL Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	1.5%	0.2%	-1.3%	Pass
PM_{coarse}	3.4%	0.0%	-3.3%	Pass
$PM_{2.5}$	0.7%	0.0%	-0.7%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	**Site Sensor Reading (atm)**	**Site Sensor Reading (mmHg)**	**Measurement Error (mm Hg) [1]**	**Pass / Fail**
559.5	0.737	560.12	0.6	Pass

[1] Acceptance criteria ± 10 mm Hg

Figure 3-7. Photo of AJM Site Shelter

Figure 3-8. Photo of AJM Site Shelter

3.6 UAM Xochimilco (UAX) Site

This station is located on the fourth-floor roof of the science building at Universidad Autónoma Metropolitana Campus Xochimilco. The system was housed in a concrete shelter on the building roof. The university is situated in a gated residential area with no major streets adjacent to the station. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (-0.04%), NO (0.1%), NO_x (-0.4%), SO_2 (-2.6%), CO (-1.7%)}. In addition, the GPT showed a NO_2 converter efficiency of 101.3%. Audit results for each of the analyzers at this site are shown in Tables 3-24 to 3-28. In addition, a flow check of the Thermo Model FH62C-14 beta gauge analyzer showed that the flow rate was within project specification. Flow rate audit data are shown in Table 3-29. Photos of the site are shown in Figures 3-9 and 3-10.

Table 3-24. Summary of Ozone (O_3) Audit Results, UAX Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0022	---	***Slope:***	1.0000
0.0510	0.0514	0.8%	***Intercept:***	-0.0008
0.1010	0.1008	-0.2%	***Correlation:***	1.0000
0.2030	0.2020	-0.5%		
0.3980	0.3970	-0.3%		
	Average	-0.04%		

[1] Objective ±15%

Table 3-25. Summary of Nitrogen Oxides (NO_x) Audit Results, UAX Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0017	0.0001	---	---	***Slope:***	0.9948	1.0009
0.0495	0.0495	0.0502	0.1%	1.5%	***Intercept:***	0.0006	-0.0002
0.0996	0.0976	0.0992	-2.0%	-0.4%	***Correlation:***	0.9999	1.0000
0.1993	0.2016	0.1993	1.1%	0.0%			
0.2993	0.2965	0.2967	-0.9%	-0.9%			
0.4500	0.4488	0.4519	-0.3%	0.4%			
		Average	-0.4%	0.1%			

[1] Objective ±15%

Table 3-26. Summary of Nitrogen Oxides (NO_x) GPT Results, UAX Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0016	---	---	*Slope:*	1.0182
0.0960	0.0970	1.0%	0.094	*Intercept:*	0.0012
0.1970	0.2040	3.6%	0.204	*Correlation:*	0.9999
0.3590	0.3660	1.9%	0.368	*Converter Efficiency*[1]	**101.3%**

[1] Acceptance Criteria >96%

Table 3-27. Summary of Sulphur Dioxide (SO_2) Audit Results, UAX Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0008	---	*Slope:*	0.99212
0.0488	0.0466	-4.6%	*Intercept:*	0.00039
0.0983	0.0944	-4.0%	*Correlation:*	0.99998
0.1968	0.1917	-2.6%		
0.2954	0.2900	-1.8%		
0.4443	0.4360	-1.9%		
	Average	-2.6%		

[1] Objective ±15%

Table 3-28. Summary of Carbon Monoxide (CO) Audit Results, UAX Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.2	---	*Slope:*	0.9926
4.88	4.8	-2.4%	*Intercept:*	-0.0430
9.82	9.5	-3.4%	*Correlation:*	1.0000
19.66	19.4	-1.5%		
29.51	29.4	-0.4%		
44.38	44.0	-0.9%		
Average		-1.7%		

[1] Objective ±15%

Table 3-29. Beta Gauge Flow Rate Audit Results, UAX Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
PM_{10} flowrate	-0.31%	-3.1%	-2.8%	Pass

Figure 3-9. Front View of UAX Shelter

Figure 3-10. Side View of UAX Shelter

3.7 MERCED (MER) SITE

This station is near the downtown of Mexico City in a shed on the third-floor roof of a junior high school. The streets around the station are wide and heavily traveled and there is an elevated Metro railway to the west. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (2.7%), NO (1.1%), NO_x (1.1%), SO_2 (-0.5%), CO (-3.9%)}. In addition, the GPT showed a NO_2 converter efficiency of 104.4%. Audit results for each of the analyzers at this site are shown in Tables 3-30 to 3-34. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Flow rate audit data for the TEOM are shown in Table 3-35. Photo of the site is shown in Figure 3-11.

Table 3-30. Summary of Ozone (O_3) Audit Results, MER Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0020	---	***Slope:***	0.9997
0.0500	0.0537	7.4%	***Intercept:***	0.0013
0.1000	0.1026	2.6%	***Correlation:***	0.9999
0.2010	0.2023	0.6%		
0.4000	0.4004	0.1%		
	Average	2.7%		

[1] Objective ±15%

Table 3-31. Summary of Nitrogen Oxides (NO_x) Audit Results, MER Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	-0.0017	-0.0002	---	---	***Slope:***	1.0178	1.0123
0.0494	0.0510	0.0507	3.3%	2.7%	***Intercept:***	-0.0015	-0.0004
0.0994	0.0990	0.0998	-0.4%	0.4%	***Correlation:***	1.0000	1.0000
0.1993	0.2002	0.1997	0.5%	0.2%			
0.2992	0.3009	0.3028	0.6%	1.2%			
0.4495	0.4577	0.4551	1.8%	1.3%			
		Average	1.1%	1.1%			

[1] Objective ±15%

Table 3-32. Summary of Nitrogen Oxides (NO_x) GPT Results, MER Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer Regression Data	
0.0000	-0.0015	---	---	*Slope:*	1.0506
0.0900	0.0964	7.1%	0.095	*Intercept:*	-0.0001
0.1940	0.2036	4.9%	0.203	*Correlation:*	1.0000
0.3490	0.3661	4.9%	0.359	*Converter Efficiency*[1]	104.4%

