FINAL AIR QUALITY MANAGEMENT AND MONITORING PLAN

AEROVOX FACILITY
740 BELLEVILLE AVENUE
NEW BEDFORD, MA

Prepared for:

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LIST OF ACRONYMS & ABBREVIATIONS

AOC	Administrative Order on Consent
AQMMP	Air Quality Management and Monitoring Plan
COC	Chain of Custody
COCs	Constituents of Concern
cm	centimeter
DQO	Data quality objective
E	East
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
FID	Flame Ionization Detector
GC	Gas Chromatograph(y)
g	gram
Hg	mercury
ICAPES	Inductively Coupled Argon Plasma Emission Spectroscopy
Kg	kilogram
mm	millimeter
mph	miles per hour
MS	Mass Spectrometry
N	North
NA	Not Applicable
ND	Not Detected
NGL	Net Ground Level
NTCRA	Non-time critical removal action
Pb	lead
PCM	Phase-contrast microscopy
PID	Photo-ionization Detector
PM_{10}	particulate matter less than 10 microns in diameter
ppbv	parts per billion on a volume basis
ppmv	parts per million on a volume basis
QA	quality assurance
QC	quality control
RPD	relative percent difference
S	South
SVOCs	Semi-Volatile Organic Compounds
SOW	Statement of Work
TEM	Transmission electron microscopy
TO	Toxic Organic
TSP	Total suspended particulates
TWA	Time Weighted Average
$\mu g/m^3$	micrograms per cubic meter
VOC	Volatile Organic Compound
W	West
XRD	X-ray diffraction
yd^3	cubic yards

1.0 PROJECT DESCRIPTION AND MANAGEMENT

This Air Quality Management and Monitoring Plan (AQMMP) was prepared by URS Corporation (URS) on behalf of AVX Corporation (AVX) and describes the ambient air program to be implemented in conjunction with the performance of a Non-Time Critical Removal Action (NTCRA) at the Aerovox Facility (the Site) in New Bedford, Massachusetts. The scope of the NTCRA includes demolition of the Aerovox building, transportation and off site disposal of the building contents and demolition debris, backfilling of the building foundation and placement of an asphalt cap over the backfilled building footprint and surrounding paved parking area. AVX is implementing a portion of the NTCRA, excluding the transportation and disposal of PCB-contaminated materials off site, in accordance with a Scope of Work (SOW) that is Attachment B to an Administrative Order of Consent (AOC) between AVX Corporation and the U.S. Environmental Protection Agency (EPA), effective June 3, 2010.

The ambient air monitoring section of the SOW (Section II.B.6.) identifies the constituents of concern (COCs), defines the ambient concentrations that needed to be met, and identifies elements to be included in this AQMMP. The SOW establishes what the air monitoring program needs to accomplish and this plan provides the details on how the air monitoring program will be performed.

For the purposes of this AQMMP, the "project" is defined as the ambient air monitoring and air quality management work to be performed. The "program" is defined as the demolition portion of the NTCRA, which begins with hazardous material removal and ends with completion of the first lift of basement backfilling. Other aspects of the NTCRA are outside the scope of this document.

The perimeter air monitoring program is an important part of the efforts to ensure that off site human exposures are minimized and are at acceptable levels. In an ideal world, this would be accomplished using analyzers that provide immediate feedback to on site decision makers. For many pollutants, including PCBs, however, this is not possible because no feasible on site monitoring options exist.

When designing an air monitoring program, there typically are trade-offs between getting information in real-time and achieving the analytical sensitivity that is needed to evaluate potential air impacts. Therefore, it is good practice to have a monitoring network that incorporates two elements:

1. **Real-time monitoring results to provide input to on site decision-makers**. At this Site, this involves monitoring dust (particulate matter) and to a lesser extent, mercury vapor. This monitoring will provide information about the general levels of air emissions and the effectiveness of emission controls. In general, if dust emissions are kept under control, the potential pollutants associated with dust such as PCBs, silica, and asbestos also will be kept under control.

2. **Monitoring with off site laboratory analysis to document potential off site exposures**. This provides data for specific pollutants (e.g., PCBs, silica, asbestos, lead) at the very low concentrations that are of interest when evaluating potential human health impacts. Note that this type of monitoring serves to document, not control, air concentrations.

The data generated both on site and off site will be reviewed to determine if the goals of the program are being met The real-time (on Site) monitoring data will be used in conjunction with an emission control program to help maintain perimeter concentrations at acceptable levels. The AQMMP project described here incorporates tiered action levels based on real time data, where steps are taken at various intermediate concentrations to limit air emissions before a problem gets out of hand. For example, the performance standard for PM_{10} of 100 $\mu g/m^3$ over a 24-hr period is more conservative than the US EPA standard of 150 $\mu g/m^3$ over a 24-hr period, but the contractor will be required to initiate dust controls at levels lower than 100 $\mu g/m^3$ and apply these values to much shorter time periods (e.g., 15-minute averages).

The turnaround time for data from the off site analytical laboratories typically is several weeks. The off site analyses, however, can be expedited, but even with expedited analysis, the data is not timely enough to guide the actions of on site decision makers. When laboratory analytical data are received, the data will be converted to mass per unit volume concentrations for direct comparison to the SOW performance standards. Whenever these converted results show that a performance standard has been exceeded, EPA will be notified immediately. A meeting (teleconference or on-site) with EPA, URS and the demolition contractor will be held as soon as practicable after that notification to discuss the steps to be taken in response to the performance standard exceedance. During this meeting, EPA, URS and the contractor will:

- review work and site conditions occurring at the time of the exceedance;
- compare those conditions to current work and site conditions;
- evaluate the need to immediately suspend work; and
- evaluate the need to modify or use additional engineering controls.

When evaluating either real-time on site data or off site analytical results, all available relevant information should be considered. These multiple lines of evidence need to be taken into account if the data will serve the purpose of predicting future air emissions from the upcoming activities or required modifications of those activities. For example, while it is useful to know that elevated PCBs or lead were measured on a given prior day, what actions if any are taken upon subsequent receipt of such knowledge as a result of those measurements will depend on whether the upcoming schedule involves similar activities or similar portions of the building or similar meteorological conditions..

EPA has established guidelines for documenting the policies and procedures used to conduct environmental monitoring so that organizations can efficiently review monitoring protocols or the acceptability of the resulting data. In accordance with these guidelines, this AQMMP describes the sampling and analytical methods that will be used to gather the measurement data, and the procedures employed to assess, control, and document the data quality. This plan follows the Quality Assurance Project Plan (QAPP) format outlined in the publication, *"EPA Requirements for Quality Assurance Project Plans for Environmental Data Operations",* EPA QA/R-5, March 2001. This plan is divided into four sections with the following contents:

- **Section 1 –** contains the project objectives and organization of the project team;
- **Section 2 –** contains a detailed description of all the elements of data generation and acquisition, including monitoring strategy and data quality objectives as well as the application of the acquired data to manage air quality;
- **Section 3 –** contains a description of the procedures that will be used to assess and report on the QA/QC elements employed in the project; and
- **Section 4 –** contains a description of the methods that will be used for data review, validation and for reconciling the generated data with applicable requirements.

1.1 OBJECTIVES

URS will monitor air quality at the Site in order to evaluate compliance with the NTCRA specific Air Quality Performance Standards established by EPA in the SOW. The goals of this monitoring effort are to:

1. Document the baseline air quality at the Site;
2. Document the air quality on all four sides of the Site throughout the demolition effort; and
3. Provide timely feedback to the Site engineer so that on site activities can be modified as necessary to maintain downwind concentrations at acceptable levels (i.e., below the levels defined as performance standards in the SOW).

As such, the ambient air monitoring work will be closely allied with the Site Health & Safety monitoring and the dust and emission control effort.

1.2 SITE BACKGROUND

1.2.1 Site Description

The Site is located at 740 Belleville Avenue, Bristol County, New Bedford, Massachusetts. The coordinates of the Site (referenced to the corner of Belleville Avenue and Hadley Street) are latitude 41° 40’ 25.12” and longitude 70° 55’ 13.84” W (UTM coordinates 340135.53m E and 4615326.34m N). The Site contains a vacant approximately 450,000 square foot former manufacturing building along with a parking lot located on approximately 10.3 acres of industrially-zoned land. The building consists of a western section containing two floors, and an eastern section containing three floors. The exterior walls are brick; the roof is constructed of wood. The first floor, which is the building foundation floor, is constructed of concrete; the second floor consists of both concrete and wood; and the third floor is constructed of wood. Ancillary structures include a brick sewer pump station and a brick boiler house located along the south side of the main manufacturing building, and a brick structure housing electrical switching equipment located at the southwest corner of the main building.

Bordering the Site to the south is a private road, Hadley Street, and a factory operated by Acushnet Company (Titleist). A private alley, Graham Street, and a factory operated by Precix, Inc. border the Site to the north. The Site is bounded by Belleville Avenue to the west, beyond which lies a mixed residential area. The Acushnet River borders the Site to the east. The Site is physically separate and distinct from the New Bedford Harbor Superfund Site.

1.2.2 Site History

The Site began to be used for electrical component manufacturing in approximately 1938. Beginning in approximately the 1940s, dielectric fluid containing polychlorinated biphenyls ("PCBs") was used in capacitor manufacturing. Various solvents were also used in manufacturing operations. Use of PCBs in the manufacturing process ceased on or about October 1978. Operations and disposal practices during the period involving the use of PCBs and solvents resulted in the release of hazardous substances which contributed to the contamination of soils, building materials and equipment, surface water runoff and groundwater at the Site. Inspections, assessments and sampling programs from the 1980s forward, undertaken by the former owner and operator Aerovox, Inc. (Aerovox) as well as EPA, confirmed the presence of PCBs in soils under the concrete foundation, in soils outside the building, and mixed into the asphalt parking lot, in groundwater, as well as throughout the interior of the building.

Measures taken at the Site to contain or mitigate the release of hazardous substances include the following (in chronological order):

- 1983-84 – placement by Aerovox of a shoreline steel sheet pile wall along the eastern edge of the Site to mitigate the potential for PCB-contaminated groundwater to discharge to the Acushnet River.

- 1983-84 – placement by Aerovox of an hydraulic asphalt concrete (HAC) cap over PCB-impacted soils in the drainage swale to the north of the building and on the eastern portion of the Site.

- 1988 – removal by Aerovox of two 10,000-gallon underground fuel oil storage tanks, and one 250-gallon condensate collection tank from a former concrete oil containment bunker.

- 1990 – removal by Aerovox of petroleum product from the bunker area, and recycling of petroleum-contaminated soils into an asphalt base course for the parking lot at the Site.

- 1999 – requirements of RCRA consent order between EPA and Aerovox included the demolition of the building and capping of the entire Site. Aerovox implemented interim measures inside the building to protect workers, but subsequently abandoned the building in 2001 and relocated operations elsewhere, leaving behind a substantial amount of contaminated equipment and machinery, PCB-contaminated rinse water, PCB-contaminated personal protective gear, solvents, acids and compressed gas cylinders.

- 2001 and after – EPA inspections after Aerovox vacated the Site noted the presence of asbestos, inorganic mercury spills, and extensive water damage throughout the building, and that cracks in the HAC cap had gone unrepaired.

- 2004 – removal and off site disposal by EPA of various drums, containers and wastes left inside the building when it was vacated by Aerovox, and general repair of cracks in the HAC cap.

- 2007-08 – removal and off site disposal by EPA of mercury-containing articles such as controls and switches within the building, as well as visible elemental mercury which had spilled on to various interior surfaces.

1.3 CONSTITUENTS OF CONCERN

The COCs for the perimeter air monitoring program are listed in Table 1 along with the air quality performance standard for each constituent, which are defined in the SOW, Section II.B.6.c.

The air quality performance standards shown in Table 1 represent the goals for the estimated nine to ten-month duration of the NTCRA beginning with hazardous materials removal through basement backfilling. Real time monitoring for particulate will occur throughout the program, and net ground level (NGL) particulate concentrations will be compared to the SOW performance standard for particulate.. For all other parameters, the SOW performance standards will be compared to analytical results that are based on the absolute concentrations measured at each station. An exception to this will be if during the course of NTCRA work New Bedford Harbor dredging activities are occurring in the vicinity of the Aerovox shoreline, NGL PCB concentrations will be compared to the performance standards, provided EPA approval is granted. NGL is calculated as the downwind concentration minus the upwind concentration (i.e., the project is only responsible for emissions generated by the program; any upwind sources of dust or other constituents are subtracted out when evaluating the measurement data.) When using NGL for particulate performance standard comparison, the prevailing wind direction will be considered. When using NGL for PCB performance standard comparison during periods when dredging is also occurring, the prevailing wind direction and PCB concentrations at all four ambient air quality monitoring stations and the dredge (if available) will be considered. For PCBs during non-dredging periods, and for all other constituents shown in Table 1, NGL may be calculated but will not be used for compliance purposes.

Exceedance of any of the values for any one day or any one set of samples does not necessarily indicate that a problem exists. If any daily values are above the target levels shown, the URS Project Manager will be notified, who will immediately notify the EPA OSC or EPA representative. As soon as practicable after notification to EPA, a meeting between EPA, URS, and the contractor will occur (teleconference or on-site, as appropriate) to review work and site conditions occurring at the time of the exceedance, compare those conditions to current work and site conditions, evaluate the need to immediately suspend work, and evaluate the need to modify or use additional engineering controls. In the interim, the demolition contractor's pre-approved corrective action plan will be enacted and real-time particulate data will continue to be reviewed to evaluate the effectiveness of corrective action implementation.

1.4 PROJECT ORGANIZATION

The URS project team is organized using Task Leaders who are responsible for execution of the primary tasks of the project. Each Task Leader is responsible for the scope and schedule of their task and will

coordinate their efforts with the other team members. The Task Leader reports to the Project Manager, who is responsible for the project team's progress toward meeting schedule and quality goals specified for the project. Under the Air Monitoring Task, various staff will serve in specific roles, with specific assigned responsibilities. An organizational chart that depicts the project team for this task is presented on Figure 1. Task Leaders for other tasks are not included for the sake of simplicity and clarity.

Ms. Marilyn Wade is the Project Manager for this project and the overall Project Coordinator for the NTCRA. Ms. Wade is responsible for ensuring compliance with the requirements of the SOW, and will oversee, all aspects of the project. Ms. Tina Parshley will be the URS Site Safety Officer for the NTCRA.

Mr. Bart Eklund (URS-Austin) is the Task Leader for the air quality management and monitoring **project**. His overall responsibility is to ensure the collection of valid and defensible measurement data. He will design the monitoring approach, review and validate the field data, and prepare regular status/data reports for the Project Manager.

Mr. Randy Stephens (URS-Austin) will be responsible for Network Operations and will direct all of the equipment preparation and maintenance efforts, as well as the on site staff (site operators) in regards to the necessary sample collection and recordkeeping for the monitoring network. He also will coordinate work with the off site laboratory to ensure sufficient filter media are provided to the project, and that filter samples are received, logged, analyzed, and correctly reported to the client and the URS staff. Finally, he will be responsible for field troubleshooting activities on an as-needed basis.

Mr. Paul Stanley will be the Construction Manager for the NTCRA and will be responsible for oversight of the day-to-day site activities and identifying staff to perform the daily, on site sample collection.

URS personnel will conduct all required site operations including: sample media installation/removal, sample documentation, equipment maintenance, and minor repairs. The Network Operations Task Leader will supervise site operations.

Mr. Darren Barton (URS-Austin) is a Quality Assurance (QA) Specialist who will provide an independent audit function. He has no other duties within this project team. Mr. Barton is responsible for assessing project team performance according to project specifications and the corporate QA requirements established by URS.

Ms. Monica Hanzel (URS-Austin) will be responsible for developing a computerized database for the project and transferring data from the Site and the off site analytical laboratories into the database.

Ms. Alea Goodmanson (URS-Austin) will be responsible for reviewing and validating the data in the database.

The analytical work will be overseen by the Air Monitoring Task Leader. The primary contacts for the analytical work are identified in Table 2.

1.5 TRAINING AND CERTIFICATION REQUIREMENTS

There are no specific certification requirements. Training for site operations will be the responsibility of Mr. Stephens, the Operations Leader. This will include training on site URS staff in how to correctly operate all sampling equipment and properly document all field procedures so that the data collected from this program meet the Data Quality Objectives (DQOs)(see Section 2.2). A copy of this AQMMP will be maintained at the Site for reference regarding sample schedule, sample documentation requirements and operational responsibilities. Manufacturers' manuals also will be provided where needed for reference. Periodic visits by the QA staff and the Network Operations Task Leader will be conducted to provide support to the site operators.

2.0 MONITORING APPROACH

The monitoring approach developed for the program is based on discussions between the parties during development of the SOW, URS project experience at similar sites and an understanding of the history and setting of the NTCRA. The monitoring approach outlined in this plan is based on the recognition that there can be a significant time lag between sample collection and receipt of data from an off site analytical laboratory and that even expedited turnaround time (TAT) does not enable the implementation of corrective action(s) with meaningful immediacy.

For the most part, the COCs listed in Table 1 and in the SOW (PCBs, asbestos and silica) are non-volatile compounds, and PCBs have a very low vapor pressure. These compounds will be present in air as dust particles or attached to dust particles. Therefore, monitoring for and the use of action levels for particulates will be the most practicable way to monitor for attainment of the SOW performance standards. The proposed air monitoring program, therefore, relies on both on site, real-time (TEOM) measurements and off site analytical data, each having a different purpose.

- The on site, real-time TEOM measurements, on the one hand, will be used as the surrogate or indicator for the other contaminants, and will provide decision makers with information about air emissions. The TEOM measurements will trigger corrective action when particulate concentrations exceed the action level. If dust is properly controlled, the associated pollutants will also be controlled.

- The off site analytical data from the initial demolition phase four-week period, on the other hand, will document any correlation existing between the particulate concentrations (based on the real time monitors) and asbestos, silica and PCB concentrations (based on laboratory analysis). Thereafter, the weekly sampling data will provide documentation of potential exposures related to the NTCRA.

- In addition, to evaluate attainment of the goal of meeting the risk-based airborne PCB performance standard included in the SOW, a running average of the PCB laboratory analytical results (TO-4A) will be calculated for each of the four perimeter air monitoring stations during the project.

The monitoring will be a mixture of real-time monitoring and sample collection for subsequent off site analysis. Particulate matter and mercury will be monitored using real-time analyzers. In addition, samples for off site analysis will be collected at four fixed locations throughout the program at the frequencies presented in the following sections of this plan. A portable meteorological station will be used to determine the predominant wind direction for each day of monitoring. For particulate, as measured by the TEOM, the NGL concentrations will be compared to the SOW performance standards. For all other constituents, the station concentrations as measured by the off site laboratory or on site mercury monitor will be compared with the SOW air quality performance standards, except in the case of particulates when New Bedford Harbor dredging activities are occurring in close proximity to the Site and EPA approval is granted to use a NGL approach.

2.1 SCOPE AND SCHEDULE

The portable meteorological station will be installed on or near the Site prior to the start of demolition activities and will be operated throughout the demolition effort. The NTCRA project will be completed in three phases: removal, transportation and disposal of hazardous materials; building demolition, transportation and disposal of demolition debris; and backfilling and capping of the Site. The phases are further defined for air monitoring activities as follows:

- **HM Removal** = hazardous material removal and Aerovox Waste Material disposal, including asbestos, mercury, universal waste, etc., per SOW III.D.
- **HM Exterior =** portion of time within HM Removal when work is occurring outside the building that could generate air impacts, including managing and loading Aerovox Waste Material for disposal.
- **HM Hg Removal =** portion of time within HM Removal when mercury cleanup is being undertaken.
- **Active Demo =** material removal, demolition, debris processing and loading for off site disposal (City Waste Material). This extends from EPA approval of hazardous material removal through loading of last truck for off site disposal.
- **AD Contents =** portion of time within Active Demo when building contents (i.e., equipment and materials) are being removed, processed and loaded for off site disposal.
- **AD Building =** portion of time within Active Demo when the building itself is being dismantled, processed and loaded. The timeframes for AD Contents and AD Building will overlap.
- **AD Impreg =** portion of time within AD Building timeframe when the impregnation room is being dismantled, processed and loaded.
- **AD CWM =** portion of time within Active Demo when processing of City Waste Material is occurring outside the building.
- **BF First Lift =** Period of time required for completion of the placement of the first full lift of basement backfill

The demolition work is expected to take approximately nine to ten months to complete, with approximately 4 months of pre-demolition (removal and disposal of hazardous and regulated material in accordance with SOW section III.D.), followed by five to six months of active demolition (removal of the building and its contents, debris processing and loading in accordance with SOW Section III.E.).. It is estimated that once the building and its contents are removed, basement backfilling (SOW Section III.F.) can be completed in a month. Work is scheduled to begin in the first quarter of 2011. The debris and other material will be loaded into haul trucks and taken off site for disposal. The material may be staged on site in temporary storage piles prior to removal.

The monitoring program is summarized in Table 3 in terms of types of monitoring to be performed, number of samplers, sampling frequency, sampling duration, and any requirements for rapid turn around time from the off site analytical laboratories. General information about the monitoring methods is summarized in Table 4. Approximate locations for the four monitoring points are shown in Figure 2. Locations may need to be changed to some extent in the field prior to or during the program if necessary due to logistical constraints (e.g availability of electrical service, proximity to active demolition, access). If a change in an air monitoring station location is required due to logistical constraints, EPA will be notified. The air monitoring station will be moved after EPA approval has been granted. In general, the exclusion zone for the work will consist of the entire property except for administrative and staging areas

expected to be located in the parking lot area to the south of the building. Predominant winds are from the southwest, as shown in the wind rose in Figure 2-2.

2.1.1 Mobile Monitoring

Real-time monitoring for mercury will be performed using a Jerome 431-X portable monitor. Measurements will be made each morning and again each afternoon at a minimum of four locations around the perimeter of the Site. Mercury measurements will be made each day that mercury removal activities are being undertaken (during the pre-demolition portion of the program), during active AD Contents, and AD Demo. If an individual mercury reading exceeds the SOW air quality performance standard, the reading will be retaken at that time, and the work will be stopped if the results are repeated. The frequency of mercury readings will be increased and time-averaged monitoring may be implemented (e.g., NIOSH Method 6009).

The monitoring results for mercury will be recorded on preformatted data sheets. Entries will be made whenever air sampling occurs. All entries are to be made in a legible and orderly manner using permanent ink, preferably black. Appendix A contains an example of a daily recordkeeping log.

In addition, the ambient concentrations in the breathing zone of workers will be periodically monitored for dust and VOCs using portable analyzers as described in Section 8 of the Health and Safety Plan.

2.1.2 Fixed Location Monitoring

A three-meter (10-foot) tower will be erected on the Site and used to collect the meteorological data. Wind direction, wind speed, temperature, barometric pressure data will be collected as 5-minute averages and rainfall will be collected as 5-minute total. The meteorological data for each parameter will be stored in an on site data logger.

Continuous PM_{10} data will be collected at four locations using a Rupprecht & Patashnick TEOM Series 1400a ambient particulate monitor. This unit uses a tapered element oscillating microbalance (TEOM) to continuously measure the particulate mass.

A total of four perimeter monitoring stations will be established at the fenceline. Each station will include a TEOM PM_{10} sampler and hi-volume PM_{10} and PS-1 samplers, and a low-volume TSP sampler (see Table 3). Sampler inlets for all parameters will be located in the breathing zone, approximately four to five feet above ground surface or building roof, if an elevated sampling location is used. The exact locations of the monitoring stations will be selected in the field at the start of the monitoring effort based on EPA siting guidelines and logistical considerations. Among the factors to take into account are the close proximity of the Site to nearby buildings and streets with vehicular traffic, the need to be out of the way of demolition activities, and the proximity to sources of electrical power. It may be necessary to reposition certain stations during the program. If this is done, the new sampling locations and the date of the change will be documented in the project files.

Samples for 10-hour time-integrated PM_{10} will be collected using Tisch PM_{10} high volume air samplers or equivalent. Quartz fiber filters will be weighed (following moisture equilibration) before and after sampling to determine the net weight gain. The total volume of air sampled will be determined from the measured sampler flow rate and the sampling duration. A portion of each filter (typically 1/12 strip) will be acid digested and analyzed for lead by inductively coupled plasma mass spectrometry (ICP-MS) following EPA Method SW6020A.

Samples for 10-hour time-integrated asbestos and silica will be collected using GAST 1532 low-volume air pumps or equivalent devices and cassette filters. The filters will be analyzed for silica by XRD and for asbestos by PCM. A subset of the asbestos results (a minimum of 10%) will be confirmed at a 2nd analytical laboratory using TEM. The detection limit for the asbestos analysis will depend on the total volume of air sampled and the quantity of any interfering dust. If necessary, the sampling duration will be extended to 24 hours to achieve better detection limits.

PCBs will be monitored using US EPA Method TO-4a (modified). In this standard method, air is drawn through a quartz fiber filter, followed by a polyurethane foam (PUF) plug that contains a layer of florisil. The PCBs are trapped on the filter or in the PUF plug. The PS-1 samplers will be operated at a flow rate of approximately 200 to 250 liters per minute. The duration of the monitoring run will typically be about 10 hours.

An Air Quality Monitoring Report will be prepared at the conclusion of the program to document the results of the monitoring project and attainment of the performance standards contained in the SOW. The report will be incorporated as an appendix to the Final Report to be prepared and submitted to EPA at the conclusion of the NTCRA in accordance with SOW section III.K.

2.2 PROJECT QUALITY OBJECTIVES

This section defines the data quality objectives (DQOs) for both the field measurement and laboratory analytical data and the criteria for measuring performance within these objectives.

Specific performance criteria must be identified so that the project team can measure progress and success in attaining the quality goals for the monitoring effort. The primary areas for which specific performance criteria can be stated are precision, accuracy, and completeness. Table 5 presents a summary of measurement performance criteria for the project.

Representativeness and comparability are also used to evaluate quality, although the evaluation is typically qualitative in nature. Representativeness is ensured through site selection, sample probe and meteorological tower siting, and sample scheduling evaluations. Comparability is accomplished through the use of standard measurement methods approved by EPA and by reporting measurement data in common units to facilitate comparison with other data sets generated by regulatory and private agencies.

2.3 AIR QUALITY MANAGEMENT AND EMISSION CONTROLS

The overall goal is to maintain air quality at acceptable levels at the property boundary (see Table 1). This will be accomplished through the use of various emission controls. Air monitoring data will be used to determine the effectiveness of these controls.

Air emission control measures will be undertaken by the demolition contractor on an as needed basis. These controls may include the use of water sprays, wind fences or barriers, covers over emitting surfaces, and reduced operating rates. In general, if there is a visible dust plume, water sprays will be employed to reduce the particulate matter levels downwind of the demolition activities. If dust is properly controlled, the associated lead, PCBs, silica and asbestos should also be controlled.

In addition to the demolition itself, the movement of trucks and other vehicles has the potential to generate significant levels of dust. Water sprays will be used on an as-needed basis on the Site to control dust emissions from vehicle traffic.

There can be significant lag time between sample collection and receipt of data from the off site analytical laboratory (e.g., days or weeks from the time the samples are received in the laboratory). To help ensure that the air quality performance standards are met, the on site PM10 measurements will be used to trigger action when certain levels are exceeded. The tiered action levels are outlined in Table 6.

After suspension of site activities, the project team will review the particular activities and means and methods to identify corrective actions (including modifying dust control procedures) that could result in lower emissions. Program activities will resume once agreed upon corrective actions are in place and approved by the EPA On-Scene Coordinator (OSC) or EPA representative.

2.4 SAMPLING IDENTIFICATION AND HANDLING PROCEDURES

For all sample types, the COC form must be filled out for all samples in the shipment with the top copy of the three-part form included with the sample, while the pink and yellow copies are archived on site.

The preferred methods of shipment are via courier or FedEx standard overnight service to ensure proper integrity of the media. Filter samples along with the COC forms will be shipped to the applicable off site analytical laboratory.

PM_{10} Samples –Each high-volume filter will be stamped with a unique number and weighed before being shipped from the laboratory to the Site. After the completion of sampling, the filters will be folded in half - particulate side in - and placed in the filter envelopes. The filters will be shipped back to the laboratory for analysis. A courier service or an overnight shipping and delivery service will be used to transport the filters to ensure proper tracking. No specific provisions are necessary for preserving or packaging the filters for shipment other than to protect them from physical damage. There are no sample stability issues that necessitate that the samples be weighed or analyzed within a specific time period.

At the laboratory, the PM_{10} filters will be analyzed gravimetrically in accordance with the EPA's approved analytical procedures. Each filter will be equilibrated for at least 24 hours in a controlled humidity chamber at 45 ± 5% relative humidity and 25°C ± 3C° before being weighed. Filters will be weighed on an analytical balance to the nearest 0.1 mg. The difference in the filter weight will be the particulate loading for that sample.

PCB Samples – After the completion of each sampling event, the cartridge holder will be sealed in aluminum foil and placed with the associated filter in a zip-lock plastic bag. These bags will be marked with the sampler identification, site location, cartridge number, run date and times, and any remarks pertinent to the sampling. Disposable latex gloves will be worn when handling the PCB filters and cartridges. Within 24 hours of the end of the sample collection period, the samples will be shipped to Alpha Analytical for analysis. The samples will be stored cold and placed on ice for shipment or transportation by courier to the laboratory.

The filter numbering will use the convention shown in Figure 4. The final number in the ID is a sequential sample number starting at 1 and continuing through the project.

After the completion of sampling, the sample media will be placed in filter envelopes. These envelopes will serve as the chain-of-custody forms for the filter samples. They will be marked with the sampler identification, site location, cartridge number, run date and times, and any remarks pertinent to the sampling. Figure 5 shows an example of the filter envelope to be used for PM_{10} samples, which also serves as the calculation sheet for each sampling run.

2.5 QUALITY CONTROL REQUIREMENTS

QC activities for the field functions on this project are discussed below. Data management QC is discussed as part of the data validation activities (see Section 4.1).

2.5.1 Field Quality Control

Field QC encompasses several areas. The tasks required of the field staff to promote quality are listed below and summarized in Table 7:

- Documentation – The operator will maintain a file of site information that will include site visit logs, calibration data, operator checklists, sample COC forms, and a maintenance log. Copies of this documentation will be submitted to the Network Operations Task Leader at least monthly and will be retained in the project files. Submittal via email is also acceptable as applicable.

- QC Sample Collection – Duplicate field samples (or collocated samples) initially will be collected using collocated samplers at a rate of 10% of the regular samples (e.g.., one pair of collocated samples every other day). Field blanks initially will be collected at a rate of 10% of the regular samples (e.g., one every other day).

- COC – A COC record, indicating sample identification number, sampling location, and any comments particular to the sample will accompany each sample during shipment from the field.

All other data will be measured on site and are polled via telephone directly from the Site, if necessary. An example of the Sample COC Form typically used is in Appendix A.

2.5.2 Equipment Testing, Inspection, and Maintenance

Specific tasks for periodic testing, inspection, and maintenance are required for the environmental sampling and monitoring equipment to provide sufficient QC to remain within the manufacturer's operating specifications and ensure that the project quality goals are met. Each piece of equipment is initially tested in the URS air quality instrumentation lab to ensure that operation is within the manufacturer's specifications. Operational checks are then repeated during installation and before field use. The maintenance tasks for each type of equipment are summarized below.

- PM_{10} TEOM Monitor Maintenance – The PM_{10} inlet needs to be cleaned (or at least checked) at the start of the field work. Other requirements are: 1) The flow controller inlet and bypass flow filters must be changed as they become dirty, and 2) A system leak check should be performed monthly.

- PM_{10}, and PS-1 Hi-Vol Sampler Maintenance – See the instructions given in Appendix B.

- Meteorological System Maintenance – The site operator shall inspect the equipment at least once per week. The inspection will include verifying that the wind vane and anemometer cups are intact and operable, the temperature aspiration fan is operable, and that the rain gauge is clear of debris. An inspection of the signal cables and fastening hardware will also be conducted at this time.

These activities must be documented in the field logbook. A schedule for all maintenance activities and checklists will be included in the field log book. A limited number of common consumable parts will be maintained at the Site. In the event that additional parts are needed, they may be obtained from the Network Operations Task Leader. The equipment used for this project is commonly in stock in the URS Austin office and spare parts, if needed, are readily available for delivery to the field via overnight air express.

2.5.3 Supplies and Consumables

The critical supplies and consumables required for this project fall into two categories: laboratory and field equipment. Laboratory equipment and supplies would be prepared filter media. Field equipment supplies and consumables are obtained directly from the original equipment vendor or from a scientific equipment and materials vendor whose products are proven to be equivalent in quality or are commonly available.

Filters and cartridges will be visually inspected prior to use and will be rejected if any visible tears or imperfections are identified.

2.6 INSTRUMENT CALIBRATION AND FREQUENCY

Multipoint calibrations for sampler flow will be performed prior to the start of the program for the hi-vol samplers and monthly thereafter for the TSP and PS-1 samplers. Monthly single point QC checks will be

performed for the hi-vol PM_{10} samplers. Initial and final sample flow checks will be performed each run for the PM_{10} and PS-1 samplers. New multipoint calibrations will be performed after any major maintenance on the hi-vol samplers.

2.6.1 PM_{10} Hi-Vol Sampler

Calibration of the Tisch PM_{10} high-volume samplers will consist of measuring the air flow through the sampler and documenting the response. Multi-point calibrations will be used to generate "Look-Up" tables that will then be used in routine sampling. Single-point calibration, required at least once each month, will be used to verify continued proper operation. When the response is within acceptable QC limits, the calibration check is complete. If the response requires adjustments or maintenance, that work must be performed as soon as possible, followed by another calibration check to verify proper operation.

PM_{10} samplers will be calibrated with a certified (within the last year) variable flow orifice calibrator. Based on a calibration relationship between manometer readings and actual flow rate, the orifice calibrator is used to calculate airflow through the sampler according to the following equation:

$$Q_a \text{ (orifice)} = (1/m)\ (\Delta P_o[T_a/P_a]^{1/2} - b)$$

Where:

Q_a (orifice)	=	The actual flow rate through the orifice calibrator at sampler calibration conditions (m^3/min);
m and b	=	The slope and intercept of the orifice calibrator calibration regression;
ΔP_o	=	The orifice calibrator manometer reading (in H_2O); and
T_a and P_a	=	The temperature (K) and pressure (millimeters Mercury [mm Hg]) at sampler calibration conditions.

The ratio of absolute stagnation pressure to ambient pressure (P_1/P_a) will be determined during sampler calibration. It will be the primary indication of sampler flow rate during operations. The flow rate indicated by the chart recorder will be noted to provide a measure of stability in sampler operation. P_1 is determined from the following equation:

$$P_1 = P_a - \Delta P_{stg}$$

Where:

P_1	=	The absolute stagnation pressure (mm Hg);
P_a	=	The barometric pressure (mm Hg) during sampler calibration; and
ΔP_{stg}	=	The relative stagnation pressure (mm Hg) read from the manometer connected to the sampler stagnation port.

The primary result of a multi-point PM_{10} sampler calibration is a regression relationship between stagnation pressure ratio [P_1/P_a] as the "y" term, and a new expression Qa (orifice) as the "x" term. The

slope and intercept of this regression, also referred to as "m" and "b", can be used in subsequent calculations of sampler flow rate from stagnation pressure ratio and temperature. Also, the expression can be used to generate site-specific "Look-Up" tables.

2.6.2 PS-1 Sampler

Calibration of the Graseby PS-1 samplers will consist of measuring the air flow through the sampler and documenting the response. A full multi-point calibration (35, 30, 25, 20, 15, and 10 settings of the Magnehelic gauge) will be performed at the beginning of the project and should be repeated if sampler maintenance or problems are encountered during subsequent flow checks (e.g., greater than 10% difference between flow checks and multi-point calibration). In addition, a flow check should be performed following each sampling run. A flow check is a three point calibration that brackets the Magnehelic readings observed during a sampling run. Calibration measurements will be made according to the protocol given in Appendix B.

2.6.3 TSP Sampler

The sampling pumps are rotary vane electric powered vacuum pumps. Sample flows for this program will be restricted to approximately 2 L/min using an in-line needle valve. The electrical requirements for proper operation of the pump are 110 volts at 2 amps. Each sample pump will be calibrated both pre- and post-testing with either a primary, intermediate, or calibrated secondary standard source.

The asbestos sampler requires fewer calibration steps than the other samplers, since a direct reading flow meter can be used to check flow rates instead of the orifice plate procedure. Ambient air temperature and pressure, recorded for the other samplers, will also be used by the asbestos sampler to correct actual flow rates into EPA standard conditions.

2.6.4 TEOM Continuous PM10 Monitor

The TEOM monitor needs periodic calibration of the flow controllers and tests of the filter weighing systems. The flow controllers (that control main and auxiliary flow rates) will be calibrated prior to field deployment with their flows verified during the on site audit. The filter weighing accuracy is tested with a reference filter. This calibration will also be verified prior to field deployment and tested during the audit. Monthly flow and leak checks will also be conducted by the site operator.

2.6.5 Meteorological Sensors

Meteorological sensor calibration is performed to verify that the factory calibration specifications continue to be met. Calibration for each sensor is as follows:

Wind Direction - Assessment of the wind direction sensor will occur during the audit performed near the beginning of the project. The assessment will consist of a true north alignment verification and sensor output linearity check. The vane will be aligned to a datalogger reading of 0°, locked in place, and then the vane will be sighted using a surveyor's transit and compass. The vane will be adjusted to account for the magnitude of magnetic declination appropriate for the tower location to within $\pm 2^{\circ}$. The vane will

then be rotated in 90° increments to check the linearity of the sensor output, through the compass points, 90°, 180°, 270°, and 360°. Acceptable linearity is for the maximum normalized linearity error for all points to be within ±3°. If the sensor does not meet the linearity specification, it will be replaced. The condition of the vane bearings will be qualitatively assessed with the bearings being replaced as needed.

Wind Speed - The accuracy of the wind speed sensor will also be checked during the calibration. This check will consist of a rotational speed check and a bearing check. The anemometer cups will be removed and inspected for loose or damaged parts. A constant speed motor drive unit will be connected to the sensor shaft and the datalogger reading corresponding to three speed inputs and zero input will be recorded. The starting threshold for the MetOne 010C sensor is 0.6 miles per hour (mph). The three speed inputs should be within the range of 2 to 20 mph with at least one speed below 5 mph. The data logger readings should be within ±0.4 mph of the known speed input value. If the speed output does not meet specification, the sensor will be replaced. The sensor bearing starting torque is then quantitatively assessed using an RM Young torque disc to verify that the force required to move the bearings is ≤0.3 grams-centimeter. If the bearings do not meet this criterion, they will be replaced and the check repeated.

Temperature - The temperature probe will be checked during the audit by inserting the probe into a temperature bath for comparison to a thermometer of known accuracy. The temperature of the bath will be adjusted to at least two different levels: near 0°F and ambient. The sensor will be allowed to equilibrate and then a 5-minute average reading taken. The probe will need to be removed from the aspirator housing for this calibration. The probe should never be exposed to temperature extremes over short intervals, so it should be allowed to equilibrate slowly between temperature points. The calibration is within specification if each temperature reading compares to the standard thermometer within ±1.8 °F for each of three consecutive readings. If this specification is not met, the probe should be replaced. A test of the sensor probe in its normal operating mode installed in an aspirator shield is conducted during the calibration by comparison to an aspirated psychrometer.

Barometric Pressure - The barometric sensor will be checked during the audit by comparison to a handheld portable NIST traceable barometric pressure sensor. The calibration is within specification if each pressure reading compares to the standard pressure sensor within ±10 mm Hg . If this specification is not met, the sensor should be recalibrated or replaced.

Rainfall - The rain gauge will be checked during the audit by comparison to known volume of water. The rain gauge will be supplied the equivalent of 0.1 inches of water. The calibration is within specification if the rain gauge reading compares to the standard volume within ±0.01 inches of water. If this specification is not met, the sensor should be recalibrated or replaced.

2.7 DATA ACQUISITION REQUIREMENTS

On site data acquisition systems (data loggers) are used to acquire field data from all of the continuous instruments (e.g., TEOM and meteorological stations). A Campbell CR-10X data logger or an equivalent unit will be used to acquire the data. These data will be routinely retrieved from the field using a wireless modem. Data will be polled and screened regularly (e.g., daily). In addition, the data logger will have

alarm alert notification capability so that on site and off site personnel can be alerted if pre-set concentration limits are exceeded.

2.8 DATA MANAGEMENT

The Campbell CR-10X data-logging unit stores the averages in an ASCII data format. At least once per week the unit will be accessed to retrieve hourly averages and status data. The data sets will be transferred to the Air Monitoring Task Leader for review and validation. Analytical data from the laboratory will also be transferred to the Air Monitoring Task Leader.