[1] Acceptance Criteria >96%

Table 3-33. Summary of Sulphur Dioxide (SO_2) Audit Results, MER Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0012	---	*Slope:*	0.9954
0.0488	0.0499	2.3%	*Intercept:*	0.0006
0.0982	0.0974	-0.8%	*Correlation:*	1.0000
0.1967	0.1955	-0.6%		
0.2954	0.2948	-0.2%		
0.4437	0.4428	-0.2%		
	Average	-0.5%		

[1] Objective ±15%

Table 3-34. Summary of Carbon Monoxide (CO) Audit Results, MER Site

CO Input (ppm-v)	*CO Response (ppm-v)*	*Percent Difference*[1]	CO Analyzer Regression Data	
0.00	*-0.3*	*---*	*Slope:*	1.0056
4.87	*4.3*	*-11.7%*	*Intercept:*	-0.4454
9.81	*9.3*	*-5.2%*	*Correlation:*	0.9999
19.65	*19.3*	*-1.8%*		
29.51	*29.5*	*0.0%*		
44.33	*44.0*	*-0.7%*		
	Average	*-3.9%*		

[1] Objective ±15%

Table 3-35. TEOM Flow Rate and Barometric Pressure Audit Results, MER Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	-1.1%	-0.1%	1.0%	Pass
PM_{coarse}	-0.7	0.0%	0.7%	Pass
$PM_{2.5}$	-0.06	0.0%	0.1%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	Site Sensor Reading (atm)	Site Sensor Reading (mmHg)	Measurement Error (mm Hg) [1]	Pass / Fail
586.5	0.766	582.16	-4.3	Pass

[1] Acceptance criteria ± 10 mm Hg

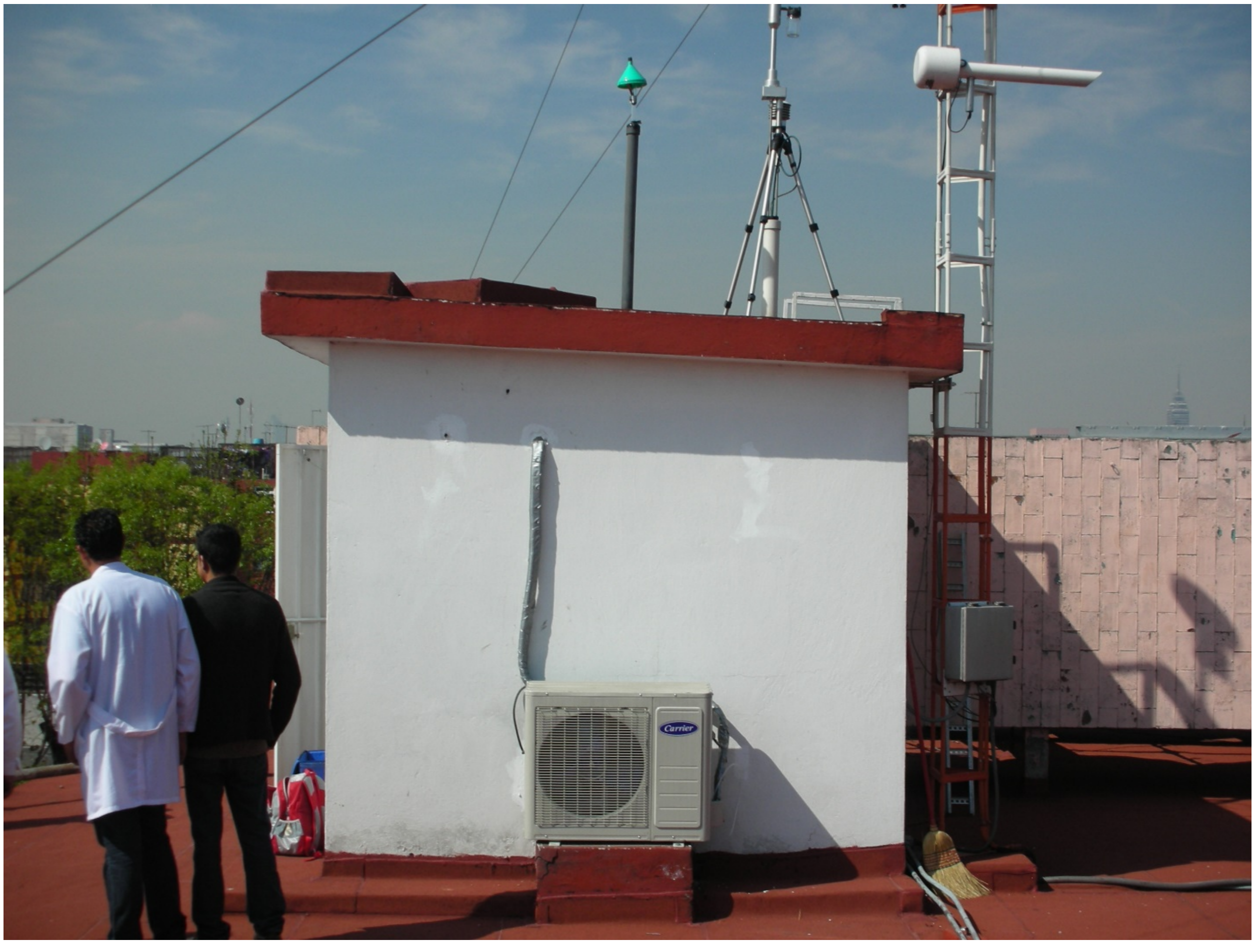


Figure 3-11. Photo of the MER Site Shelter

3.8 UAM Iztapalapa (UIZ) Site

This station is located on the top of the third-floor building at Universidad Autónoma Metropolitana Campus Iztapalapa and housed in an Ekto Shelter. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (0.6%), NO (-3.7%), NO_x (-3.2%), SO_2 (-0.8%), CO (-0.9%)}. In addition, the GPT showed a NO_2 converter efficiency of 101.0%. There is normally a TEOM 1405DF at this site but at the time of the audit it was at the laboratory undergoing annual maintenance and service. Audit results for each of the analyzers at this site are shown in Tables 3-36 to 3-40. Photos of the site are shown in Figures 3-12 and 3-13.

Table 3-36. Summary of Ozone (O_3) Audit Results, UIZ Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0005	---	*Slope:*	0.9791
0.0500	0.0513	2.6%	*Intercept:*	0.0020
0.1000	0.1026	2.6%	*Correlation:*	0.9999
0.2020	0.2003	-0.8%		
0.4000	0.3927	-1.8%		
	Average	0.6%		

[1] **Objective ±15%**

Table 3-37. Summary of Nitrogen Oxides (NO_x) Audit Results, UIZ Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0027	0.0001	---	---	*Slope:*	0.9782	0.9812
0.0493	0.0483	0.0469	-2.0%	-4.9%	*Intercept:*	-0.0006	-0.0019
0.0995	0.0937	0.0944	-5.9%	-5.2%	*Correlation:*	0.9999	1.0000
0.1994	0.1919	0.1921	-3.8%	-3.7%			
0.2993	0.2923	0.2910	-2.3%	-2.8%			
0.4493	0.4407	0.4406	-1.9%	-1.9%			
		Average	-3.2%	-3.7%			

[1] Objective ±15%

Table 3-38. Summary of Nitrogen Oxides (NO_x) GPT Results, UIZ Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0026	---	---	*Slope:*	0.9827
0.0960	0.0958	-0.2%	0.097	*Intercept:*	0.0023
0.1960	0.1956	-0.2%	0.198	*Correlation:*	1.0000
0.3550	0.3510	-1.1%	0.358	*Converter Efficiency*[1]	**101.0%**

[1] **Acceptance Criteria >96%**

Table 3-39. Summary of Sulphur Dioxide (SO_2) Audit Results, UIZ Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0000	---	***Slope:***	1.0041
0.0487	0.0480	-1.4%	***Intercept:***	-0.0012
0.0983	0.0960	-2.3%	***Correlation:***	1.0000
0.1969	0.1960	-0.4%		
0.2955	0.2950	-0.2%		
0.4436	0.4450	0.3%		
	Average	-0.8%		

[1] Objective ±15%

Table 3-40. Summary of Carbon Monoxide (CO) Audit Results, UIZ Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference [1]	CO Analyzer Regression Data	
0.00	0.2	---	***Slope:***	0.9968
4.86	4.7	-3.3%	***Intercept:***	0.0455
9.82	9.7	-1.2%	***Correlation:***	0.9999
19.67	19.6	-0.3%		
29.52	29.9	1.3%		
44.31	44.0	-0.7%		
	Average	-0.9%		

[1] Objective ±15%

Figure 3-12. Rear View of the UIZ Ekto Shelter

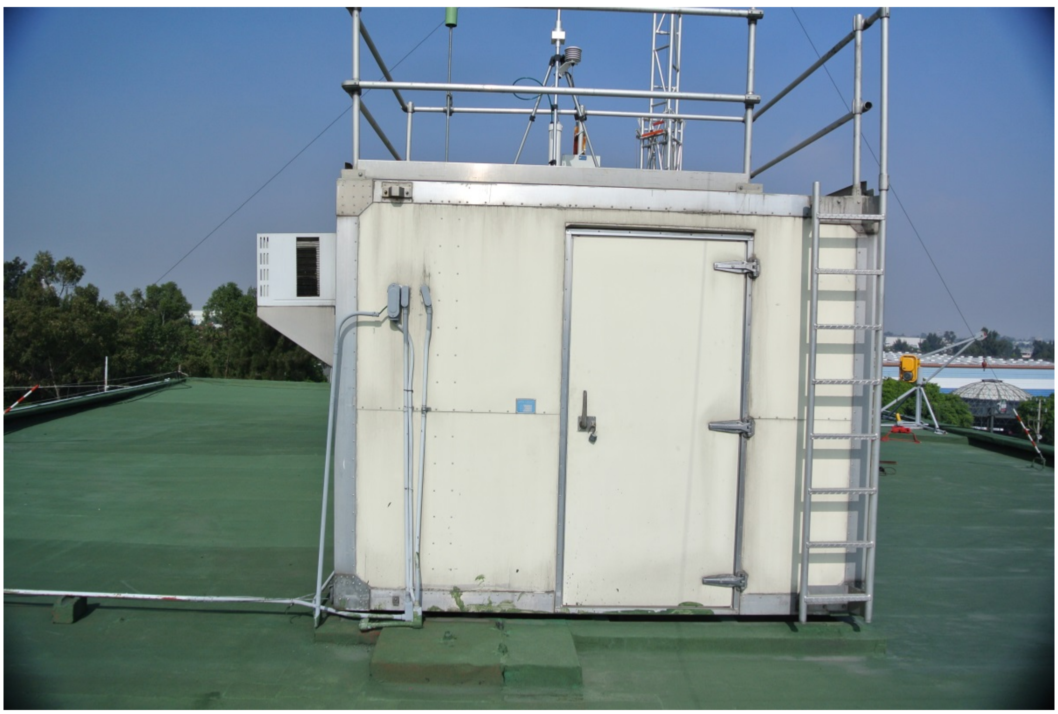


Figure 3-13. Front View of the UIZ Ekto Shelter

3.9 MIGUEL HIDALGO (MGH) SITE

This site was located on the roof of a community center in a residential neighborhood. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (3.7%), NO (-0.1%), NO_x (-0.1%), SO_2 (-2.9%), CO (-2.1%)}. In addition, the GPT showed a NO_2 converter efficiency of 101.5%. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Audit results for each of the analyzers at this site are shown in Tables 3-41 to 3-45. Flow rate audit data for the TEOM are shown in Table 3-46. Photo of the site is shown in Figure 3-14.