The meteorological and TEOM data will be stored on a dedicated air quality server. The network servers have an incremental backup performed nightly, and once a week a full backup is performed. At this point all data will be in an unedited, non-validated form. When a month of data is complete and present on the server, the data will be imported for reporting and validation tasks. The record of edit instructions will be stored in the project files as hard copy and will be available for further review if necessary.

The data generated by the analytical laboratories, including measurement results and associated quality control information, will be transferred to a computer database where it will be managed and maintained by the URS air monitoring staff. In addition to the electronic database files maintained by project staff, the analytical laboratory will store hardcopy records of all quantification reports and quality control data for at least ten years.

2.9 DOCUMENTATION AND RECORDS

Thorough documentation of project activities will be conducted during this monitoring effort. Three main areas of documentation are field operation, laboratory, and data management records.

Field operation records include field logbooks, sample COC forms, operator checklists, calibration records, and maintenance logbooks. The type of information to be recorded includes the name of the sampling personnel, sample locations, start times, end times, flow rate information, and observations about relevant on site activities. These records will be transmitted from the field to the Operations Leader at least monthly either as hard copy or electronic files via e-mail.

The laboratory will maintain records for the various aspects of the PM_{10} and other analyses. This will include sample custody records, raw data from the analyses, Quality Control (QC) checks of data, analysis reports, and electronic data files. Under normal circumstances, these data will be maintained and archived by the laboratory and will normally not be transmitted as part of the data submittal. These data are available and may be reviewed if there are any anomalies with the data. The laboratory is responsible for maintaining these analytical records and transmitting the analytical results to the Air Monitoring Task Leader as hard copy and electronic files (i.e., Excel spreadsheets) for loading to the project database. At a minimum, EPA Level II data packages will be obtained from the laboratory.

Data management records include the database contents log, editing instructions for the data set, and verification documents demonstrating validation of the data. The Air Monitoring Task Leader will work

with the laboratory to ensure that the data files are received as scheduled and will request supporting documentation from the laboratory as needed. The Air Monitoring Task Leader will work with the data management team to ensure that field records are forwarded for inclusion in the project files and that the routine downloading of meteorological and TEOM data occurs as scheduled.

For all documentation in written form, black indelible ink will be used with any hand corrections being made by a single line through the incorrect entry with the author's initials immediately following the correction. All work performed during the data collection, review, and validation process will be traceable to the author. All data products will have the ability to be reversed to their original result if required.

Air monitoring corrective actions, whether taken in the field, laboratory, or data management center, must be documented. Corrective action may be taken in response to an audit finding, QC check that does not meet specifications, or any other obvious malfunction in hardware or software. Documentation of any corrective action should show the nature of the deficiency, actions taken, and evidence gathered to verify resolution of the deficiency. Corrective actions may be documented as:

- Field calibration or trip report forms;
- Laboratory narratives accompanying the analytical data;
- Instructions or notes included in the original data validation package; or
- Project e-mails copied to the project staff impacted by the situation (with a copy always to the Project Manager).

The validated data generated for this project will be stored electronically. Project records will be maintained after the conclusion of the monitoring program in accordance with the requirements of the AOC.

2.10 REPORTING

Data summaries will be prepared monthly and submitted to EPA. In addition, if any exceedances of the performance standards are identified, EPA will be notified immediately of the exceedance. In some cases, this may be based on data that has not yet undergone validation. A meeting (teleconference or on-site) will be held as soon as practicable between EPA, URS, and the contractor to discuss the steps to be taken in response to a performance standard exceedance. During this meeting, EPA, URS and the contractor will:

- review work and site conditions occurring at the time of the exceedance;
- compare those conditions to current work and site conditions;
- evaluate the need to immediately suspend work; and
- evaluate the need to modify or use additional engineering controls.

3.0 ASSESSMENT/OVERSIGHT

3.1 ASSESSMENT AND RESPONSE ACTIONS

The URS project team includes a QA specialist whose sole duties are to provide an independent assessment of the measurement effort. This individual is part of the same corporate organization as the project team, but holds no duties or interests in the operation of any of the monitoring sites and networks that he audits and uses designated audit equipment. Field audits will be performed at least twice during the course of the project, once near the start of the monitoring effort and once near the end. The field audits will consist of both a technical systems audit and a performance evaluation audit to provide information regarding the status of the project team operation and how well the measurement data adhere to the quality specifications of the AQMMP. No audits of the analytical laboratories are planned. All performance and technical systems audits will be conducted following the guidance documents "EPA Quality Assurance Handbook - Volume II: Ambient Air Specific Methods" and "EPA Quality Assurance Handbook - Volume IV: Meteorological Measurements."

3.2 SYSTEM AUDITS

A systems audit is an on site qualitative review of the various aspects of the total sampling and/or monitoring systems to assess their overall effectiveness. The audit includes a review of monitor siting, sample collection records (i.e., COC forms and field logs), and site maintenance activities. From this assessment, the auditor is able to report on the level of adherence to the specifications and quality requirements for the monitoring effort. Where the specification appears incomplete or inadequate, the auditor will apply EPA guidance document information and personal experience in assessing whether the quality of the monitoring activity will produce defensible data.

Checklists that delineate the critical aspects of each method will be used during the audit to document all observations. An example field checklist is presented on Figure 7. In addition to evaluating sampling procedures and techniques, the systems audit emphasizes review of all record keeping and data handling systems including the following:

- Calibration documentation for the sampling equipment;
- Documentation of QC data;
- Completeness of data forms and notebooks;
- Data storage and filing procedures;
- Sample logging procedures;
- COC procedures;
- Documentation of maintenance activities; and

- Data review and validation procedures.

If the auditor identifies procedures that could result in unacceptable data quality, the auditor is authorized to stop sample collection until corrective action is taken and sampling procedures are altered.

3.2.1 Performance Evaluation Audits

A performance audit is an independent check to evaluate the data produced by a measurement system. Audit standards and test equipment that are traceable to acceptable reference standards are used to assess the performance of each analytical method and/or measurement device (performance audit). The performance audits are designed to provide a quantitative, point-in-time evaluation of the data quality of the sampling and analytical systems being tested. This is accomplished by addressing specific components of the overall system.

Audit activities consist of challenging the various measurement systems with standards and test equipment traceable to accepted reference standards. The accuracy specifications for these audits are presented in Table 8. Each on site performance audit will address the following activities:

- Flow rate accuracy of the PM_{10} samplers;
- Flow rate accuracy of the TSP samplers;
- Flow rate accuracy of the PS-1 samplers;
- Flow rate accuracy of the main and auxiliary TEOM flows;
- Weighing accuracy of the TEOM microbalance;
- Wind direction alignment accuracy;
- Wind speed accuracy & starting threshold; and
- Temperature accuracy.

Performance of the PM_{10}, TSP, and PS-1 sampling systems are assessed as a function of their flow rate accuracy. The accuracy of the flow rate measurement of the samplers is tested using independent flow rate standards. The monitors are audited for flow rate measurement accuracy using a primary standard volume displacement meter (such as a certified critical orifice for PM_{10}, TSP and PS-1) or a traceable flow meter connected to the sample inlet with an adapter. For each system, the flow rate through the sample inlet must also be accurate and, if applicable, within specification for correct particle size fractionation.

Meteorological performance audits are accomplished by direct comparison with a known audit standard or an artificial test field in which the instrument response can be predicted. For the wind direction sensor, the output of the sensor with the vane turned to each cardinal direction is assessed, as is the orientation of the vane with respect to true north. The wind speed sensor is tested using a constant velocity motor drive unit for which the rotational speed inputs have a predicted result. The condition of the wind instrument

bearings is also checked to ensure that the starting threshold is within specification. The ambient temperature sensor audits are conducted using collocated aspirated psychrometers. Table 8 also presents the audit specifications for the meteorological measurements.

3.3 REPORTS TO MANAGEMENT

Reports for field performance evaluation audits and technical systems audits (TSAs) conducted by URS include a statement of the scope of the audit, summary presentation of results, and a listing of specific observations or findings related to the specifications under review. Also, the field data and traceability documents for each audit standard used are included. The auditor will always provide the Air Monitoring Task Leader and field staff with a list of preliminary findings and recommendations during a debriefing meeting held at the conclusion of the audits. A formal report will be provided to the project team within approximately two weeks of completion of the audit. If there are no corrective action items, the auditor may close the audit. If further action is required, the audit will be classified as open, pending verification that the corrective action was completed and the audit specification is being met.

Responsibility for follow-up on audit recommendations belongs to everyone on the project team, but the Air Monitoring Task Leader is designated after each audit to provide a written response to the findings and communicate the outcome of the corrective action effort. If the auditor does not receive a response or the response is inadequate, he must communicate the situation to the Project Manager, who has the ultimate responsibility for the technical execution of the project.

If a major systemic problem is noted, a formal corporate Recommendation for Corrective Action system is available to document situations at a level that supersedes the project team. This system is available for use by any technical discipline within the company, and contains formal documents that outline the nature of the deficiency, system or systems that are affected by the deficiency, proposed corrective action, actions taken by the responsible party, and the follow-up verification of the resolution of the deficiency.

4.0 DATA VALIDATION AND USABILITY

4.1 DATA REVIEW, VALIDATION AND VERIFICATION REQUIREMENTS

Data review, validation, and verification procedures are presented in this section. Several types of data are collected for this project:

- Real-time dust and mercury measurements;
- Daily PM_{10}, TSP, and PCB measurements; and
- Continuous meteorological data recorded as 1-hour averages.

Data will be declared invalid whenever documented evidence exists demonstrating that a monitor or sampler was not collecting data under representative conditions or was malfunctioning. In rare cases where a consistent offset can be verified, a factor may be applied to the data set with clear identification of the affected data. The project data documentation files will contain the supporting documentation of the use of and justification for the factor.

The Air Monitoring Task Leader will validate the data set each month with assistance from the data management team. This task will include verification that the data for the meteorology measurements and real-time analyzers are complete for the month and that PM_{10}, lead, PCB, asbestos, and silica data have been reported from the subcontract labs. When the data set is complete for the month, the Air Monitoring Task Leader will begin the data review and validation.

The activities involved in validation of the data in general include the following:

- Reviewing the site visit logs, calibration data, audit data, and project memoranda for indications of malfunctioning equipment or instrument maintenance events;
- Reviewing the data packages from the subcontract laboratories, which contains COC, sample collection conditions, and QC check results; and
- Examining the hourly meteorological data for spikes in the data, unusual persistence, unusually high rates of change, or measurement values that seem incongruous with normal measurement ranges and/or diurnal variations.

For PM_{10}, TSP, and PCB data, the data review will check that: 1) the sampling period was the expected duration of 10 hours, and 2) that sufficient volume was collected. These checks will be made by the field staff and be reviewed by the Air Monitoring Task Leader or his designate. Samples may be invalidated if:

- The sampling period is <75% of the intended sampling duration for that day,
- The final sample volume is less than 250 m^3 for PM_{10} samples;

- The final sample volume is less than 0.25 m^3 for TSP samples; or
- The final sample volume is less than 50 m^3 for PCB samples.

The meteorological data are retrieved via periodic downloading and subjected to regular manual data review by an experienced air quality scientist. Screening tests, such as those recommended by EPA in the "On site Meteorological Program Guidance for Regulatory Modeling Applications," (EPA-450/4-87-013) are performed to aid in identifying data that require further investigation. If a problem is detected in the daily/weekly reviews, the Task Leader and Project Manager are immediately notified so they can direct the appropriate corrective action efforts. This contact is documented via e-mail and distributed to the project team so that the situation may be accounted for in the monthly validation process.

Data are never declared invalid solely because they are unlikely to occur in nature, but may be flagged as suspect and be subjected to further review until the cause for the apparent anomaly is determined. The results from all QC and QA checks are evaluated to determine if the DQOs for each measurement are being met. Evidence of overwhelming measurement bias, external influences on the representativeness of the data, or lack of reproducibility of the measurement data may be cause for the data to be judged invalid.

After the edit and validation review is complete, the editor returns a set of instructions to the data manager for application to the data set. The final edited version of the data is then produced and peer reviewed to ensure that the edits were properly applied and that the validation process was consistent with project requirements and URS standard procedures. A record of the edit instructions is retained in the project files, as is the final data product.

4.2 Reconciliation With Data Quality Objectives

Periodically throughout the data collection effort, it is the Air Monitoring Task Leader's responsibility to evaluate the project's progress in meeting the goals for the measurement data. Two areas will be reviewed: the performance of the project in respect to the quality goals specified in the QA Plan, and the limitations (if any) on the measurement data for their intended use.

4.2.1 Assessment of Measurement Performance

As part of the data reporting, the performance of the monitoring network will be assessed to determine to what extent the measurement data meet the requirements of the data user. In the DQO section, a discussion of the key indicators was presented in relation to precision, accuracy, completeness, representativeness, and comparability goals for the monitoring effort. Specific quantitative measures of precision, accuracy, and completeness were defined for use in estimating the quality of the data set. These measures will be calculated and compared to the goals for the project.

4.2.2 Data Quality Assessment

If any of the data quality measures indicate performance outside the desired objective (e.g., an audit result outside the project specification or a monthly or quarterly completeness average less than the annual

goal), the data associated with that result are not considered useless. The burden is on the project team to determine the extent to which a quality issue affects the related data, and ultimately how the issue impacts the fitness for use of the data.

Most often a single isolated incident in which the performance objective is not met does not automatically render the data useless, but rather slightly reduces the confidence that the measurement is reliable, and indicates that increased quality control measures are needed. The DQOs are assessed periodically throughout the monitoring project, but only at the completion of the project can a complete evaluation be conducted. A period in which the completeness statistic for a given site is below the objective is cause for concern and corrective action, but if the other data are within the objective, the confidence in the project data set should remain high.

Any potential limitations of the data set will be identified and communicated. The project team will present any known or potential limitations on the data in the final report.

TABLES

TABLE 1
CONSTITUENTS OF CONCERN
AEROVOX FACILITY, NEW BEDFORD, MA

Class of Pollutant	Measurement Parameter	Air Quality Performance Standards
Particulate Matter (dust)	PM_{10}	100 $\mu g/m^3$ (10-hr TWA)
Polychlorinated Biphenyls	PCBs	10 $\mu g/m^3$ – N, S, and E 0.25 $\mu g/m^3$ – W (station-specific average)
Crystalline Minerals	Asbestos	0.1 fibers/cc
	Silica	25 $\mu g/m^3$
Metals	Lead (Pb)	50 $\mu g/m^3$
	Mercury (Hg)	50 $\mu g/m^3$

TWA = Time weighted average

TABLE 2
ANALYTICAL LABORATORY INFORMATION
AEROVOX FACILITY, NEW BEDFORD, MA

Analyte	Laboratory	Contact
PM10 (gravimetric)	Alpha Analytical Inc. 320 Forbes Blvd Mansfield, MA 02048	Andy Rezendes (508) 844-4181
Lead		
PCBs		
Silica	Galson 6601 Kirkville Road East Syracuse, NY 13057	(315) 432-5227 [a]
Asbestos (by PCM)	URS 5 Industrial Way Salem, NH 03079-2830	Doug Lawson (603) 893-0616 x-2225 Jamie Noel (603) 893-0616 x-2282
Asbestos (by TEM, NIOSH Method 7402)	AmeriSci 8 School Street E. Weymouth, MA 02189	(781) 337-9334 [a]

a – All contacts with these Galson and AmeriSci will go through Ms. Jamie Noel.

TABLE 3
SUMMARY OF AMBIENT AIR MONITORING PROGRAM
AEROVOX FACILITY, NEW BEDFORD, MA

	Analyte & Analytical Method	Sampler	# of Units	Site Activity	Sampling Frequency	Estimated Sampling Duration	Comments
1	**PM_{10}** (microbalance)	TEOM	4	HM Exterior + Active Demo + BF First Lift	Continuous	10 months	Continuous reading, results reported
2	**PM_{10}** (gravimetric)	Hi-vol PM_{10}	2	AD CWM	Daily	20 weeks	24-hr TAT
3	**Lead (Pb)** by Method 6020A ICP-MS	Hi-vol PM_{10}	4 + dup	HM Removal	Weekly	1 week (baseline)	3 day TAT
				HM Exterior	Weekly	2 weeks	3 day TAT
				HM Exterior	Bi-Weekly	10 weeks	Standard TAT
				AD Building	Weekly	1st four weeks only	Standard TAT
4	**Asbestos** by PCM Plus 10% by TEM	TSP	4 + dup	HM Removal	Weekly	1 week (baseline)	3 day TAT
				HM Exterior	Weekly	2 weeks	3 day TAT
				HM Exterior	Bi-Weekly	10 weeks	Standard TAT
				AD Building	Daily	1st two weeks only	1st day=3 day TAT, remainder Standard TAT
				AD Building	Bi-Weekly	Until end of Active Demo	Standard TAT
5	**Silica** by XRD	TSP	4 + dup	HM Removal	Weekly	1 week (baseline)	3 day TAT
				HM Exterior	Weekly	2 weeks	3 day TAT
				HM Exterior	Bi-Weekly	10 weeks	Standard TAT
				AD Building	Daily	1st two weeks only	1st day=3 day TAT, remainder Standard TAT
				AD Building	Weekly	Until end of Active Demo	Standard TAT

TABLE 3 (CONTINUED)
SUMMARY OF AMBIENT AIR MONITORING PROGRAM
AEROVOX FACILITY, NEW BEDFORD, MA

	Analyte & Analytical Method	Sampler	# of Units	Site Activity	Sampling Frequency	Estimated Sampling Duration	Comments
6	**PCBs** by GC/MS	PS-1	4 + dup	HM Removal	Weekly	1 week (baseline)	3 day TAT
				HM Exterior	Weekly	2 weeks	3 day TAT
				HM Exterior	Bi-Weekly	10 weeks	15 day TAT
				AD Content	Weekly	2 weeks	3 day TAT
				AD Content	Weekly	6 weeks	15 day TAT
				AD Building	3 times per week	1st 4 weeks only	1st sample each week = 3 day TAT, All others = 15 day TAT
				AD Impreg	3 times per week	1st week demolition at Impregnation Room	All 3 day TAT
				AD Building	Weekly	Until end of Active Demo	15 day TAT
				BF First Lift	Weekly	2 weeks	15 day TAT
7	**Mercury (Hg)** by gold film amalgam	Jerome 431-X	1	HM Hg Removal	Daily	4 weeks	Real-time on site portable monitor
				AD Content	Daily	1 week	
				AD Building	Daily	1 week	

TABLE 3 (CONTINUED)
SUMMARY OF AMBIENT AIR MONITORING PROGRAM
AEROVOX FACILITY, NEW BEDFORD, MA

NOTES:

1. Site activity definitions:

HM Removal = hazardous material removal and Aerovox Waste Material disposal, including asbestos, mercury, universal waste, etc. per SOW III.D.
HM Exterior = portion of time within HM Removal when work is occurring outside the building that could generate air impacts, including managing and loading Aerovox Waste Material for disposal
HM Hg Removal = portion of time within HM Removal when mercury cleanup is being undertaken
Active Demo = material removal, demolition, debris processing and loading for off site disposal (City Waste Material) This extends from EPA approval of hazardous material removal through loading of last truck for off site disposal.
AD Contents = portion of time within Active Demo when building contents (i.e. equipment and materials) are being removed, processed and loaded for off site disposal
AD Building = portion of time within Active Demo when the building itself is being dismantled, processed and loaded. The timeframes for AD Contents and AD Building will overlap
AD Impreg = portion of time within AD Building timeframe when the impregnation room is being dismantled, processed and loaded.
AD CWM = portion of time within Active Demo when processing of City Waste Material is occurring outside the building
BF First Lift = Period of time required for completion of the placement of the first full lift of basement backfill

2. Standard TAT is 7 to 10 days.

3. In the event that performance standards provided in SOW section III.C. are exceeded, the frequency of sampling may be modified until subsequent sampling shows a return to consistent compliance with those standards.

TABLE 4
GENERIC AMBIENT AIR MONITORING INFORMATION FOR VARIOUS MONITORING OPTIONS
AEROVOX FACILITY, NEW BEDFORD, MA

Analyte	Method	Sampler	Collection Media	Nominal Flow Rate (L/min)	Typical Volume (m^3)	Analytical Approach	Analytical Sensitivity	Method Sensitivity
PM_{10}	IO-2.1	PM_{10} Hi-Vol	Filter	1,000	>480 (10-hr run)	Gravimetric	0.1 mg	<0.2 $\mu g/m^3$
Elemental Analysis	SW6010	PM_{10} Hi-Vol	Quartz fiber filter	1,000	>480 (10-hr run)	ICAPES	20 µg	<0.04 $\mu g/m^3$
PCBs	TO-4A	PS-1	Filter + PUF	200 – 250	>100 (10-hr run)	GC/MS (congeners)	10 ng	<0.10 ng/m^3
Silica	NIOSH 7500	Low flow pump	Cellulose Ester Membrane Filter	2	1 (10-hr run)	XRD	10 µg	10 $\mu g/m^3$
Asbestos	NIOSH 7400					PCM	5 fibers / 100 fields	<0.01 fibers/cc
	NIOSH 7402					TEM	--	<0.01 fibers/cc

GC-ECD = Gas chromatography - electron capture detector
GC/MS = Gas chromatography/mass spectrometry
ICAPES = Inductively coupled argon plasma emission spectroscopy
PCBs = Polychlorinated biphenyls
PCM = Phase contrast microscopy
PM_{10} = Particulate matter with an aerodynamic diameter less than or equal to 10 micrometers
PUF = Polyurethane foam (plug)
TEM = Transmission electron microscopy
XRD = X-ray diffraction

Milligram (mg) = 10^{-3} g
Microgram (µg) = 10^{-6} g
Nanogram (ng) = 10^{-9} g

TABLE 5
MEASUREMENT PERFORMANCE CRITERIA
AEROVOX FACILITY, NEW BEDFORD, MA

Measurement Parameter	Measurement Method	Precision Criteria	Accuracy Criteria	Completeness Criteria
PM_{10}	PM_{10} Hi-volume sampler	Not Assessed[a]	± 10% Flowrate[b]	>90%[c]
	Gravimetric (Balance)	25% RPD for PM_{10} mass	± 5% Balance Constant[b]	>90%[c]
PCBs	PS-1 Sampler	Not Assessed[a]	± 10% Flowrate[b]	>90%[c]
TSP	TSP Low-volume sampler	Not Assessed[a]	± 10% Flowrate[b]	>90%[c]
Wind Direction	Vane/ Potentiometer (e.g. MetOne 020C)	Not Assessed[a]	± 5° azimuth[d] Resolution: ± 1°	>90%[c]
Wind Speed	Anemometer (3-cup)/ Frequency Counter (e.g., MetOne 010C)	Not Assessed[a]	± 0.4 miles per hour[d] Threshold Limit: 0.6 mph	>90%[c]
Ambient Temperature	Aspirated Thermistor (e.g., MetOne model 076,060A)	Not Assessed[a]	± 1.8 degrees Fahrenheit (°F)[d]	>90%[c]
Barometric Pressure	Pressure Transducer (e.g., MetOne model 092)	Not Assessed[a]	± 1 millimeter Mercury (mmHg)[d]	>90%[c]
Rainfall	Tipping Bucket (e.g., MetOne model 370)	Not Assessed[a]	± 0.01 inches Water ("H_20) [d]	>90%[c]

[a] Precision of this variable or method typically is not assessed in ambient monitoring programs
[b] Percent difference based on flowrate assessments and operational checks for frequency constant and sample inlet particle cut-point (PM_{10})
[c] Completeness of the data set based on the number of valid samples compared with the number of samples attempted
[d] Represents total error for the measurement, taking into account sensor and data logger bias contributions
RPD – relative percent difference

TABLE 6
PROPOSED ACTION LEVELS FOR DUST CONTROL
AEROVOX FACILITY, NEW BEDFORD, MA

Measured PM_{10} Value[a]	**Action**
Any visible dust emissions from site activities	Notify OSC. Implement Corrective Measures. Implement dust controls (e.g., water sprays)
> 75 $\mu g/m^3$	Increase application rate of dust controls
>150 $\mu g/m^3$	Continue wetting of source area. Suspend Site Activities

[a]Based on 5-min average TEOM data

TABLE 7
SUMMARY OF SAMPLING QUALITY CONTROL SAMPLES
AEROVOX FACILITY, NEW BEDFORD, MA

Analyte	Sampler	Blanks	Duplicates	Comments
PM_{10}	TEOM	n/a	n/a	
PM_{10}	Hi-Vol PM_{10}	10%	10%	The frequency may be reduced to 5% after 20 QC samples of each type have been collected.
Lead	Hi-Vol PM_{10}	10%	10%	
Asbestos	TSP	2 per sampling event	10%	
Silica	TSP	2 per sampling event	10%	
PCBs	PS-1	10%	10%	
Mercury	Jerome 431-X	n/a	n/a	

TABLE 8
PERFORMANCE AUDIT SPECIFICATIONS
AEROVOX FACILITY, NEW BEDFORD, MA

Audit Activity	Specification
Continuous TEOM Sampler	
Sampler Flow	±10%
Weighing Accuracy	±2.5%
Hi-Vol PM_{10} Samplers	
Sampler Flow	±7%
Flow vs. Design	±10%
Leak Check	No leaks
PS-1 Samplers	
Sampler Flow	±7%
Leak Check	No leaks
TSP Samplers	
Sampler Flow	±10%
Leak Check	No leaks
Wind Direction	
True North Alignment	±2°
Sensor Linearity	±3°
Wind Speed	
Starting Threshold	≤ 0.3 g-cm
Artificial Field Input (0 – 54 mph)	± 0.4 mph
Temperature	
Collocated Certified Thermometer	± 1.8° Fahrenheit
Barometric Pressure	
Collocated Certified Pressure Transducer	± 10 mmHg
Rainfall	
Volumetric Standard	± 0.01" H_2O

g – gram
cm – centimeter
mph – miles per hour

FIGURES

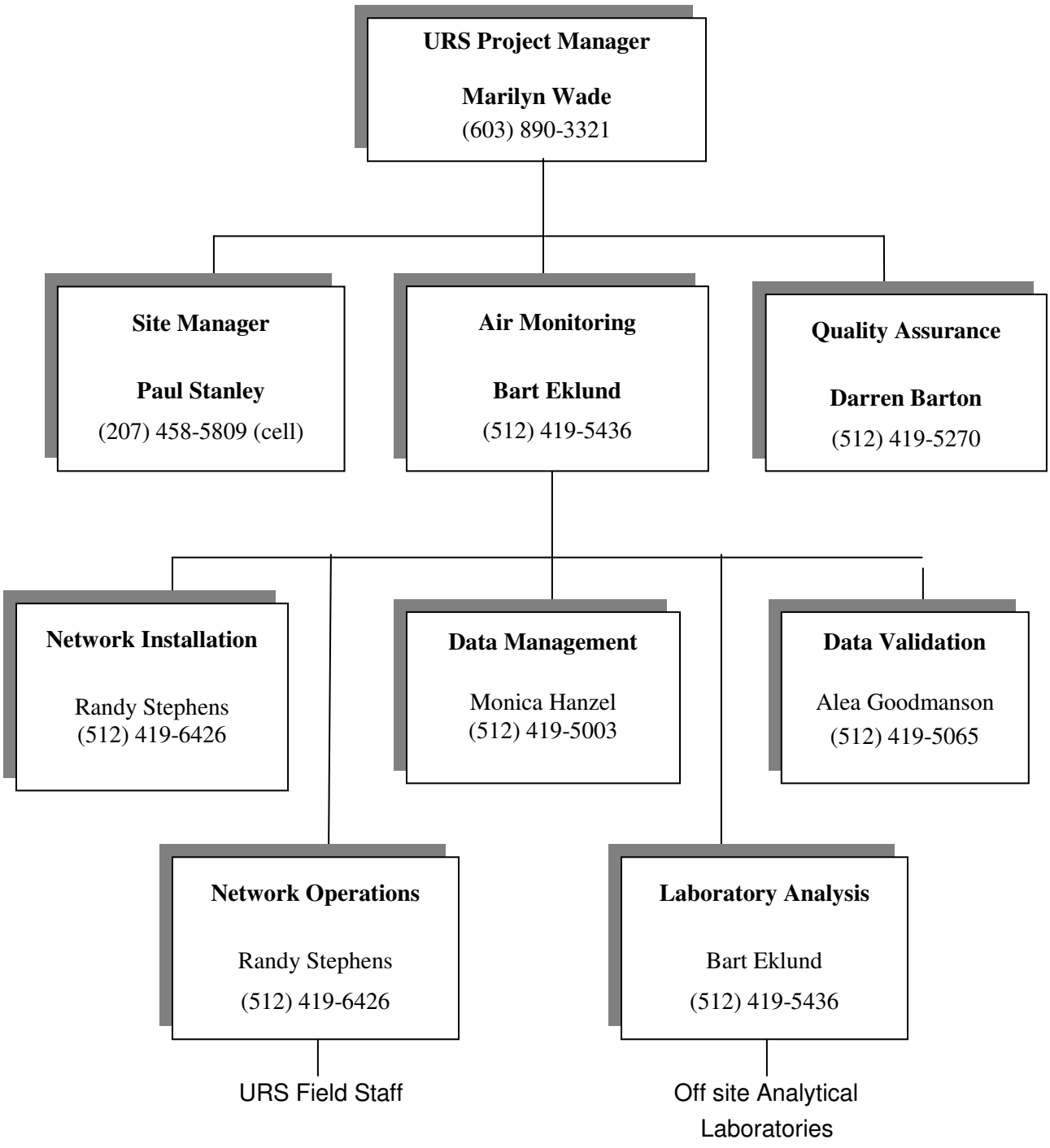
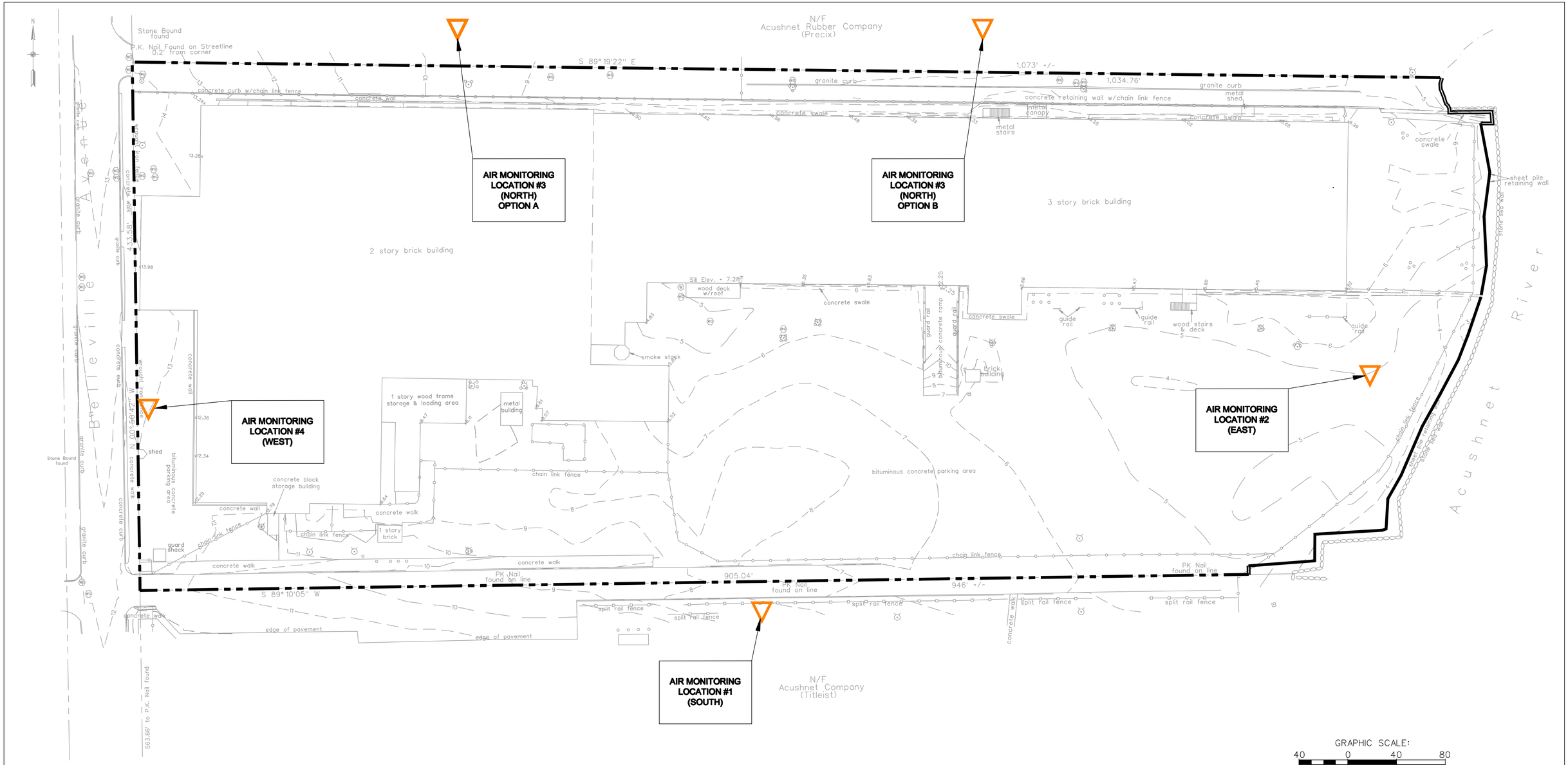


Figure 1
Task Organization



GRAPHIC SCALE:
40 0 40 80

Notes:

1. Bearings as depicted hereon are based upon the maps referenced in note 2.
2. Reference is made to the following maps:
   - A. Plan of Land in New Bedford, Tibbetts Engineering Corp., Surveyors, dated March 20, 1964 and revised March 22, 1968, Sheets 1-4, Land Court NO. 33314A.
   - B. Plan of Land in New Bedford, Tibbetts Engineering Corp., Surveyors, scale 1"=120', dated June 14, 1976 and revised December 26, 1990, Sheets 1 and 2 of 2, Land Court No. 39434A.
   - C. Plan Showing 15 Foot Wide Utility Easement Over Land Court Lot 17164A of Aerovox Corp. in New Bedford, Mass., Surveyed for Acushnet Process Company, scale 1"=50', dated February 14, 1968, prepared by Tibbetts Engineering Corp., New Bedford, Mass., Land Court Document No. 27932.
3. Property is subject to a 15' Utility Easement in Favor of the Acushnet Process Company as recorded in Land Court Document No. 27932.
4. Property is subject to rights in favor of the Acushnet Company to use the northerly half of Way as recorded in Book 91 Page 315.
5. Elevations as depicted hereon are based upon the National Geodetic Vertical Datum of 1929, holding RM 2 with a published elevation of 17.063 feet as depicted on Flood Insurance Rate Map, City of New Bedford, Massachusetts, Bristol County, Panel 7 of 15, Community Panel Number 255216 0007 B, with a revision date of January 5, 1984.

LEGEND

SITE FEATURES

- WATER GATE/VALVE
- FIRE HYDRANT
- CHAIN LINK FENCE

SITE BOUNDARIES

- PROPERTY LINE
- SHEET PILE
- STONE WALL
- NE & SE CORNER SITE BOUNDARY LINE

PROPOSED AIR MONITORING LOCATION

NOTE: AIR MONITORING LOCATIONS MAY VARY BASED ON POWER AVAILABILITY AND OTHER LOGISTICAL CONSIDERATIONS.

AIR MONITORING LOCATION PLAN

AEROVOX FACILITY
740 BELLEVILLE AVENUE
NEW BEDFORD, MASSACHUSETTS

URS
5 Industrial Way
Salem, New Hampshire 03079
TEL: (603) 893-0616
FAX: (603) 893-6240
http://www.urscorp.com

SCALE:	NTS	DRAWN BY:	KP	JOB NO.:	39743350
DATE:	10/10	APPR. BY:	JL	FIGURE 2	

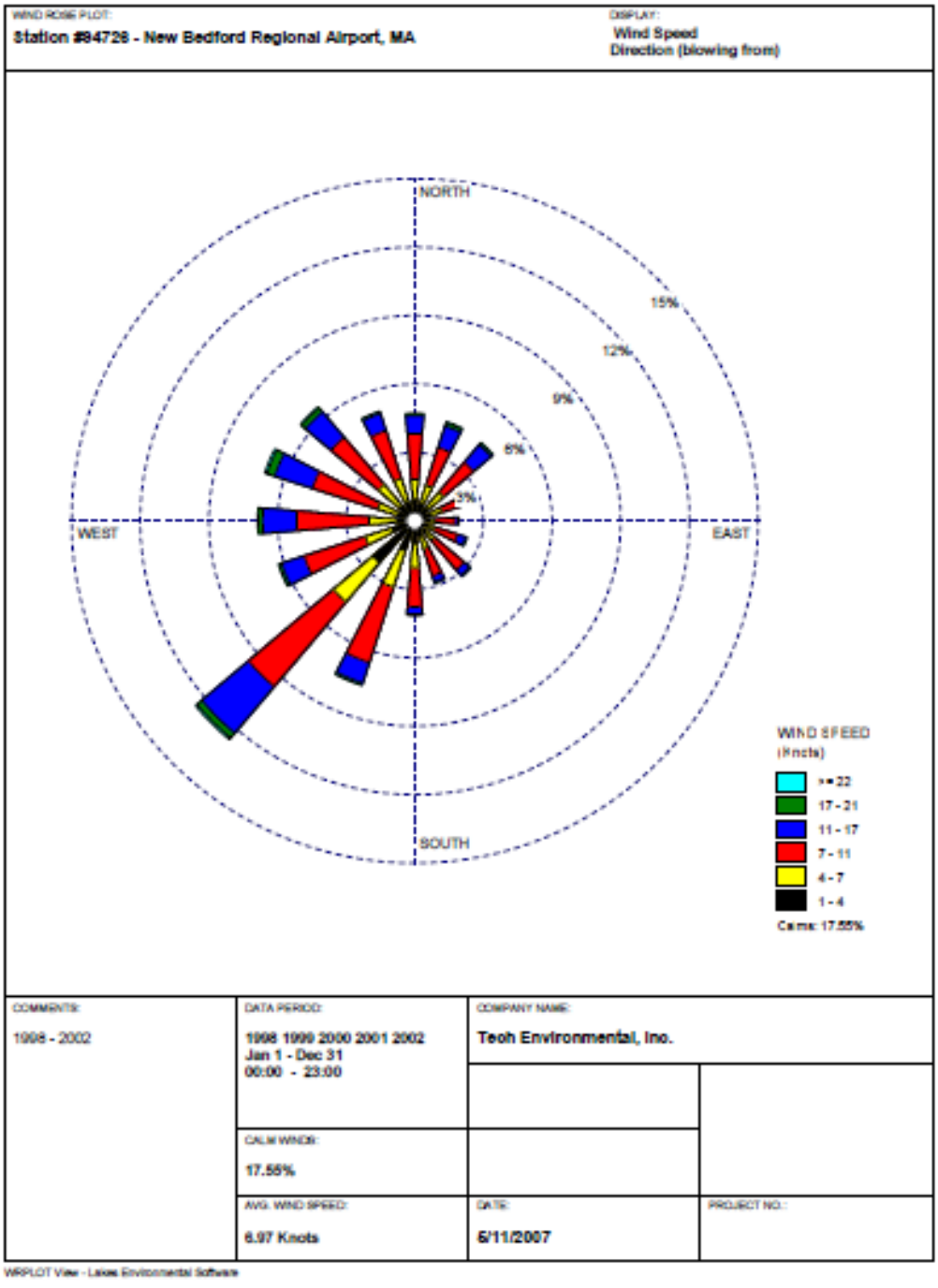


Figure 3
Wind Rose for New Bedford

Source: Tech Env. Acoustic Study of Vestas V82 Wind Turbines, Fairhaven, Massachusetts. May 11, 2007

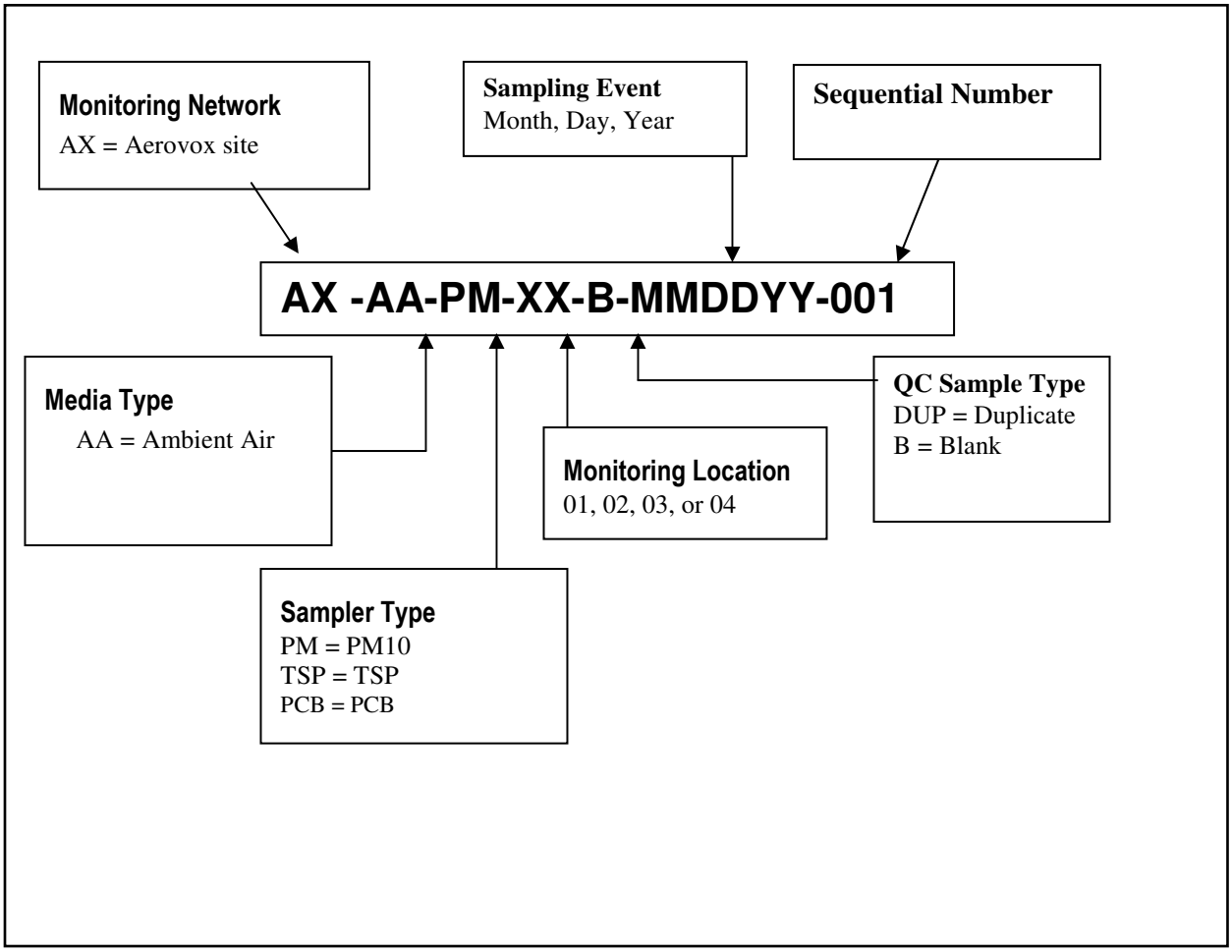


Figure 4
Sample Identification Scheme

PM_{10} Filter Sample Calculation Sheet

Monitoring Site No:		**Sampling Run No:**	
Filter ID:			
Start Date:		**Start Time (hh:mm)**	
End Date:		**End Time (hh:mm)**	
Elapsed Run Time			**(min)**
Initial Stagnation Pressure	**(in H_2O)**	**Final Stagnation Pressure**	**(in H_2O)**
Average Stagnation Pressure			**(in H_2O)**
Average BP (P_{av})	**(mm Hg)**	**Average Temperature**	**(°C)**
ΔPcfd	**(mm Hg)**	**P_1 = (P_{av} - ΔPcfd)**	**(mm Hg)**
P_1/P_{av}		**Flowrate (Q_a)**	**(m^3/min)**
Total Run Flow (Q_a)*run time (min)			**(m^3)**
Initial Filter Weight	**(g)**	**Final Filter Weight**	**(g)**
Total Particulate Mass Concentration			**(μg/m^3)**

Notes:

ΔPcfd is equal to average Stagnation pressure in inches of H_2O converted to mm Hg (obtained by multiplying inches H_2O
by 1.87).

Q_a Obtained from look-up tables using average ambient temperature during run along with P_1/P_{av} ratio.

Total Particulate Mass Concentration = (Final filter weight - Initial filter weight)/total volume (m^3)

Figure 5
Filter Envelope

Figure 6
Example of Field Checklist for Systems Audits

AIR MONITORING SYSTEMS AUDIT CHECKLIST

Client X
Date:

Response (Y/N/NC)	Operational Function (Indicate NA if question does not apply to operation under review)	Comments
	I. System Equipment Inspection	
	Particulate Matter Samplers for PM_{10} --	
Y	Are collocated samplers operated at this site?	
Y	Are the samplers between 2 and 5 meters apart?	Samplers are two meters apart
Y	Are sampler gasket materials in good condition?	
Y	Is each sampler leak-free?	
Y	Is the timing device set properly?	
Y	Are sample elapsed time records normal? How measured?	Chart and Digital meter
Y	If present, have PM_{10} sample inlets been cleaned <6 months ago?	
	Particulate Matter Monitor for $PM_{2.5}$ --	
Y	Sampling flow rate monitored? How?	Mass flow controlled
Y	Is the sampler leak-free?	
Y	Is a clean filter medium in place? Specify date of last change.	Last changed 11/29/99
Y	Is the sampler in the continuous run mode?	
N	Are there any status conditions that prevent normal sampling operation?	
Y	Is the data recorder operational and accurate to nearest 5 minutes?	
Y	Is the A/C unit for the enclosure maintaining a stable temperature?	
	Meteorological Instruments--	
Y	Are all meteorological instruments operational?	
Y	Are calibration checks performed? Specify.	Upon initial installation in Sept 1999; 6 mo. thereafter
N	Is the instrument tower plumb and the base secured?	Temporary tower. Base is not secure.
Y	Are instrument mountings level?	
NA	Is tower winch assembly secure and easy to operate?	Temporary tower
Y	Are all signal cable connections clean and corrosion-free?	
N	Lightning protection in place?	Temporary tower. No lightning protection.
	Data Collection Systems-	
Y	Data logger operational? Specify.	Zeno DAS for meteorological system
Y	Date/Time accurate to nearest 5 minutes?	
Y	Are wind Sigma values calculated and recorded?	
Y	Are wind vector and scalar values recorded?	
Y	Are current weather conditions consistent with recorded data?	

Figure 6 (Continued)

AIR MONITORING SYSTEMS AUDIT CHECKLIST(continued)

Response	Operational Function	Comments
	II. Operational Procedures	
	Sampling Operations--	
N	Copy of task plan or AQMP available?	
Y	Sampling schedule available?	
Y	Samples collected according to schedule?	
	Calibrations--	
Y	Is the site technician trained to perform valid calibrations?	
Y	Is a certified, traceable orifice used for PM_{10} calibrations?	
Y	Are PM_{10} calibrations performed monthly? Specify last calibration date(s).	Last calibrations performed 12/7/99
Y	Are calibrations performed before and after major maintenance?	
	Recordkeeping--	
Y	Is a bound, document-controlled station logbook used?	
Y	Do logbook entries show arrival/departure time and date?	
Y	Do logbook entries show the most recent filter changes?	
Y	Are any events that affect the samples noted?	
Y	Do logbook entries show recent data retrieval times?	
Y	Is the authorship of each entry noted?	
Y	Are incorrect entries marked out with a single line?	
	III. Data Chain-of-Custody	
Y	Are hourly averages from the data system periodically retrieved?	
Y	Is a data shipment package sent from the field periodically?	
Y	Are duplicate copies of all written records kept on-site?	
Y	Are data shipment custody forms used?	
Y	Are particulate matter C-O-C filter envelope forms complete?	
Y	Is a copy of the shipping bill of lading kept for tracking purposes?	
	IV. Maintenance	
Y	Is a schedule for preventative maintenance available?	
Y	Are adequate parts and tools available for maintenance?	
Y	Are maintenance activities recorded in a logbook?	
NC	Are maintenance procedures consistent with project expectations?	None observed
	V. Overall Observations	
N	Does the field operation meet project expectations?	Site has been scheduled for relocation.
Y	Are the current readings consistent with ambient conditions?	
Y	Are all data system recording channels on-line? Note date/time.	

Auditor:_____

APPENDIX A

A-1 Mercury Measurements Daily Recordkeeping Form
A-2 Sample Chain of Custody Form

A-1 Record of Daily Mercury Measurements

Date:			Analyzer: Jerome 431-X
			Serial Number:
Concurrent On site Activities:			Zero Check:
			Approximate Weather Conditions: AM PM Wind Direction: Wind Speed: % Cloud Cover:
Time	Location	Mercury Conc. (μg/m3)	Comment
			Sampler's Initials =

A-2 Chain of Custody Form

URS

Chain of Custody Record

Page ____ of ____

Project											
Site											
Project Number											
Prepared by											
Sample ID Code	**Sample Matrix**	Date/Time									Comments

Relinquished by:		Date	Time	Received by:		Date	Time		Relinquished by:		Date	Time
Received by:		Date	Time	Relinquished by:		Date	Time					
Received for Laboratory by		Date	Time	Airbill No.	Opened by:		Seal #		Date	Time	Temp (C)	
Seal #	Condition											
Remarks												

APPENDIX B

Sampling Procedures

B-1 Sampling Procedures for PM10 Hi-Vol Samplers
B-2 Sampling Procedures for PS-1 (PUF) Hi-Vol Samplers
B-3 Sampling Procedures for TSP (silica and asbestos) Samplers

B-1

PM_{10} Sampler Calibration and Operation Procedures

1.0 PM_{10} CALIBRATION PROCEDURE

The following is a step by step process of the calibration of a **TE-6070V Volumetric Flow Controlled PM10 Particulate Sampling System.**

Following these steps are example calculations determining the calibration flow rates for the sampler. The flow rate of the sampling system is controlled by a Volumetric Flow Controller (VFC) or dimensional venturi device. This calibration differs from that of a mass flow controlled PM10 sampler in that a slope and intercept does not have to be calculated to determine air flows. The flows are converted from actual to standard conditions when the particulate concentrations are calculated.

With a **V**olumetric **F**low **C**ontrolled (VFC) sampler, the calibration flow rates are provided in a **Flow Look Up Table** that accompanies each sampler. The attached example calibration worksheet uses a TE-5028A **Variable Orifice Calibrator** that uses an adjustable or variable orifice, which we recommend when calibrating a **VFC**.

Proceed with the following steps to begin the calibration.

Step one: Mount the calibrator orifice and top loading adapter plate to the sampler. A sampling filter is generally not used during this procedure. Tighten the top loading adapter hold down nuts securely for this procedure to assure that no air leaks are present.

Step two: Turn on the sampler and allow it to warm up to its normal operating temperature.

Step three: Conduct a leak test by covering the holes on top of the orifice and pressure tap on the orifice with your hands. Listen for a high-pitched squealing sound made by escaping air. If this sound is heard, a leak is present and the top loading adapter hold-down nuts need to be re-tightened.

"WARNING" Avoid running the sampler for longer than 30 seconds at a time with the orifice blocked. This will reduce the chance of the motor overheating.

"WARNING" never try this leak test procedure with a manometer connected to the side tap on the calibration orifice or the blower motor. Liquid from the manometer could be drawn into the system and cause motor damage.

Step four: Connect one side of a water manometer or other type of flow measurement device to the pressure tap on the side of the orifice with a rubber vacuum tube. Leave the opposite side of the manometer open to the atmosphere

Step five: Connect a water manometer to the quick disconnect located on the side of the aluminum outdoor shelter (this quick disconnect is connected to the pressure tap on the side of the filter.

Step six: Make sure the orifice is all the way open (turn the black knob counter clockwise). Record both manometer readings the one from the orifice and the other from the side of the sampler. To read the manometer one side goes up and the other side goes down you add both sides, this is your inches of water. Repeat this process for the other four points by adjusting the knob on the variable orifice (just a slight turn) to the four different positions and recording the four different manometer readings. You should have five sets of numbers, ten numbers in all.

Step seven: Remove the variable orifice and the top loading adapter and install a clean Micro-Quartz filter. Record the manometer reading from the side tap on the side of the sampler. This is used to calculate the operational flow rate of the sampler.
Step eight: Record the ambient temperature, the barometric pressure, the sampler serial number, the orifice serial number, the orifice Qactual slope and intercept with the date last certified, today's date and time, site location and operator name on the calibration form.

2.0 PM10 SAMPLER OPERATION

1. After performing calibration procedure, remove calibrator and top loading adapter. Install TE-3000 Cartridge and remove filter holder frame.

2. Carefully center a new filter, rougher side up, on the supporting screen. Properly align the filter on the screen so that when the frame is in position the gasket will form an airtight seal on the outer edges of the filter.

3. Secure the filter with the frame, brass bolts, and washers with sufficient pressure to avoid air leakage at the edges (make sure that the plastic washers are on top of the frame).

4. Wipe any dirt accumulation from around the filter holder with a clean cloth.

==========

PM_{10} Size Selective Inlet Shim Plate

An anodized aluminum Shim Plate is supplied on top of the 1st stage plate of the SSI and can be seen by opening the body of the SSI. This collection Shim Plate needs to be heavily greased according to the following frequency and procedure.

Cleaning Frequency

Average frequency based on TSP levels at site and usage rate:

40 $\mu g/m^3$	50 sampling day or 10 months for every 6th day sampling
75 $\mu g/m^3$	25 sampling day or 5 months for every 6th day sampling
150 $\mu g/m^3$	13 sampling day or 3 months for every 6th day sampling
200 $\mu g/m^3$	10 sampling day or 2 months for every 6th day sampling

Cleaning of the Shim Plate is done after removal from the SSI.

- To remove the Shim Plate, unlatch the four SSI hooks located on the sides of the SSI body. Slowly tilt back the top inlet half exposing the 9 acceleration nozzles. Tilt the SSI top half until the SSI body support strut drops and locks into the second, fully open, notch and supports the top half of the inlet. Two Shim Plate Clips located on the right and left sides should be rotated 90° to release the fastening pressure on the shim. The Shim Plate should be handled by the edges and slowly lifted vertically to clear the height of the 16 vent tubes and pulled out forward toward the operator. A clean cloth is used to wipe the soiled grease from the Shim Plate. Acetone or any commercially available solvent can be used to clean the Shim Plate to its original state.

- Clean the interior surfaces of the SSI using a clean cloth.

- Place Shim Plate on a clean flat surface away from the rest of the SSI assembly and spray the Shim Plate with a coating of Dow Corning Silicone #316. This grease is available from Tisch Environmental or from your local Dow Corning Distributor.

- Make sure the Shim Plate is clean, and apply a "generous" amount of the silicone spray after shaking the aerosol can. Spray holding the can 8 to 10 inches away. Spray is necessary in the areas which are below the acceleration nozzles. Allow 3 minutes for the solvent in the spray to evaporate leaving the final greased Shim Plate tacky, but not slippery. After drying, a cloudy film is visible, with a film thickness at least twice the diameter of the particles to be captured. Over spraying with the silicone will not hurt the performance of the SSI, so when in doubt, apply more silicone spray.

- Before reinserting the greased Shim Plate, wipe off all interior surfaces of the SSI and brush any loose dirt or insects off the Bug Screen located below the removable Shim Plate.

- Lift the greased Shim Plate by the edges and place it on the SSI 1st stage plate over top of the vent tubes with the greased side up in reverse order of the above removal procedure. Swing the two Shim Plate Clips over the edge of the greased Shim Plate to hold it securely in place.

- Close the SSI making sure of a good snug fit. Latch the 4 hooks firmly in place.

==========

5. Close PM10 Inlet carefully and secure with all hooks and catches.

6. Make sure all cords are plugged into their appropriate receptacles and on all VFC systems make sure the clear tubing between the filter holder pressure tap and the bulkhead fitting is connected (be careful not to pinch tubing when closing door).

7. Prepare the Timer: See Timer Instructions on page 10, 11, and 12.

8. At the end of the sampling period, remove the frame to expose the filter. Carefully remove the exposed filter from the supporting screen by holding it gently at the ends (not at the corners). Fold the filter lengthwise so that sample touches sample.

9. It is always a good idea to contact the lab you are dealing with to see how they may suggest you collect the filter and any other information that they may require.

3.0 PM_{10} ROUTINE MAINTENANCE

A regular maintenance schedule will allow a monitoring network to operate for longer periods of time without system failure. Many users find the adjustments in routine maintenance frequencies are necessary due to the operational demands on their sampler(s). We recommend that the following cleaning and maintenance activities be observed until a stable operating history of the sampler has been established.

1. Inspect all gaskets (including motor cushion) to assure they are in good shape and that they seal properly. For the PM-10 Inlet to seal properly, all gaskets must function properly and retain their resilience. Replace when necessary.

2. Power cords should be periodically inspected for good connections and for cracks (replace if necessary). **CAUTION:** Do not allow power cord or outlets to be immersed in water.

3. Inspect the filter screen and remove any foreign deposits.

4. Inspect the filter media holder frame gasket each sample period. This gasket must make an airtight seal.

5. For Brush type systems: Check or replace motor brushes every 300 to 500 hours. If motor has exhausted brush changes, then replace motor.

6. Insure the elapsed time indicator is operating by watching under power.

7. Be certain the continuous flow recorder pen is making contact with the chart and depositing ink each sample period. Be sure the door is sealed completely. Tubing should be inspected for crimps or cracks. Replace when necessary.

8. Clean shim plate periodically, excess dirt will cause false reading and bounce of heavier particulate. See Section SAMPLER OPERATION

9. Be certain the alignment pins are aligning properly. The upper and lower tubs must have an airtight seal. Be careful not to bend any parts of inlet out of their original aerodynamic shape, mainly the hood, acceleration nozzle plate, nozzles and vent tubes.

Example Calibration Worksheet

PM-10 / VOLUMETRIC FLOW DATA

SITE NAME:
DATE:
TIME:
Pressure (mm Hg):
Temperature (F):

FLOW ORIFICE S/N:
Slope:
Incercept:
Correlation:
Cert. Expiration Date:

PM-10 SAMPLER #1 INFORMATION
Model ID
Sampler S/N
Sampler Slope
Sampler Intercept
Sampler Correlation
Cert. Expiration

PM-10 SAMPLER #2 INFORMATION
Model ID
Sampler S/N
Sampler Slope
Sampler Intercept
Sampler Correlation
Cert. Expiration

	Pressure (in. H_2O)		Flow Rate (m^3/min)		Flow Percent Difference		
	Orifice Pressure	Stagnation Pressure	Orifice Flow	Sampler Flow	Sampler & Orifice	Design & Orifice	Sampler & Design
Sampler #1			--	--	--	--	--
Sampler #2			--	--	--	--	--

*Design flow is 1.13 m^3/min

PM-10 Sampler # 1 - Flow Recalibration Data

Orifice Pressure (in. H_2O)	Stagnation Pressure (in. H_2O)	Orifice Flow (m^3/min)
		--
		--
		--
		--
		--

Slope: --
Intercept: --
Correlation: --

PM-10 Sampler # 2 - Flow Recalibration Data

Orifice Pressure (in. H_2O)	Stagnation Pressure (in. H_2O)	Orifice Flow (m^3/min)
		--
		--
		--
		--
		--

Slope: --
Intercept: --
Correlation: --

Alerts: None.

Operator Comments:

Operator:

filename: PM0_SITE_MMDDYY_HHMM_NA

Rev. 7.5.8 (11/08)

B-2

PS-1 (PUF) Sampler Calibration and Operation Procedures

1.0 PUF CALIBRATION PROCEDURE

Step 1: Calibration of the PS-1 (PUF) Sampler is performed without a foam plug (TE-1010) or filter paper in the sampling module. However the empty glass cartridge must remain in the module to insure a good seal through the module.

Step 2: Install the TE-5040A Calibrator (orifice) on top of the 4" Filter Holder. Tighten and make sure of no leaks.

Step 3: Open both ports on top of manometer and connect tubing from manometer port to the pressure tap on the TE-5040A Calibrator. Leave the opposite side of manometer port
open to the atmosphere.

Step 4: Open ball valve fully (handle should be straight up), this is located inside of shelter directly above the blower motor.

Step 5: Turn the system on by tripping the manual switch on the timer. Allow a few minutes for motor to warm-up.

Step 6: Adjust and tighten the voltage control screw (variac) on the PUF sampler to obtain a reading of 70 inches on the dial of the Magnehelic Gage (or 80 whatever is desired).Do not change until completion of calibration.

Step 7: With 70 inches on the gage as your first calibration point, record this figure and the orifice manometer reading on your data sheet. To read a manometer one side goes up
and one goes down, add both sides together, this is your inches of water.

Step 8: Close the ball valve slightly to readjust the dial gage down to 60 inches. Record this figure and the orifice manometer reading on your data sheet.

Step 9: Using the above procedure, adjust the ball valve for readings at 50, 40, and 30 inches and record on data sheet. You should have 5 sets of numbers 10 numbers in all.

Step 10: Manually turn sampler off.

An example of a TE-PUF Sampler Calibration Data Sheet is attached with data filled in from a typical calibration. This includes the transfer standard orifice calibration relationship which was taken from the Orifice Calibration Worksheet that accompanies the calibrator orifice. Since this calibration is for a PUF sampler, the slope and intercept for this orifice uses **standard** flows rather than actual flows.

The five orifice manometer readings taken during the calibration have been recorded in the column on the data worksheet titled H_2O (in). The five Magnehelic Gage readings taken during the calibration have been recorded under the column titled FLOW (magn).
The orifice manometer readings need to be converted to the standard air flows they represent using the following equation:

$$\mathbf{Q_{std} = 1/m\ [Sqrt((H_20)(Pa/760)(298/T_a))-b]}$$

where:
Q_{std} = actual flow rate as indicated by the calibrator orifice, m_3/min
H_20 = orifice manometer reading during calibration, in. H_20
T_a = ambient temperature during calibration, °K (°K = 273 + °C)
298 = standard temperature, a constant that never changes, K
Pa = ambient barometric pressure during calibration, mm Hg
760 = standard barometric pressure, a constant that never changes, mm Hg
m = *Qstandard slope of orifice* calibration relationship
b = *Qstandard intercept of orifice* calibration relationship.

Once these standard flow rates have been determined for each of the five run points, they are recorded in the column titled Q_{std}, and are represented in cubic meters per minute.
The Magnehelic Gage readings taken during the calibration need to be corrected to the current meteorological conditions using the following equation:

$$\text{FLOW (corrected)} = \text{Sqrt}((\text{magn})(Pa/760)(298/T_a))$$

where:
FLOW (corrected) = Magnehelic Gage readings corrected to current Ta and Pa
magn = Magnehelic Gage readings during calibration
Pa = ambient barometric pressure during calibration, mm Hg
760 = standard barometric pressure, a constant, mm Hg
Ta = ambient temperature during calibration, K (K = 273 + °C)
298 = standard temperature, a constant, K

After each of the Magnehelic Gage readings have been corrected, they are recorded in the column titled FLOW (corrected).

Using Q_{std} and FLOW (corrected) as the x and y axis respectively, a slope, intercept, and correlation coefficient can be calculated using the least squares regression method. The correlation coefficient should never be less than 0.990 after a five point calibration. A coefficient below 0.990 indicates a calibration that is not linear and the calibration should be performed again. If this occurs, it is most likely the result of an air leak during the calibration.

If you wanted to set this sampler at .242 m_3/min (8.5 CFM or 242 LPM)(Make sure the ball valve is open fully, a 4" filter is in place, and the module is loaded), you would turn the voltage control screw or variac until the Magnehelic Gage read 60 inches. By making sure that the sampler is operating at a Magnehelic Gage reading that is within the acceptable range, it can be assumed that valid PUF data is being collected.

A calibration that has a correlation coefficient of less than 0.990 is not considered linear and should be re-calibrated.

2.0 PUF SAMPLER OPERATION

1. The PUF Sampler may be operated at ground level or on roof tops. In urban or congested areas, it is recommended that the sampler be placed on the roof of a single story building. The sampler should be located in an unobstructed area, at least two meters from any obstacle to air flow. The exhaust hose should be stretched out in a down wind direction if possible.

2. The sampler should be operated for 24 hours in order to obtain average daily levels of airborne constituents.

3. On and off times and weather conditions during sampling periods should be recorded. Air concentrations may fluctuate with time of day, temperature, humidity, wind direction and velocity and other climatologically conditions.

4. Magnehelic Gage readings should be taken at the beginning and end of each sampling period to obtain an average magnehelic gage reading.

5. Blower motor brushes should be inspected frequently and replaced before expending. An electrical source of 110 volts, 15 amps is required.

3.0 PUF SAMPLING MODULE

1. Release the three (3) swing bolts on the 4" filter holder (FH-2104) and remove the triangle cover (cover must be off when sampler is **"ON"**) and hold down ring.

2. Install a clean 102mm dia. glass fiber filter on the support screen in between the Teflon gaskets and secure it with the hold down ring and swing bolts.

3. Unscrew together the 4" filter holder and the sampling module cap leaving the module tube in place with the glass cartridge exposed.

4. Load the glass cartridge with foam and or foam/granular solids and replace in the module tube. Fasten the glass cartridge with the module cap and 4" filter holder assembly while making sure that the module assembly, 4" filter holder and all fittings are snug.

5. The glass cartridge and glass fiber filter should be removed from the sampler with forceps and clean gloved hands and immediately placed in a sealed container for transport to the laboratory. Similar care should be taken to prevent contamination of the filter paper and vapor trap (foam) when loading the sampler.

6. It is recommended to have two (2) sampling modules for each sampling system so that filter and foam exchange can take place in the laboratory.

4.0 DESCRIPTIONS OF PUF SAMPLING MEDIA (SORBENTS)

1. Two types of sampling media are recommended for use with the PUF Sampler: polyurethane foams and granular solid sorbents. Foams may be used separately or in combination with granular solids. The sorbent may be extracted and reused (after drying) without unloading the cartridge.

2. Polyurethane Foam (PUF): Part number TE-1010 three inch plug is recommended. Also available are two inch (TE-1011) and one inch (TE-1012). This type of foam is white and yellows on exposure to light. Color does not effect the collection efficiency of the material.

3. Granular Solids: a. Porous (macroreticular) chromatography sorbents recommended. Pore sizes and mesh sizes must be selected to permit air flow rates of at least 200 liters/minute. Approximately 25 cm^3 of sorbent is recommended. The granular solids may be sandwiched between two layers of foam to prevent loss during sampling and extraction.

5.0 PUF DETERMINATION OF FLOW RATE

To figure out the total volume of air that flowed through the PUF sampler during your sampling run take a set-up magnehelic gage reading (when you set the sampler up manually turn it on and take a magnehelic gage reading; in our example it should be 60 inches) and a pick-up reading (after the sample has been taken again manually turn sampler on and take a magnehelic gage reading; for our example let's say it read 54 inches). Take 60 + 54 = 114 114/2 = 57 so the magnehelic gage reading you would use is 57 inches. Put that into the formula (on bottom of worksheet):

$$\mathbf{1/m([Sqrt(magn)(P_{av}/760)(298/T_{av})]- b)}$$

where:
m = sampler slope
b = sampler intercept
magn = average magnehelic gage reading
T_{av} = daily average temperature
P_{av} = daily average pressure
Sqrt = square root

Example:
m^3/min = 1/30.278([Sqrt(57)(727/760)(298/295)]-(-.2293))
m^3/min = .033 ([Sqrt(57)(.957)(1.01)] + .2293)
m^3/min = .033 ([Sqrt(55.094)] + .2293)
m^3/min = .033 ([(7.423)] + .2293)
m^3/min = .033 (7.423 + .2293)
m^3/min = .033 (7.652)
m^3/min = .253
lpm = 253

Total liters of air = lpm x 60 x hours that sampler ran

Let's say our sampler ran 23.3 hours (end ETI reading - start ETI reading)
** Make sure ETI is in hours otherwise convert to hours **

Total liters of air = 253 x 60 x 23.3 = 353,694 liters of air

6.0 PUF SAMPLER MAINTENANCE

A regular maintenance schedule will allow a monitoring network to operate for longer periods of time without system failure. Our customers may find the adjustments in routine maintenance frequencies are necessary due to the operational demands on their sampler(s). We recommend that the following cleaning and maintenance activities be observed until a stable operating history of the sampler has been established.

TE-PUF Sampler
The TE-PUF sampler should be routinely inspected and maintained as follows:

1. Power cords should be checked for crimps, cracks or exposed junctions each sample day. Do not allow power cords or outlets to be immersed in water; if necessary raise the cords above the ground by taping them to the shelter legs.

2. Inspect the TE-1002 Dual Sampling Module.
    a. Make sure all gaskets are sealing properly; replace if necessary.
    b. Clean any dirt that is built up around the module and filter holder.
    c. Make sure quick disconnect is working correctly by making a good seal.

TE-1004 Blower Motor Assembly
The motor assembly is durable and has a long life if maintained properly. The routine maintenance required is:

a) Inspecting and replacing the motor flange gasket and motor cushion routinely.
b) Replacing the motor **TE-33384** carbon brushes every 400 to 500 hours of operation. It is imperative that the brushes be replaced before the brush shunt touches the motor commutator.
Totally expended brushes greatly reduce motor life!!

MOTOR BRUSH REPLACEMENT

Model TE-PUF Sampler–Brush part #TE-33384. **CAUTION:** Ensure that all electrical power to the TE-PUF Sampler is disconnected prior to opening the motor housing. Unplug the motor power cord.

1. Remove the Motor Mounting Cover by removing the four bolts. This will expose the flange gasket and the motor. Turn motor over.

2. Remove ground wires from backplate and carefully lift the metal housing from the motor.

3. With a screwdriver carefully remove the plastic fan cover by prying in between brush and cover until both sides pop loose.

4. With a screwdriver carefully pry the brass quick disconnect tabs away from the expended brushes.

5. With a screwdriver remove brush holder and release **TE-33384** brushes.

6. With new **TE-33384** brushes, carefully slide quick disconnect tabs firmly into tab slot until seated.

7. Push brush carbon against commutator until plastic brush housing falls into place on commutator end bracket.

8. Replace brush holder clamps onto brushes.

9. Assemble motor after brush replacement: snap plastic fan cover back into place, feed ground wires back through backplate, put housing back on to motor, pull cord set back to normal position, **** Make sure wires do not get smashed between metal ring and housing! **** fasten ground wires to backplate, turn motor over, tighten flange on top of housing and gasket.

****WARNING** Change Brushes Before Brush Shunt Touches Commutator !!**

MOTOR BRUSH SEATING PROCEDURE

CAUTION: Direct application of full voltage after changing brushes will cause arcing, commutator pitting, and reduce overall life.

To achieve best performance from new **TE-33384** brushes they must be seated on the commutator before full voltage is applied. After brush change apply 50% voltage for fifteen to twenty minutes to accomplish this seating. Use of **TE-5010** Flow Selector on system provides the reduced voltage for brush seating.

Example Calibration Worksheet

PS-1 SAMPLER FLOW DATA

SITE NAME:
DATE:
TIME:
Pressure (mm Hg):
Temperature (F):

FLOW ORIFICE S/N:
Slope:
Incercept:
Correlation:
Cert. Expiration Date:

PS1 SAMPLER #1 INFORMATION
Model ID
Sampler S/N
Sampler Slope
Sampler Intercept
Sampler Correlation
Cert. Expiration
Design Set Point

PS1 SAMPLER #2 INFORMATION
Model ID
Sampler S/N
Sampler Slope
Sampler Intercept
Sampler Correlation
Cert. Expiration
Design Set Point

	Sampler Magnehelic Reading	Orifice Pressure (in. H_2O)	Vol. Flow Rate (m^3/min)		Flow Percent Difference		
			Sampler Flow (Qstd)	Orifice Flow (Qstd)	Sampler & Orifice	Design & Orifice	Sampler & Design
Sampler #1			--	--	--	--	--
Sampler #2			--	--	--	--	--

*Design flow is 0.225 m^3/min at standard temperature and pressure

PS1 Sampler # 1 - Flow Recalibration Data

Sampler Magnehelic Reading	Orifice Pressure (in. H2O)	Corrected Magnehelic Value	Orifice Flow (Qstd)
70		--	--
60		--	--
50		--	--
40		--	--
30		--	--
20		--	--
10		--	--

Slope: --
Intercept: --
Correlation: --
Set Point: --

PS1 Sampler # 2 - Flow Recalibration Data

Sampler Magnehelic Reading	Orifice Pressure (in. H2O)	Corrected Magnehelic Value	Orifice Flow (Qstd)
		--	--
		--	--
		--	--
		--	--
		--	--
		--	--
		--	--

Slope: --
Intercept: --
Correlation: --
Set Point: --

Alerts: None.

Operator Comments:

Operator:

filename: PS1_SITE_MMDDYY_HHMM_NA

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B-3

TSP (silica and asbestos) Sampler Calibration and Operation Procedures

Initial Calibration

1. Asbestos Sampler Calibration – Intermediate Standard
   A. Connect a pump, in-line rotameter and clean cassette to the electronic calibrator. Start the pump and let it run for a few minutes to allow the flow to stabilize.
      i. Press the black button to start a reading
      ii. Adjust the flow rate if necessary.
      iii. Make five (5) consecutive readings.
      iv. Record data in the initial calibration sheet.

2. Asbestos Sampler Calibration – Precision Rotameter
   A. Connect a pump, line, and cassette to the electronic calibrator (in the office). Record ambient temperature and barometric pressure

   B. Use the electronic calibrator to precisely measure flow rates of approximately 1.0, 1.5, 2.0, 2.5, and 3.0 L/min

      i. Start the pump and let it run for a few minutes to allow the flow to stabilize.
      ii. Press the black button to start a reading
      iii. Adjust the flow rate if necessary.
      iv. Make five (5) consecutive readings.
      v. Record data on calibration sheet.

   C. Determine a rotameter reading that corresponds to the measured flow rate.
      i. Replace the electronic calibrator with the precision rotameter
      ii. Note the reading on the precision rotameter
      iii. Read the <u>center</u> of the ball
      iv. Record data on the calibration sheet

   D. Replace the rotameter with the electronic calibrator and check to see that the flow has not changed.

   E. Repeat steps 2 through 4 until readings are obtained that correspond with flows of approximately 1, 1.5, 2, 2.5, and 3 L/min.

   F. Prepare a graph
      i. Label the vertical axis “liters per minute” and the horizontal axis “rotameter scale.
      ii. Plot the points and draw a line that best fits..

   G. At sample site connect a pump, line, and cassette to the precision rotameter. Following pump warm up take a reading of the precision rotameter and compare to the generated calibration graph. Record rotameter reading on the initial field calibration information.

Sampling

1. Sample open-faced at a 45^{o} angle to the ground.
2. Verify electrical grounding the cassette during sampling
3. Set sampler rate at ≈ 2 L/min
4. Record timer start time
5. Record in-line rotameter reading

Final Calibration

1. Repeat the same steps as above for the calibration device being used.
2. Perform the final field calibrations with the cassette used for sampling in-line. DO NOT remove the cassette used to collect the sample. This is done in order to determine actual flow with the loaded cassette should there be a buildup of particulate.
3. Record final calibration data on the field calibration sheet.
4. Submit at least two field blanks for each set of samples. Open field blank at the same time as the other cassettes just prior to sampling. Store top covers and cassettes in a clean area (e.g., closed bag of box) during sampling. Replace covers when sampling is completed.

APPENDIX C

Air Monitoring Methods

C-1 TSP and PM10 Hi-Vol Sampling (EPA IO-2.1)
C-2 PM10 TEOM (EPA IO-1.3)
C-3 USEPA Method TO-4A
C-4 Jerome 431-X Operations Manual

EPA/625/R-96/010a

Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air

Compendium Method IO-2.1

SAMPLING OF AMBIENT AIR FOR TOTAL SUSPENDED PARTICULATE MATTER (SPM) AND PM_{10} USING HIGH VOLUME (HV) SAMPLER

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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DISCLAIMER

Method IO-2.1
Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM_{10} Using High Volume (HV) Sampler

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Chapter IO-2
Integrated Sampling of Suspended Particulate Matter (SPM)

Method IO-2.1
SAMPLING OF AMBIENT AIR FOR TOTAL SUSPENDED PARTICULATE MATTER (SPM) AND PM_{10} USING HIGH VOLUME (HV) SAMPLER

1. Scope

1.1 Suspended particulate matter (SPM) in air generally is a complex, multi-phase system of all airborne solid and low vapor pressure liquid particles having aerodynamic particle sizes from below 0.01-100 µm and larger. Historically, SPM measurement has concentrated on total suspended particulates (TSP), with no preference to size selection.

1.2 The U. S. Environmental Protection Agency (EPA) reference method for TSP is codified at 40 CFR 50, Appendix B. This method uses a high-volume sampler to collect particles with aerodynamic diameters of approximately 100 µm or less. The high-volume samples 40-60 ft^3/min of air with the sampling rate held constant over the sampling period. The high-volume design causes the TSP to be deposited uniformly across the surface of a filter located downstream of the sampler inlet. The TSP high-volume can be used to determine the average ambient TSP concentration over the sampling period, and the collected material subsequently can be analyzed to determine the identity and quantity of inorganic metals present in the TSP.

1.3 Research on the health effects of TSP in ambient air has focused increasingly on particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter less than 10 µm. The health community generally recognizes that these particles may cause significant adverse health effects. Recent studies involving particle transport and transformation strongly suggest that atmospheric particles commonly occur in two distinct modes: the fine (< 2.5 µm) mode and the coarse (2.5-10.0 µm) mode. The fine or accumulation mode (also termed the respirable particulate matter) is attributed to growth of particles from the gas phase and subsequent agglomeration, while the coarse mode is made of mechanically abraded or ground particles. Particles that have grown from the gas phase (either because of condensation, transformation, or combustion) occur initially as very fine nuclei--0.05 µm. These particles tend to grow rapidly to accumulation mode particles around 0.5 µm which are relatively stable in the air. Because of their initially gaseous origin, particle sizes in this range include inorganic ions such as sulfate, nitrate, ammonia, combustion-form carbon, organic aerosols, metals, and other combustion products. Coarse particles, on the other hand, are produced mainly by mechanical forces such as crushing and abrasion. Coarse particles, therefore, normally consist of finely divided minerals such as oxides of aluminum, silicon, iron, calcium, and potassium. Coarse particles of soil or dust mostly result from entrainment by the motion of air or from other mechanical action within their area. Since the size of these particles is normally > 2.5 µm, their retention time in the air parcel is shorter than the fine particle fraction.

1.4 On July 1, 1987, the U. S. Environmental Protection Agency (EPA) promulgated a new size-specific air quality standard for ambient particulate matter. This new primary standard applies only to particles with aerodynamic diameters #10 micrometers (PM_{10}) and replaces the original standard for TSP. To measure concentrations of these particles, the EPA also promulgated a new federal reference method (FRM). This method is based on the separation and removal of non-PM_{10} particles from an air sample, followed by filtration and gravimetric analysis of PM_{10} mass on the filter substrate.

1.5 The new primary standard (adopted to protect human health) limits PM_{10} concentrations to 150 µg/std. m^3 averaged over a 24-h period. These smaller particles are able to reach the lower regions of the human respiratory tract and, therefore, are responsible for most of the adverse health effects associated with suspended particulate pollution. The secondary standard, used to assess the impact of pollution on public welfare, has also been established at 150 µg/std. m^3.

1.6 Ambient air SPM measurements are used (among other purposes) to determine whether defined geographical areas are in attainment or non-attainment with the national ambient air quality standards (NAAQS) for PM_{10}. These measurements are obtained by the States in their State and local air monitoring station (SLAMS) networks as required under 40 CFR Part 58. Further, Appendix C of Part 58 requires that the ambient air monitoring methods used in these EPA-required SLAMS networks must be methods that have been designated by the EPA as either reference or equivalent methods.

1.7 Monitoring methods for particulate matter are designated by the EPA as reference or equivalent methods under the provisions of 40 CFR Part 53, which was amended in 1987 to add specific requirements for PM_{10} methods. Part 53 sets forth functional specifications and other requirements that reference and equivalent methods for each criteria pollutant must meet and explicit test procedures by which candidate methods or samplers are to be tested against those specifications. General requirements and provisions for reference and equivalent methods are also given in Part 53, as are the requirements for submitting an application to the EPA for a reference or equivalent method determination.

1.8 Several methods are available for measuring SPM in ambient air. As mentioned earlier, the most commonly used device is the high-volume sampler, which consists essentially of a blower and a filter, and which is usually operated in a standard shelter to collect a 24-h sample. The sample is weighed to determine concentration and may be analyzed chemically. The high volume sampler is considered a reliable instrument for measuring the mass concentration of TSP in ambient air. When EPA first regulated TSP, the NAAQS was stated in terms of SPM captured on a filter with aerodynamic particle size of < 100 µm as defined by the TSP sampler; therefore, the TSP sampler was used as the reference method.