Table 3-41. Summary of Ozone (O_3) Audit Results, MGH Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0036	---	***Slope:***	1.0209
0.0490	0.0542	10.6%	***Intercept:***	-0.0003
0.1020	0.1015	-0.5%	***Correlation:***	0.9998
0.2020	0.2080	3.0%		
0.3990	0.4060	1.8%		
	Average	3.7%		

[1] Objective ±15%

Table 3-42. Summary of Nitrogen Oxides (NO_x) Audit Results, MGH Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0008	0.0008	---	---	***Slope:***	1.0086	1.0098
0.0494	0.0495	0.0490	0.2%	-0.8%	***Intercept:***	-0.0010	-0.0009
0.0997	0.0985	0.0989	-1.2%	-0.8%	***Correlation:***	1.0000	1.0000
0.1993	0.1978	0.1985	-0.8%	-0.4%			
0.2992	0.3000	0.3010	0.3%	0.6%			
0.4494	0.4540	0.4540	1.0%	1.0%			
		Average	-0.1%	-0.1%			

[1] Objective ±15%

Table 3-43. Summary of Nitrogen Oxides (NO_x) GPT Results, MGH Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0000	---	---	***Slope:***	1.0155
0.0970	0.1000	3.1%	0.099	***Intercept:***	0.0007
0.2030	0.2070	2.0%	0.206	***Correlation:***	1.0000
0.3640	0.3700	1.6%	0.367	***Converter Efficiency[1]***	**101.5%**

[1] Acceptance Criteria >96%

Table 3-44. Summary of Sulphur Dioxide (SO_2) Audit Results, MGH Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	-0.0003	---	*Slope:*	0.9774
0.0488	0.0480	-1.6%	*Intercept:*	-0.0006
0.0984	0.0944	-4.0%	*Correlation:*	1.0000
0.1968	0.1908	-3.0%		
0.2954	0.2890	-2.2%		
0.4437	0.4330	-2.4%		
	Average	-2.9%		

[1] **Objective +15%**

Table 3-45. Summary of Carbon Monoxide (CO) Audit Results, MGH Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.0	---	*Slope:*	0.9848
4.87	4.8	-2.3%	*Intercept:*	-0.0471
9.83	9.5	-3.4%	*Correlation:*	1.0000
19.66	19.3	-1.8%		
29.51	29.2	-1.0%		
44.32	43.5	-1.8%		
	Average	-2.1%		

[1] **Objective +15%**

Table 3-46. TEOM Flow Rate and Barometric Pressure Audit Results, MGH Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	-0.2%	0.0%	0.2%	Pass
PM_{coarse}	-1.0	-0.3%	0.7%	Pass
$PM_{2.5}$	-3.5	0.0%	3.6%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	**Site Sensor Reading (atm)**	**Site Sensor Reading (mmHg)**	**Measurement Error (mm Hg) [1]**	**Pass / Fail**
578.5	0.752	571.52	-7.0	Pass

[1] Acceptance criteria ± 10 mm Hg

Figure 3-14. Photo of the MGH Site Shelter

3.10 SANTA FE (SFE) SITE

This site is located at "Parque Prados de la Montaña". This site is in a new, upscale and growing part of Mexico City but was once a landfill that has been closed but is currently undergoing landfill gas recovery with wells and gas lines crisscrossing the property. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (2.6%), NO (-1.2%), NO_x (-1.3%), SO_2 (-2.9%), CO (0.8%)}. In addition, the GPT showed a NO_2 converter efficiency of 101.3%. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Audit results for each of the analyzers at this site are shown in Tables 3-41 to 3-45. Flow rate audit data for the TEOM are shown in Table 3-46. Photo of the site is shown in Figure 3-15.

Table 3-47. Summary of Ozone (O_3) Audit Results, SFE Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0010	---	***Slope:***	1.0060
0.0500	0.0530	6.0%	***Intercept:***	0.0013
0.1010	0.1020	1.0%	***Correlation:***	0.9999
0.2000	0.2060	3.0%		
0.4000	0.4020	0.5%		
	Average	2.6%		

[1] **Objective ±15%**

Table 3-48. Summary of Nitrogen Oxides (NO_x) Audit Results, SFE Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NO_x	NO	Parameter	NO_x	NO
0.0000	0.0018	0.0001			***Slope:***	1.0134	1.0148
0.0495	0.0477	0.0480	-3.6%	-3.0%	***Intercept:***	-0.0022	-0.0029
0.0995	0.0968	0.0964	-2.7%	-3.1%	***Correlation:***	0.9999	0.9999
0.1992	0.1958	0.1961	-1.7%	-1.6%			
0.2992	0.3000	0.2990	0.3%	-0.1%			
0.4494	0.4560	0.4560	1.5%	1.5%			
		Average	-1.3%	-1.2%			

[1] Objective ±15%

Table 3-49. Summary of Nitrogen Oxides (NO_x) GPT Results, SFE Site

NO_2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0017	---	---	*Slope:*	1.0142
0.0960	0.0993	3.4%	0.099	*Intercept:*	0.0017
0.2010	0.2050	2.0%	0.202	*Correlation:*	1.0000
0.3610	0.3680	1.9%	0.362	*Converter Efficiency*[1]	**101.3%**

[1] Acceptance Criteria >96%

Table 3-50. Summary of Sulphur Dioxide (SO_2) Audit Results, SFE Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0005	---	*Slope:*	1.0102
0.0488	0.0485	-0.7%	*Intercept:*	-0.0017
0.0982	0.0963	-2.0%	*Correlation:*	0.9999
0.1967	0.1943	-1.2%		
0.2954	0.2950	-0.1%		
0.4437	0.4490	1.2%		
	Average	-2.9%		

[1] Objective ±15%

Table 3-51. Summary of Carbon Monoxide (CO) Audit Results, SFE Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.0	---	*Slope:*	0.9804
4.88	5.2	6.6%	*Intercept:*	0.2251
9.81	9.9	0.9%	*Correlation:*	1.0000
19.65	19.6	-0.2%		
29.51	29.0	-1.7%		
44.32	43.7	-1.4%		
	Average	0.8%		

[1] Objective ±15%

Table 3-52. TEOM Flow Rate and Barometric Pressure Audit Results, SFE Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	0.2%	-0.2%	-0.4%	Pass
PM_{coarse}	2.0%	0.0%	-2.0%	Pass
$PM_{2.5}$	2.3%	0.0%	-2.2%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	Site Sensor Reading (atm)	Site Sensor Reading (mmHg)	Measurement Error (mm Hg) [1]	Pass / Fail
558.5	0.725	551	-7.5	Pass