1.9 Under Part 53 requirements, reference methods for PM_{10} must be shown to use the measurement principle and meet other specifications set forth in 40 CFR 50, Appendix J. They must also include a PM_{10} sampler that meets the requirements specified in Subpart D of 40 CFR 53. Appendix J specifies a measurement principle based on extracting an air sample from the atmosphere with a powered sampler that incorporates the inertial separation of PM_{10} size range particles followed by the collection of PM_{10} particles on a filter over a 24 h period. The average PM_{10} concentration for the sample period is determined by dividing the net weight gain of the filter over the sample period by the total volume of air sampled, corrected to EPA's standard temperature (25EC) and standard pressure (760 mm Hg). Other specifications for flow rate control and measurement, flow rate measurement device calibration, filter media characteristics and performance, filter conditioning before and after sampling, filter weighing, sampler operation, and correction of sample volume to EPA reference temperature and pressure are prescribed in Appendix J. In addition, sampler performance requirements in Subpart D of Part 53 include sampling effectiveness (the accuracy of the PM_{10} particle size separation capability) at each of the three wind speeds and at "50% cutpoint" (the primary measure of 10-µm particle size separation). Field tests for sampling precision and flow rate stability are also specified. In spite of the instrumental nature of the sampler, this method is basically a manual procedure, and all designated reference methods for PM_{10} are therefore defined as manual methods.

1.10 This document describes the procedures for sampling SPM in ambient air for both TSP and PM_{10} based upon active sampling using a high volume air sampler. The ambient particles are collected on quartz fiber filters. The sampler collects TSP or PM_{10} ambient particles depending upon the type of inlet selected.

2. Applicable Documents

2.1 ASTM Documents

- D4096 *Application of the High Volume Sample Method for Collection and Mass Determination of Airborne Particulate Matter*.
- D1356 *Definition of Terms Related to Atmospheric Sampling and Analysis*.
- D1357 *Practice for Planning the Sampling of the Ambient Atmosphere*.
- D2986 *Method for Evaluation of Air Assay Media by the Monodisperse DOP (Dioctyl Phthalate) Smoke Test*.

2.2 Other Documents

- U. S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide for Environmental Quality Assurance*, EPA/600/R-94/038a.
- U. S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods (Interim Edition)*, EPA/600/R-94/038b.
- *Reference Method for the Determination of Particulate Matter in the Atmosphere*, 40 CFR 50, Appendix J.
- *Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method)*, 40 CFR 50, Appendix B.
- *Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air*, 40 CRF 50, Appendix G.
- *Reference Method for this Determination of Suspended Particulates in the Atmosphere (PM_{10} Method)*, 40 CFR 50, Appendix J.

3. Summary of Method

3.1 The sampling of a large volume of atmosphere, 1,600-2,400 m^3 (57,000-86,000 ft^3), with a high-volume blower, typically at a rate of 1.13-1.70 m^3/min (40-60 ft^3/min), is described in this method. The calibration and operation of typical equipment used in this sampling is also described.

3.2 Air is drawn into the sampler and through a glass fiber or quartz filter by means of a blower, so that particulate material collects on the filter surface. Without a 10 µm size-selective inlet, particles of 100 µm size and less enter the sampling inlet and are collected on the downstream filter. The collection efficiencies for particles larger than 20 µm decreases with increasing particle size, and it varies widely with the angle of the wind with respect to the roof ridge of the sampler shelter. When glass fiber filters are used, particles 100-0.1 µm or less in diameters are ordinarily collected. With a size-select inlet, particles 10 µm diameter or less are collected on the quartz filter.

3.3 The upper limit of mass loading is determined by plugging the filter medium with sample material, which causes a significant decrease in flow rate. For very dusty atmospheres, shorter sampling periods will be necessary.

3.4 The volume of air sampled is determined by a flow-rate indicator. The instrument flow-rate indicator is calibrated against a reference orifice meter. The latter is a working standard which, in turn, has been calibrated against a master flow meter certified by the National Institute of Standards and Technology (NIST).

3.5 Airborne particulate matter retained on the filter may be examined or analyzed chemically by a variety of methods (ICP, ICP/MS, AA, GFAA, and NAA) as delineated in Inorganic Compendium Methods IO-3.2 through IO-3.7.

4. Significance

4.1 The area of toxic air pollutants has been the subject of interest and concern for many years. Recently the use of receptor models has resolved the elemental composition of atmospheric aerosol into components related to emission sources. The assessment of human health impacts resulting in major decisions on control actions by federal, state and local governments is based on these data. Accurate measures of toxic air pollutants at trace levels is essential to proper assessments.

4.2 The high volume sampler is commonly used to collect the airborne particulate component of the atmosphere. A variety of options available for the sampler provides broad versatility and allows the user to develop information about the size and quantity of airborne particulate material and, using subsequent chemical analytical techniques, information about the chemical properties of the particulate matter. The advent of inductively coupled plasma spectroscopy has improved the speed and performance of metals analysis in many applications.

5. Definitions

[Note: Definitions used in this document are consistent with those used in ASTM Methods. All pertinent abbreviations and symbols are defined within this document at point of use.]

5.1 High-Volume Air Sampler (HV). A device for sampling large volumes of an atmosphere for collecting the contained particulate matter by filtration. Consists of a high-capacity blower, a filter to collect suspended particles, and a means for measuring the flow rate.

5.2 Working Flow-Rate Standard. A flow-rate measuring device, such as a standard orifice meter, that has been calibrated against a master flow-rate standard. The working flow-rate standard is used to calibrate a flow measuring or flow rate indicating instrument.

5.3 Master Flow-Rate Standard. A flow-rate measuring device, such as a standard orifice meter, that has been calibrated against a primary standard.

5.4 Primary Flow-Rate Standard. A device or means of measuring flow rate based on direct primary observations such as time and physical dimensions.

5.5 Spirometer. A displacement gasometer consisting of an inverted bell resting upon or sealed by liquid (or other means) and capable of showing the amount of gas added to or withdrawn from the bell by the displacement (rise or fall) of the bell.

5.6 Absolute Filter. A filter or filter medium of ultra-high collection efficiency for very small particles (submicrometer size) so that essentially all particles of interest or of concern are collected. Commonly, the efficiency is 99.95% or higher for a standard aerosol of 0.3 µm diameter.

5.7 Calibration. The process of comparing a standard or instrument with one of greater accuracy (small uncertainty) to obtain quantitative estimates of the actual values of the standard being calibrated, the deviation of the actual value from a nominal value, or the difference between the value indicated by an instrument and the actual value.

5.8 Differential Pressure Meter. Any flow measuring device that operates by restricting air flow and measuring the pressure drop across the restriction.

5.9 Emissions. The total of substances discharged into the air from a stack, vent, or other discrete source.

5.10 Flowmeter. An instrument for measuring the rate of flow of a fluid moving through a pipe or duct system. The instrument is calibrated to give volume or mass rate of flow.

5.11 Impaction. A forcible contact of particles of matter. A term often used synonymously with impingement.

5.12 Impactor. A sampling device that employs the principle of impaction (impingement).

5.13 Impingement. The act of bringing matter forcibly in contact. As used in air sampling, refers to a process for the collection of particulate matter in which the gas being sampled is directed forcibly against a surface.

5.14 Inhalable Particles. Particles with aerodynamic diameters of < 10 µm that are capable of being inhaled into the human lung.

5.15 Interference. An undesired positive or negative output caused by a substance other than the one being measured.

5.16 Mass Flowmeter. Device that measures the mass flow rate of air passing a point, usually using the rate of cooling or heat transfer from a heated probe.

5.17 Matter. The substance of which a physical object is composed.

5.18 Orifice Meter. A flowmeter, employing as the measure of flow rate the difference between the pressures measured on the upstream and downstream sides of the orifice (that is, the pressure differential across the orifice) in the conveying pipe or duct.

5.19 Aerodynamic Diameter (a.d.). The diameter of a unit density sphere having the same terminal settling velocity as the particle in question. Operationally, the size of a particle as measured by an inertial device.

5.20 Particle. A small discrete mass of solid or liquid matter.

5.21 Particulate. Solids of liquids existing in the form of separate particles.

5.22 Precision. The degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

5.23 Pressure Gage. The difference in pressure existing within a system and that of the atmosphere. Zero gage pressure is equal to atmospheric pressure.

5.24 Rotameter. A device, based on the principle of Stoke's law, for measuring rate of fluid flow. It consists of a tapered vertical tube having a circular cross section, and containing a flow that is free to move in a vertical path to a height dependent upon the rate of fluid flow upward through the tube.

5.25 Sampling. A process consisting of the withdrawal or isolation of a fractional part of a whole. In air or gas analysis, the separation of a portion of an ambient atmosphere with or without the simultaneous isolation of selected components.

5.26 Standard. A concept that has been established by authority, custom, or agreement to serve as a model or rule in the measurement of quantity of the establishment of a practice or procedure.

5.27 Traceability to NIST. Documented procedure by which a standard is related to a more reliable standard verified by the National Institute of Standards Technology (NIST).

5.28 Uncertainty. An allowance assigned to a measured value to take into account two major components of error: The systematic error and the random error attributed to the imprecision of the measurement process.

6. Apparatus Description

6.1 General Description

6.1.1 The essential features of a typical non size-specific TSP high-volume sampler are shown in Figure 1. The high volume sampler is a compact unit consisting of a protective housing; an electric motor driven; a high-speed, high-volume blower; a filter holder capable of supporting a 203 x 254-mm (8 in. by 10 in.) filter; and a flow-controller for controlling the air-flow rate through the instrument at 40-60 ft^3/min.

6.1.2 In operation, this traditional TSP sample draws ambient air into the sampler through the air inlet gap between the cover and the sampler housing walls (see Figure 2). The air inlet is uniform on all sides of the sampler to provide an effective particle capture air velocity between 20-35 cm/sec. at the recommended flow rate between 40-60 ft^3/min. The gable roof design of the sampler allows the sampled air to be evenly distributed over the surface of a downstream filter, where TSP is collected.

6.1.3 For PM_{10} measurement, the traditional gable roof of the TSP sampler is replaced with an impactor design size-select inlet, as illustrated in Figure 3. For the impaction design, an air sample enters a symmetrical (therefore wind-direction insensitive) hood and is deflected upward into a buffer chamber. The buffer chamber is evacuated at a rate of 68 m^3/h (40 cfm) through multiple circular nozzles. Particles are accelerated as they pass through the nozzles to an impaction chamber (see Figure 4). Because of their momentum, particles having diameters larger than the inlet's 10-µm cut design impact the surface of the

impaction chamber. Smaller particles rise through the impaction chamber at speeds slow enough to minimize reentrainment of the impacted particles and then pass through multiple vent tubes to the high-volume sampler's filter where they are collected.

6.1.4 The second size-select design for PM_{10} measurement is the cyclone inlet, as illustrated in Figure 5. The omnidirectional cyclone used for fractionation in this inlet allows particles to enter from all angles of approach. An angular velocity component is imparted to the sample air stream and the particles contained in it by a series of evenly spaced vanes. Larger particle removal occurs in an inner collection tube. This tube incorporates a "perfect absorber," which is an oil-coated surface to eliminate particle bounce and reentrainment. The sample flow (with the unremoved smaller particles) then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory to allow the remaining particles (i.e., PM_{10} fraction) to deposit on a filter for subsequent analysis. As with the impaction inlet, control of air velocities in the cyclonic inlet is critical to maintain the correct particle size cutpoint. Maintaining the correct design volumetric flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, a popular cyclonic impaction inlet has a design flow rate of 1.13 m^3/min.

6.2 Filter Medium

6.2.1 Selecting a filtration substrate for time-integrated SPM monitoring must be made with some knowledge of the expected characteristics and a pre-determined analytical protocol. For any given standard test method, the appropriate medium will normally be specified.

6.2.2 Of the various types of filters listed in Table 1 of Chapter IO-2 Overview, four general types of filter material have been used to capture SPM. They include cellulose fiber, quartz/glass fiber, mixed fiber and membrane filter types. Selecting a filter depends upon variables such as background metal content, artifact formation, and affinity for moisture. The basic characteristics of the types of filter material used in air monitoring are outlined in Table 1, while useful filter properties are identified in Table 2. Several characteristics are important in selection of filter media. They are:

- **Particle Sampling Efficiency.** Filters should remove more than 99% of SPM from the air drawn through them, regardless of particle size or flow rate.
- **Mechanical Stability.** Filters should be strong enough to minimize leaks and wear during handling.
- **Chemical Stability.** Filters should not chemically react with the trapped SPM.
- **Temperature Stability.** Filters should retain their porosity and structure during sampling.
- **Blank Correction.** Filters should not contain high concentrations of target compound analytes.

6.2.3 Quartz fiber filters are the most commonly used filters for SPM sampling for determining mass loading. Typical characteristics of quartz fiber filters are (1) a fiber content of high purity quartz, (2) a binder of below 5% (zero for binderless types), (3) a thickness of approximately 0.5 mm, (4) a surface with no pinholes, and (5) an allowance of no more than 0.05% of smoke particles to pass through the filter at a pressure of 100 mm of water with a flow rate of 8.53 m/min (28 ft/min), as determined by a DOP smoke test (see ASTM Method D2986).

6.2.4 Quartz fiber filters are made from finely spun glass fiber by combining the fiber with an organic binder and compressing this material in a paper machine. These filters are increasingly used in air sampling. These filters have the ability to withstand high temperatures (up to 540EC). They are further typified by high-collection efficiency. In some cases, the organic binder may interfere with subsequent analysis, so the filter is flash-fired to remove the binder material. This action causes some loss in tensile strength and usually requires that a backing material be used during sampling. The quartz filters are nonhydroscopic, thus allowing them to be used in areas where humidity is high. Because they are glass, they are the filter choice for most corrosive atmospheres. All the filters in this category are fragile and must be handled with care. Quartz fiber filters, because of the high silicate content, are extremely difficult to ash by chemicals or heat.

Therefore, extraction procedures are performed on these filters to remove the sample for subsequent chemical analysis. For this reason, flash-fired quartz filters are the major atmospheric sampling filters.

6.3 Flow Control System

The high-volume sampler employs two basic types of flow control systems. One is a mass-flow-control (MFC) system; the other is a volumetric-flow-control (VFC) system. Because the calibration and standard operating procedures differ considerably between these two types of flow-control systems, this method presents procedures that are control-system-specific. PM_{10} inlets can be used with either the MFC and VFC systems.

6.3.1 Mass-flow-control (MFC) system. The flow rate in a MFC system is actively sensed and controlled at a predetermined set point. Air is pulled through the filter into the intake of a blower and subsequently exits the sampler through an exit orifice, which facilitates measurement of the flow with a manometer or pressure recorder. The flow rate is controlled by an electronic mass-flow controller, which uses a flow sensor installed below the filter holder to monitor the mass flow rate and related electronic circuitry to control the speed of the motor accordingly to provide a constant sampling rate. The controlled flow rate can be changed by an adjustment knob on the flow controller.

6.3.2 Volumetric-flow-control (VFC) system. A VFC system maintains a constant volumetric flow rate through the inlet, rather than a constant mass flow rate as in the MFC system. In a popular commercial VFC system, a choked-flow venturi is operated such that the air attains sonic velocity in the throat of the device. In this "choked" mode, the flow rate is unaffected by downstream conditions, such as motor speed or exit pressure and is a predictable function of upstream conditions, such as the stagnation pressure ratio and temperature. Thus, the volumetric flow is controlled without any moving parts or electronic components. In this type of flow control system, no means is provided for adjusting the controlled flow rate. The controlled flow rate is set by the manufacturer through engineering design of the venturi.

7. Calibration

7.1 Introduction

[Note: All sampling equipment must be properly calibrated. Calibration is the relationship between an instrumental output and the input of a known reference standard. The objective of this section is to provide technically sound flow-rate calibration procedures for the MFC and VFC HV samplers.]

[Note: Consistency of temperature and barometric pressure is required. All temperatures should be expressed in kelvin (K = EC + 273). All barometric pressures should be expressed in mm Hg. Avoid calibrating an HV sampler using one set of units and then performing sample calculations using another set.]

7.1.1 HV sampler inlet. Two types of size-selective inlets available are impaction and cyclonic for monitoring inhalable particles (< 10 µm). The particle size discrimination characteristics of both the impaction and cyclonic type inlets depend critically on maintaining certain air velocities within the inlet; a change in velocity will result in a change in the nominal particle size collected. For this reason, the flow rate through the inlet must be maintained at a constant value that is as close as possible to the inlet's design flow rate. The design flow rate for a given sampler is specified in the sampler's instruction manual. The manual may also provide tolerance limits (or upper and lower limits) within which the sampler flow must be maintained. If the tolerance is not specified by the manufacturer, it should be assumed to be ± 10%.

7.1.1.1 The symmetrical design of the impaction inlet (see Figure 4) ensures wind-direction insensitivity. Ambient air that is drawn into the inlet is evacuated from the buffer chamber through nine acceleration nozzles into the first impaction chamber, where initial particle separation occurs. The air is then accelerated through an additional 16 jets into a second impaction chamber. The acceleration jets have critical diameters calculated by the manufacturer to provide the necessary changes in velocity to effect correct particle size fractionation within the impaction chambers. The air flow finally exits the inlet through nine vent tubes onto a sample filter. Because air velocities are critical to maintain the correct particle size cutpoint within the inlet, maintaining the correct design flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, the design flow rate for one popular impaction inlet is 1.13 m^3/min.

7.1.1.2 The omnidirectional cyclone inlet (see Figure 5) used for fractionation allows particles to enter from all angles of approach. A angular velocity component is imparted to the sample air stream and the particles contained in it by a series of evenly spaced vanes. Larger particle removal occurs in an inner collection tube. This tube incorporates a "perfect absorber," an oil-coated surface to eliminate particle bounce and reentrainment. The sample flow (with the unremoved smaller particles) then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory to allow the remaining particles (i.e., PM_{10} fraction) ultimately to deposit on a filter for subsequent analysis. As with the impaction inlet, control of air velocities in the cyclonic inlet is critical to maintain the correct particle size cutpoint. Maintaining the correct design volumetric flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, as in the case of the impaction inlet, a popular cyclonic inlet also has a design flow rate of 1.13 m^3/min.

7.1.2 Total suspended particulate (TSP). As illustrated in Figure 2, particles of less than 100 µm are collected at a flow rate of 1.13-1.70 m^3/min (40-60 ft^3/min) using the conventional high-volume sampler, without size selection.

7.2 Summary of Calibration Procedures

[Note: During calibration, a closure plate perforated with a number of circular orifices is connected to the inlet of the sampler. The pressure drop across this orifice plate provides a measure of instrument air flow rate at any time. This pressure drop may be indicated by a rotameter, manometer, or other pressure-responsive device traceable to an NIST certified standard.]

7.2.1 A simple and sufficiently accurate method of calibrating is to compare the sampler meter with an orifice meter (working standard) that has been calibrated against a primary or master standard such as a Roots meter.

7.2.2 The preferable primary standard is a Roots meter of sufficient capacity to allow an accurate time-volume reading, which would be at least 30 s.

7.2.3 A positive displacement pump or blower may be used as a master flow-rate standard. In this case, the delivery rate of the master standard must be known accurately and the equipment must be in sound mechanical condition (no bypass leakage).

7.3 Certification of an Orifice Transfer Standard

[Note: The following certification procedure is applicable to an orifice transfer standard such as those that have been used previously in the calibration of both the traditional HV sampler and the PM_{10} samplers. Two common types of orifice devices are available: one equipped with a set of fixed resistance plates (e.g., a reference flow [Ref] device or a top-hat orifice) and one with an externally variable resistance valve. The

series of plates normally provided by the orifice manufacturer include an 18-, 13-, 10-, 7-, and 5-hole plate. Unfortunately, the 5-hole plate provides too low a flow rate to be useful for HV calibration, and other plates may produce flow rates substantially outside the design flow-rate range of the commercially available HV inlets. One may opt to fabricate or procure a different series of resistance ranges or use the variable-resistance type orifice device.]

7.3.1 Orifice Calibration Procedure.

7.3.1.1 Assemble the following equipment (see Figure 6):

- Orifice transfer standard (i.e., top-hat orifice, variable orifice, or ReF device) to be calibrated.
- Water or oil manometer with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1"). This manometer should be permanently associated with the orifice transfer standard.
- Variable voltage transformer, a set of resistance plates, or available flow orifice (see Figure 7).
- Calibrated positive displacement, standard volume meter (such as a Roots Meter®) traceable to National Institute of Standards and Technology (NIST).

  [Note: As they are sold, standard volume meters may not be traceable to NIST. Traceability can be established directly through NIST or indirectly through the meter manufacturer's repair department. Periodic recertification is not normally required under clean service conditions unless the meter has been damaged and must be repaired. In general, damage will be indicated by a substantial (e.g., 50%) increase in the pressure drop across the meter. The meter's traceability certificate should contain a graph of the pressure drop as a function of flow rate.]

- High-volume air mover (e.g., a blower motor from a HV sampler).
- Accurate stopwatch.
- Mercury manometer, with a 0-200 mm (0-8") range and minimum scale divisions of 1 mm (0.1").
- Thermometer, capable of accurately measuring temperatures over the range of 0-50EC (273-323 K) to the nearest ±1EC and referenced to an NIST or ASTM thermometer within ±2EC at least annually.
- Barometer, capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg (66-106 kPa) to the nearest mm Hg and reference within ±5 mm Hg of a barometer of known accuracy at least annually.
- Orifice transfer standard certification worksheet (see Figure 8).

7.3.1.2 Record on the orifice transfer standard certification worksheet the standard volume meter's serial number; orifice transfer standard's type, model, and serial number; the person performing the certification; and the date.

7.3.1.3 Observe the barometric pressure and record it as Pa. Read the ambient temperature in the vicinity of the standard volume meter and record it as Ta (K = EC + 273).

7.3.1.4 Connect the orifice transfer standard to the inlet of the standard volume meter. Connect the mercury manometer to measure the pressure at the inlet of the standard volume meter. Connect the orifice (water or oil) manometer to the pressure tap on the orifice transfer standard. Connect a high-volume air mover to the outlet side of the standard volume meter. Make sure that all gaskets are present and are in good condition.

7.3.1.5 Check that the standard volume meter table is level and adjust its legs if necessary.

7.3.1.6 Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Start the high-volume air mover and note any change in the standard volume meter's reading. The reading should

remain constant. If the reading changes, locate any leaks by listening for a whistling sound and/or retightening all connections, making sure that all gaskets are properly installed.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime; it can raise temperatures to the point of defeating the electrical insulation which could result in fire or electric shock to the user.]

7.3.1.7 After satisfactorily completing the leak check, turn off the high-volume air sampler, unblock the orifice, and unclamp both manometer lines. Zero the water and mercury manometers by sliding their scales so that their zero lines are even with the bottom of the meniscuses.

7.3.1.8 Turn on the high-volume air sampler. Adjust the variable voltage transformer to achieve an appropriate flow rate (i.e., within the approximate range of 0.9-1.3 m^3/min (32-46 ft^3/min)). If necessary, use fixed resistance plates or the variable resistance valve to achieve the appropriate flow rate (see Figure 7). The use of fixed resistance plates is discouraged (but not prohibited) because the leak check must be repeated each time that a plate is installed.

7.3.1.9 After setting a flow rate, allow the system to run for at least 1 min to attain a constant motor speed. Observe the standard volume meter dial reading and simultaneously start the stopwatch. Error in reading the meter dial can be minimized by starting and stopping the stopwatch on whole number dial readings (e.g., 4091.00).

7.3.1.10 Record the initial volume that the meter dial indicated when the stopwatch was started. Maintain this constant flow rate until at least 3 m^3 of air have passed through the standard volume meter. Record the standard volume meter's inlet pressure manometer reading as) Hg and the orifice manometer reading as) H_2O. If) H_2O changes significantly during the run, abort the run and start again.

7.3.1.11 When at least 3 m^3 of air have passed through the system, note the standard volume meter reading and simultaneously stop the stopwatch. Record the final volume that the meter dial was indicating when the stopwatch was stopped. Record the elapsed time (Time) indicated on the stopwatch.

7.3.1.12 Calculate the volume measured by the standard volume meter (Vol.) using the following equation:

$$) \text{ Vol.} = \text{Final Volume} - \text{Initial Volume}$$

7.3.1.13 Correct this volume to ambient atmosphere pressure.

$$Va =) \text{ Vol.} (Pa -) \text{ Hg})/Pa$$

where:

Va = actual volume at ambient barometric pressure, m^3.
) Vol. = actual volume measured by the standard volume meter, m^3.
Pa = ambient barometric pressure during calibration, mm Hg.
) Hg = differential pressure at inlet to volume meter, mm Hg.

7.3.1.14 Calculate the actual volumetric flow rate (m^3/min).

$$Qa = Va/) \text{ Time}$$

where:

Qa = actual volumetric flow rate through the orifice, m^3/min.
) time = elapsed time, min.

7.3.1.15 Repeat Sections 7.3.1.8 through 7.3.1.14 for at least four additional flow rates within the approximate range of 0.9-1.3 m^3/min (32-46 ft^3/min). At least five evenly distributed different flow rates are required, and at least three flow rates must be in the specified inlet flow-rate interval (1.02-1.24 m^3/min [36-44 ft^3/min]). Better calibration precision may be obtained by running additional flow rates or repeating the flow rates.

7.3.1.16 For each flow, compute $[(\ ) H_2O)(Ta/Pa)]^{½}$, and plot these values against the corresponding values of Qa. Draw the orifice transfer standard's certification curve. For the model $[(\ ) H_2O)(Ta/Pa]^{1/2}$ = m (Qa) + b, calculate the linear least squares regression's slope (m), intercept (b), and correlation coefficient (r) of the certification relationship. Plot the regression line on the same graph as the calibration data, as illustrated in Figure 9. A certification graph should be readable to 0.02 m^3/min.

7.3.1.17 If any calibration point does not fall within ± 2% of the line, rerun the point, recalculate, and replot.

7.3.1.18 For subsequent use of the orifice transfer standard, calculate Qa from the calibration relationship as:

$$Qa(orifice) = \{[(\ ) H_2O)(Ta/Pa)]^{½} - b\} \{l/m\}$$

where:

Qa(orifice) = actual volumetric flow rate as indicated by the orifice transfer standard, m^3/min
) H_2O = pressure drop across the orifice, mm H_2O.
Ta = ambient temperature during use, K (K = EC + 273).
b = intercept of the orifice calibration relationship.
m = slope of the orifice calibration relationship.

7.3.2 Orifice Transfer Standard Calibration Frequency. Upon receipt and at l-yr intervals, the calibration of the orifice transfer standard should be certified with a standard volume meter (such as a Roots Meter®) traceable to NIST. An orifice transfer standard should be visually inspected for signs of damage before each use and should be recalibrated if the inspection reveals any nicks or dents.

7.4 Procedure for a Mass-Flow-Controlled (MFC) High Volume Sampler

The MFC sampler calibration procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has been certified according to the procedure presented in Section 7.3.1. The exit orifice plenum is the area within the motor housing (below the motor unit) that contains the air flow just before it is exhausted to the atmosphere through the exit orifice. This exit orifice plenum pressure should be measured with a 25-cm (10") water or oil manometer. Also, each sampler should have its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement devices may be used provided they have comparable accuracy. The 4" continuous pressure (flow) recorders of the type often supplied with high volume PM_{10} samplers are generally not sufficiently accurate and are not recommended for quantitative sampler pressure or flow measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sample period. The flow recorder may be connected in parallel with the manometer or other pressure

measuring device, using a tee or "y" tubing connection. For this MFC calibration procedure, the following conditions are assumed:

- The high volume PM_{10} sampler is equipped with a mass flow controller to control its sample flow rate.
- The sampler flow rate is measured by measuring the exit orifice plenum pressure, using a water or oil manometer [or, if necessary, a continuous-flow recording device using square-root-scale chart paper].
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.

[Note: Because flow recorders are still widely used for quantitative flow measurements, the calibration procedure includes specific instructions for quantitatively calibrating a flow recorder. These flow recorder instructions are enclosed in brackets [ ] and should be used only when a manometer or other pressure measurement device cannot be used.]

7.4.1 Calibration Equipment.

7.4.1.1 Orifice transfer standard with calibration traceable to NIST (see Section 7.3).

7.4.1.2 An associated water or oil manometer, with a 0-400 mm (0-16") range and an minimum scale division of 2 mm (0.1")

[Note: Digital manometers may also be used in place of water or oil manometers, especially in cold/frigate climates. Ensure the battery in the manometer is new before use.]

7.4.1.3 A water or oil manometer, with a 0-400 mm (0-16") range and a minimum scale division of 2 mm (0.1") for measurement of the sampler exit orifice plenum pressure. This manometer should be associated with the sampler.

[*Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.*]

7.4.1.4 Thermometer, capable of accurately measuring temperature over the range of 0-50EC (273-323 K) to the nearest ± 1 EC and referenced to an NIST or ASTM thermometer within ± 2 EC at least annually.

7.4.1.5 A portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg (66-106 kPa) to the nearest mm Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.

7.4.1.6 Miscellaneous handtools, calibration data sheets or station log book, and 51 mm (2") duct tape.

7.4.2 Multipoint Flow-Rate Calibration. The procedure presented here is basic and generic, given the assumptions listed in Section 7.4. More detailed calibration procedures, variations, or alternative procedures may be presented in the manufacturer's instruction manual. The manual should be reviewed carefully and the various calibration variations or alternative procedures should be evaluated. In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

[Note: Do not attempt to calibrate the MFC sampler under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of pressure variations.]

7.4.2.1 Set up the calibration system as recommended by the manufacturer. A typical MFC PM_{10} sampler calibration configuration is illustrated in Figure 10. MFC samplers are calibrated without a filter or filter cassette installed.

7.4.2.2 Disconnect the motor from the flow controller and plug it directly into a stable line voltage source (i.e., the sampler's on-off timer, if so equipped, or other source of the line voltage).

7.4.2.3 Install the orifice transfer standard and its adapter faceplate on the sampler. Check all gaskets and replace any questionable ones.

[Note: Tighten the faceplate nuts evenly on alternate corners to properly align and seat the gaskets. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.]

7.4.2.4 Select the first calibration flow rate and install the appropriate resistance plate or adjust the variable orifice valve. At least four flow rates are required to define the calibration relationship. For resistance plate orifices, make sure that the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.

7.4.2.5 To leak check, block the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. A leak-free system will not produce an upscale response in the sampler's exit orifice manometer or flow recorder. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime and can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.]

7.4.2.6 Inspect the connecting tubing of both manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid.
Adjust the manometers' sliding scales so that their zero lines are at the bottom of the meniscuses. Connect the orifice transfer standard manometer to the orifice transfer standard. Connect the sampler's exit orifice manometer [and the continuous-flow recorder, if used] to the exit orifice plenum port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure that the tubing fits snugly on the pressure ports and on the manometer.

7.4.2.7 If a continuous flow recorder is to be used quantitatively in lieu of a manometer, record the site location, sampler S/N, date, and the operator's initials on the blank side of a clean recorder chart. Make sure the chart has a square-root scale. Open the front door of the sampler and install the clean recorder chart.

7.4.2.8 Read and record the following parameters on the HV data sheet. An example calibration data sheet for the MFC sampler is illustrated in Figure 11.

- Date, location, and operator's signature.
- Sampler S/N and model.
- Ambient Pa, mm Hg.
- Ambient temperature (Ta), K (K = EC + 273).
- Orifice S/N and calibration relationship.

[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin (K = EC + 273). Also, all barometric pressures should be expressed in mm Hg. Avoid calibrating a sampler using one set of units and then performing sampler calculations using another set.]

[Note: Ideally, the temperature of the air in the exit orifice plenum should be measured because it will be somewhat higher than ambient temperature. However, an adequate approximation of this temperature may be obtained by adding 30 K to the ambient temperature. This addition is incorporated in the calculations given in Section 7.4.3.]

7.4.2.9 Turn on the sampler and allow it to warm up to operating temperature (3-5 min). Then read and record the orifice transfer standard's manometer deflection,) H_2O (in. H_2O), and the corresponding sampler's manometer deflection,) Pex [or flow recorder chart reading, I].

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

7.4.2.10 Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Section 7.4.2.9 for each. At least four calibration flow rates are required.

7.4.2.11 Plot the calibration data on a sheet of graph paper as specified in Section 7.4.3.4.

[Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.]

Repeat Section 7.4.2.9 for any data that are questionable on the plot.

[Note: Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.]

7.4.2.12 Turn off the sampler and remove the orifice transfer standard.

7.4.2.13 Reconnect the sampler motor to the flow controller.

7.4.2.14 Perform the calibration calculations presented in the following section. The data generated will be used to set the mass flow controller (see Section 7.4.4) to a value that will result in optimal volumetric flow based on the seasonal average temperature and barometric pressure at the monitoring site.

7.4.3 Calibration Calculations. Gather all calibration data, including the orifice calibration information and the sampler calibration data sheet (and, if used, the flow recorder chart, which should graphically display the various calibration flow rates).

[Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.]

7.4.3.1 Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.

7.4.3.2 Calculate and record Qa for each calibration point from the orifice calibration information using the following equation.

$$Qa(orifice) = \{\Delta H_2O(Ta/Pa)\}^{1/2} - b\} \{l/m\}$$ where:

Qa(orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min
ΔH_2O = pressure drop across the orifice, in. H_2O.
Ta = ambient temperature during use, K (K = EC + 273).
Pa = ambient barometric pressure during use, mm Hg.
b = intercept of the orifice calibration relationship.
m = slope of the orifice calibration relationship.

7.4.3.3 Calculate and record the quantity for each calibration point as:

$$\Delta Pext = [\Delta Pex(Ta + 30)/Pa]^{1/2}$$

where:

Δ Pext = transformed manometer reading.
Δ Pex = sampler manometer reading, in. H_2O Ta = ambient temperature, K (K = EC +273).
Pa = ambient barometric pressure, mm Hg.

[If a continuous-flow recorder is used quantitatively, calculate and record the quantity [It] as follows:

$$[It] = I[Ta + 30)/Pa]^{1/2}$$

where:

[It] = transformed flow recorder chart reading.
I = flow recorder chart reading, arbitrary units on square root scale.

[Note: If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for I in the above equation.]

7.4.3.4 On a sheet of graph paper, plot the calculated Qa(orifice) flow rates on the x-axis and the transformed sampler manometer response, Δ Pext [or the transformed flow recorder reading, It], on the y-axis.

Because determining the sampler's average operational flow rate (Qa) during a sample period depends on the ambient average temperature and pressure, using a graphic plot of the calibration relationship is not recommended for subsequent data reduction. This plot is used only to visually assess the calibration points to see if any should be rerun. Plot the regression line on the same graph paper as the calibration data. For the regression model y = mx + b, let y +2 Δ Pext and x = Qa(Orifice) so that the model is given by:

$$\Delta Pext = m[Qa(orifice)] + b$$

For the flow recorder, the model is:

$$It = m[Qa(orifice)] + b]$$

Using a programmable calculator or a calculation data form, determine the linear regression slop (m), intercept (b), and correlation coefficient (r) and record them on the data sheet. A five-point calibration should yield a regression equation with a correlation coefficient of $r > 0.990$, with no point deviating more

than ± 0.04 m^3/min from the value predicted by the regression equation. Plot the regression line on the same graph paper that has the individual calibration points.

7.4.3.5 For subsequent sample periods, the sampler's average actual operational flow rate, $\overline{Qa}$, is calculated from the calibration slope and intercept using the equation.

$$\overline{Qa} = \{) \overline{Pex}(Tav + 30)/Pav]^{1/2} - b\} \{l/m\}$$

where:

$\overline{Qa}$ = the sampler's average actual flow rate, m^3/min.
) $\overline{Pex}$ = average of initial and final sampler manometer readings ( ) Pex_i +) Pex_f), mm Hg.
Tav = average ambient temperature for the sample period, K(K = EC + 273).
Pav = average ambient pressure for the sampling period, mm Hg.
b = intercept of the sampler calibration relationship.
m = slope of the sampler calibration relationship.

[For the flow controller,

$$\overline{Qa} = \{\overline{I}(Tav + 30)/Pav]^{1/2} - b\} \{l/m\}$$

where:

$\overline{I}$ = average flow recorder reading for the sample period.]

[*Note: If recorder charts with linear scales are used, substitute* $(I)^{1/2}$ *for (I) in the above equation.]*

7.4.4 Mass Flow Controller Adjustment Procedure. The controlled flow rate of an MFC sampler is adjustable and must be set to the proper design flow rate. The constant mass flow maintained by the MFC causes the actual volumetric flow rate through the inlet to fluctuate as the ambient temperature and barometric pressure change at the monitoring site. Normally, the range of these fluctuations is within the allowable tolerance limits for the inlet. However, the flow-rate set point of the mass flow controller must be correctly adjusted so that the deviations are "centered" with respect to the seasonal average temperature and barometric pressure at the site, not the temperature and pressure prevailing at the time of setting. The correct seasonal volumetric setpoint flow rate (SFR) at Ta and Pa has had the same mass flow rate as the inlet design volumetric flow rate at Ts and Ps.

[Note: The correct SFR may differ from day to day and may be somewhat higher or lower than the inlet design flow rate on any particular day.]

7.4.4.1 Determine the seasonal average temperature (Ts) and seasonal average pressure (Ps) at the site and record them on the calibration data sheet. (Determination of the number of "seasons," i.e., the number of different seasonal average temperatures needed for the year, is left to the discretion of the operator.)

7.4.4.2 Calculate SFR and record on the calibration data sheet:

$$SFR = (1.13)\ (Ps/Pa)(Ta/Ts)$$

where:

SFR = set-point actual volumetric flow rate for adjustment of the mass flow controller, based on seasonal average temperature and average pressure at site, m^3/min.
1.13 = inlet design flow rate (as specified by the manufacturer), m^3/min.
Ps, Pa = seasonal average and current ambient barometric pressure at the site, respectively, mm Hg.
Ts, Ta = seasonal average and current ambient temperature, respectively, K (K = EC + 273).

7.4.4.3 Calculate and record on the sampler's calibration data sheet the sampler set-point manometer reading [or flow recorder reading] that corresponds to the SFR calculated in Section 7.4.4.2.

$$SSP = [Pa/(Ta + 30)][m(SFR) + b]^2$$

where:

SSP = sampler set-point manometer reading, in H_2O.
Pa = ambient barometric pressure, mm Hg.
Ta = ambient temperature, K (K = EC + 273).
m = slope of the sampler's calibration relationship.
SFR = set-point flow rate from 7.4.4.2, m^3/min.
b = intercept of the sampler's calibration relationship.

[For the flow recorder,

$$SSP = [m(SFR) + b]\ [Pa/(Ta + 30)]^{½}]$$

7.4.4.4 Visually check to make sure the motor is connected to the mass flow controller and the manometer is properly connected.

7.4.4.5 Install a clean filter (in a filter cassette) in the sampler according to the manufacturer's instructions. [If the continuous flow recorder is used quantitatively, install a clean chart and verify that the recorder is zeroed (i.e., the pen rests on the innermost circle of the chart).]

7.4.4.6 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

7.4.4.7 Following the manufacturer's instructions, adjust the mass flow controller until the manometer reading [or flow recorder response] indicates the sampler set point (SSP) as calculated in Section 7.4.4.3.

7.4.4.8 Verify that the flow controller will maintain this flow rate for at least 10 min. Turn off the sampler.

7.4.4.9 The sampler can now be prepared for the next sample run day.

7.5 Procedure for a Volumetric-Flow-Controlled (VFC) Sampler

The VFC sampler calibration procedure presented in this section relates known flow rates (Qa, as determined by an orifice transfer standard) to the ratio of the stagnation pressure to the ambient barometric pressure (Pl/Pa). The stagnation pressure (Pl) is the air pressure inside the sampler in the area just under the filter. VFC samplers have a stagnation pressure tap or port through which the stagnation pressure can be measured. A VFC sampler may also have an exit orifice below the motor similar to those in MFC samplers. In this case, the sampler flow rate can be measured and calibrated using the exit orifice plenum pressure generally described in Section 7.4. However, using the stagnation pressure generally provides a more accurate

indication of sampler flow rate. Additionally, a continuous-flow recorder may be connected to the exit orifice pressure tap for nonquantitative determination that the flow rate was constant and uninterrupted over the sample period.

The stagnation pressure should be measured with a 0-1000 mm (0-36") oil, water, or digital manometer. Also, each sampler should have its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement instruments may be used provided they have comparable accuracy. However, the 4" continuous pressure (i.e., flow) recorders often supplied with HV samplers are generally not sufficiently accurate and are **not recommended** for quantitative sampler pressure or flow rate measurements.

The VFC sampler's flow control system is a choke-flow venturi. This system must be precisely sized for a given average annual temperature and pressure because no means is provided for the user to adjust the operational flow rate. Therefore, the purchasing agency should notify the manufacturer of the **operational** location of the sampler; differences in temperature and pressure between the shipping address and the monitoring site may result in an incorrect operational flow rate. As with the MFC sampler, both the ambient temperature and barometric pressure readings must be determined or estimated during the sampling period for the subsequent calculation of total sampler volume in standard volume units.

For this VFC calibration procedure, the following conditions are assumed:

- The VFC sampler uses a choked-flow venturi to control the actual volumetric flow rate.
- The sampler flow rate is measured by measuring the stagnation pressure ratio, and the sampler is not equipped with a continuous flow recorder.
- The sampler inlet is designed to operate at a constant actual volumetric flow rate of 1.13 m^3/min.
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.
- The sampler will be calibrated in actual volumetric flow-rate units (Qa), and the orifice transfer standard is also calibrated in Qa, as specified in Section 7.3.

7.5.1 Calibration Equipment.

7.5.1.1 Orifice transfer standard with proper calibration traceable to NIST (see Section 7.3).

7.5.1.2 An associated water, oil, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 2 mm (0.1").

7.5.1.3 An oil, water, or digital manometer, with a 0-1000 mm (0-36") range and minimum scale divisions of 2 mm (0.1") or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure instrument) should be associated with the sampler.

[Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.]

7.5.1.4 Thermometer, capable of accurately measuring temperature over the range of 0-50EC (273-323 K) to the nearest ± 1EC and referenced to an NIST or ASTM thermometer within ± 2EC at least annually.

7.5.1.5 A portable, aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg to the nearest mm Hg and referenced within ± 5 mm Hg to a barometer of known accuracy at least annually.

7.5.1.6 Calibration data sheets or the station log book and 51 mm (2")-wide duct tape.

7.5.1.7 A clean filter.

7.5.2 Multipoint Flow-Rate Calibration Procedure - VFC Sampler. The procedure presented here is basic and intended to be generic, given the assumptions listed in Section 7.5. More detailed calibration procedures, variations, or alternative procedures may be presented in the manufacturer's instruction manual. The manual should be reviewed carefully and that the various calibration variations or alternative procedures be evaluated. In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

[Note: The calibration of some VFC samplers may be affected by changes in line voltage, particularly if the line voltage is below normal (normal is about 115 V). For this reason, VFC samplers should always be calibrated at the monitoring site. Further, if the line voltage at the site is low and likely to fluctuate significantly, a line voltage booster or regulator may be advisable. Also, be sure that replacement blower motors are of the correct type.]

[Note: Do not attempt to calibrate the VFC sampler under windy conditions. Short-term velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of the pressure variations.]

7.5.2.1 Set up the calibration system as recommended by the manufacturer. A typical VFC sampler calibration configuration is illustrated in Figure 12. The VFC sampler manufacturer may specify that the sampler be calibrated with a filter installed, which generally precludes calibration flow rates higher than normal operating flow rate. Additional calibration flow rates obtained without a filter may be appropriate, as discussed in Section 7.5.2.8.

7.5.2.2 Install the orifice transfer standard and its adapter faceplate on the sampler. First inspect all gaskets and seals and replace any doubtful ones.

[Note: Tighten the faceplate nuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only; too much compression can damage the sealing gasket.]

7.5.2.3 Select a calibration flow rate and install the appropriate resistance plate (or no plate) or adjust the variable resistance valve. At least four flow rates are required to define the calibration relationship. At least three flow rates should be within the acceptable flow-rate range (i.e., 1.02-1.24 m^3/min) for the sampler inlet. For resistance plate orifices, make sure the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.

7.5.2.4 Leak check the system by blocking the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by crossthreading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime. It can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.]

7.5.2.5 Inspect the connecting tubing of the manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometers' sliding scales so that their zero lines are at the bottom of the meniscuses. Connect the transfer standard manometer to the transfer standard and the sampler stagnation pressure manometer (or other pressure instrument) to the stagnation pressure port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure the tubing fits snugly on the pressure ports and on the manometers.

7.5.2.6 Read and record the following parameters on the VFC Sampler Data Sheet. An example calibration data sheet for the VFC sampler is illustrated in Figure 13.

- Date, location, and operator's signature.
- Sampler S/N and model.
- Ambient barometric pressure (Pa), mm Hg.
- Ambient temperature (Ta), EC and K (K = EC + 273).
- Orifice S/N and calibration relationship.

[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin (K = EC + 273). Also, all barometric pressures should be expressed in mm Hg. Avoid calibrating a HV sampler using one set of units and then performing sampler calculations using another set.]

7.5.2.7 Turn on the sampler and allow it to warm to operating temperature (3-5 min). Read and record the orifice transfer standard's manometer reading, H_2O, and the corresponding sampler relative stagnation pressure manometer reading, Pstg, on the data sheet. (Relative stagnation pressure is a negative pressure [i.g., a vacuum] relative to atmospheric pressure as measured by a manometer with one leg open to the atmosphere.) Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the calibration data sheet:

$$\text{mm Hg} = 25.4 \text{ (in. } H_2O/13.6)$$

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom of air flow and for the manometer tubing).]

7.5.2.8 Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Section 7.5.2.7 for each. At least four calibration flow rates are required with at least three in the acceptable flow-rate range. Difficulties may be encountered in obtaining flow rates in the acceptable range. Even with modified resistance plates (or with no plates) installed, it may be impossible to obtain three acceptable flow rates with a filter mounted on the sampler. Lower flow rate calibration points may be used by extrapolation into the acceptable range without a filter installed in the sampler. If additional calibration points are obtained without a filter, they should be examined carefully to make sure they are consistent with the calibration points obtained with a filter (i.e., they fall on a smooth curve through all the calibration points).

7.5.2.9 Plot the calibration data on a sheet of graph paper as specified in Section 7.5.3.5 of the next section. Repeat Section 7.5.2.7 for any data that are questionable on the plot. Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.

[Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.]

7.5.2.10 Turn off the sampler and remove the orifice transfer standard.

7.5.2.11 Install a clean filter on the sampler in the normal sampling mode (use a filter cassette if one is normally used). Turn on the sampler and allow it to warm up to operating temperature.

7.5.2.12 Read the relative stagnation pressure as in Section 7.5.2.7 and record it on the data sheet in the row for the operational flow rate.

7.5.2.13 Perform the calibration calculations presented in the following sections.

7.5.3 Calibration Calculations. Gather together all the calibration data, including the orifice transfer standard's calibration information and the sampler calibration data sheet.

[Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.]

7.5.3.1 Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.

7.5.3.2 Calculate the record Qa(orifice) for each calibration point from the orifice calibration information and the equation.

$$Qa(orifice) - \{[\ ) H_2O(T_a/Pa)]^{½} - b\} \{l/m\}$$

where:

Qa(orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min.
) H_2O = pressure drop across the orifice, in. H_2O.
Ta = ambient temperature during use, K (K = EC + 273).
Pa = ambient barometric pressure during use, mm Hg.
b = intercept of the orifice transfer standard's calibration relationship.
m = slope of the orifice transfer standard's calibration relationship.

7.5.3.3 Calculate and record the value of the absolute stagnation pressure ratio, [Pl], for each calibration point:

$$[Pl] = Pa -) Pstg$$

where:

[Pl] = absolute stagnation pressure, mm Hg.
Pa = ambient barometric pressure, mm Hg.
) Pstg = relative stagnation pressure, mm Hg.

7.5.3.4 Calculate and record the stagnation pressure ratio:

$$\text{Stagnation pressure ratio} = Pl/Pa$$

7.5.3.5 On a sheet of graph paper, plot the calculated orifice transfer standard's flow rates, Qa(orifice), on the x-axis vs. the corresponding stagnation pressure ratios, Pl/Pa, on the y-axis. Draw a smooth curve through the plotted data. If necessary, extrapolate the curve to include the acceptable flow-rate range.

7.5.3.6 If the sampler manufacturer has provided a factory calibration table (i.e., the lookup table) for the sampler, compare Qa(orifice) for several points on the calibration plot with Qa(sampler) determined from the factory calibration. Calculate the percentage difference between Qa(orifice) and Qa(sampler) using the following equation.

$$\% \text{ Difference} = \frac{Qa(\text{sampler}) - Qa(\text{orifice})}{Qa(\text{orifice})} \times [100]$$

If the agreement is within a few (i.e., 2 or 4) percent, the factory calibration is validated and may be used for subsequent sample periods. Proceed to Section 7.5.5.

7.5.3.7 If the agreement is not within a few percentage points, recheck the accuracy of the orifice transfer standard and recheck the calibration procedure. Look for leaks, manometer reading errors, incorrect temperature or pressure data, or miscalculations. Also check for abnormally low line voltage at the site (it should be at least 110 V ac), for the correct blower motor, and for the presence of a gasket between the motor and the choked-flow venturi. A factory calibration is not likely to be substantially incorrect, and any discrepancy of more than a few percent is probably due to some problem with the sampler or with the calibration procedure. However, if no errors or problems with the sampler or with the calibration can be found, or if no factory calibration is provided by the manufacturer, proceed as described in Section 7.5.4.

7.5.4 Generation of Calibration Relationship - VFC Sampler.

7.5.4.1 For each calibration point, calculate and record the quantity,

$$[Pl/Pa)Ta]^{1/2}$$

where:

Pl/Pa = stagnation pressure ratio from the equation in Section 7.5.3.
Ta = ambient temperature during sampler calibration, K (K = EC + 273).

7.5.4.2 For the general linear regression model, $y = mx + b$, let $y = [(Pl/Pa)Ta]^{1/2}$ and let $x = Qa(\text{orifice})$, such that the model is given by:

$$[(Pl/Pa)Ta]^{1/2} = m[Qa(\text{orifice})] + b$$

Calculate the linear regression slope (m), intercept (b), and correlation coefficient (r).

[Note: Inspect the plotted calibration curve to determine whether any of the calibration points that are substantially outside of the acceptable flow-rate range need to be eliminated so that they do not result in an inappropriate linear regression line.]

7.5.4.3 For subsequent sample periods, the sampler's average actual operating flow rate, Qa, is calculated from the calibration slope and intercept using the following equation.

$$\overline{Qa}(\text{sampler}) = \{[\overline{P1}/Pav)Tav]^{1/2} - b\} \{1/m\}$$

where:

$\overline{Qa}$(sampler) = the sampler's average actual flow rate, m^3/min.
$\overline{P1}$/Pav = average stagnation pressure ratio for the sampling period.
Tav = average ambient temperature for the sampling period, K (K = EC + 273).
b = intercept of the sampler calibration relationship.
m = slope of the sampler calibration relationship.

[Note: The average value for Pl should be calculated from stagnation pressure measurements taken before and after the sampling period. Pav should be estimated from barometric pressure for the sampling period. See also Section 9.4 for additional information.]

7.5.4.4 If a calibration (Lookup) table is desired, evaluate the above equation for various appropriate values of Pl/Pa and Ta and list the corresponding values of Qa(sampler) in tabular form.

7.5.5 Single-Point Operational Flowrate Ventilation. This procedure compares the VFC sampler's normal operating flow rate to the design flow rate of the inlet (e.g., 1.13 m^3/min).

7.5.5.1 Determine the value of Pl/Pa for the operational flow rate obtained with only the filter cassette installed (see Section 7.5.2.11 and Section 7.5.2.12).

7.5.5.2 Determine the new sampler flow rate, Qa(sampler) from the lookup table that corresponds to this value of Pl/Pa. Use the manufacturer's calibration table if it has been validated in 7.5.3.6; otherwise, use the equation in Section 7.5.4.3.

7.5.5.3 Compare Qa(sampler) with the inlet design flow rate (e.g., 1.13 m^3/min) using the following equation:

$$\text{Design flow rate\% difference} = \frac{\text{Qa(sampler)} - 1.13}{1.13} \times 100$$

This design flow rate percentage difference must be less than the allowable flow rate tolerance (i.e., ± 10, if not otherwise specified by the manufacturer). However, this value should be well within ± 7 to allow for some variation with ambient temperature. If this value is not within ± 7, recheck the calibration procedure and data for errors. Check the sampler for leaks, bad motor brushes, missing gaskets, incorrect motor type, or abnormally low line voltage. Because the VFC flow rate is not adjustable, the VFC manufacturer must be consulted to resolve cases of substantially incorrect VFC flow rates.

7.6 Sampler Calibration Frequency

To ensure accurate measurement calibrate HV samplers upon installation and recalibrate as follows:

7.6.1 At least quarterly or annually (see 40 CFR 58, Appendix A for a description of the quality assurance requirements);

7.6.2 After any repairs that might affect sampler calibration (e.g., replacing the motor);

7.6.3 After relocation of the sampler to a different site;

7.6.4 If the results of a field flow-check exceed quality control limits (e.g., greater than $\pm 7\%$ from the sampler's indicated flow rate); or

7.6.5 Whenever a field flow-check or performance audit indicates that the sampler is out (or nearly out) of the acceptable flow-rate range.

[Note: Multipoint flow-rate calibrations should be distinguished from single-point, quality control flow checks (see Section 13). The latter are done more frequently than calibrations and are intended to check if the sampler flow rate, Qa(sampler), or the calibration relationship has changed significantly since the last calibration.]

8. Filters

8.1 Pre-weighing of Filters

8.1.1 Filters ready for field use have been pre-weighed in the laboratory, under prescribed climate control conditions of temperature and relative humidity, using Inorganic Compendium Method IO-3.1, *Selection, Extraction and Preparation of Filter Material*.

8.1.2 Within Method IO-3.1, the user is provided guidance on proper selection of filter material in order to meet project specific data quality objectives (DQOs), how to visually inspect a new lot of filters for consistency and identification of defects, and initial weighing of the filters so a net concentration of particulate matter can be calculated after sampling.

8.1.3 The user should follow the procedures outlined within Method IO-3.1 as part of meeting the program's standard operating procedures (SOPs) and quality control (QC) requirements.

8.2 Filter Handling

8.2.1 Filter material may be brittle and subject to shearing and breakage. Laboratory and field personnel must be aware of these characteristics and handle sample filters with care.

8.2.2 For convenience, filters can be packed in groups of 50 or less in their original containers or in a box of comparable size. The filters should be separated by a sheet of 8 ½ x 11" tracing paper. Filter inventory can be controlled by stacking the filters in numerical order so that the operator will use the proper filter first. One side of the shipping box can be cut away to allow the operator to remove the filter easily without damaging the corners.

8.2.3 A filter identification number must be assigned to each filter. Because of difficulty in seeing the "up" side (i.e., the side with the slightly rougher texture) of the filter, consistency in labeling these filters will allow the operator easy access to the filter ID number for documentation and cross-referencing laboratory data forms. This consistency will also eliminate confusion in loading the filter cassettes for subsequent sampling. If the filter ID number is embossed by the operating agency, gentle pressure must be used to avoid filter damage, and extreme care must be taken to avoid duplication or missed numbers.

8.2.4 If samples are to be mailed, the field operator should be supplied with reinforced envelopes and manila folders for protection of the exposed filters during their return to the analytical laboratory. These manila folders may be printed to serve as sample data sheets.

8.3 Visual Filter Inspection

All filters must be visually inspected for defects, and defective filters must be rejected if any are found. Batches of filters containing numerous defects should be returned to the supplier.
The following are specific defects to look for:

- **Pinhole** - a small hole appearing as a distinct and obvious bright point of light when examined over a light table or screen, or as a dark spot when viewed over a black surface.
- **Loose material** - any extra loose material or dirt particles on the filter that must be brushed off before the filter is weighed.
- **Discoloration** - any obvious visible discoloration that might be evidence of a contaminant.
- **Filter nonuniformity** - any obvious visible nonuniformity in the appearance of the filter when viewed over a light table or black surface that might indicate gradations in porosity across the face of the filter.
- **Other** - a filter with any imperfection not described above, such as irregular surfaces or other results of poor workmanship.

9. Sampling Procedure

[Note: This section describes routine operation of a monitoring site using an HV sampler and covers an array of topics, ranging from initial site selection to final data documentation. The procedures herein are intended to serve as guidelines for developing a monitoring program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends on responsible day-to-day operation of the monitoring site. The operators who conduct sampling activities offer a unique perspective on the sampler's performance, and their awareness and attention to detail will salvage data that may otherwise be lost. Note, however, that "routine" does not mean "unimportant." The site operator provides cohesiveness in a sampling program.]

9.1 Summary

9.1.1 The PM_{10} sampler can be used in a number of ways. Procedure variations may include the kind of filter medium, the surface area of the filter, prescreening to exclude particles up to a given size, and the manner of placing and exposing the filter during the test. The procedure most commonly used will be described here.

9.1.2 Calibrate the sampler as described in the Section 7. Do not make any change or adjustment on the sampler flow indicator after calibrating. Remove the calibrating orifice. The filters may be packed into a box with sheets of glassine between the filters, or they may be individually packed in self-sealing plastic bags for transportation to the field.

9.1.3 Mount the filter sheet in the filter holder taking care not to lose any of the fiber. Clamp it in place by means provided. Seal into place easier by facing the smooth side into the housing if there is a difference in texture. If the filter holder is separate from the sampler, mount the holder on the intake port, making sure that the coupling gasket is in place and that it is tight.

9.1.4 Place the sampler in the position and location called for in the test, which is with the filter face up, in a horizontal plane, and inside a housing. The dimensions and clearances specified are intended to provide uniformity in sampling practice.

9.1.5 Start the sampler motor and record the time and date. Read the flow-rate indicator and record this reading and the corresponding flow rate as read from the calibration curve. Note also the temperature and barometric pressure. An electric clock should be connected to the same line as the motor so as to detect any loss of test time due to power interruption. A continuous record of the sampling flow rate and sampling time can be obtained by the use of a continuous pressure (or flow rate) recorder.

9.1.6 Allow the sample to run for the specified length of time, which is commonly 24 h, $\pm$ 1 h. During this period several readings of flow rate, temperatures, barometric pressure, and time should be taken if this is feasible. A final set of reading is taken at the end of the test period. If only initial and final readings are made, assume that change of readings is linear over the period of test. Intermediate readings will improve the accuracy of volume measurement.

9.1.7 At the end of the sampling period, record all final readings. Remove the filter from the mount very carefully so as not to lose any of the fiber material or collected particulate matter. Fold the filter in half upon itself with the collected material enclosed within. Place the folded filter in a clean tight envelope and mark it for identification. In some applications it may be desirable to place the used filter in a tight metal container to prevent any loss or damage to the filter.

9.1.8 In the laboratory remove the filter from its container. Tap the container and knock any loose fiber or particulate matter onto the inside surface of the folded filter. Examine the inside surface and, with a pair of tweezers, remove any accidental objects such as insects.

9.2 Siting Requirements

9.2.1 As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a monitoring project is to select a site or sites where the collected particulate mass is representative of the monitored area.

9.2.2 Basic siting criteria for the placement of high-volume sampler (either TSP or PM_{10}) are documented in Table 3. This list is not a complete listing of siting requirements; instead, an outline to be used by the operating agency to determine a sampler's optimum location. Complete siting criteria are presented in 40 CFR 58, Appendix E.

9.2.3 Additional factors not specified in the Code of Federal Regulations (CFR) must be considered in determining where the sampler will be deployed. These factors include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment. The sampler must be situated where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibrations, filter installation and recovery, flow checks, and audits) involves transporting supplies and equipment to and from the monitoring site.

9.2.4 To ensure that adequate power is available, consult the manufacturer's instruction manual for the sampler's minimum voltage and power requirements. Lack of a stable power source can result in the loss of many samples because of power interruptions.

9.2.5 The security of the sampler itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

9.3 Sampler Installation Procedures

9.3.1 On receipt of a high-volume sampler (TSP or PM_{10}) from the manufacturer, visually inspect it and account for all components. Compare the equipment delivered with the enclosed packing slip. Notify the manufacturer immediately of any missing or damaged equipment.

9.3.2 Perform a laboratory check to determine if the sampler is operational. Turn on the sampler and observe the vacuum motor performance and shift the recorder response (if so equipped).

9.3.3 Carefully transport the sampler to the field site. If possible, install the sampler in the center of the site platform. This practice will ensure easy access to the sampler's inlet during maintenance procedures and will reduce inlet damage if the sampler should topple over.

9.3.4 Following manufacturer's instructions, carefully assemble the base and inlet of the sampler. The sampler must be bolted down to a secure mounting surface.

9.3.5 Check all tubing and power cords for crimps, cracks, or breaks.

9.3.6 Plug the power cord into a line voltage outlet. If possible, this outlet should be protected by a ground fault interrupter (GFI) for the operator's safety. The use of waterproof interlocking electrical connectors is also recommended to ensure operator safety and to avoid shorts or power interruptions. Do not allow any electrical connections to be submerged during periods of inclement weather.

9.3.7 Turn on the sampler and make sure that it is still working properly. Investigate and correct any malfunctions before proceeding. Operate the sampler for approximately 30 min to ensure that the motor brushes are properly seated and that the motor is operating at full performance.

9.3.8 Perform a multipoint flow-rate calibration, as described in Section 7.

9.4 Sampling Operations

9.4.1 General.

9.4.1.1 Operational procedures will vary according to the sampler model and options (e.g., the types of flow-rate controller and timer) selected for use in the monitoring program. Consult the instrument manual before putting the sampler into operation. Significant differences exist in the field operation of the two types of flow-controlling systems and, hence, in the determination of operational flow rates. The following assumptions are made in this section:

- The flow rate through a sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer (or a flow recorder).
- The flow rate through a sampler that is equipped with a volumetric-flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- The sampler has been calibrated according to procedure presented in Section 7.

9.4.1.2 The sampler has been calibrated according to procedures presented in Section 7.

9.4.1.3 The average actual flow rate for MFC samplers is calculated by determining the following:

- The average of the initial and final manometer readings of the exit orifice plenum pressure (or the average flow recorder reading).
- The average ambient temperature (Tav).
- The average ambient barometric pressure (Pav) during the sampling period.

These values are then applied to the sampler's calibration relationship. The 4" pressure flow recorders often supplied with HV samplers generally are not sufficiently accurate and are *not recommended* for quantitative sampler pressure or flow rate measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sampling period. The flow recorder may be connected in parallel with the manometer or other pressure measuring device using a tee or "Y" tubing connector.

[Note: Because flow recorders are still widely used for quantitative flow rate measurements, the procedures in this section include specific instructions for the use of a flow recorder. These flow recorder instructions are enclosed in brackets.]

9.4.1.4 The average actual flow rate for VFC samplers is calculated by determining the following:

- The average of the initial and final relative stagnation pressures (Pstg).
- The average ambient temperature (Tav).
- The average barometric pressure (Pav) during the sampling period and then by applying these values to the calibration relationship.

*[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin (K = EC + 273). Also, all barometric pressures should be expressed in either mm Hg or kPa (**but don't mix the two units**). Avoid calibrating a PM_{10} sampler using one set of units and then performing sample calculations using another set.]*

9.4.2 Presampling Filter Preparation Procedures.

9.4.2.1 Most high-volume samplers (TSP or PM_{10}) have been designed to accept filter cassettes. Loading these cassettes in the laboratory will minimize damage; however, if extreme care is exercised, they can be loaded at the site when ambient conditions permit. Wear protective gloves when handling filters to avoid contaminating the filters with body oils and moisture. Keep the filters in protective folders or boxes. Never bend or fold unexposed filters. The analytical laboratory (and/or filter manufacturer) will give each filter an ID number. Because it is extremely difficult to see the "up" side of a quartz filter (i.e., the side with the slightly rougher texture), the filters should be consistently labeled on one side. When a filter that has

been labeled on its "down" side is folded for transport to the laboratory, its sample number will be readily accessible for documentation on laboratory log sheets upon arrival at the laboratory.

9.4.2.2 Following the manufacturer's instructions, carefully load the pre-weighted filter in the filter cassette. The filter should be centered on the wire screen so that the gasket will form an airtight seal on the outer edge of the filter when the faceplate is in place. Poorly aligned filters show uneven white borders after exposure. Care should be taken to ensure that the filter cassette is not excessively tightened, as the filer may stick or the gasket may be permanently damaged. Check that the gasket is in good condition and has not deteriorated.

9.4.3 Sampling Procedures--MFC Sampler.

9.4.3.1 Filter Installation Procedure.

9.4.3.1.1 Following the manufacturer's instructions, loosen the nuts that secure the inlet to the base and gently tilt back the inlet to allow access to the filter support screen.

9.4.3.1.2 Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

9.4.3.1.3 If an inlet is being used, lower the sample inlet. Inspect the sample inlet to make sure that it is resting on the filter cassette and not on the sampler's frame. Secure the sample inlet to the sampler base.

9.4.3.1.4 Open the front door of the sample and examine the flow recorder. Remove any moisture inside by wiping it with a clean cloth. Record the sampler S/N, filter ID number, site location, and sampling data on the back of a clean chart and install the chart in the flow recorder.

[Note: Charts used for PM_{10} samplers normally have square-root-function scales; however, linear-function scales may be used. If charts with linear-function scales are used, Equations in Section 7.4.3.3 and Section 7.4.3.5 will have to be modified from their current form by replacing I with $(I)^{½}$]

[Note: While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen air (or by using the pen lift). Be sure that the chart tab is centered on the slotted drive to ensure full 360E rotation in 24 h. Make sure that the chart edges are properly located beneath the retainers. Lower the pen arm and tap the recorder face lightly to make certain that the pen is free.]

[Note: During periods of inclement weather, the chart tends to stick to the recorder face. Two charts can be installed simultaneously to enable the sample (top, annotated) chart to rotate freely.]

9.4.3.1.5 Using a coin or slotted screwdriver, advance the chart and check to see that the pen rests on zero--the smallest circle diameter. If necessary, adjust the zero set screw while gently tapping on the side of the flow recorder. If a chart with a linear function scale is used, some positive zero offset may be desirable to allow for normal variation in the zero readings.

9.4.3.1.6 Turn on the sampler and allow it to equilibrate to operating temperature (3-5 min).

9.4.3.1.7 While the sampler is equilibrating, record the following parameters on the MFC Sampler Field Data Sheet (see Figure 14):

- Site Location.
- Sample date.
- Filter ID number.
- Sampler model and S/N.
- Operator's initials.

9.4.3.1.8 Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer while watching for the free flow of the fluid. Adjust the manometer's sliding scale so that its zero line is at the bottom of the meniscuses.

9.4.3.1.9 Measure the initial exit orifice plenum pressure (Pex) using an oil or water manometer, with a 0-200-mm (0-8") range and a minimum scale division of 1 mm (0.1"). Record the initial Pex on the MFC Sampler Field Data Sheet. If Pex is substantially different than for previous samples or otherwise appears abnormal, carry out a Quality Control (QC) flow check as described in Section 13.1.

9.4.3.1.10 Verify that the flow recorder (if used) is operational and that the pen is inking. Note the flow recorder reading. If it is substantially different than for previous samples or otherwise appears abnormal, carry out a QC flow-check as described in Section 13.1.

9.4.3.1.11 Turn the sampler off.

9.4.3.1.12 Check the time indicated by the time-set pointer on the flow recorder. If it is in error, rotate the chart clockwise by inserting a screwdriver or coin in the slotted drive in the center of the chart face until the correct time is indicated.

9.4.3.1.13 Reset the elapsed time meter to 0000 min and the sampler timer for the next run day. Close the sampler door, taking care not to crimp the vacuum tubing or any power cords. The sampler is now ready to sample ambient air.

9.4.3.2 Filter Recovery Procedure. As soon as possible after sampling, the operator should return to the monitoring site to retrieve the exposed filter. Particle loss or filter damage will result if the filter is left in the sampler for extended periods.

9.4.3.2.1 Turn on the sampler and allow it to equilibrate to operating temperature (3-5 min).

9.4.3.2.2 Measure the final Pex and record it on the MFC Sampler Field Data Sheet.

9.4.3.2.3 Turn off the sampler.

9.4.3.2.4 Open the door of the sampler, remove the flow recorder chart, and examine the recorder trace. If the trace indicates extensive flow fluctuations, investigate and correct before the next sampling day.

9.4.3.2.5 Record the following parameters on the MFC Sampler Field Data Sheet:

- Elapsed time of the sampling period, min.
- Average recorder response, arbitrary units.
- Average ambient temperature for the run day (Tav), K (K = EC + 273).
- Average ambient barometric pressure for the run day (Pav), mm Hg or kPa.

[Note: Tav and Pav readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the evaluation are not available, seasonal average temperature (Ts) and barometric pressure (Ps) may be substituted for Tav and Pav, respectively. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values may represent actual values within 20EC and 40 mm Hg.]

The calculations presented in this section assume that the sampler has been calibrated in terms of actual temperature and barometric pressure and that the substitution of seasonal values is used only to determine the sampler's operational flow rate during a sample period. Although additional calculations to convert the sampler's calibration curve to seasonal can be made, the error represented by this method is negligible.

9.4.3.2.6 Calculate and record the average actual flow rate (as determined by the sampler's calibration relationship) on the MFC Sampler Field Data Sheet and on the back of the chart. Attach the chart to the data sheet.

$$Qa = \{[\ )\ \overline{\overline{Pex}}(Tav + 30)/Pa]^{1/2} - b\}\ \{l/m\}$$

or for the flow recorder,

$$\overline{\overline{Qa}} = \{[\overline{I}(Tav + 30)/Pa]^{1/2} - b\}\ \{1/m\}$$

where:

$\overline{\overline{Qa}}$ = average sampler flow rate, actual m^3/min.
$\overline{\overline{Pex}}$ = average exit orifice plenum pressure, mm Hg.
I = average flow recorder response, arbitrary units.
Tav = average ambient temperature for the run day, K.
Pav = average ambient pressure for the run day, mm Hg.
b = intercept of the MFC sampler calibration relationship.
m = slope of the MFC sampler calibration relationship.

[Note: If charts with linear-function scales are used, substitute $(I)^{½}$ for I.]

9.4.3.2.7 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (e.g., paving, mowing, fire) and record this information on the MFC Sampler Field Data Sheet.

9.4.3.2.8 Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.

9.4.3.2.9 The sampler may now be readied for the next run day.

9.4.3.2.10 Keeping the filter cassette level, carefully transport it, the data sheet, and the flow recorder chart to the laboratory sample custodian.

9.4.4 Sampling Procedures--VFC Sampler.

9.4.4.1 Filter Installation Procedure.

9.4.4.1.1 Following the manufacturer's instructions, loosen the nuts that secure the inlet to the base and gently tilt back the inlet to allow access to the filter support screen.

9.4.4.1.2 Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts sufficiently to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

9.4.4.1.3 If an inlet is used, lower the sample inlet and secure it to the sampler base. For impaction inlets, inspect the sample inlet to make sure that it is resting on the filter cassette and not on the sampler's frame. Secure the sampler inlet to the sampler base.

9.4.4.1.4 Record the following parameters on the VFC Sampler Field Data Sheet (see Figure 15):
- Site location.
- Sample date.
- Filter ID number.
- Sampler model and S/N.
- Operator's initials.

9.4.4.1.5 Turn on the sampler and allow it to reach a stable operating temperature (3-5 min).

9.4.4.1.6 Bring an oil or water manometer to the side of the sampler. This manometer should have a range of 0-400 mm (0-16") and a minimum scale division of 1 mm (0.1").

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the VFC Sampler Field Data Sheet.]

$$\text{mm Hg} = (25.4)\ (\text{in. } H_2O/13.6)$$

Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid.
Adjust the manometer's sliding scale so that its zero line is at the bottom of the meniscuses.

9.4.4.1.7 Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attach one side of the manometer to the port. Leave the other side of the manometer open to atmospheric pressure. Make sure the tubing snugly fits the port and the manometer.

9.4.4.1.8 Measure the initial relative stagnation pressure ( ) Pstg) and record this reading on the VFC Sampler Field Data Sheet.

9.4.4.1.9 Turn off the sampler, disconnect the manometer, and replace the vacuum cap on the stagnation pressure port.

9.4.4.1.10 Reset the elapsed-time meter to 0000 min and the sampler timer for the next run day. The sampler is now ready to sample ambient air.

9.4.4.2 Filter Recovery Procedure. As soon as possible after sampling, the operator should return to the monitoring site to retrieve the exposed filter. Particle loss or filter damage will result if the filter is left in the sampler for extended periods.

9.4.4.2.1 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

9.4.4.2.2 While the sampler is equilibrating, record the following parameters on the VFC Sampler Field Data Sheet:
- Elapsed time of the sampling period, min.
- Average ambient temperature for the run day (Tav), EC and K.
- Average ambient barometric pressure for the run day (Pav), mm Hg.

[Note: Tav and Pav readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office, National Weather Service (NWS) station, or an airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If Tav and Pav readings are not available, seasonal average temperature (Ts) and barometric pressure (Ps) can be substituted. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values may represent actual values within 20EC and 40 mm Hg.]

9.4.4.2.3 Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid. Adjust the manometer sliding scale so that its zero line is at the bottom of the meniscuses.

9.4.4.2.4 Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attached one side of the manometer to the port. Make sure that the tubing snugly fits the port and the manometer. Leave the other side open to atmospheric pressure.

9.4.4.2.5 Record the final Pstg on the VFC Sampler Field Data Sheet. Turn off the sampler and replace the vacuum cap.

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the Sampler Field Data Sheet.]

$$\text{mm Hg} = 25.4\ (\text{in. } H_2O/13.6)$$

9.4.4.2.6 Calculate the average relative stagnation pressure ($\overline{)\text{Pstg}}$) and record it on the data sheet.

9.4.4.2.7 Calculate the average absolute stagnation pressure ($\overline{\text{P1}}$) for the sample run day and record it on the data sheet.

$$\overline{\text{P1}} = \text{Pav} - \overline{)\text{Pstg}}$$

where:

$\overline{\text{P1}}$ = average absolute stagnation pressure, mm Hg.
Pav = average ambient barometric pressure for the run day (not the retrieval day), mm Hg.
$\overline{)\text{Pstg}}$ = average stagnation pressure drop, mm Hg.

9.4.4.2.8 Calculate and record the average stagnation pressure ratio:

$$\text{Average stagnation pressure ratio} = \text{P1/Pav}$$

where:

Pl = average absolute stagnation pressure, mm Hg.
Pav = average ambient barometric pressure on the sample run day, mm Hg.

9.4.4.2.9 Using the manufacturer's lookup table (or an alternate calibration relationship as described in Section 7.5.4), locate the column and row corresponding to $\overline{\text{P1}}$/Pav and the Tav value for the sample run day. Read and record the indicated $\overline{\text{Qa}}$ value.

9.4.4.2.10 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (paving, mowing, fire) and record this information on the VFC Sampler Field Data Sheet.

9.4.4.2.11 Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.

9.4.4.2.12 The sampler may now be readied for the next sampling period.

9.4.4.2.13 Keeping the filter cassette level, carefully transport it and the Sampler Field Data Sheet to the laboratory sample custodian.

9.4.5 Post-Sampling Filter Handling Procedures. If a sample will not be analyzed immediately, the sample custodian should store the filter within a protective covering. Because filter cassettes often prove too expensive and unwieldy for storage purposes, the use of a manila folder and a protective envelope of comparable size to that of the filter is recommended. Laboratory personnel should adhere to the following procedure:

9.4.5.1 Following the manufacturer's instructions, remove the top frame of the filter cassette.

9.4.5.2 Conduct a secondary check of a sample's validity as presented in "Laboratory Validation Criteria" (see Section 9.5).

9.4.5.3 Carefully slip a manila folder underneath the edge of the exposed filter. The filter may stick in the cassette because of overcompression of the filter cassette gasket. Be extremely careful to avoid damage to the brittle quartz filter.

9.4.5.4 Center the filter on the folder. If the filter must be touched, do not touch or jar the deposit. Fold the manila folder lengthwise at the middle with the exposed side of the filter in. If the collected sample is not centered on the filter (i.e., the unexposed border is not uniform around the filter), fold it so that only deposit touches deposit. **Do not crease the folder**--the sample filter may tear. If the filter shears or breaks, ensure that all pieces of the filter are included within the folder.

9.4.5.5 Insert the folder into the protective envelope.

9.4.5.6 Deliver the filter in its protective folder and envelope, accompanied by the completed data sheet, to the analytical laboratory.

9.5 Sample Validation and Documentation

9.5.1 Field Validation Criteria. After each sampling period, calculate the percentage difference between Qa and the design flow rate (1.13 m^3/min) using the following formula:

$$\% \text{ Difference } = 100 \frac{\overline{Qa} - 1.13}{1.13}$$

Record this value on a control chart for the field validation of the sampler's actual volumetric flow rate as is shown in Figure 16.

- Decreases in flow rate during sampling (due to mechanical problems) of more than 10% from the initial set point result in sample invalidation. Recalibrate the sampler. A sample flow rate may also fluctuate due to heavy filter loading. If a high concentration is suspected, the operator should indicate this on the field data sheet. The laboratory supervisor will make the final decision regarding the sample's validity.
- Changes in flow-rate calibration of more than 10%, as determined by a field QC flow-rate check (see Section 13), will invalidate all samples collected back to the last calibration or valid flow check. Recalibrate the sample.

9.5.2 Laboratory Validation Criteria.

9.5.2.1 Upon receiving the filter from the field, check the filter for signs of air leakage by observing the border around the filter. If the border is clear, then the gasket on the sampler is still usuable. However, if particulate matter is on the border, then air leakage has occurred and the gasket on the sampler should be changed. Leakage may result from a worn or improperly installed faceplate gasket. A gasket generally deteriorates slowly. The sample custodian should be able to decide well in advance (by the increased fuzziness of the sample outline) when to change the gasket before total gasket failure results. If signs of leakage are observed, void the sample, determine the cause, and instruct the operator to take corrective actions before starting another sampling period.

9.5.2.2 Check the exposed filter for physical damage that may have occurred during or after sampling. Physical damage after sampling would not invalidate the sample if all pieces of the filter were put in the

folder; however, complete losses of loose particulate after sampling (e.g., loss when folding the filter) would void the sample. Mark such samples as "void" on the HV data sheet.

9.5.2.3 Check the appearance of the particles. Any changes from normal color may indicate new emission sources or construction activity in the area. Note any change on the data sheet.

9.5.2.4 The filters should be weighed according to the procedures described in Inorganic Compendium Method IO-3.1, Section 5, *Gravimetric Analysis*.

9.5.3 Data Documentation. Recordkeeping is a critical part of the QA program. Careful documentation of sampling data will salvage samples that may otherwise be lost. The sheer repetition of recording data may result in errors; however, this cross-referencing between data sheets, log books, and (for those samplers so equipped) the continuous-flowrecorder charts will allow the operator to pinpoint discrepancies that may result in a sample's invalidation.

[Note: The use of log books at monitoring sites is highly encouraged.]

9.5.3.1 Presampling Documentation and Inspection. The following information should be recorded on the Sampler Field Data Sheet (SFDS), sampler recorder chart (RC), flow-rate control chart (CC), and in the site log book (LB):

- Site Location.
- Sample Date.
- Filter ID number.
- Sample model and S/N.
- Operator's initials.

9.5.3.2 Post-Sampling Documentation and Inspection. Upon receipt of exposed filters from the field, the sample custodian should adhere to the following procedures.

9.5.3.2.1 Examine the field data sheet. Determine whether all data needed to verify sample validity and to calculate mass concentration are provided (e.g., average flow rate, ambient temperature, barometric pressure, and elapsed time). Void the sample if data are missing or unobtainable from a field operator or if a sampler malfunction is evident.

9.5.3.2.2 If the exposed filter was packaged for shipment, remove the filter from its protective envelope and examine the shipping envelope. If sample material has been dislodged from a filter, recover as much as possible by brushing it from the envelope onto the deposit on the filter with a soft camel's-hair brush.

9.5.3.2.3 Match the filter ID number with the correct laboratory data/coding form on which the original balance ID number, filter ID number, filter tare weight, and other information are inscribed. The sample custodian should group filters according to their recorded balance ID numbers. Initial separation of filters by balance ID number will decrease the probability of a balance error that could result from the use of different balances for tare and gross weights.

9.5.3.2.4 Remove the filter from the protective manila folder. Should the filter be retained in its filter cassette, loosen the nuts on the top and remove the filter. Overtightening the nuts may cause the filter to adhere to the cassette gasket. Gently remove it by the extreme corners to avoid damage. Inspect the filters for any damage that may have occurred during sampling. Conduct a secondary check of a sample's validity (as presented in Section 9.4). If insects are embedded in the sample deposit, remove them with Teflon®-tipped tweezers and disturb as little of the sample deposit as possible. If more than 10 insects are observed, refer the sample to the supervisor for a decision on acceptance or rejection of the filter for analysis.

9.5.3.2.5 Place defect-free filters in protective envelopes and forward them to the laboratory for weighing and analysis. File the data sheets for subsequent mass concentration calculations.

9.5.3.2.6 Place defective filters, with the type of defect(s) listed, in separate clean envelopes. Label the envelopes and submit them to the laboratory supervisor for final approval of filter validity.

10. Interferences

10.1 Large extraneous objects, such as insects, may be swept into the filter.

10.2 Liquid aerosols, such as oil mists and fog droplets, are retained by the filter. If the amount of liquid so collected is sizeable, the filter can become wet and its function may be impaired.