[1] Acceptance criteria ± 10 mm Hg

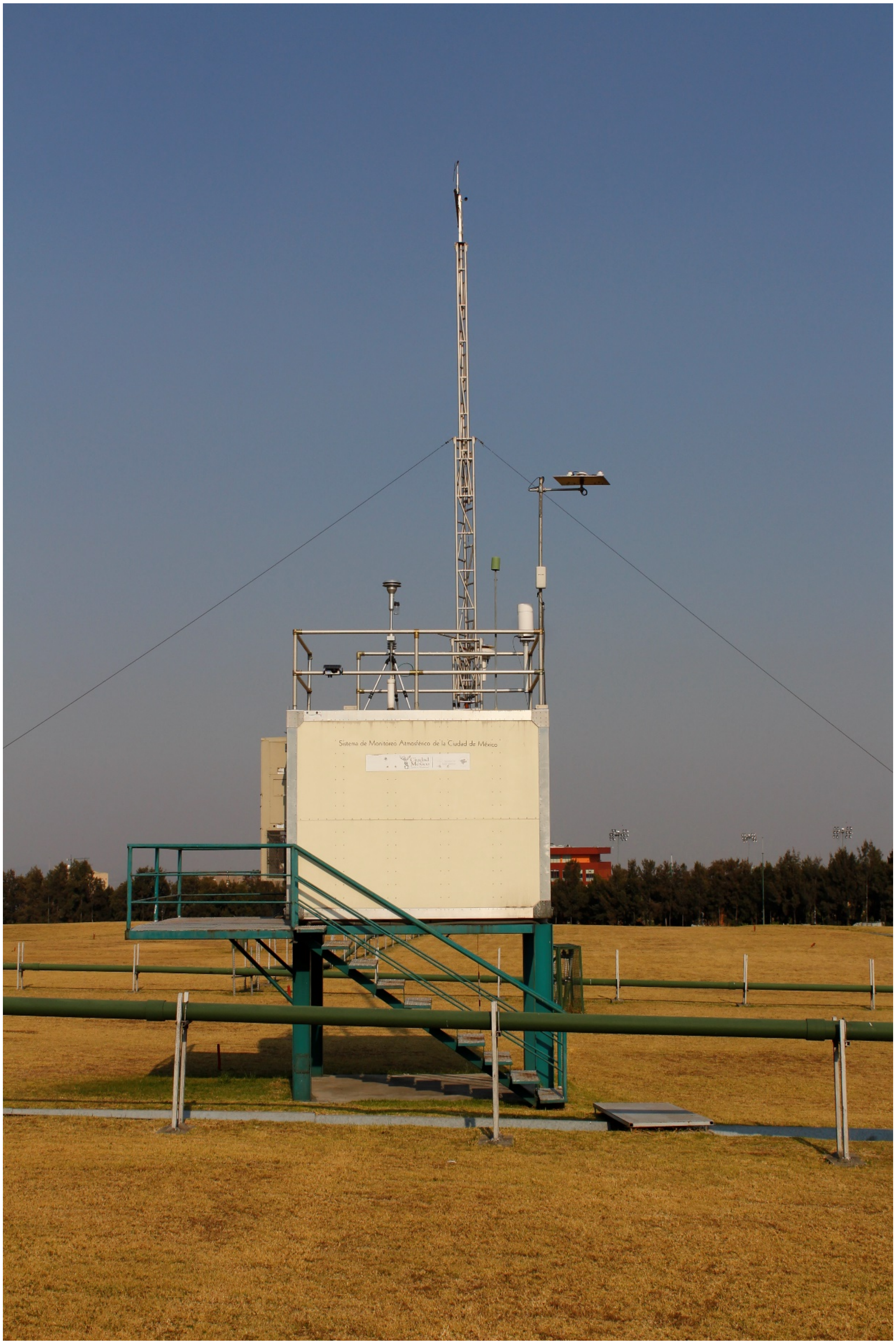


Figure 3-15. Photo of the SFE Site Shelter

3.11 Tlalnepantla (TLA) Site

This site was housed in an elevated shed about 3 meters above ground level adjacent to a municipal water storage tank. This was an older site but was well maintained and relatively clean. The audit results showed that all criteria pollutant parameters were well within the audit objectives of ± 15% with average percent differences being {O_3 (0.1%), NO (-1.2%), NO_x (-1.0%), SO_2 (-0.8%), CO (-4.1%)}. In addition, the GPT showed a NO_2 converter efficiency of 102.5%. In addition, a flow check of the TEOM 1405DF showed that all flows (total, PM_{coarse} and $PM_{2.5}$) as well as barometric pressure were all within project specification. Audit results for each of the analyzers at this site are shown in Tables 3-53 to 3-45. Flow rate audit data for the TEOM are shown in Table 3-46. Photo of the site is shown in Figure 3-16.

Table 3-53. Summary of Ozone (O_3) Audit Results, TLA Site

O_3 Input (ppm-v)	O_3 Response (ppm-v)	Percent Difference[1]	O_3 Analyzer Regression Data	
0.0000	-0.0028	---	***Slope:***	1.0045
0.0510	0.0518	1.6%	***Intercept:***	-0.0013
0.1000	0.0990	-1.0%	***Correlation:***	1.0000
0.1990	0.1985	-0.3%		
0.3970	0.3973	0.1%		
	Average	0.1%		

[1] Objective ±15%

Table 3-54. Summary of Nitrogen Oxides (NO_x) Audit Results, TLA Site

NO_x / NO Input (ppm-v)	Response		Percent Difference[1]		NO_x Analyzer Regression Data		
	NO_x (ppm-v)	NO (ppm-v)	NOx	NO	Parameter	NO_x	NO
0.0000	0.0000	0.0000	---	---	***Slope:***	1.0191	1.0283
0.0494	0.0480	0.0470	-2.8%	-4.8%	***Intercept:***	-0.0031	-0.0041
0.0996	0.0960	0.0960	-3.6%	-3.6%	***Correlation:***	0.9999	0.9998
0.1994	0.1970	0.1970	-1.2%	-1.2%			
0.2992	0.3010	0.3020	0.6%	0.9%			
0.4492	0.4570	0.4610	1.7%	2.6%			
		Average	-1.0%	-1.2%			

[1] Objective ±15%

Table 3-55. Summary of Nitrogen Oxides (NO_x) GPT Results, TLA Site

NO2 Audit Data					
NO_2 Input (ppm-v)	NO_2 Response (ppm-v)	NO_2 Percent Difference	NO_2 Converted (ppm-v)	NO_2 Analyzer	Regression Data
0.0000	0.0000	---	---	*Slope:*	1.0257
0.0910	0.0970	6.6%	0.095	*Intercept:*	0.0018
0.1990	0.2070	4.0%	0.203	*Correlation:*	0.9999
0.3580	0.3680	2.8%	0.362	*Converter Efficiency*[1]	102.5%