10.3 Any gaseous or vaporous constituent of the atmosphere under test that is reactive with or absorbed on the filter will be retained.

10.4 As the filter becomes loaded with collected matter, the sampling rate is reduced. If a significant drop in flow rate occurs, the average of the initial and final flow rate will not give an accurate estimate of total flow during the sampling period. The magnitude of such errors will depend on the amount of reduction of airflow rate and on the variation of the mass concentration of dust with time during the 24-h sampling period. As an approximate guideline, any sample should be suspect if the final flow rate is less than one-half the initial rate.

10.5 Power failure or voltage change during the test period will lead to an error, depending on the extent and time duration of such failure.

10.6 The passive loading of the filter left in place for any time prior to or following a sampling period can introduce an error. The timely installation and removal of the filter is advisable, or a sampler with shutters may be used.

10.7 If two or more samplers are used at a given location, they should be placed at least 2 meters apart so that one sampler will not affect the results of an adjacent sampler.

10.8 Recent wind tunnel studies have shown significant possible sampling errors as a function of sampler orientation in atmospheres containing high relative concentrations of large particles.

10.9 Metal dusts from motors, especially copper, may significantly contaminant samples under some conditions.

10.10 Under some conditions, atmospheric SO_2 and NO_x may interfere. Artifact formation errors are caused by the retention of sulfur dioxide in the form of sulfate particulate on alkaline filters. Experiments involving a variety of filters indicate that sulfate loading errors of 0.3-3.0 $\mu g/m^3$ can be expected with the use of common glass fiber filters under normal sampling conditions and that larger sulfate errors are possible under extreme sampling conditions. A neutral or low-alkalinity filter medium will eliminate excessive artifact formation.

10.11 Guidelines to help prevent post-sampling particle loss are presented in Section 8.

11. Calculations, Validations, and Reporting of TSP and PM_{10} Data

11.1 Basic Information Used for Calculations

11.1.1 The design flow rate is specified as an actual volumetric flow rate (Qa), measured at existing conditions of temperature (Ta) and pressure (Pa). The sampler's operational flow rate should be very close to the design flow rate. All samplers have some means for measuring the operational flow rate, and that flow rate measurement system must be calibrated periodically with a certified flow rate transfer standard. Usually, measurements (or estimates) of ambient temperature and barometric pressure are required to get an accurate indication of the operational flow rate. To determine the average sampler flow rate over a sample period, use the average temperature (Tav) and average barometric pressure (Pav) over the sample period. However, if average temperature and pressure values (or reasonable estimates) cannot be obtained for each sample period, seasonal average temperature (Ts) and barometric pressure (Ps) for the site may be substituted.

[Note: Tav and Pav readings may be recorded on site or estimated from data obtained from a nearby U.S. National Weather Service Forecast Office, NWS station, or local airport weather station. Barometric pressure readings obtained from airports or other sources must be at station pressure (i.e., not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If individual Tav and Pav readings cannot be obtained for each sample period and seasonal averages for the site are routinely substituted, care must be taken to ensure that the actual temperature and barometric pressure at the site are reasonably represented by such averages. Therefore, seasonal average temperature and pressure values (Ts and Ps) for the site by should be used only when these values are within 20 K and 40 mm Hg (5 kPa) of the actual average temperature and barometric pressure (Tav and Pav) for the sample period.]

11.1.2 The calculations presented in this section assume that the sampler has been calibrated in actual volumetric flow rate units (Qa) and that individual average temperature and barometric pressure values are used for each sample period. If seasonal average temperature and pressure values for the site are to be used, Ts may be substituted for Tav, and Ps may be substituted for.

11.1.3 The true or actual flow rate through the sampler inlet must be known and controlled. A common source or error in a monitoring program is confusion of various air volume flow-rate measurement units. Although the sampler's operational flow rate must be monitored in terms of actual volume flow rate units (Qa), sampler flow rates can be corrected to standard volume flow rate units (Qstd) at EPA standard conditions of temperature (25EC) and pressure (760 mmHg).

- $\overline{Qa}$: Actual volumetric air flow rates, measured and expressed at existing conditions of temperature and pressure and denoted by Qa (Qactual). Typical units are L/min and m^3/min. Inlet design flow rates for PM_{10} samplers are always given in actual volumetric flow rate units.
- Qstd: Airflow rates that have been corrected to equivalent standard volume flow rates at EPA standard conditions of temperature and pressure (25EC or 298 K and 760 mm Hg or 101 kPa) and denoted by Qstd (Qstandard). Typical units are std. L/min, and std. m^3/min. Standard volume flow-rate units are often used by engineers and scientists because they are equivalent to mass flow units.

11.1.4 The Qa and Qstd measurement units must not be confused or interchanged. The flow-rate units can be converted as follows, provided the existing temperature and pressure (or in some cases the average temperature and pressure over a sampling period) are known:

$$\overline{Qstd} = \overline{Qa}(Pa/Pstd)(Tstd/Ta)$$
$$Qstd = (Pav/Pstd)(Tstd/Tav)$$
$$Qa = Qstd(Pstd/Pa)(Ta/Tstd)$$

where:

Qstd = standard volume flow rate, std m^3/min.
Qa = actual volume flow rate, actual m^3/min.
Pa = ambient barometric pressure, mm Hg.
Pstd = EPA standard barometric pressure, 760 mm Hg.
Tstd = EPA standard temperature, 298 K.
Ta = standard temperature, K (K = EC + 273).
Qstd = average standard volume flow rate for the sample period, std. m^3/min.
$\overline{Qa}$ = average actual volume flow rate for the sample period, m^3/min.
Pav = average ambient barometric pressure during the sample period, mm Hg.
Tav = average ambient temperature during the sample period, K.

Inorganic Compendium Method IO-2.4 provides guidance on calculating sample volume corrected to EPA standard temperature and pressure.

11.2 Flow-Rate Calculations. Because flow control methods (and hence, calibration procedures) vary among different sampler models, the calculations necessary to determine the average actual flow rate during a sample run will also differ. The following general procedures are recommended for calculating the average ambient flow rate of the sampler. In this section, it is assumed that the samplers have been calibrated according to procedures outlined in Section 7.

[Note: Consistency in units is required. Adoption of uniform designations of K for temperature and mm Hg (or kPa) for pressure is recommended in all calculations.]

11.2.1 MFC Sampler.

11.2.1.1 The average actual flow rate for sample period is calculated by determining:

- The average of the initial and final manometer readings ($\overline{)Pex}$) [or the average flow recorder trace];
- The average ambient temperature (Tav); and
- The average ambient barometric pressure (Pav) during the sampling period and applying these values to the calibration relationship.

11.2.1.2 Each sampler's flow measurement system should be calibrated periodically, and the calibration should be described by a mathematical expression (e.g., a least-squares linear regression equation) that indicates the slope and intercept of the calibration relationship. Following the procedure in Section 7, this expression is in the form of:

$$\overline{Qa} = \{[\overline{Pex}(Tav + 30)/Pav)]^{½} - b\} \{l/m\}$$

where:

$\overline{Qa}$ = the sampler's average actual flow rate for the sample period, m^3/min.
$\overline{Pex}$ = average of initial and final sampler manometer readings, ( ) Pex_i +) Pex_f)/2, in. H_2O.
Tav = average barometric pressure for the sample period, K (K = EC + 273).
Pav = average barometric pressure for the sample period, mm Hg.
b = intercept of the sampler calibration relationship.
m = slope of the sampler calibration relationship.

For the flow recorder,

$$\overline{Qa} = \{[\bar{I}(Tav + 30)/Pav]^{1/2} - b\} \{l/m\}$$

where:

$\bar{I}$ = average flow recorder reading for the sample period.

11.2.1.3 The average actual flow rate is then corrected to EPA-standard conditions, calculated as:

$$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav)$$

where:

$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m^3/min.
$\overline{Qa}$ = average actual sampler flow rate for the sample period, m^3/min.
Pstd = standard barometric pressure, 760 mm Hg.
Tstd = standard temperature, 288 K.

11.2.2 VFC Sampler.

11.2.2.1 The average actual flow rate for the sample period is calculated by determining the ratio of the average absolute stagnation pressure of the average ambient barometric pressure ($\overline{P1}$/Pav) and the ambient average temperature (Tav) for the sampler period.

11.2.2.2 Calculate the value of Pl in mm Hg:

$$\overline{P1} = Pav - \overline{)Pstg}$$

where:

Pl = average absolute stagnation pressure for the sample period, mm Hg .
Pav = average barometric pressure for the sample period, mm Hg.
$\overline{)Pstg}$ = average of initial and final relative stagnation pressure readings, mm Hg.

[Note: Be sure to convert a water manometer reading to mm Hg using the following equation before recording the reading on the data sheet:]

$$mmHg = 25.4 (\ ) H_2O/13.6)$$

11.2.2.3 Calculate and record the value of the average stagnation pressure ratio.

$$\text{Average stagnation pressure ratio} = (\overline{P1}/Pav)$$

11.2.2.4 Use the manufacturer's lookup table (or alternate calibration relationship; see Section 7) to determine Qa from the average stagnation pressure ratio ($\overline{P1}/Pav$) and Tav for the sample period. The value of $\overline{Qa}$ is the average volumetric flow rate for the sampler period.

11.2.2.5 The average actual flow rate is then corrected to EPA-standard conditions using the following equation:

$$\overline{Qstd} = \overline{Qa}(Pav/Pstd)(Tstd/Tav)$$

where:

$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m^3/min.
$\overline{Qa}$ = average actual sampler flow rate for the sample period, m^3/min.
Pstd = standard barometric pressure, 760 mm Hg.
Tstd = standard temperature, 298 K.

11.3 The total standard volume of air sampled is calculated by the following equation:

$$Vstd = (\overline{Qstd})(t)$$

where:

Vstd = total volume of air sampled in standard volume units, std m^3.
$\overline{Qstd}$ = average sampler flow rate corrected to EPA-standard conditions, std m^3/min.
t = total elapsed sampling time, min.

11.4 Percent Difference

11.4.1 After each sampling period, calculate the percentage difference between Qa and the design flow rate (1.13 m^3/min) using the following formula:

$$\% \text{ Difference } = 100 \frac{Qa - 1.13}{1.13}$$

Record this value on a control chart for the field validation of the sampler's actual volumetric flow rate as is shown in Figure 14.

11.4.2 The following criteria should be used as the basis for determining a sample's validity:

- Decreases in flow rate during sampling (due to mechanical problems) of more than 10% from the initial set point cause sample invalidation. A sample flow rate may also fluctuate due to heavy filter loading. If a high concentration is suspected, the operator should indicate it on the field data sheet. The laboratory supervisor will make the final decision regarding the sample's validity.
- Changes in flow-rate calibration of more than 10%, as determined by a field QC flow-rate check, will invalidate all samples collected back to the last calibration or valid flow check.

12. Records

12.1 MFC Sampler

Record the following parameters on the MFC Sampler Field Data Sheet (see Figure 14):

- Final Pex.
- Elapsed time of the sampling period, min.
- Average record response, arbitrary units.
- Tav for the run day K (K = EC + 273).
- Pav for the run day, mm Hg.

12.2 VFC Sampler

Record the following parameters on the VFC Sampler Field Data Sheet (see Figure 15):

- Site location.
- Sample date.
- Filter ID number.
- Sampler model and S/N
- Operator's initials.
- Initial Relative Stagnation Pressure (Pstg).
- Elapsed time of the sampling period, min.
- Tav for the run day Tav, EC and K.
- Pav for the run day Pav, mm Hg.
- Pstg, mm Hg.
- Relative Stagnation Pressure.
- Absolute Stagnation Pressure.
- Qa value (from chart generated in Section 7.5.4.).

12.3 Tav and Pav readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level); they may have to be corrected for differences between elevation of the monitoring site and that of the airport. If Tav and Pav readings are not available, seasonal average temperature (Ts) and barometric pressure (Ps) may be substituted for Tav and Pav, respectively. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values should represent actual values within 20EC and 40 mm Hg.

12.4 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (paving, mowing, fire) and record this information on the VFC Sampler Field Data Sheet.
Document any factors that may cause a sample's invalidation on the sample data sheet. Forward the data sheet and the filter to the laboratory supervisor, who will make the final decision regarding the sample's validity.

12.5 Record the percentage difference between Qa and the design flow rate on Figure 16.
12.6 Recordkeeping is a critical part of the QA program. Careful documentation of sampling data will salvage samples that may otherwise be lost. The sheer repetition of recording data may result in errors;

however, this cross-referencing between data sheets, log books, and (for those samplers so equipped) the continuous-flow-recorder charts will allow the operator to pinpoint discrepancies that may result in a sample's invalidation.

[Note: The use of log books at monitoring sites is highly encouraged. The following information should be recorded on the Sampler Field Data Sheet (SFDS), sampler recorder chart (RC), in the site log book (LB), and on the flow-rate control chart (CC).]

12.6.1 The following information should be recorded by the operator who starts the sample. (The designation in parentheses indicates where the data must be inscribed):

- Site designation and locations (SFDS)(RC)(LB). This information should be recorded in the log book only once, at the initiation of a monitoring program.
- Sampler model and S/N (SFDS)(RC)(LB). This information needs to be recorded in the log book only at the commencement of monitoring, unless there is more than one sampler or a new sampler has been deployed.
- Filter ID number (SFDS)(RC)(LB).
- Sample date (SFDS)(RC)(LB).
- Initial Pex for MFC or initial) Pstg for VFC (SFDS)(LB).
- Unusual conditions that may affect the results (e.g., subjective evaluation of pollution that day, construction activity, weather conditions) (SFDS)(LB).
- Operator's initials (SFDS).
- Signature (LB).

12.6.2 The following information should be recorded by the operator who removes the samples.

- Elapsed time of the sample run (SFDS)(RC)(LB).
- Final) Pex [or mean I] for MFC or final) Pstg, $\overline{P1}$, and $\overline{P1}$/Pav for VFC (DS)(LB)[RC].
- The calculated standard average flow rate (Qstd) in std m^3/min (SFDS)(LB).
- The percentage difference between the actual and design flow rates (CC).
- Average ambient temperature and barometric pressure on the sample run day (SFDS)(LB).
- Seasonal average temperature and pressure, if needed (SFDS/LB). This information needs to be recorded in the logbook once, at the change of each season.
- Existing conditions that may affect the results (SFDS)(LB).
- Explanations for voided or questionable samples (SFDS)(LB).
- Operator's initials (SFDS).
- Signature (LB).

13. Field QC Procedure

For HV samplers, a field-calibration check of the operational flow rate is recommended at least once per month. The purpose of this check is to track the sampler's calibration stability. A control chart (e.g., Figure 14) that contains the percentage difference between a sampler's indicated and measured flow rates should be maintained. This chart is a quick reference of instrument flow-rate drift problems and is useful for tracking the performance of the sampler. Either the sampler log book or a data sheet must be used to document flow-check information. This information includes, but is not limited to, instrument and transfer standard model and serial numbers, ambient temperature and pressure conditions, and collected flow-check data.

In this section, the following is assumed:

- The flow rate through sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer [or a flow recorder].
- The flow rate through a sampler that is equipped with a volumetric flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- The acceptable flow-rate fluctuation range is 10% of the design flow rate.
- The transfer standard will be an orifice device equipped with a water or oil manometer.
- The orifice transfer standard's calibration relationship is in terms of the actual volumetric flow rate (Qa).

13.1 QC Flow-Check Procedure--MFC Sampler. The indicated flow rate [Qa (sampler)] for MFC samplers is calculated by determining:

- The manometer reading of the exit orifice plenum pressure [or the flow recorder reading],
- The ambient temperature (Ta), and
- The barometric pressure (Pa) during the flow check.

These values are then applied to the sampler's calibration relationship. The 4" pressure (flow) recorders of the type often supplied with high-volume PM_{10} samplers are generally not sufficiently accurate and are not recommended for quantitative sampler pressure or flow measurements. The flow recorder may be connected in parallel with the manometer or other pressure measuring device, using a tee or "Y" tubing connector. An alternate QC flow-check procedure may be presented in the manufacturer's instruction manual. The manual should be reviewed and the various methods evaluated. Inhouse equipment and procedural simplicity should be considered in determining which method to use.

[Note: Do not attempt to conduct a flow check of samplers under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The flow check will be less precise because of the pressure variations.]

13.1.1 Collect the following equipment and transport it to the monitoring station:

[Note: An independent person should perform the QC flow check, with an outside observer present.]

- A water, oil, or digital manometer with a 0-200 mm (0-8") range and a minimum scale division of 1 mm (0.1") for measuring the sampler's exit orifice plenum pressure. This manometer should be the same as is used routinely for sampler flow rate measurements.
- An orifice transfer standard and its calibration relationship (different from initial orifice standard).
- An associated water or oil manometer with a 0- to 400-mm (0- to 16") range and a minimum scale division of 1 mm (0.1") for measuring the orifice transfer standard.
- A thermometer capable of accurately measuring temperature 0-50EC (273-323 K) to the nearest ± 1EC and referenced to an NIST or ASTM thermometer within ± 2EC at least annually.
- A portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient pressure 500-800 mm Hg (66-106 kPa) to the nearest millimeter Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.
- The sampler's calibration information.
- Spare recorder charts and a clean flow-check filter.
- MFC Sampler Flow-Check Data Sheet or site log book.

13.1.2 Record the site location, sampler S/N, and date on the back of a clean chart and install it in the flow recorder. While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen arm (or by using the pen lift) and simultaneously insert the chart.

13.1.3 Lower the pen arm and tap the recorder face lightly to make certain that the pen can move freely.

13.1.4 Using a coin or slotted screwdriver, advance the chart and check to see that the pen head rests on zero (i.e., that smallest diameter circle). If necessary, adjust the zeroset screw while gently tapping on the side of the recorder. A quarter turn of the set screw usually results in large offsets; adjust the set screw carefully.

13.1.5 Set up the flow-check system as previously illustrated in Figure 10. MFC samplers are normally flow-checked with a filter in line (i.e., between the orifice transfer standard and the motor). Install a clean filter in the sampler. Place the filter directly upon the sampler's filter screen. Do not use a filter cassette. A flow-check filter should never be used for subsequent sampling because particles larger than 10 Fm can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.

13.1.6 Install the orifice transfer standard and its faceplate on the sampler. Do not restrict the flow rate through the orifice (i.e., by using fixed resistance plates or closing the variable-resistance valve).
Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The nuts should be hand-tightened; too much compression can damage the sealing gasket. Make sure the orifice transfer standard gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.

13.1.7 Connect the orifice manometer to the pressure port of the orifice transfer standard and the sampler manometer to the sampler's exit orifice plenum. Inspect the manometers' connecting tubings for crimps and cracks. Open the manometer valves and blow gently through the tubings. Watch for the free flow of fluid. Adjust the manometers' scales so that their zero lines are at the bottom of the meniscuses. Make sure that the connecting tubing snugly fits the manometer and the pressure port.

13.1.8 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

13.1.9 Read and record the following parameters on the MFC Sampler Flow-Check Data Sheet:
- Sampler location and date.
- Sampler model and S/N.
- Ambient temperature (Ta), EC and K.
- Ambient barometric pressure (Pa), mm Hg.
- Unusual weather conditions.
- Orifice transfer standard S/N and calibration relationship.
- Operator's signature.

13.1.10 Observe the) H_2O across the orifice by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet (see Figure 11).

13.1.11 Measure the exit orifice plenum pressure ( ) Pex) by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet.

13.1.12 Using a coin or small screwdriver, advance the recorder chart to read the sampler's corresponding response (I) and record on the data sheet. A gentle tap on the recorder face is often necessary to ensure that the pen is not sticking to the chart.

13.1.13 Turn off the sampler and remove the orifice transfer standard, but not the filter. Turn on the sampler and repeat Section 13.1.11 [or Section 13.1.12] to check the flow rate under normal operating conditions. Turn off the sampler and remove the filter.

13.1.14 Calculate and record Qa(orifice) at actual conditions using the following equation:

$$Qa(orifice) = \{[(\Delta H_2O)(Ta/Pa)]^{½} - b\}\ \{l/m\}$$

where:

Qa(orifice) = actual volumetric flow rate as indicated by the orifice transfer standard, m^3/min
ΔH_2O = pressure drop across the orifice, in. H_2O.
Ta = ambient temperature, K.
Pa = ambient barometric pressure, mm Hg.
b = intercept of the orifice calibration relationship.
m = slope of the orifice calibration relationship.

13.1.15 Calculate and record the corresponding sampler flow rate at actual conditions using the following equation:

$$Qa(sampler) = \{\Delta Pex\ (Ta + 30)/Pa]^{1/2} - b\}\ \{l/m\}$$

or use the following if a flow recorder is being used to measure the exit orifice plenum pressure:

$$Qa(sampler) = \{I(Ta + 30)/Pa]^{1/2} - b\}\ \{l/m\}$$

where:

Qa(sampler) = sampler flow rate, actual m^3/min.
ΔPex = exit orifice plenum pressure, in. H_2O.
Ta = ambient temperature during the flow check, K (K = EC + 273).
Pa = ambient barometric pressure during the flow check, mm Hg.
b = intercept of the MFC sampler calibration relationship.
m = slope of the MFC sampler calibration relationship.

[Note: If charts with linear-function scales are used, substitute $(I)^{½}$ for I.]

13.1.16 Using this information and the formulas provided on the MFC Sampler Flow-Check Data Sheet, calculate the QC check percentage differences.

$$QC\&check\ \%\ difference = \frac{[Qa(sampler)\ \&\ Qa(orifice)]}{Qa(orifice)}\ [100]$$

where:

Qa(sampler) is measured with the orifice transfer standard being installed.

Record this value on the MFC Sampler Flow-Check Data Sheet and plot on the QC control chart. If the sampler flow rate is within 93-107% (±7% difference) of the calculated Qa(orifice) flow rate (in actual volumetric units), the sampler calibration is acceptable. If these limits are exceeded, investigate and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding ±10% may result in the invalidation of all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the orifice transfer standard's calibration and all calculations.

13.1.17 Calculate the corrected sampler flow rate, Qa(corr. sampler), using the following equation:

$$\text{Qa(corr. sampler } = \text{[Qa(sampler)]} \frac{\text{[(100 \& \% difference)]}}{100}$$

where:

Qa(sampler) is measured without the orifice transfer standard being installed and where the QC-check percentage difference was obtained from the equation above.

[Note: Take care to use the correct sign (i.e., positive or negative) for the percent difference.]

13.1.18 Calculate and record on the MFC Sampler Flow-Check Data Sheet the percentage difference between the inlet's design flow rate and the corrected sampler flow rate as:

$$\text{Design flow rate \% difference } = \frac{\text{[Qa(corr. sampler) \& 1.13]}}{1.13)}[100]$$

[Note: The author assumes in this section that the inlet is designed to operate at a flow rate of 1.13 actual m^3/min. If the design flow rate percentage difference is less than or equal to ±7%, the sampler calibration is acceptable. If the difference is greater than ±7%, investigate potential error sources and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding ±10% may invalidate all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.]

[Note: Deviations from the design flow rate may be caused in part by deviations in the site temperature and pressure from the seasonal average conditions. Recalculate the optimum set-point flow rate (SFR) according to Section 7.4.4 to determine if the flow controller should be adjusted.]

13.1.19 Set up the sampler for the next sampling period according to the operating procedure in Section 9.4.

13.2 QC Flow-Check Procedure--VFC Sampler

The indicated flow rate (Qa (sampler)) for VFC samplers is calculated by determining:

- The relative stagnation pressure (Pstg),
- The ambient temperature (Ta), and
- The barometric pressure (Pa) during the flow check.

These values are then applied to the sampler's calibration relationship. An alternative QC flow-check procedure may be presented in the manufacturer's instruction manual. The manual should be reviewed and the various methods evaluated. Inhouse equipment and procedural simplicity should be considered in determining which method to use.

[Note: Do not attempt to conduct a flow check of samplers under windy conditions. Short-term wind velocity fluctuations will provide variable pressure readings by the orifice transfer standard's manometer.]

The flow check will be less precise because of the pressure variations.

13.2.1 Collect the following equipment and transport it to the monitoring station:

- An orifice transfer standard and its calibration relationship in actual volumetric flow units (Qa).
- An associated oil, water, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1").
- An oil, water, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1") or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure measurement device) should be associated with the sampler.

[Note: Manometers used for QC flow-checks may be subject to damage or malfunction and thus should be checked frequently.]

- A thermometer capable of accurately measuring temperature from 0E-50EC (273-323 K) to the nearest ± 1EC and referenced to an NIST or ASTM thermometer within 2EC at least annually. To calculate the orifice flow rates, convert EC to K.
- A portable aneroid barometer (e.g., a climber or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg to the nearest millimeter Hg and referenced within 5 mm Hg of a barometer of known accuracy at least annually.
- The sampler's calibration relationship (i.e., lookup table or alternative calibration relationship).
- A clean flow-check filter loaded into a filter cassette.
- A VFC Sampler Flow-Check Data Sheet (see Figure 13) or a site log book.

13.2.2 Set up the flow-check system as previously illustrated in Figure 12. VFC samplers are normally flow-checked with a loaded filter cassette in line (i.e., between the orifice transfer standard and the motor). The orifice transfer standard should be installed without fixed resistance plates or with the adjustable resistance value fully open. A flow-check filter should never be used for subsequent sampling because particles larger than 10 Fm can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.
Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The fittings should be hand-tightened; too much compressing can damage the sealing gasket. Make sure the orifice gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.

13.2.3 Turn on the sampler and allow the sampler to warm up to operating temperature (3-5 min).

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

13.2.4 Read and record the following parameters on the VFC Sampler Flow-Check Data Sheet (see Figure 13):

- Sampler location and date.
- Sampler S/N and model.
- Ambient temperature (Ta), EC and K.
- Ambient barometric pressure (Pa), mm Hg.
- Unusual weather conditions.
- Orifice transfer standard S/N and calibration relationship.
- Operator's signature.

13.2.5 Inspect the manometers for crimps or cracks in the connecting tubing. Open the valves and blow gently through the tubing, watching for the free flow of the fluid.
Adjust the manometers' sliding scales so that the zero lines are at the bottom of the meniscuses.

13.2.6 Connect the orifice manometer to the orifice transfer standard and the sampler manometer to the sampler stagnation pressure port located on the side of the sampler base. Ensure that one side of each manometer is open to atmospheric pressure. Be sure that the connecting tubing snugly fits the pressure ports and the manometers.

13.2.7 Read the pressure drop as indicated by the orifice manometer ( ) H_2O) and record the value on the VFC Sampler Flow-Check Data Sheet. Read the stagnation pressure drop and record it as) Pstg (mm Hg) on the data sheet.

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the data sheet.]

$$\text{mm Hg} = 25.4(\text{in. } H_2O/13.6)$$

13.2.8 Turn off the sampler and remove the orifice transfer standard.

13.2.9 With only a loaded filter cassette in line, turn on the sampler and allow it to warm up to operating temperature.

13.2.10 Read and record the stagnation pressure drop ( ) Pstg) for the normal operating flow rate. Turn off the sampler. Replace the vacuum cap on the stagnation pressure port.

13.2.11 Calculate and record Qa(orifice) flow rate for the flow-check point, as in the equation, reproduced below:

$$Qa(\text{orifice}) = \{[(\ ) H_2O)(Ta/Pa)]^{½} - b]\ [l/m]$$

where:

Qa(orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min.
) H_2O = pressure drop across the orifice, in. H_2O.
Ta = ambient temperature, K (K = EC + 273).
Pa = ambient barometric pressure, mm Hg.
b = intercept of the orifice calibration relationship.
m = slope of the orifice calibration relationship.

13.2.12 Calculate and record the value of Pl (mm Hg) for the measurements, with and without the orifice installed, according to the following equation:

$$Pl = [Pa -)\ Pstg\ ]$$

where:

Pl = stagnation pressure, mm Hg.
Pa = ambient barometric pressure, mm Hg.
) Pstg = stagnation pressure drop, mm Hg.

13.2.13 Calculate and record the stagnation pressure ratio for the measurements, with and without the orifice installed, according to the following equation:

$$\text{Stagnation pressure ratio} = Pl/Pa$$

where:

Pl = stagnation pressure, mm Hg.
Pa = ambient barometric pressure, mm Hg.

13.2.14 Refer to the instrument manufacturer's lookup table (or alternative calibration relationship as described in Section 7.5.4) and determine the Qa(sampler) flow rates (m^3/min) for the measurements with

and without the orifice installed as indicated for the ratio of Pl/Pa and ambient temperature in EC. Record these values on the VFC sampler flow check data sheet.

13.2.15 Using Qa(orifice) and Qa(sampler) for the measurements with the orifice installed, calculate the QC-check percentage difference as:

$$\text{QC\&check \% difference} = \frac{[\text{Qa(sampler)} - \text{Qa(orifice)}]}{\text{Qa(orifice)}} [100]$$

Record this value on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for QC flow checks. If the QC-check percentage difference is less than or equal to ± 7%, the sampler calibration is acceptable. Those differences exceeding ± 7% will require recalibration. Differences exceeding ± 10% may invalidate all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calibrations.

13.2.16 Using this percentage difference and Qa (sampler) from the measurements without the orifice installed (i.e., for the normal operating flow rate), calculate the corrected sampler flow rate as:

$$\text{Qa(corr. sampler} = [\text{Qa(sampler)}] \frac{[(100 - \text{\% difference})]}{100}$$

Record Qa (corr. sampler) on the VFC Sampler Flow-Check Data Sheet.

13.2.17 Determine the design flow rate percentage difference between the PM_{10} sampler inlet design flow rate (e.g., 1.13 m^3/min) and Qa (corr. sampler) as:

$$\text{QC\&check \% difference} = \frac{[\text{Qa(sampler)} - \text{Qa(orifice)}]}{\text{Qa(orifice)}} [100]$$

Record this design flow rate percentage difference on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for the field validation of flow rates. When plotting this value, use a different symbol than is normally used for plotting values that are obtained during sampling periods. If the design flow rate percentage difference is less than or equal to ± 7%, the sampler calibration is acceptable. Those differences exceeding ± 7% will require recalibration. Differences exceeding ± 10% may invalidate all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.

14. Maintenance

Maintenance is defined as a program of positive actions aimed toward preventing failure of monitoring and analytical systems. The overall objective of a routine preventive maintenance program is to increase measurement system reliability and provide more complete data acquisition. The general maintenance procedures for HV samplers are outlined in this section. For more complete information on a particular sampler or on laboratory equipment maintenance, refer to the manufacturer's instruction manual for the individual instrument. Maintenance activities for the HV sampler are summarized in Table 4. Records should be maintained for the maintenance schedule of each HV sampler. Files should reflect the history of maintenance, including all replacement parts, suppliers, costs, expenditures, and in inventory of on-hand spare equipment for each sampler. Check sheets should be used to record preventive and/or corrective maintenance activities and the subsequent sampler calibration curve.

14.1 Maintenance Procedures

The HV sampler is comprised of two basic components: the inlet and the flow control system. Because of the differences between sampler models, refer to the manufacturer's instruction manual for specific maintenance guidelines and necessary supplies.

14.2 Recommended Maintenance Schedules

14.2.1 MFC Base. The MFC base is equipped with the following items:

14.2.1.1 Connecting tubing and power lines, which must be checked for crimps, cracks, or obstructions on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.

14.2.1.2 A filter screen, which should be inspected on sample recovery days for any impacted deposits.

14.2.1.3 Filter cassette gaskets, which need to be inspected each time a cassette is loaded. A worn cassette gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulate and the filter border.

14.2.1.4 Motor and housing gaskets, which should be checked at 3-month intervals and replaced as necessary.

14.2.1.5 Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600-1,000 hours of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions and perform the operator's field-calibration check as presented in Section 13. If the sampler's indicated flow rate exceeds the manufacturer-specified design-flow-rate range, adjust the sampler before the next run day.

To achieve the best performance, new brushes should be properly seated on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50-75% of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30-45 min at normal line voltage.

[Note: The motors that are used for HV samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motors are different. Make sure that the correct replacement brushes are used for the maintenance of HV samplers. If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV sampling. When lower-current motors are installed in HV samplers, the flow rate has been found to vary with changes in the line voltage.]

14.2.1.6 A flow controller should be replaced if the flow recorder indicates no flow, low flow, excessive flow, or erratic flow. Minor adjustments can be made to alter sampling flow rates; however, the controller generally cannot be repaired in the field.

[Note: A flow recorder requires very little maintenance, but does deteriorate with age. Difficulty in zeroing the recorder and/or significant differences (i.e., greater than 0.3 m^3/min) in average flow rates obtained from consecutive sampling periods usually indicate a faulty recorder. The recorder pens should be replaced every 30 recording days. In dry climates, a more frequent replacement schedule may be required.]

14.2.2 VFC Base. The VFC base is equipped with the following items:

14.2.2.1 Power lines, which must be checked for crimps or cracks on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.

14.2.2.2 A filter screen at the throat of the choked-flow venturi, which should be inspected on sample recovery days for any impacted deposits.

14.2.2.3 Filter cassette gaskets, which should be checked each time a filter is installed. A worn casket gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulates and the filter border.

14.2.2.4 Motor and housing gaskets, which should be checked at 3-month intervals and replaced as necessary.

14.2.2.5 Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600-1,000 hours of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions, and perform the operator's field-calibration check as presented in Section 13. If the sampler's indicated flow rate exceeds the manufacturer-specified design flow-rate range, recalibrate the sampler before the next run day.

To achieve the best performance, new brushes should be seated properly on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50-75% of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30-45 min at normal line voltage.

Caution: Motors that are used for HV PM_{10} samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motor are different. Make sure that the correct replacement brushes are used for the maintenance of HV PM_{10} samplers.

14.2.2.6 If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV PM_{10} sampling. When lower-current motors are installed in HV PM_{10} samplers, the flow rate has been found to vary with changes in the line voltage.

14.3 Refurbishment of HV Samplers

If operated in the field for extended periods, HV PM_{10} samplers may require major repairs or complete refurbishment. If so, refer to the manufacturer's instrument manual before work is undertaken. A sampler that has undergone major repairs or refurbishment must be leak-checked and calibrated prior to sample collection.

15. REFERENCES

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TABLE 1. EXAMPLE OF BASIC CHARACTERISTICS OF SOME COMMON FILTER MATERIAL

QUARTZ FIBER FILTER (Glass Spun with Organic Binder)
! Whatman QMA Filter ! Maximum temperature of up to 540EC ! High Collection Efficiency ! Non-hydroscopic ! Good for Corrosive Atmospheres ! Fragile ! Lowest background metals content
CELLULOSE FIBER FILTER (Cellulose Pulp)
! Whatman # 41/MSA "s" ! Low Ash ! Maximum Temperature of 150EC ! High Affinity for Water ! Enhanced Artifact Formation for $SO_4^=$ and NO_3 ! Good for X-Ray/Neutron Activation Analysis ! Low Metal Content
MEMBRANE FILTER (Dry Gel of Cellulose Esters)
! Whatman #41 ! Fragile, Therefore Requires Support Pad ! High Pressure Drop ! Low Residue when Ashed

TABLE 2. EXAMPLE OF SUMMARY OF USEFUL FILTER PROPERTIES

Filter and Filter Composition	Density mg/cm^2	pH	Filter Efficiency %
Teflon® (Membrane) $(CF_2)_n$(2µm Pore Size)	0.5	Neutral	99.95
Cellulose (Whatman 41) $(C_6H_{10}O_5)_n$	8.7	Neutral (Reacts with HNO_3)	58% at 0.3 µm
Glass Fiber (Whatman GF/C)	5.16	Basic pH - 9	99.0
"Quartz" Gelman Microquartz	6.51	pH - 7	98.5
Polycarbonate (Nuclepore) $C_{15}H_{14} + CO_3$ (0.3µm Pore Size	0.8	Neutral	93.9
Cellulose Acetate/Nitrate Millipore $(C_9H_{13}O_7)_n$(1.21 µm Pore Size)	5.0	Neutral (Reacts with HNO_3)	99.6

TABLE 3. EXAMPLE OF MINIMUM SAMPLER SITING CRITERIA

Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
		Vertical	Horizontal[a]	
Micro	2 to 7	> 2	> 2	1. Should be > 20 meters from trees. 2. Distance from sampler to obstacle, such buildings, must be twice the height and the obstacle protrudes above the sampler. 3. Must have unrestricted airflow 270 degrees around the sampler inlet. 4. No furnace or incineration flues should be nearby.[b] 5. Spacing from roads varies with traffic (see 40 CFR 58, Appendix E). 6. Sampler inlet is at least 2 m but not greater than 4 m from any collocated PM_{10} sampler. (See 40 CFR 58, Appendix E.)
Middle, neighborhood, urban, and regional scale	2 to 15	> 2	> 2	

[a]When inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

[b]Distance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources.

TABLE 4. EXAMPLE OF ROUTINE MAINTENANCE ACTIVITIES FOR SAMPLERS

Equipment	Frequency and/or method	Acceptance limits	Action if requirements are not met
Sampler inlet	Dismantle and clean at manufacturer-specified internals	No obvious particulate deposits or damage	Clean, replace damaged equipment before sampling
Sampler base			
Power lines	Check for crimps or cracks	No obvious damage	Replace as necessary
Filter screen and throat	Visually check on sample-recovery days	No obvious deposits; clean with wire brush	Clean
Gaskets	At 3-mo intervals, inspect all gaskets in the sampler	No leaks; no compression damage evident	Replace as necessary
Brushes	Replace after 600-1,000 h of operation	Stable flow rate	Replace as necessary
Motor	Replace if needed	Correct model must be used	Obtain correct model
Flow controller	Check when flowrate changes are evident	Stable flow rate throughout sample run	Replace or repair if possible
Recording device	Inspection with experiencing difficulty in zeroing, or when large changes in flow rates occur	Recorder stays zeroed; chart advances; pen inks	Replace or repair if possible
Tubing, fittings	Visually inspect on sample-recovery days	No crimps, cracks, or obstructions; no crossthreading	Replace as necessary.

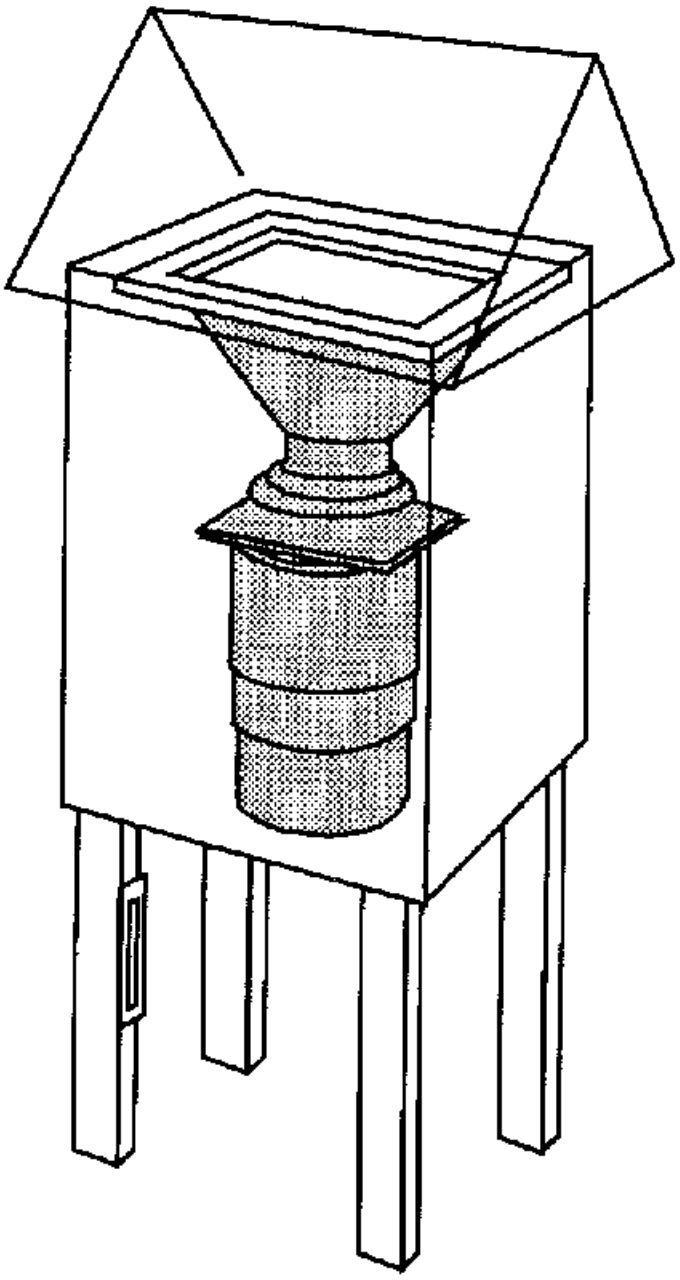

Figure 1. High-volume sampler with shelter.