[1] **Acceptance Criteria >96%**

Table 3-56. Summary of Sulphur Dioxide (SO_2) Audit Results, TLA Site

SO_2 Input (ppm-v)	SO_2 Response (ppm-v)	Percent Difference [1]	SO_2 Analyzer Regression Data	
0.0000	0.0010	---	*Slope:*	0.9856
0.0487	0.0490	0.6%	*Intercept:*	0.0010
0.0983	0.0960	-2.3%	*Correlation:*	1.0000
0.1969	0.1970	0.1%		
0.2954	0.2930	-0.8%		
0.4435	0.4370	-1.5%		
	Average	-0.8		

[1] **Objective ±15%**

Table 3-57. Summary of Carbon Monoxide (CO) Audit Results, TLA Site

CO Input (ppm-v)	CO Response (ppm-v)	Percent Difference[1]	CO Analyzer Regression Data	
0.00	0.0	---	*Slope:*	0.9900
4.87	4.4	-9.6%	*Intercept:*	-0.2463
9.82	9.3	-5.3%	*Correlation:*	0.9999
19.66	19.1	-2.9%		
29.51	29.3	-0.7%		
44.30	43.5	-1.8%		
	Average	-4.1%		

[1] Objective ±15%

Table 3-58. TEOM Flow Rate and Barometric Pressure Audit Results, SFE Site

Audit Flow rate	Percent Difference (Indicated vs. Audit) (Criteria ± 10.0%)	Percent Difference (Indicated vs. Design) (Criteria ± 10.0%)	Percent Difference (Audit vs. Design) (Criteria ± 10.0%)	Pass / Fail
Total Flow	-1.1%	-0.1%	1.0%	Pass
PM_{coarse}	-0.7%	0.0%	0.7%	Pass
$PM_{2.5}$	-0.1%	0.0%	0.1%	Pass
Sampler Barometric Pressure Sensor				
Audit Sensor Reading (mmHg)	**Site Sensor Reading (atm)**	**Site Sensor Reading (mmHg)**	**Measurement Error (mm Hg) [1]**	**Pass / Fail**
586.5	0.766	582.16	-4.3	Pass

[1] Acceptance criteria ± 10 mm Hg

Figure 3-16. Side Views of the TLA Site

4.0 RESPONSE REQUIREMENTS

This section summarizes the primary and secondary concerns and observations from the audit. It also provides some recommendations for future network improvements that may simplify and reduce network hardware and operational costs in the future. Table 4-1 presents a summary of the audit observations and concerns from the previous audit and the resolution observed during the 2017 audit. Table 4-2 presents a summary of audit observations and concerns from the 2017 audit.

Primary concerns are those that may affect the ability of the measurement system to produce data within the data quality objectives (DQOs) of the program while secondary concerns are minor issues that likely do not have significant impact on the DQOs.

Primary concerns or observations identified in this audit report require a written response by the appropriate personnel assigned to each portion of the monitoring program. The purpose of a written response is to ensure that all project team members are aware of the area of concern and that a corrective action plan is in place to prevent reoccurrence. Once the written response is received, the auditor can review the action or actions and close the audit. Based on the results of the 2017 audit there are two secondary concerns, one associated with calibration methodology that differs from US EPA guidance and the need to update and revise site SOPs. It needs to be noted that these concerns, at the time of the audit, were NOT impacting data quality.

Table 4-1. Summary of the Previous Audit Observations and Concerns

Site	Description of Concern or Observation	2017 Resolution
Primary Concerns		
All Sites	GPTs are only being performed at two concentrations instead of three per US EPA guidance	SIMAT has added three-point GPTs to their quarterly multipoint calibrations and had added two-point GPTs on each every 6th day automatic calibration. All GPTs now target a NO concentration of 100 ppb (e.g., 450 NO plus 350 O_3, etc)
All Sites	Since the stations have been automated the precision check (Level One) calibration is no longer performed through the sample line on a bi-weekly basis.	Each automatic calibration (performed every 6th day) includes a precision check point at 20% of span. In addition, a manual precision check (along with other calibration point) is performed monthly.

Table 4-2. Summary of 2017 Audit Observations and Concerns

Site	Description of Concern or Observation	Discussion
Primary Concerns – NONE		
Secondary Concerns		
All Sites	US EPA requires that the precision check (Level One) calibration be performed through the sample port on a bi-weekly basis.	The precision check calibration is being performed every 6th day through the zero/span ports and manually through the sample port monthly. This is very good practice, assuming there are no issues with the sample valving between manual calibrations. In the rare event when there may be a leak in the sample valving (which would allow shelter air to be sampled instead of ambient air), a month could go by without this being detected. If possible, considering labor and time constraints, manual calibrations every two weeks would put the network in full compliance with US EPA protocols.
General	Instrument and procedural SOPs are not fully up-to-date, particularly for the new Thermo analyzers, the TEOM 1405DF's as well as certain processes that have been put in place since the new inclusion of automated zero, spans, and precision checks.	As time and man-power are available work on updating and revising the SOPs. These documents have proven invaluable for training new staff and as new staff are added, this acts as a good training tool.

Overall, the SIMAT network is extremely well run and operated. The technical systems that SIMAT has in place to track data, train operations staff, manage huge data sets, perform basic maintenance and calibration activities, and track and maintain QA/QC data is exemplary. It should be noted that currently there are six operators for 32 automated sites, or one operator for every 5.3 sites. The normal "rule of thumb" is that a network should have about 1 operator for every 3 sites. Therefore, it is even more remarkable the job SIMAT is doing with minimal staff.

It is understood that calibration gases are very expensive and somewhat difficult to get in Mexico, particularly the blends required for ambient monitoring. If possible, SIMAT should consider getting bids for US EPA Protocol 1 gases instead of the ±2% standards they are currently using. This may result in an upfront cost with purchasing cylinders from the US, but this cost would be recouped once the standards are returned for refilling (and could be returned and refilled for years). The Protocol 1 gases are certified to ±1% and receive multiple analyses prior to being released to the customer. Additionally, the Protocol 1 gases must undergo more rigorous cylinder cleaning protocols that will eliminate some of the issues that have been seen with the current calibration standards, particularly when the cylinders get below 500 psig.