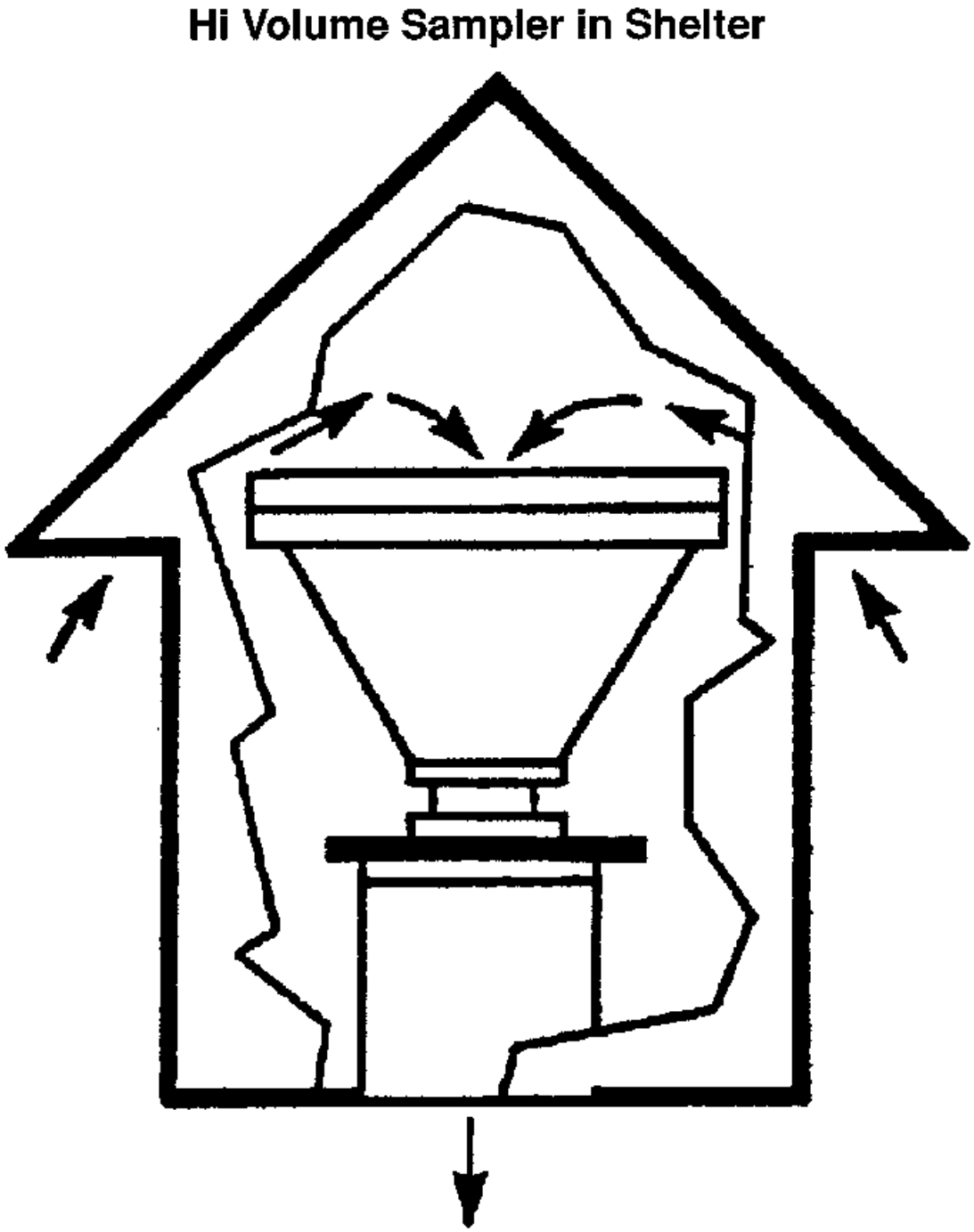

Figure 2. Inlet to EPA approved high volume sampler.

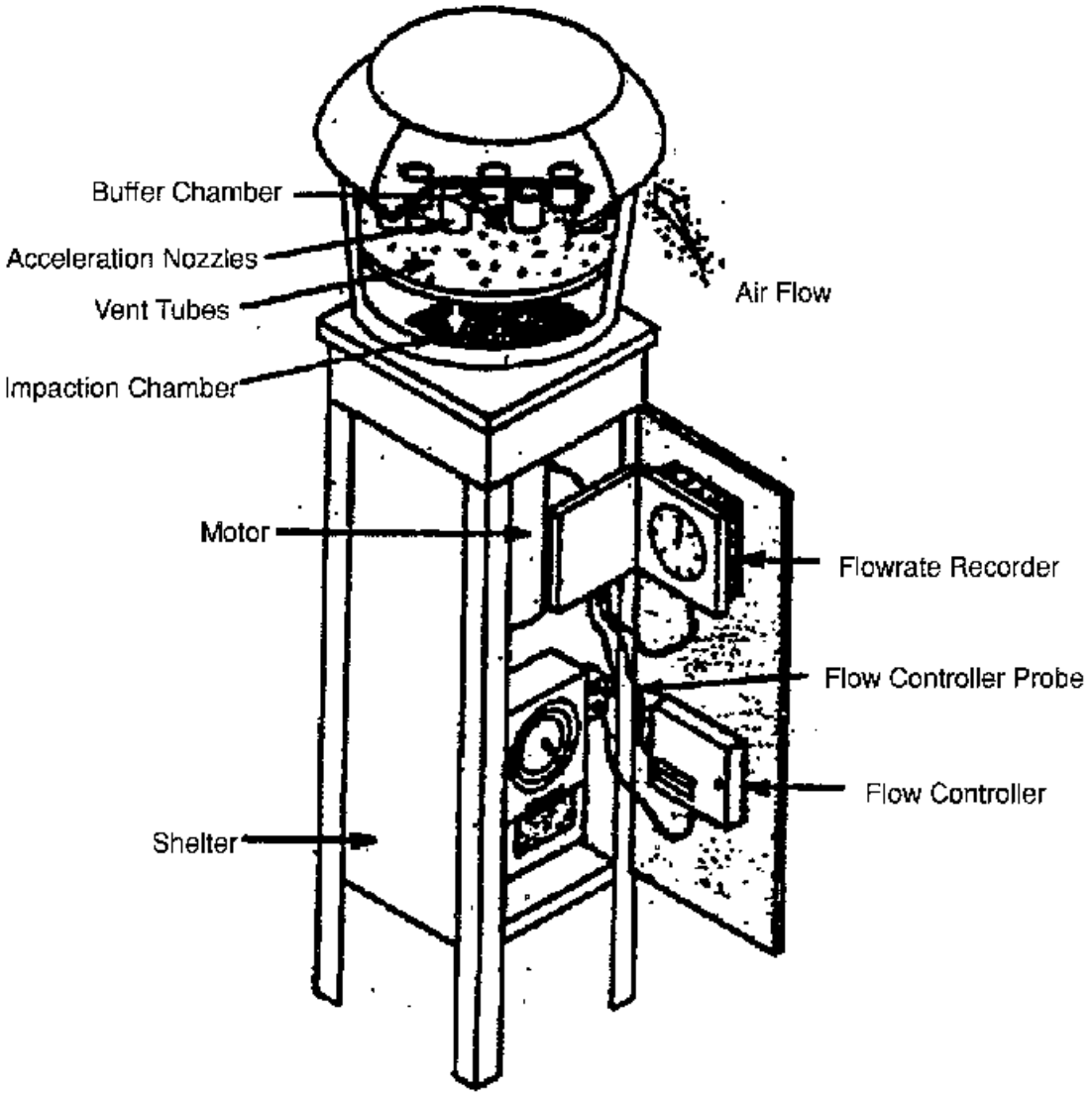

Figure 3. High-volume sampler with mass flow controller and impactor design size select inlet.

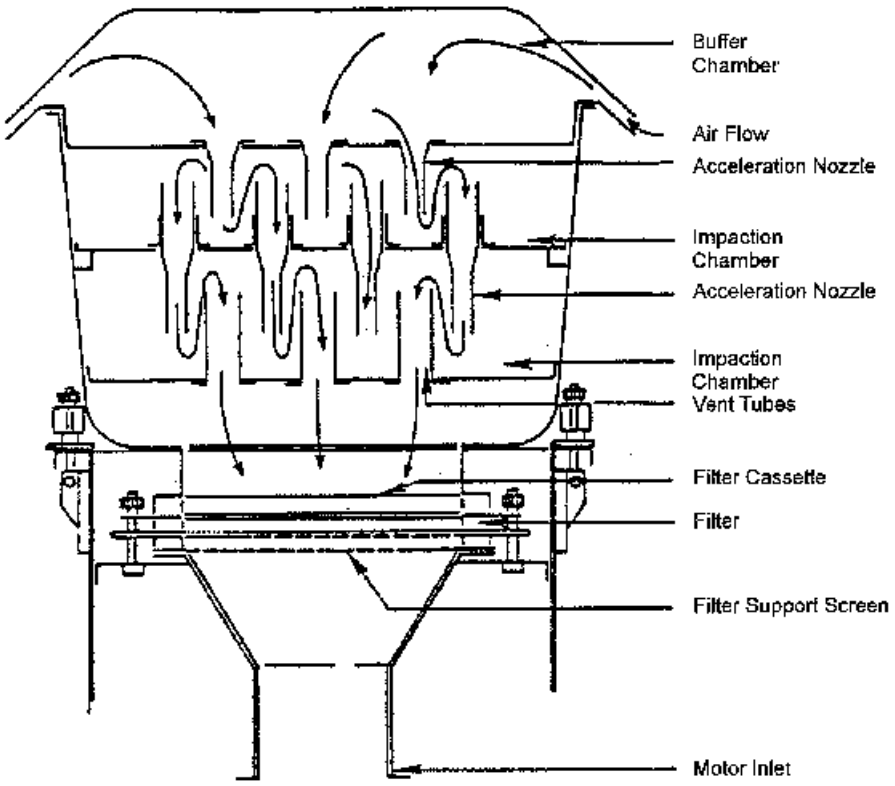

Figure 4. Schematic diagram of an impaction inlet for size select sampling for particulate matter.

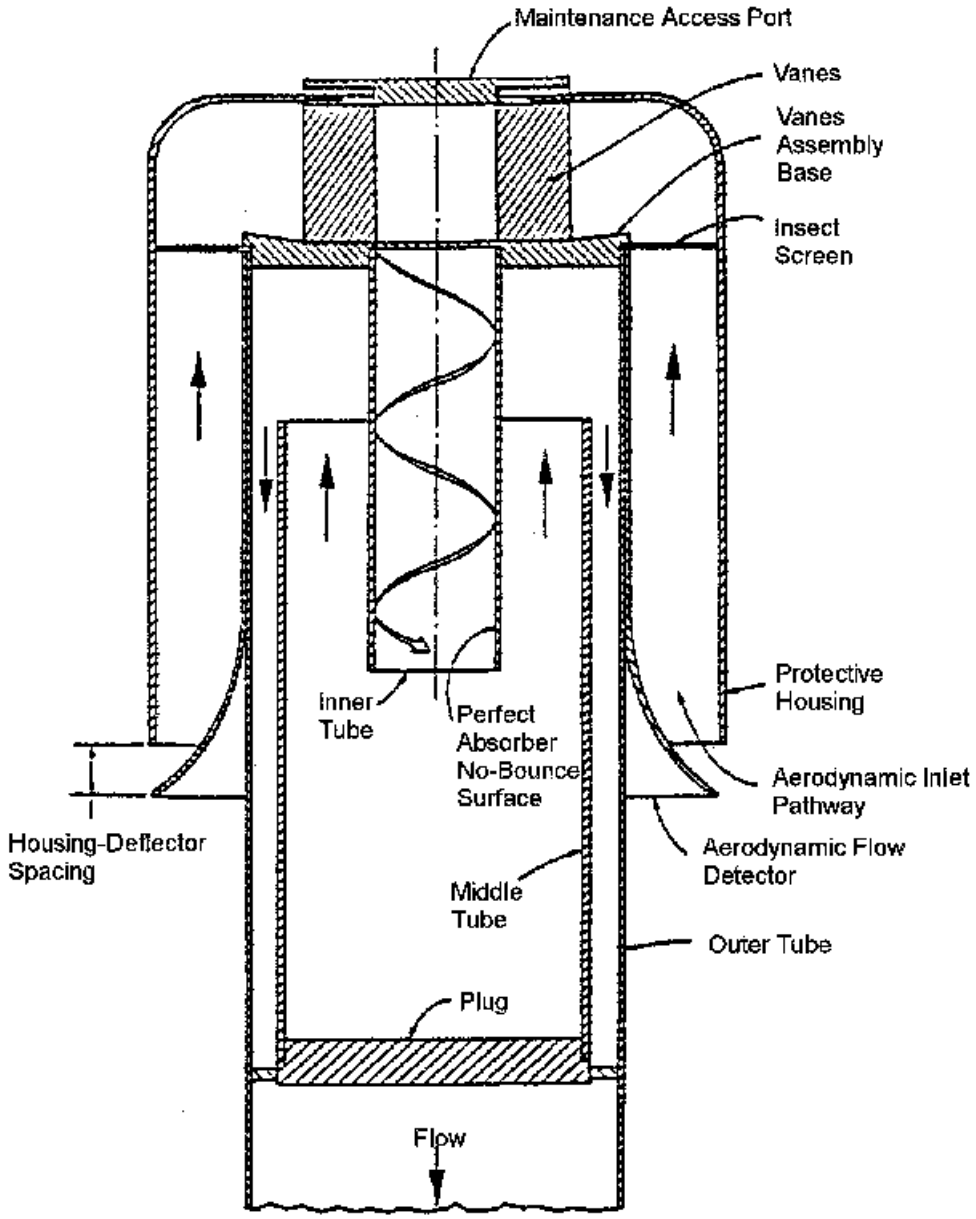

Figure 5. Schematic diagram of a cyclonic inlet for size select sampling for particulate matter.

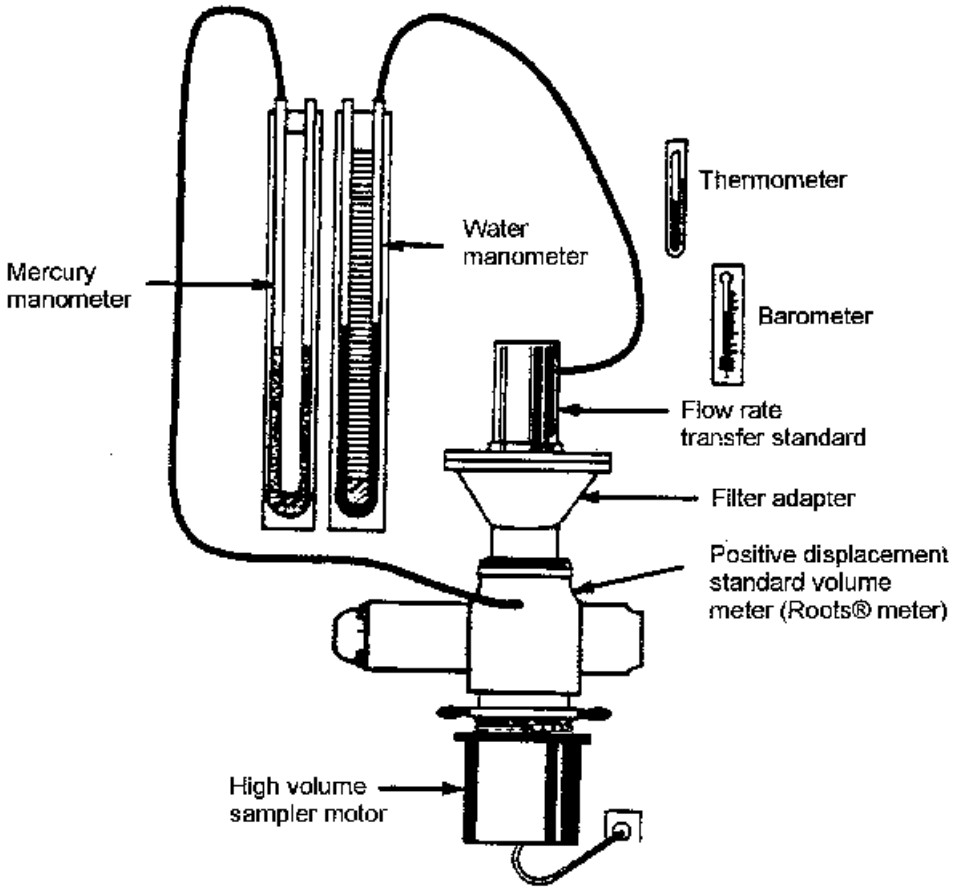

Figure 6. Flow rate transfer standard calibration setup.

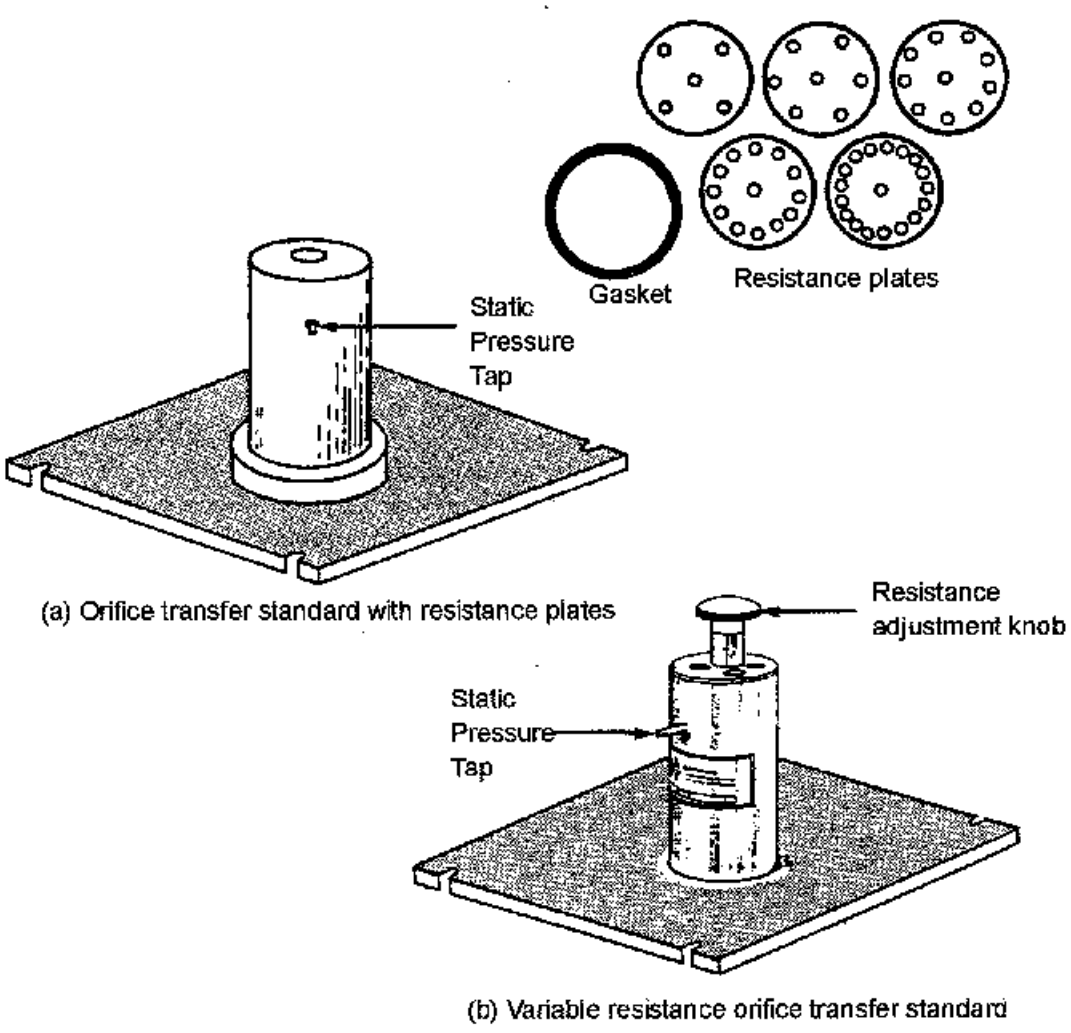

Figure 7. Typical orifice-type flow rate transfer standards.

ORIFICE TRANSFER STANDARD CERTIFICATION WORKSHEET

Date:	Roots meter S/N:	Ta:	K
Operator:	Orifice S/N:	Pa:	mm Hg

Plate or Volts AC	Initial Volume	Final Volume	Δ Vol.	ΔTime (min)	ΔHg (mm)	ΔH_2O (in.)

DATA TABULATION

Vstd	*(x-axis)* Qstd	*(y-axis)* $[\Delta H_2O\ (Pa/Ta)]^{1/2}$	Va	*(x-axis)* Qa	*(y-axis)* $[\Delta H_2O\ (Ta/Pa)]^{1/2}$
	m =			m =	
	b =			b =	
	r =			r =	

CALCULATIONS

Vstd = Δ Vol [(Pa − ΔHg)/760] (298/Ta)*
Qstd = Vstd/ΔTime*
y = mx + b

Va = ΔVol [(Pa − ΔHg)/Pa]
Qa = Va/ΔTime
y = mx + b

For subsequent flow rate calculations:

Qstd = {[ΔH_2O (Pa/Ta)]$^{1/2}$ − b} {1/m}*

Qa = {[ΔH_2O (Ta/Pa)]$^{1/2}$ − b} {1/m}

*NOTE: For PM10 monitoring, a calibration curve corrected to standard conditions is optional.

Figure 8. Example orifice transfer standard certification worksheet.

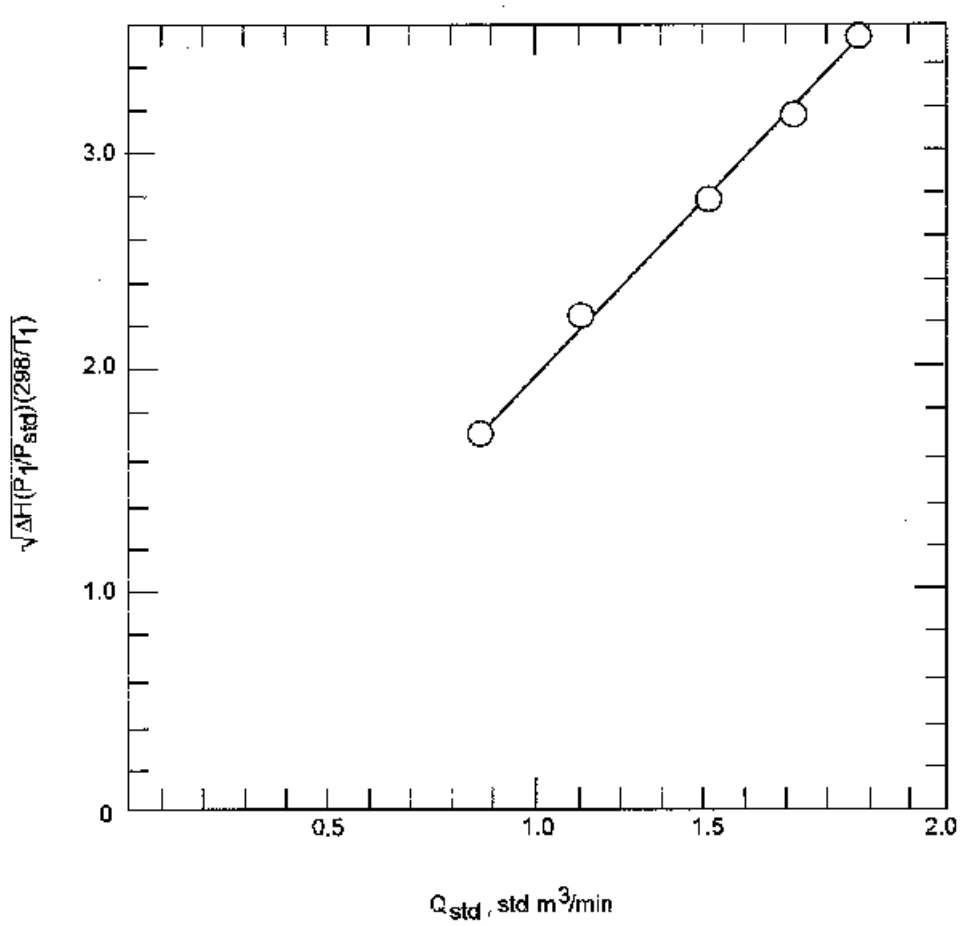

Figure 9. Typical calibration curve for a flow rate transfer standard.

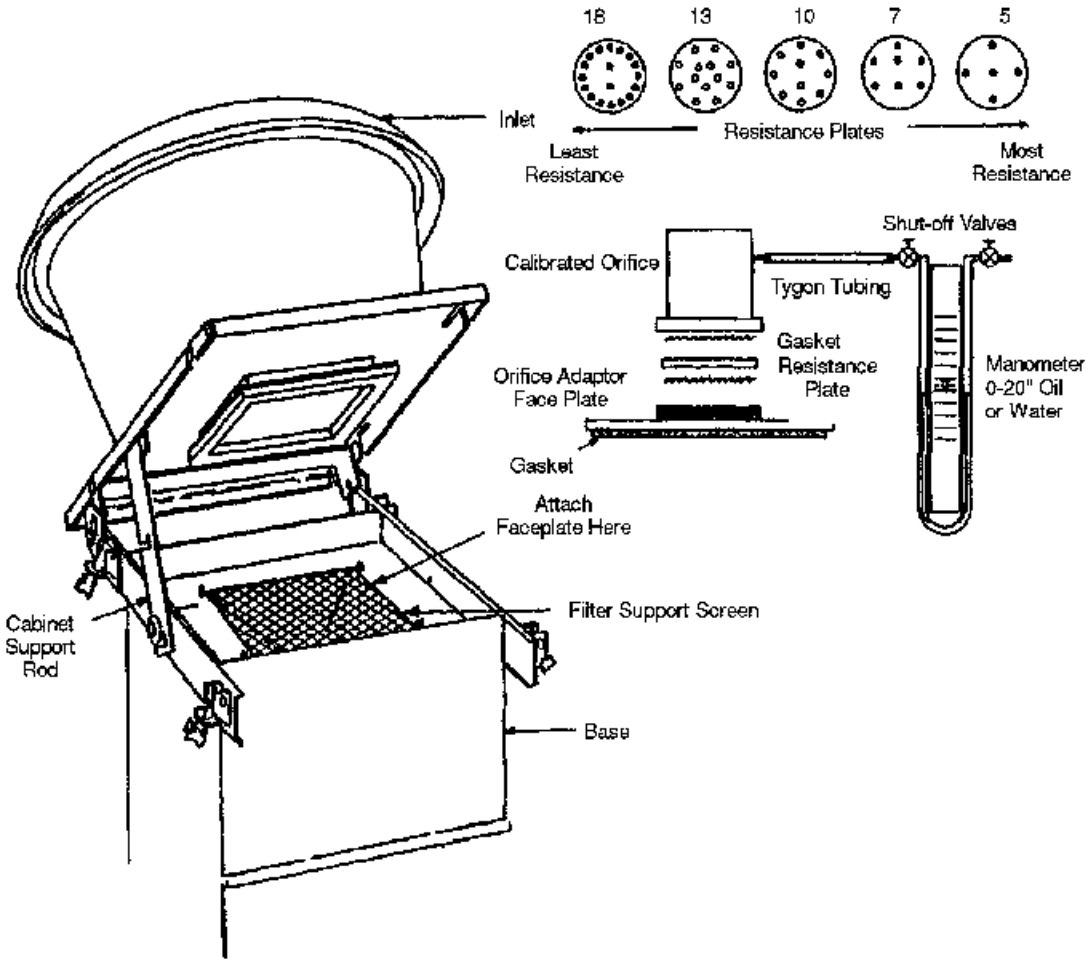

Figure 10. Typical calibration set-up for a mass flow controller (MFC).

MFC SAMPLER CALIBRATION DATA SHEET

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual conditions: _____

Ps* _____ mm Hg, Ts* _____ °C _____ K, (*seasonal average Ta and Pa)

Orifice S/N _____ Orifice Calibration Date _____

Orifice calibration relationship: m = _____ b = _____ r = _____

Plate Number	Total ΔH_2O (in.)	X-Axis = Qa (orifice) flow rate[a] (m^3/min)	Sampler ΔPex (in. H_2O) [or I for flow recorders]	Y-Axis = Sampler ΔPext[b] [or It for flow recorders][c]

[a] $Qa = \{[(\Delta H_2O)(Ta/Pa)]^{1/2} - b\}\ \{1/m\}$

[b] $\Delta Pext = \{\Delta Pex(Ta + 30)/Pa)\}^{1/2}$

[c] $It = [I]\ [(Ta + 30)/Pa]^{1/2}$ if a flow recorder is used

Sampler Calibration Relationship (Qa on x-axis; ΔPext or [It] on y-axis):
$\Delta Pext = m[Qa\ (Orifice)] + b$ or $It = m[Qa(Orifice)] + b$

m = _____ b = _____ r = _____

For subsequent calculation of sampler flow rate:
$\overline{Qa} = \{[\text{mean } \Delta Pex\ (Tav + 30)/Pav]^{1/2} - b\}\ \{1/m\}$
or $\overline{Qa} = \{\text{mean } I[(Tav + 30)/Pav]^{1/2} - b\}\ \{1/m\}$

Set point flow rate (SFR) _____
$SFR = 1.13\ (Ps/Pa)\ (Ta/Ts)$

Sampler set point (SSP) _____
$SSP = [Pa/(Ta + 30)]\ [m(SFR) + b]^2$
or $SSP = [Pa/(Ta + 30)]^{1/2}\ [m(SFR) + b]$ for flow recorders

Figure 11. Example MFC sampler calibration data sheet.

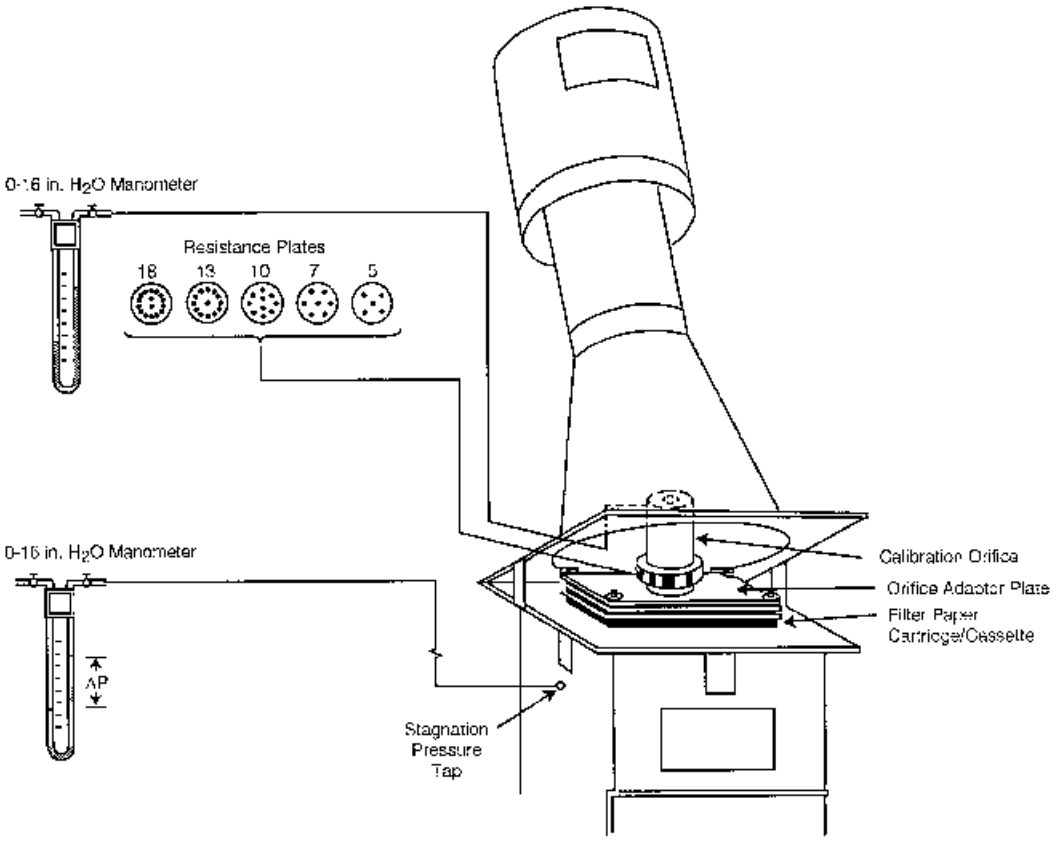

Figure 12. Calibration of a typical volumetric flow controller (VFC).

VFC SAMPLER CALIBRATION DATA SHEET

Station Location _____ Date _____ Time _____

Sampler Model _____ S/N _____ Operator _____

Pa _____ mm Hg, Ta _____ °C _____ K, Unusual Conditions _____

Orifice S/N _____, Orifice Calibration Date _____

Orifice Calibration Relationship: m = _____ b = _____ r = _____

Plate No.	ΔH_2O (in.)	ΔPstg (mm Hg)[a]	P1=Pa−ΔPstg (mm Hg)	P1/Pa (mm Hg)	Qa (orifice) flow rate[b] (m^3/min)	$\frac{Qa\ (orifice)}{[Ta]^{1/2}}$
Operational Flow Rate						

[a] mm Hg = 25.4 (in. H_2O/13.6)

[b] Qa (orifice) = 1/m {[(ΔH_2O) (Ta/Pa)]$^{1/2}$ − b}

[c] % Difference = $\left[\frac{Qa\ (sampler) - Qa\ (orifice)}{Qa\ (orifice)}\right]$ [100]

Qa (Orifice)	Qa (sampler) (Lookup Table)	% Difference[c]

Sampler Calibration Relationship

☐ Lookup Table Validated (i.e., % difference ≤ 4)

☐ New calibration relationship:

$X = \frac{Qa\ (orifice)}{[Ta]^{1/2}}$, Y = (P1/Pa)

m = _____ b = _____ r = _____

For subsequent calculation of sampler flow rate:

$Qa = \{[P1/Pa - b][Ta]^{1/2}\}\ \{1/m\}$

Operational Flow Rate _____ m^3/min

Figure 13. Example VFC sampler calibration data sheet.

MFC SAMPLER FIELD DATA SHEET

Station
Location _____ Date _____ SAROAD# _____

Sampler Model _____ S/N _____

Filter ID No. _____ Pav _____ mm Hg. Tav _____ °C _____ K

Sampler Manometer Readings

Initial ΔPex _____ in. H_2O

Final ΔPex _____ in. H_2O

Mean ΔPex _____ in. H_2O

Flow Recorder Readings

Mean I _____

Sampler Calibration Relationship: m = _____ b = _____ r = _____

$\overline{Qa}$ _____ m^3/min Elapsed Time _____ min

$\overline{Qa} = \{[\text{mean } \Delta Pex\ (Tav + 30)/Pav]^{1/2} - b\}\ \{1/m\}$

$\overline{Qa} = \{\text{mean I}\ [(Tav + 30)/Pav]^{1/2} - b\}\ \{1/m\}$ for flow recorders

Operator _____

Comments: _____

Laboratory Calculations:

$\overline{Qstd}$ _____ std m^3/min

$\overline{Qstd} = \overline{Qa}\ (Pav/Pstd)\ (Tstd/Tav)$

Vstd _____ std m^3

Vstd = $(\overline{Qstd})$ (elapsed time)

Gross weight (Wg) _____ g

Tare weight (Wt) _____ g

Net Weight (Wn) _____ g

PM10 Concentration _____ μg/std m^3

PM10 Concentration = (Wn) (10^6)/Vstd

Figure 14. Example MFC sampler field data sheet.

VFC SAMPLER FIELD DATA SHEET

Station Location _____ Date _____ SAROAD# _____

Sampler Model _____ S/N _____

Filter ID No. _____ Pav _____ mm Hg, Tav _____ °C _____ K

Relative Stagnation Pressure Readings

Initial ΔPstg _____ mm Hg

Final ΔPstg _____ mm Hg

Average ΔPstg = _____ mm Hg

Absolute Stagnation Pressure

$\overline{P1}$ = _____ mm Hg

$\overline{P1}$ = Pav − Average ΔPstg

Average Stagnation Pressure Ratio ($\overline{P1}$/Pav) _____

Average Flowrate ($\overline{Qa}$)* _____ m^3/min

*Obtained from manufacturer's lookup table (or from alternate calibration relationship)

Elapsed Time _____ min

Operator _____

Comments: _____

Laboratory Calculations:

$\overline{Qstd}$ _____ Std m^3/min

$\overline{Qstd}$ = $\overline{Qa}$ (Pav/Pstd) (Tstd/Tav)

Vstd _____ std m^3

Vstd = ($\overline{Qstd}$) (Elapsed Time)

Gross Weight (Wg) _____ g

Tare Weight (Wt) _____ g

Net Weight (Wn) _____ g

PM10 Concentration _____ μg/std m^3

PM10 Concentration = (Wn) (10^6)/Vstd

Figure 15. Example VFC sampler field data sheet.

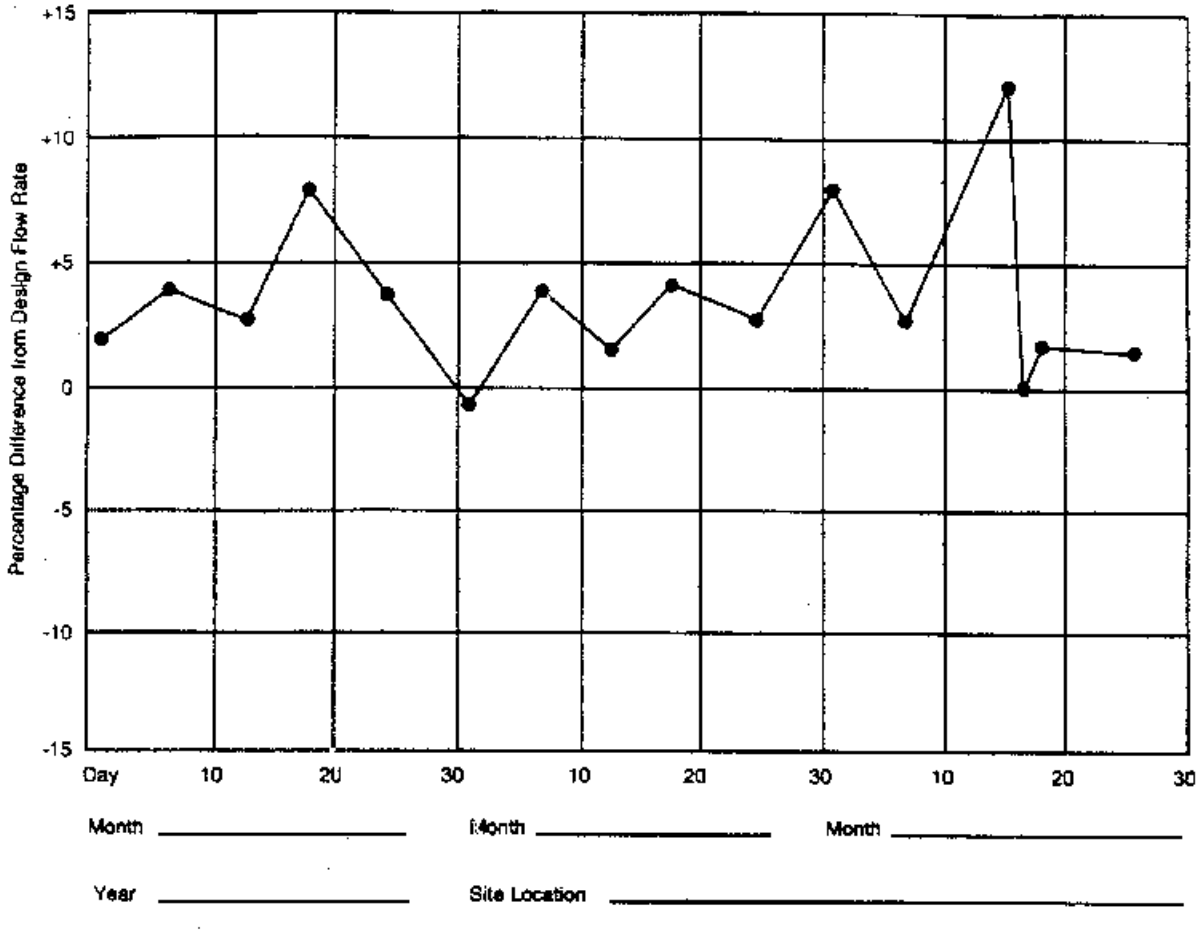

Figure 16. Field data control chart.