The last suggestion was briefly discussed in Section 2 and pertains to future site expansion or future site refurbishments. Using the CARB octopus sample manifolds in new sites reduces the system plumbing complexity and makes additional automation easier. For instance, since all calibrations would be performed by flooding the manifold with excess calibration gas, all calibrations would now be through the probe and sample ports, hence there would be no difference between a manual and an automatic calibration. This has the potential to reduce manpower requirements as more of the calibration events could be automated. While there are absolutely no technical or regulatory issues with the current methodology being used at the SIMAT sites, this discussion is included as a suggestion to simplify future site installation and operation, increase efficiency of site operations, and significantly reduce hardware costs for new sites and equipment. Also, the use of the CARB octopus could potentially save well over $10,000 per site by reducing the need to have zero/span ports on the instruments, reducing the sample manifold hardware costs, and reducing the costs of associated tubing and Swagelok connectors associated with the current calibration systems.

Appendix A

Calibration and Certification Data

Airgas Specialty Gases
Airgas USA, LLC
12722 S. Wentworth Ave.
Chicago, IL 60628
Airgas.com

CERTIFICATE OF ANALYSIS

Grade of Product: EPA Protocol

Part Number:	E04NI99E15A01H4	Reference Number:	54-401035835-1
Cylinder Number:	CC502682.	Cylinder Volume:	144.4 CF
Laboratory:	124 - Chicago (SAP) - IL	Cylinder Pressure:	2015 PSIG
PGVP Number:	B12017	Valve Outlet:	660
Gas Code:	CO,NO,NOX,SO2,BALN	Certification Date:	Nov 08, 2017

Expiration Date: Nov 08, 2025

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

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

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty	Assay Dates
NOX	55.00 PPM	55.75 PPM	G1	+/- 1.2% NIST Traceable	10/30/2017, 11/08/2017
NITRIC OXIDE	55.00 PPM	55.75 PPM	G1	+/- 1.2% NIST Traceable	10/30/2017, 11/08/2017
SULFUR DIOXIDE	55.00 PPM	55.04 PPM	G1	+/- 1.0% NIST Traceable	10/30/2017, 11/08/2017
CARBON MONOXIDE	5500 PPM	5498 PPM	G1	+/- 1.0% NIST Traceable	11/01/2017
NITROGEN	Balance				

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Uncertainty	Expiration Date
NTRM	16060606	CC442563	50.42 PPM NITRIC OXIDE/NITROGEN	+/- 0.8%	Jun 27, 2020
PRM	12367	APEX1099237	10.0 PPM NITROGEN DIOXIDE/AIR	+/- 1.5%	Jun 02, 2017
GMIS	1114201605	CC506716	4.995 PPM NITROGEN DIOXIDE/NITROGEN	+/- 2.0%	Nov 14, 2019
NTRM	16061017	CC473206	49.02 PPM SULFUR DIOXIDE/NITROGEN	+/- 0.8%	Jun 17, 2022
NTRM	10360235	CC401988	4950 PPM CARBON MONOXIDE/NITROGEN	+/- 0.4%	Feb 15, 2019

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

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
CO-2 SIEMENS ULTRAMAT 6E N1J5700	NDIR	Oct 28, 2017
Nicolet 6700 AMP0900100	FTIR	Oct 21, 2017
Nicolet 6700 AMP0900100	FTIR	Oct 21, 2017
Nicolet 6700 AMP0900100	FTIR	Oct 21, 2017

Triad Data Available Upon Request

Signature on file

Approved for Release

Certificate of Calibration

Calibration Date:	November 27, 2017
Calibration Due:	November 27, 2018 (annual)

Calibration for:
EPA Systems, LLC
4201 W. Parmer Ln Bld. B Suite 280
Austin TX 78727
United States

Calibrated By:
Ozone Solutions
451 Black Forest Rd
Hull, IA 51239

Model Number___Environics 6103____

Unit Number_____4880____

Description___ Ozone/ Multi Gas Calibrator_____

Unit Condition As Received____Physically good condition___________

Accuracy of Device______+/-1%_________________

Environmental Conditions______73°F, 42.1% RH___________________

This is to certify that the instrument described above was calibrated in our facilities according to the manufacturer's procedures.

The calibration was performed with Thermo Scientific ozone analyzer (serial# 0712821685, accuracy of +/- 1% of full scale). This analyzer is certified to be NIST traceable and is calibrated according to Thermo Scientific specifications in their facility.
The calibration of the monitor is checked several times over several hours of testing. The calibration data is entered with the serial number, customer and date in our permanent calibration database.

As Received and Final Values (all units in ppm):

Ozone Calibrator Span Level	Unit as Received	After Calibration
.45	.43	.45

Ozone Calibrator Zero Level	Unit as received	After Calibration
0	0	0

Calibration Performed by:
Chris Ewoldt

Technician
Ozone Solutions, Inc.

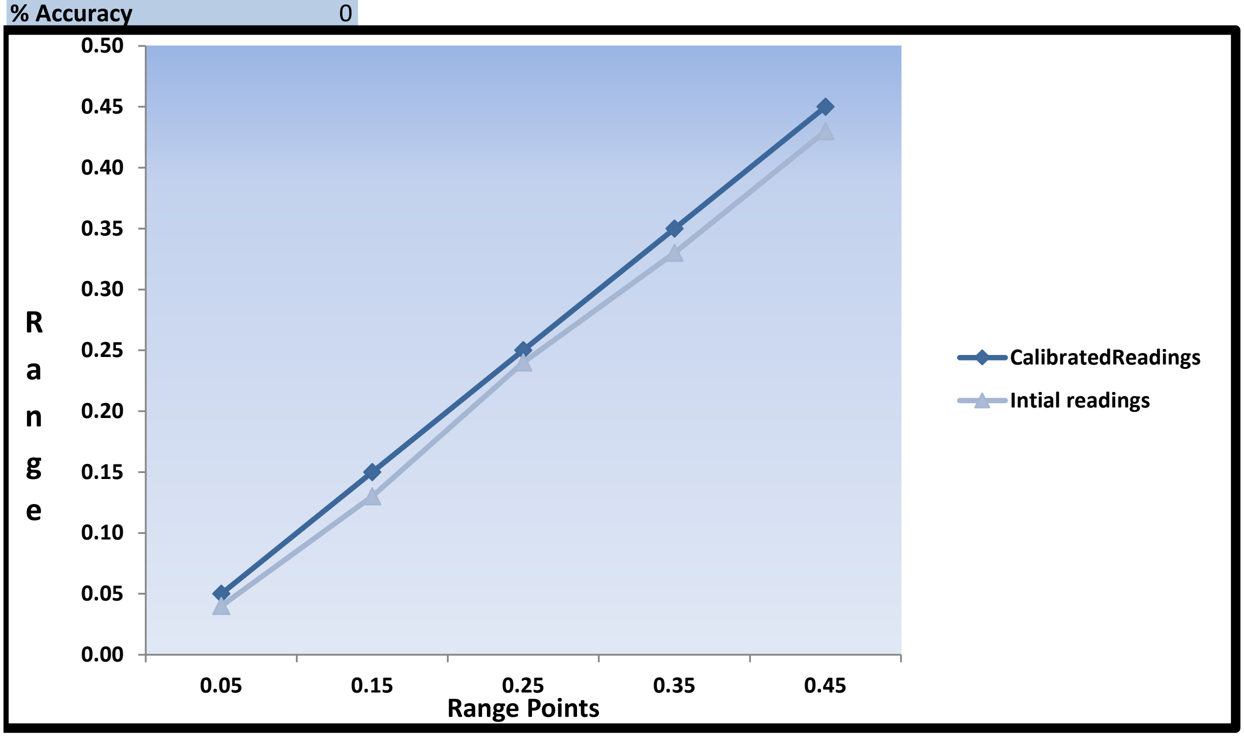
Calibration Details

Model	Environics 6103	**Units measured**	PPM	**Calibration**	
Serial #	4880	**Accuracy of device**	1%	Gas	
Date	11/27/2017				
Std model	ThermoScientific 49i	**Environment Conditions**		73F, 42.1% RH	
	SN: 0712821685				

Ozone Range	
High	0.5
low	0
Range	0.5

Units	Range points	O3 Reading	Customer's Int. O3	Error	After Cal.	Error After CAL
PPM	0.05	0.05	0.04	0.01	0.05	0.00
PPM	0.15	0.15	0.13	0.02	0.15	0.00
PPM	0.25	0.25	0.24	0.01	0.25	0.00
PPM	0.35	0.35	0.33	0.02	0.35	0.00
PPM	0.45	0.45	0.43	0.02	0.45	0.00

Max error	0.02
% Accuracy	0



X________________

Mesa Labs 10 Park Place Butler, NJ 07405
NIST Traceable Calibration Facility, ISO 9001:2008 Registered

MesaLabs

CERTIFICATE OF CALIBRATION - NIST TRACEABILITY

(Refer to instruction manual for further details of calibration)

tetraCal Serial Number: **682** DATE: 28-Nov-2017

Calibration Operator: E. Albujar

Critical Venturi Flow Meter: Max Uncertainity = 0.346%
Serial Number: 1A *CEESI NVLAP NIST Data File 07BGI-0001*
Serial Number: 2A *CEESI NVLAP NIST Data File 07BGI-0003*
Serial Number: 3A *CEESI NVLAP NIST Data File 07BGI-0004*
Serial Number: 4A *CEESI NVLAP NIST Data File 07BGI-0002*

Room Temperature: +- 0.03°C from -5°C - 70°C Room Temperature: 24.3 °C
Brand: Telatemp Serial Number: 358654
Std Cal Date 23-Oct-17 Std Cal Due Date 23-Oct-18
tetraCal:
Ambient Temperature (set): 24.3 °C
Aux (filter) Temperature (set): °C

Barometric Pressure ans Absolute Pressure
Vaisala Model PTB330(50-1100) Digital Accuracy: 0.03371%
Serial Number: C4310002
Std Cal Date 27-Mar-17 Std Cal Due Date 27-Mar-18
tetraCal:
Barometric pressure (set): 760 mm of Hg

Results of Venturi Calibration
Flow Rate (Q) vs. Pressure Drop (ΔP). Where: Q=Lpm, ΔP= Cm of H2O

No. 1 C 5.41480 ΔP ^ 0.51590
No. 2 C 1.16245 ΔP ^ 0.52626
No. 3 C 0.21563 ΔP ^ 0.53362

Overall Uncertainty: 0.35%

Date Placed In Service________________________
(To be filled in by operator upon receipt)

Recommended Recalibration Date ___________________
(12 months from date placed in service)

Revised: March 2016
Cal102-03T1 Rev B

To Check a Tetra Cal 28-Nov-2017 E. Albujar
6 - 30.00 Lpm BP= 760 mm of Hg
VER. **3.41P**

Maximum allowable error at any flow rate is .75%.
Serial No. 682

Reading Abs. P Crit. Vent. mm of Hg	Room TEMP	CV Qa Flow Lpm	Qa TriCal Indicated	**% Error**	
205.21	24.3	8.01	8.07	**0.72**	
451.81	24.3	17.88	17.83	**-0.28**	**Average %**
732.68	24.3	29.11	29.23	**0.40**	**0.28**

To Check a Tetra Cal BP= 760 mm of Hg
1.20 - 6.00 Lpm

Reading Abs. P Crit. Vent. mm of Hg	Room TEMP	CV Qa Flow Lpm	Qa Tri Cal Indicated	**% Error**	
157.8	24.0	1.75	1.76	**0.22**	
346.7	24.0	3.90	3.89	**-0.25**	**Average %**
524.6	24.0	5.93	5.96	**0.51**	**0.16**

To Check a Tetra Cal BP= 760 mm of Hg
0.10 - 1.20 Lpm

Reading Abs. P Crit. Vent. mm of Hg	Room TEMP	CV Qa Flow Lpm	Qa TriCal Indicated	**% Error**	
251.81	23.4	0.456	0.457	**0.23**	
514.17	23.4	0.962	0.961	**-0.10**	**Average %**
634.18	23.4	1.193	1.199	**0.47**	**0.20**