EPA/625/R-96/010a

Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air

Compendium Method IO-1.3

DETERMINATION OF PM_{10} IN AMBIENT AIR USING A CONTINUOUS RUPPRECHT AND PATASHNICK (R&P) TEOM® PARTICLE MONITOR

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

June 1999

Method IO-1.3

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DISCLAIMER

This Compendium has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Method IO-1.3
Determination of PM_{10} in Ambient Air
Using a Continuous Rupprecht and Patashnick (R&P)
TEOM® Particle Monitor
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Chapter IO-1

CONTINUOUS MEASUREMENT OF SUSPENDED PARTICULATE MATTER (SPM) IN AMBIENT AIR

Method IO-1.3
DETERMINATION OF PM_{10} IN AMBIENT AIR USING A CONTINUOUS RUPPRECHT AND PATASHNICK (R&P) TEOM® PARTICLE MONITOR

1. Scope

1.1 The area of toxic air pollutants has been the subject of interest and concern for many years. Recently the use of receptor models has resolved the elemental composition of atmospheric aerosol into components related to emission sources. The assessment of human health impacts resulting in major decisions on control actions by federal, state and local governments is based on these data. Accurate measures of toxic air pollutants at trace levels are essential to proper assessment.

1.2 Suspended particulate matter (SPM) in air generally is a complex, multi-phase system of all airborne solid and low vapor pressure liquid particles having aerodynamic particle sizes from below 0.01 µm to 100 µm and larger. Historically, SPM measurement has concentrated on total suspended particulates (TSP), with no preference to size selection.

1.3 The U. S. Environmental Protection Agency (EPA) reference method for TSP is codified at 40 CFR 50, Appendix B. This method uses a high-volume sampler to collect particles with aerodynamic diameters of approximately 100 µm or less. The hi-vol samples 40 and 60 ft^3/min of air with the sampling rate held constant over the sampling period. The high-volume design causes the TSP to be deposited uniformly across the surface of a filter located downstream of the sampler inlet. The TSP high volume can be used to determine the average ambient TSP concentration over the sampling period, and the collected material subsequently can be analyzed to determine the identity and quantity of inorganic metals present in the TSP.

1.4 Research on the health effects of TSP in ambient air has focused increasingly on those particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter less than 10 µm. Researchers generally recognize that these particles may cause significant, adverse health effects.

1.5 On July 1, 1987, the EPA promulgated a new size-specific air quality standard for ambient particulate matter. This new primary standard applies only to particles with aerodynamic diameters $\leq$ 10 µm (PM_{10}) and replaces the original standard for TSP. To measure concentrations of these particles, the EPA also promulgated a new federal reference method (FRM). This method is based on the separation and removal of non-PM_{10} particles from their size distribution, followed by filtration and gravimetric analysis of PM_{10} mass on the filter substrate.

1.6 Monitoring methods for particulate matter are designated by the EPA as reference or equivalent methods under the provisions of 40 CFR Part 53, which was amended in 1987 to add specific requirements for PM_{10} methods. Part 53 sets forth functional specifications and other requirements that reference and equivalent methods for each criteria pollutant must meet, along with explicit test procedures by which candidate methods or samplers are to be tested against those specifications. General requirements and provisions for reference

and equivalent methods are also given in Part 53, as are the requirements for submitting an application to the EPA for a reference or equivalent method determination.

1.7 Under the Part 53 requirements, *reference methods* for PM_{10} must use the measurement principle and meet other specifications set forth in 40 CFR 50, Appendix J. They must also include a PM_{10} sampler that meets the requirements specified in Subpart D of 40 CFR 53. Appendix J specifies a measurement principle based on extracting an air sample from the atmosphere with a powered sampler that incorporates inertial separation of the PM_{10} size range particles followed by collection of the PM_{10} particles on a filter over a 24-h period. The average PM_{10} concentration for the sample period is determined by dividing the net weight gain of the filter over the sample period by the total volume of air sampled. Other specifications are prescribed in Appendix J for flow rate control and measurement, flow rate measurement device calibration, filter media characteristics and performance, filter conditioning before and after sampling, filter weighing, sampler operation, and correction of sample volume to EPA reference temperature and pressure. In addition, sampler performance requirements in Subpart D of Part 53 include sampling effectiveness (the accuracy of the PM_{10} particle size separation capability) at each of three wind speeds and "50% cutpoint" (the primary measure of 10-micron particle size separation). Field tests for sampling precision and flow rate stability are also specified. In spite of the instrumental nature of the sampler, this method is basically a manual procedure, and all designated reference methods for PM_{10} are therefore defined as manual methods.

1.8 The protocol for operating the only continuous particulate mass monitor that directly measures particulate mass at concentrations between 5 $\mu g/m^3$ and several g/m^3 on a real-time basis is described in this method.

1.9 The Ruppecht and Patashnick TEOM® continuous monitor calculates mass rate, mass concentration, and total mass accumulation on exchangeable filter cartridges. In addition, the instrument provides hourly and daily averages.

1.10 The methodology detailed in this document is currently employed by such U.S. research organizations as the U.S. EPA, Argonne National Laboratory, R.J. Reynolds Tobacco Company, and Philip Morris, Inc. for indoor and outdoor air quality studies, aerosol behavior studies, and cigarette smoke behavior studies. It is used for ambient monitoring by agencies such as the California Air Resource Board (CARB), South Coast Air Quality Management District (SCAQMD), Northwest Air Pollution Authority, Puget Sound Air Pollution Control District and many others throughout the United States. By changing the size inlet separator the TEOM® can be used to meet the new $PM_{2.5}$ NAAQS.

2. Applicable Documents

2.1 ASTM Standards

- D1356 *Definitions of Terms Related to Atmospheric Sampling and Analysis*.

2.2 Other Documents

- Technical Manuals (1-2).
- Laboratory and Field Studies (3-19).

3. Summary of Method

3.1 Particle-laden air is drawn into the TEOM® monitor through an air inlet followed by an exchangeable filter cartridge, where the particulate mass collects. The inlet system may or may not be equipped with the optional sampling head, which pre-separates particles at either a 2.5 or 10 µm diameter.

3.2 The filtered air then proceeds through the sensor unit, which consists of a patented microbalance system.

3.3 As the sample stream moves into the microbalance system (filter cartridge and oscillating hollow tapered tube), it is heated to the temperature specified by the control unit. This is done to minimize the deposition of water due to changes in ambient humidity.

3.4 The control unit contains the automatic flow controller, which pulls the sample stream through the monitor at flow rates between 0.5 and 5 Lpm. The hollow tube is attached to a platform at its wide end and is vibrated at its natural frequency.

3.5 As particulate mass gathers on the filter cartridge, the tube's natural frequency of oscillation decreases. The electronic microbalance system continually monitors this frequency.

3.6 Based upon the direct relationship between mass and frequency, the instrument's microcomputer computes the total mass accumulation on the filter, as well as the mass rate and mass concentration, in real time.

3.7 The control unit contains software that allows the user to define the operating parameters of the instrumentation through menu-driven routines.

3.8 During sample collection, the program plots total mass, mass rate and/or mass concentration, and operating conditions on the 4-line liquid crystal display (LCD). Figure 1 illustrates the assembled TEOM® control and sensor unit.

4. Significance

4.1 SPM in ambient air generally is a complex, multi-phase system of all airborne solid and low vapor pressure particles from below 0.01 µm up to 100 µm and larger. Historically, measurement of particulate matter (PM) has concentrated on TSP, with no preference to size selection. Research on the health effects

of TSP in ambient and outdoor air has focused increasingly on particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter less than 10 µm. Researchers generally recognize that these particles may cause significant, adverse health effects.

4.2 Particles are formed by two processes: (1) the grinding or atomization of matter and (2) the nucleation of supersaturated vapors. The particles formed in the first process are products of direct emissions into the air, whereas particles formed in the second process usually result from reaction of gases, then nucleation to form secondary particles. Particle growth in the atmosphere occurs through gas-particle interactions and particle-particle (coagulation) interaction.

4.3 Recent studies involving particle transport and transformation suggest strongly that atmospheric particles commonly occur in two distinct modes. The fine, or accumulation, mode is attributed to the growth of particles from the gas phase and subsequent agglomeration, while the coarse mode is made up of mechanically abraded or ground particles. Particles that have grown from the gas phase, either because of condensation, transformation, or combustion, occur initially as very fine nuclei--0.05 µm. These particles tend to grow rapidly to accumulation mode particles around 0.5 µm, which are relatively stable in the air. Because of their initially gaseous origin, this range of particle sizes includes inorganic ions such as sulfate, nitrate, ammonia, combustion-form carbon, organic aerosols, metals (Pb), cigarette smoke by-products, and consumer spray-products.

4.4 Coarse particles, on the other hand, mainly are produced by mechanical forces such as crushing and abrasion. Coarse particles, therefore, normally consist of finely divided minerals such as oxides of aluminum, silicon, iron, calcium, and potassium. Coarse particles of soil or dust result from entrainment, the motion of air, or other mechanical action within their area. Since the mass of these particles is normally > 3 µm, their retention time in the air parcel is shorter than the fine particle fraction.

4.5 The composition and sources of coarse particles are not as thoroughly studied as those of fine particles; coarse particles are more complex than fine particles and similar in chemical composition. However, dozens of particle types, such as soil, limestone, flyash, and oil soot, are possible to recognize based on microscopic examination.

4.6 Outdoor concentrations of TSP are of major concern in estimating air pollution effects on visibility, ecological and material damage, and health effects. Consequently, a continuous particulate monitor has been developed to allow mass measurement of particulate concentration on a real-time basis. The monitor utilizes the filter-based measurement system for providing real-time mass monitoring capability.

5. Definitions

[Note: Definitions used in this document and any user prepared SOPs should be consistent with ASTM D1356. All abbreviations and symbols are defined with this document at the point of use.]

5.1 Air Pollution. The presence of unwanted material in the air. The term "unwanted material" here refers to material in sufficient concentrations, present for a sufficient time, and under circumstances to interfere significantly with comfort, health, or welfare of persons or with the full use and enjoyment of property.

5.2 Coarse and Fine Particles. Coarse particles are those with diameters (aerodynamic) greater than 2.5 µm that are removed by the sampler's inlet; fine particles are those with diameters (aerodynamic) less than 2.5 µm. These two fractions are usually defined in terms of the separation diameter of a sampler.

5.3 Filter. A porous medium for collecting particulate matter.

5.4 Mass Concentration. Concentration expressed in terms of mass of substance per unit volume of gas.

5.5 Particle. A small discrete mass of solid or liquid matter.

5.6 Particle Concentrations. Concentration expressed in terms of number of particles per unit volume of air or other gas. NOTE: On expressing particle concentration the method of determining the concentration should be stated.

5.7 Sampling. A process consisting of the withdrawal or isolation of a fractional part of a whole. In air or gas analysis, the separation of a portion of an ambient atmosphere with or without the simultaneous isolation of selected components.

5.8 Sampling, Continuous. Sampling without interruptions throughout an operation or for a predetermined time.

6. Interferences

6.1 The R&P TEOM® primary operating mechanism is the microbalance system, which relies upon changes in the frequency of an oscillating tapered element to determine changes in the particulate mass collected. Because of this characteristic, the instrument should be isolated from mechanical noise and should be located in the area to be measured so that external objects are not likely to disturb the instrument's enclosure or the air sampling tube. Additionally, the instrument should be located in an environment with minimal temperature fluctuations. The units operate effectively in environments with temperatures ranging between 7.2 and 52EC.

6.2 Although the instrument may retrieve a sample from indoor or outdoor environments, the sample stream temperature should be maintained within as narrow a range as possible. Large abrupt temperature fluctuations (7-8EF/min) of the sample stream may cause measurement accuracy to decrease due to the inlet system's inability to adjust the temperature of the sample to that specified by the software before traveling to the microbalance system. Sample temperature can range from ambient to 60EC.

[Note: For aerosols, such as cigarette smoke, that may contain substantial fractions of dissolved semivolatiles, heating the aerosol may decrease the apparent mass and may introduce errors into subsequent chemical analyses. As a precaution the TEOM® may be operated at low inlet temperatures (-30-35EC).]

7. Apparatus

The R&P TEOM® Series 1400a Ambient Particulate Monitor is comprised of two main components (see Figure 1): the TEOM® 1400a Control Unit and the TEOM® Sensor Unit. However, when purchased, these

units are not fully assembled. Therefore, the following section describes the components contained in these two main units which are available separately as needed.

7.1 TEOM® 1400a Control Unit

The control unit (see Figure 2) houses the mass flow controllers and the control electronics for operation of the TEOM® instrument.

7.1.1 The main electrical and air connections to the main power supply, the auxiliary control, and the main vacuum pump connections are located on the back panel.

7.1.2 The main power switch, status light, and the keypad for operating the control unit are located on the front panel. The keypad allows the user to define and adjust system parameters and functions once the software has been uploaded to the control unit. The status light flashes when there is a problem with mass flow rate, temperature, or filter loading.

7.2 TEOM® 1400a Sensor Unit

7.2.1 The sensor unit houses the mass transducer sensing unit and an electronic circuit board with the appropriate wiring for electricity and frequency signal output (inside enclosure on left hand side). Located on the outside left panel are the main electric and air connections. The enclosure houses the mass transducer sensing unit, sensor unit heater, and an amplifier circuit board that processes all signals from the mass transducer.

7.2.2 The back side of the enclosure contains a shipping latch that secures the sensor/preheater unit when moving or shipping the instrument.

7.3 TEOM® Sensor/Preheater Assembly

7.3.1 The TEOM® sensor/preheater assembly (see Figure 3) consists of the sensor inlet and the microbalance. The sensor inlet consists of a ½" diameter metal tube. The upper end of the tube is inserted directly into the flow splitter assembly, which allows a small portion of the total flow to be drawn through the sensor unit and the remaining air sample to be drawn through the bypass line. The lower end of the sensor inlet tube is connected to the microbalance top outer wall. The connection accommodates an air temperature probe assembly that controls the temperature of the air in the inlet tube. The ½" metal tubing between the flow splitter and the sensor unit is surrounded by thick insulation to help maintain a constant temperature of the inlet air stream.

7.3.2 The microbalance is an insulated cylindrical enclosure that houses a metal cylinder (the sensor head) the size of the inlet tube. The metal cylinder contains an oscillating tapered element, an electronic feedback system, and a filter cartridge. The tapered element is attached to a platform at its wide end (bottom) and has a small metal tip onto which the filter cartridge sits. The electronic feedback system consists of an amplifier board, which maintains the elements oscillation, and the electronics, which allow frequency signals to be transcribed to mass units. At the bottom of the microbalance, a silicone tube, which is connected to the mass flow controller in the control unit, carries the air sample.

7.4 TEOM® PM_{10} Inlet

The PM_{10} inlet (see Figure 4) is designed to allow only particulate matter #10 µm in diameter to remain suspended in the sample air stream as long as the flow rate of the system is maintained at 16.67 L/min. The monitor can be operated as a total suspended particulate monitor or as a PM_{10} monitor.

7.5 TEOM® Flow Splitter Assembly

The flow splitter assembly (see Figure 5) consists of two concentric hollow metal tubes. The outer tube is approximately 24" long and 1½" in diameter. The inner tube is approximately 12" long and ½" in diameter. The top of the assembly (outer tube) is configured to accommodate the PM_{10} Inlet (normal use) or the flow audit adapter (for calibration only). The lower end of the assembly consists a pipe fitting that allows for the inner tube to enter into the outer tube and make a leak-proof connection. Also at the bottom of the flow splitter assembly is the bypass air outlet. The inner tube is connected directly to the inlet tube of the sensor unit, and the bypass air outlet is connected to the bypass air line.

7.6 Electric and Air Cable Assembly

The electric and air cable assembly is used to connect the control unit to the sensor unit.

7.7 Filter Cartridge

The filter cartridge (see Figure 6) is a ½" diameter thin aluminum base (foil-like) assembly. The foil is crimped around the filter edges to contain it. Attached to the aluminum base is a water resistant plastic cone that fits onto the metal tip of the oscillating element.

7.8 Filter Exchange Tool

The filter exchange tool is a small fork with a 4" long handle, as illustrated in Figure 6. The lower part of the tool has two perpendicular connections. The top connection is an aluminum disc that is slightly smaller than ½" in diameter, which is made to fit over the filter face when assembling and disassembling. The bottom connection is a "U-shaped" fork. The tines of the fork straddle the cone of the filter cartridge during assembling and disassembling.

7.9 Other Components

The TEOM® has both a coarse and fine filter located within the sensor unit to protect additional components downstream. In addition, an oil-free pump is located in this unit to provide a constant vacuum during sampling.

8. Siting Requirements and Assembly

[Note: When the instrument is used outdoors, protect it from the elements, particularly rain. When the central instrument is installed in the outdoor environmental shelter, be certain the sampler tube leading out of the shelter roof has a watertight fit.]

8.1 Siting Requirements

8.1.1 As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a monitoring project is to select a site or sites where the collected particulate mass is representative of the monitored area.

8.1.2 Basic siting criteria for the placement of ambient air samplers are documented in Table 1. This list is not a complete listing of siting requirements; instead, an outline to be used by the operating agency to determine a sampler location. Complete siting criteria are presented in 40 CFR 58, Appendix E.

8.1.3 Additional factors not specified in the Code of Federal Regulations (CFR) must be considered in determining where the sampler will be deployed. These factors include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment. The sampler must be situated where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibrations, filter installation and recovery, flow checks and audits) involves transporting supplies and equipment to and from the monitoring site.

8.1.4 To ensure that adequate power is available, consult the manufacturer's instruction manual for the sampler's minimum voltage and power requirements. Lack of stable power source can result in the loss of many samples because of power interruptions.

8.1.5 The security of the sampler itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

8.2 Assembling the TEOM® Series 1400a Monitor

The TEOM® Monitor consists of two components (1) the control unit and (2) the sensor/preheater unit. A schematic diagram of the flow system is illustrated in Figure 7.

8.2.1 If the barbed hose fitting is not installed, attach the supplied barbed hose fitting to the back of the TEOM® control unit at the connection marked "Pump", as illustrated in Figure 8.

8.2.2 Make sure that the voltage setting on the card below the fuse (see Figure 8) is appropriate for installation. If not, remove the card and reinsert with proper voltage facing upward. The allowable voltage settings are 120 and 240 VAC. Contact your distributor representative if you need additional information about the proper voltage setting.

8.2.3 Insert the power cord into the socket.

8.2.4 Install the mating section of the mounting bracket (packaged separately from the control unit) by sliding the slotted end onto the Mounting Bracket section on the control unit and inserting the in-line filters into the push-to-connect fitting. Secure the two parts of the bracket together with thumb screws.

8.2.5 Attach the bypass fine particulate assembly (the dual-filter device) to the bypass flow fitting on the Mounting Bracket.

8.2.6 Identify the end of the electric and air connecting cable whose electrical connection fits into the "Sensor Unit" connector of the control unit. Insert the ¼" sensor flow line into the sensor flow fitting on the Mounting Bracket. Insert the **d** " bypass flow line into the open end of the bypass fine particulate assembly.

8.2.7 Attach the 28-pin electrical connector.

8.2.8 Attach an oil-free vacuum pump to the barbed hose fitting using a vacuum hose of at least ¼" inside diameter. The pump must be capable of maintaining 20" Hg vacuum at a flow of 16.7 L/min.

8.2.9 Install the sensor unit on a sturdy surface below the location of the flow splitter assembly. The sensor inlet should be directly below the flow splitter. Otherwise the particulate may settle out of the air stream and collect on the tubing walls.

8.2.10 Route the electric and air connecting cable to the sensor unit (see Figure 10) so that the cable is protected and the sample and bypass tubings are not kinked.

8.2.11 Make the electrical connection of the electric and air connecting cable at the 28-pin connector on the left panel of the TEOM® Sensor Unit (see Figure 10).

8.2.12 Connect the end of the small air tube (¼" diameter) to the air outlet on the left side wall of the sensor unit.

8.2.13 Remove the end cap from the top of the air inlet on the sensor unit.

8.2.14 Carefully remove all packaging materials, such as molded foam pack, from within the enclosure of the sensor unit. Then release the shipping latch located on the back panel of the sensor unit (see Figure 9). To do so, hold the mass transducer with one hand and use a coin or screwdriver in the other hand to turn the slot in the shipping latch counter clockwise. To retract the shipping latch fully, continue turning the slot until it will not turn any further. The mass transducer should be able to swing freely when it is unlocked.

8.2.15 Make sure that the electrical connection and air connection are in their attached positions, as illustrated in Figure 10.

[Note: The Series 1400a monitor uses push-to-connect fittings for all air lines. To engage the connection, the air tube must be pushed completely into the fitting so that the tube cannot be pulled out. To disengage the connection, push the small collar toward the fitting and pull on the tube.]

9. Installing the Flow Splitter and PM_{10} Inlet

The isokinetic flow splitter is used in combination with a second automatic flow controller to divide the sample flow into two components after the air steam passes through the PM_{10} sample inlet: 1) a main flow of 3 L/min for the TEOM® mass transducer and 2) an auxiliary flow of 13.67 L/min that is maintained by the second flow controller. The flow splitter should be located directly above the sample inlet of the TEOM® Sensor Unit (see Figure 11).

9.1 Loosen the nut on the bottom of the flow splitter and adjust the inner tube so that the end of the inner tube is 15.5 cm (6") from the open end of the outer tube (see Figure 5). Tighten the nut.

9.2 Mount flow splitter assembly in optional tripod or other rigid mounting device.

9.3 Drill a hole in roof to allow the sample tube to connect the flow splitter assembly and the TEOM® sensor unit (make sure the sensor unit can be placed directly underneath the flow splitter assembly).

9.4 Connect any sample tube extensions to exit of flow splitter and to the sample inlet on the TEOM® Sensor Unit with the push-to-connect fittings.

9.5 Install the bypass flow tubing (**d** " diameter) from the control unit to the bypass flow exit of the flow splitter through the same hole in the roof as the sample tube (see Figure 11).

9.6 Weatherseal the opening in the roof to avoid leaks.

9.7 Install the rain collection jar in the port on the side of the PM_{10} sample inlet.

9.8 Install the PM_{10} sample inlet over the open end of the flow splitter assembly.

9.9 Reverify that the inlet to the PM_{10} sample inlet is 1.8 to 2.1 m above the roof.

10. Exchanging the Filter Cartridge

Upon arrival of a new TEOM® series 1400a Ambient Particulate Monitor, the sensor unit will not be equipped with a filter cartridge. Therefore, follow the filter exchange procedures outlined below to prepare the instrument for operation. The new instrument comes with a box of 20 blank filter cartridges. Before proceeding with the exchange, some special precautions must be taken:

- Do not handle new TEOM® filter cartridges with fingers. Use the filter tool provided with the instrument to exchange filters.
- Do not exchange filter cartridges when the TEOM® system is taking data, (i.e., when the instrument is in the Run Mode). Filter cartridges should be exchanged either when the instrument is in the Initialization Mode, Data Stop Mode, or when the instrument is turned off.
- Keep the sample pump running to facilitate filter exchange.
- Store the box of filter cartridges and filter exchange tool inside the sensor unit enclosure to provide a warm, dry, safe storage location.

10.1 Loading the Filter Cartridge

10.1.1 Open the door of the sensor unit.

10.1.2 Locate the horizontal handle on the TEOM® mass transducer (shown in its upward position in Figure 3). Carefully rotate this handle upward. The TEOM® mass transducer then swings into its filter changing position (see Figure 6).

[Note: When the mass transducer is in this open position, the tapered element automatically stops vibrating to facilitate filter exchange.]

10.1.3 Remove a clean filter cartridge from its shipping/storage box using the filter exchange tool. The tool's upper metal disc should cover the filter's surface, while the lower tines of the fork should straddle the hub of the filter base.

10.1.4 Hold the filter exchange tool in line with the tapered element and lightly insert the hub of the filter cartridge onto the tip of the tapered element, as illustrated in Figure 12. Ensure that the filter is seated properly. The tools metal disc should be centered over the filter before pressure is applied. Apply downward pressure to set it firmly in place, which will reduce the chances of distorting the crimped filter (see Figure 6).

10.1.5 Remove the filter exchange tool by retracting it sideways until it clears the filter. Do not disturb the filter.

10.1.6 Gently move the horizontal handle to the down position to close the mass transducer. Allow the springs to pull it closed for the last centimeter so that the distinct sound of metal-to-metal contact is heard.

[Note: Do not let the TEOM® mass transducer slam closed from the full open position.]

10.1.7 Close and latch the door to the TEOM® Sensor Unit. Keep the door open for as short a time as possible to minimize the temperature upset to the system.

10.1.8 If the instrument is turned on, reset it by pressing < F1 > or < RUN > on the keypad of the TEOM® Control Unit.

10.1.9 After 5 min, open the sensor unit and mass transducer again. Press straight down on the filter cartridge with the bottom of the filter exchange tool. This pressure ensures that the filter cartridge is properly seated after is has experienced an increase in temperature. Then close the mass transducer and enclosure.

10.2 Removing the Filter Cartridge

[Note: Filter lifetime depends upon the nature and concentration of the particulate sampled. The lifetime is determined by the filter loading, as shown on the status line of the Main Screen of the TEOM® Control Unit. TEOM® filter cartridges must be exchanged when the filter loading value approaches 100%, which generally corresponds to a total mass accumulation of approximately 3 to 5 mg (about 14 to 21 days of sampling at an average PM_{10} concentration of 50 $\mu g/m^3$).]

10.2.1 Open the door of the sensor unit.

10.2.2 Locate the horizontal handle on the TEOM® mass transducer (shown in its upward position in Figure 3). Carefully rotate this handle upward. The TEOM® mass transducer then swings into its filter changing position (see Figure 6).

[Note: When the mass transducer is in this open position, the tapered element automatically stops vibrating to facilitate filter exchange.]

10.2.3 Using the filter exchange tool (see Figure 12), remove the filter cartridge from the mass transducer. Carefully insert the lower fork of the tool under the filter cartridge so that the fork straddle the hub of the filter cartridge. The tool's upper metal disc should be centered over the filter's surface, but not touching it. Gently lift the filter from the tip of the tapered element with a straight pull.

[Note: Never twist the filter or apply sideways force to the tapered element.]

10.2.4 Store the used filter or discard as necessary.

10.2.5 Use a Kimwipe to remove any particulate from the back side of the metal disc and the tines of the fork on the filter exchange tool. During the filter removal process, the filter may be heavily loaded with particulate. When the tool comes in contact with the filter, the particulate often will transfer to the tool due to a small static charge. Cleaning the filter exchange tool will prevent any particulate from being transferred to a new filter and thus increase filter life.

10.2.6 Remove a clean filter cartridge from its shipping/storage box using the filter exchange tool. Grasp the clean filter as instructed in Section 10.1.2. Do not touch the filter cartridge with your fingers; only use the exchange tool.

10.2.7 Follow the procedures detailed in Sections 10.1.3 through Section 10.1.8 to insert the clean filter cartridge onto the sensor head and resort the instrument to operation mode.

11. System Operation and Data Storage

Before the instrument procedures are implemented, follow the instructions detailed below or those found in Section 4 of the TEOM® Operator's Manual. Appendices A and B of the Operator's Manual contain helpful information about the program variables and instrument screens, respectively. Each variable and parameter used by the program is represented by a 3-digit code called a Program Register Code (PRC). The monitor's entire menu structure is summarized at the beginning of Appendix B of the Operator's Manual.

11.1 Instrument Start-Up

11.1.1 Supply power to the instrument at the appropriate voltage.

11.1.2 Press the "Power" button on the front panel of the TEOM® Control Unit. A screen appears on the instrument's four-line display showing the name of the instrument. Soon thereafter, the Main Screen appears (see Figure 13).

11.1.3 Turn on the pump to draw the sample stream through the system. After turning on the instrument, the "Check Status" light appears because the flow rates and temperatures are outside of tolerance when the monitor is powered up. The status light automatically turns off after all flow rates and temperatures return to within tolerance.

11.1.4 The instrument automatically resets itself when it is turned on. As part of this initialization procedure, the monitor waits until the flow rates and temperatures remain stable (within a narrow band) for ½ h before starting data collection, which ensures the validity of all data points computed by the system

11.1.5 Press < 8 > and < 9 > to move the cursor (" > ") up and down through the four-line display. The informational lines of the display scroll up as the < 9 > is pressed repeatedly.

11.1.6 If the Series 1400a monitor was received directly from R&P, the only change that needs to be made before the instrument can be used for EPA equivalent PM_{10} measurements is the input of the proper

seasonal average temperature and average pressure. The instructions for doing so are found in the unit's operating manual. If the instrument has been used before and the user desires to return it to its original settings, the user should first re-initialize the unit according to Section 11.5.1 before entering the seasonal average temperature and average pressure. Once these actions are taken, no additional keystrokes are necessary for the instrument to commence its operation.

11.2 Instrument Shutdown and Shipping

11.2.1 Press the "Power" button on the front panel of the TEOM® Control Unit. The four-line display becomes blank.

11.2.2 Turn off the vacuum pump.

11.2.3 Disconnect the TEOM® Control Unit from the electric supply.

11.3 Information Shown on the Main Screen

As is the case with all screens shown by the TEOM® Series 1400a monitor, the Main Screen is divided into two sections: (1) the status line on the top of the screen and (2) the three informational lines. If the screen contains more informational lines than can be viewed at one time, pressing the < 9 > repeatedly makes the informational lines scroll upward. The status line always remains visible. The Main Screen, which contains the most important data generated by the instrument and is the screen that is normally displayed by the monitor during operation of the unit, is shown in Figure 13.

The status line of the main screen provides an overview of important parameters such as filter loading, the instrument status condition, various types of operational settings, and the keypad protection status. The informational lines display mass concentration results in $\mu g/m^3$ for a number of averaging times, the total mass accumulation on the filter in µg, the current system temperature and flow rates, and diagnostic indicators.

11.3.1 Status Line on the Main Screen. The status line of the Main Screen provides a quick summary of the current operational condition of the instrument. The information contained in the fields of this line is summarized in Figure 13.

11.3.1.1 Status Condition. The status condition is a 1-4 number character code that summarizes the operational status of the instrument, indicating whether any exception condition exists. Whenever a status code other than "OK" is shown on the display, the instrument automatically turns on the light labeled "Check Status" on the front panel of the control unit. The status condition shown by the TEOM® Series 1400a monitor can consist of one or more codes, which are summarized in Table 2. Press < Main/Status > when the instrument is in the Main Screen to view an explanation of the current status conditions of the Status Code Screen. The < Main/Status > key toggles the instrument between the Main Screen and the Status Code Screen.

11.3.1.2 Operating Mode. The operating mode indicates the instrument's current operating setting and the type of data being computed by the monitor. An explanation of the different operating modes of the TEOM® are documented in Table 3.

11.3.1.3 Analog Output 1 Mode. The instrument normally transmits the values of three chosen variables in analog format through its three user-defined analog outputs. Analog output channel 1, however, can be defined to act in one of two different ways:

- If the "A/O 1" field of the Main Screen status line is blank, analog output 1 operates in its usual fashion; or

- If a " + " appears in the A/O a field, analog output 1 is also used as status watch indicator. When defined this way, analog output 1 transmits a full-scale signal (for example, 5 VDC if the channel is configured for 0-5 VDC operation) if a status condition exists in the temperatures, flow(s) or oscillation of the mass transducer. If no such status condition exists, analog output channel 1 operates in its usual fashion.

Press < F5 > to toggle the " + " in the A/O 1 field

11.3.1.4 Filter Loading. The value for filter loading indicates the fraction of the TEOM® filter cartridge's total capacity that has been used. Since this value is determined by the pressure drop of the main (sample) flow line, the instrument shows a non-zero value even if no filter is mounted in the mass transducer. New filters generally exhibit figures of 15-30%.

11.3.1.4.1 TEOM® filter cartridges must be exchanged before this figure reaches 100% to ensure the validity of the data generated by the instrument. At some point above 100%, the main flow drops below its set point.

11.3.1.4.2 If the filter loading percentage is high when a new TEOM® filter is placed on the mass transducer, or if the lifetime of TEOM® filter cartridges becomes noticeably shorter, this usually indicates the in-line filter in the main flow line probably needs to be exchanged.

11.3.1.5 RS-232 Mode. The RS-232 mode defines the current usage of the 9-pin RS-232 connectors on the front and back panels of the TEOM® Control Unit. The selection of the current RS-232 mode is made in the Set RS-232 Mode Screen. Alternatively, the instrument can be toggled between the None Mode (N) and Print On Line Mode (P) by pressing < F2 > .

11.3.1.5.1 Use the supplies 9-to-9 pin RS-232 cable when connecting the instrument to an IBM AT-compatible computer with a 9-pin RS-232 connector. If the computer has a 25-pin RS-232 connector, use the 9-to-9 pin RS-232 cable in combination with the 2-to-25 pin Computer Adapter.

11.3.1.5.2 The 9-to-25 pin Serial Cable is designed to connect the Series 1400a monitor to a serial printer.

[Note: Never connect two serial devices to the RS-232 ports of the instrument at once, which may cause the RS-232 features of the monitor to malfunction.]

11.3.1.6 Protection. The Series 1400a monitor incorporates three states of password protection. The user has access to all capabilities of the instrument when it is unlocked (U). In the low-lock setting (L), the user is prevented from editing any of the system parameters, but may view all screens and change the operating mode of the instrument to perform such functions as filter exchange. When the monitor is in its high lock mode (H), the user cannot make any changes from the keypad, including scrolling, except for turning off the high-lock mode with the proper password.

11.3.1.7 Time. Time is displayed on the instrument in 24-h format.

11.3.2 Informational Lines on the Main Screen. The informational lines of the Main Screen show the current values of important system variables. Additional lines of information can be viewed by scrolling this display up and down. Press < 8 > to move the cursor upward and < 9 > to move it downward. Because the Main Screen displays data computed by the instrument, none of these values can be edited by the user. An explanation of the data that can be viewed on the display is illustrated in Figure 13.

11.4 When to Exchange TEOM® Filter Cartridges

TEOM® filter cartridges must be exchanged before the figure for filter loading on the status line of the Main Screen reaches 100%. The "Check Status" light turns on and status code F is shown on the status line of the Main Screen when the filter loading percentage is greater then 90%.

11.5 Summary of Instrument Operation

The monitor is always in operating mode 1 when it is turned on. In this mode, the instrument waits until temperatures and flows have equilibrated before successively entering modes 2, 3, and 4. The unit normally resides in operating mode 4 and is fully operation in this setting. The location of the operating mode on the instrument's Main Screen is documented in Figure 13. Table 4 provides guidance associated with data notation.

11.5.1 The S mode (set mode) allows changing of operating parameters (i.e., temperature and flow rate). The X mode indicates that the normal operation of the instrument has been suspended and the monitor is "sleeping."

11.5.2 When in the Setup Mode (S), the user may change all of the possible system parameters. During instrument operation, on the other hand, the user is restricted to changing the values of only certain system variables.

11.5.3 Press < Data Stop > from any of the data collection modes (1, 2, 3, or 4) or when in the Stop All Mode (X) to enter the Setup Mode. The instrument automatically re-enters operating mode 1 if no keystrokes are entered on the keypad for 5 min when the monitor is in the Setup Mode. Otherwise, press < F1 > or < Run > to re-enter operating mode 1.

[Note: The instrument enters the Stop All Mode (X) after the < Stop All > key is pressed. The Stop All Mode is meant to be an emergency mode. When the instrument resides in this mode, the flow and output to the temperature control circuits ate turned off.]

11.5.4 Press < F1 > or < Run > to reset the instrument from any operating mode. This action causes the instrument to enter operating mode 1.

11.5.5 Reinitialize the Instrument. The instrument operating parameters shown in this manual are the initial settings for the monitor. Reinitialization resets the instrument to its original configuration.

11.5.5.1 If the Main Screen is not displayed on the instrument, press < Main/Status > to return the monitor to the Main Screen.

11.5.5.2 Press < Data Stop > to enter the Setup Mode.

11.5.5.3 Press < Shift > < Stop All > to reset the system variables to their original values.

11.5.5.4 Enter the appropriate average temperature and pressure for the sampling location.

[Note: The listing of Program Register Codes (PRC's) in Appendix A and the listing of screens in Appendix B in the Operator's Manual both contain a column entitle "Re-Init." These columns contain the new settings of each program variable after the above re-initialization routine is executed.]

12. System Calibration

This Section describes the calibration procedures for the TEOM® PM_{10} Monitor and the method for auditing flow rates and mass.

12.1 Overview of Calibration Procedures

The routine calibration procedures recommended for the instrument are as follows: flow controller calibration (software) is recommended every 6 mo, analog calibration every 1-2 yr, flow controller calibration (hardware) every yr, and mass calibration verification every 2 yr.

[Note: These calibration intervals provided are guidelines. Requirements for routine calibration are site-specific and may be defined better by the user as necessary.]

12.2 Flow Controller Calibration (Software)

12.2.1 Turn off the TEOM® Control Unit.

12.2.2 Disconnect the electric cable that links the control unit with the sensor unit.

12.2.3 Remove the Mounting Bracket with the in-line filters and flow lines from the back panel of the TEOM® Control Unit.

12.2.4 Turn on the TEOM® Control Unit and make sure that the pump is on.

12.2.5 Display the Set Temps/Flows Screen on the instrument by selecting "Set Temps/Flows" from the Menu Screen, or by typing 12 < Enter > . Press < f > and < i > to position the screen so that "F-Main" and "F-Aux" appear. Record the set points for the main and auxiliary flows.

12.2.6 Press < f > and < j > to position the cursor so that the lines entitled "T-A/S" and "P-A/S" appear on the screen. Note the existing settings for Average Temperature (on the left) and Average Pressure (on the left). If the monitor is not in the Setup Mode, press < Data Stop > . Then set the Average Temperature and Average pressure to the current local conditions at the flow meter.

12.2.7 Press < f > and < j > to position the cursor so that the lines entitled "FAdj Main" and "FAdj Aux" appear on the screen.

12.2.8 Attach a reference flow meter (such as a bubble meter, dry gas meter, or mass flow meter) to the location labeled "Sensor Flow" on the back panel of the TEOM® Control Unit. This reference flow meter should have been recently calibrated to a primary standard and should have an accuracy of 1% at 3 L/min.

12.2.9 Compare the TEOM® Series 1400a set point recorded in step 5 above with the flow rate indicated by the flow meter. This set point indication is in volumetric L/min. If a mass flow meter is being used, its reading must be adjusted for temperature and pressure to obtain volumetric flow under the test conditions. No adjustment is necessary in the case of a volumetric flow meter.

12.2.10 If necessary, edit the values for "FAdjMain" so that the volumetric flow rates indicated by the flow meter match the set point recorded in step 5 above. The value for "FAdjMain" can be incremented and decremented easily by pressing < f > and < j > keys during editing.

12.2.11 If a step adjustment greater than ±5% is necessary to calibrate the mass flow controller, a hardware calibration must be performed as documented in the Operator's Manual.

12.2.12 If your system has an auxiliary flow controller, repeat Sections 12.2.8 to 12.2.11 above, replacing the references to the Main Flow with Auxiliary (Bypass) Flow. Connect the flow meter to the port labeled "By-pass Flow" on the rear panel of the TEOM® Control Unit.

12.2.13 Change the values for Average Temperature and Average Pressure to their original values recorded in Section 12.2.6 (the seasonal average temperature and barometric values).

12.2.14 Turn off the TEOM® Control Unit.

12.2.15 Reattach the air lines and Mounting Bracket to the back panel of the TEOM® Control Unit.

12.2.16 Reconnect the electric cable that links the control unit with the sensor unit.

12.2.17 Turn on the TEOM® Control Unit.

12.3 Procedures for Analog Calibration

[Note: The following equipment is required to calibrate the instrument's analog input and output sections.
- *Calibrated 3 ½ digit multimeter*
- *30 cm Jumper wire (12").]*

12.3.1 Turn off the TEOM® Control Unit.

12.3.2 Remove the external cables from the Sensor and Auxiliary connectors on the back of the control unit.

12.3.3 Remove the bottom cover of the control unit.

12.3.4 Detach the ribbon cables connected to P2, P3 and P4 on the L-shaped analog Input/output board.

12.3.5 Note which channels are set for 0-2 VDC and 0-10 VDC (check jumpers W40-W47) on the analog output section and which ones are set of ±2 VDC and ±10 VDC (check jumpers W1-W15) on the analog input section.

12.3.6 Turn on the TEOM® Control Unit.

12.3.7 Press < Data Stop > to enter the Setup Mode.

12.3.8 Bring the Analog Calibration Screen onto the four-line display by selecting "Analog Calibration" from the Menu Screen or by typing 11 < Enter > when in any screen.

12.3.9 Enter "YES" on the line entitled "Calibrate" by pressing < Edit > < Yes > .

12.3.10 Move the cursor to the line shown as "A/O Value."

12.3.11 Place the " + " lead of the multimeter on white analog output test point 0 and the "-" lead on a black GND (ground) test point.

[Note: The readings on the Analog Calibration Screen are in percent of full scale (% FS) for both the inputs and outputs. Therefore, to output 6.500 VDC on a 0-10 VDC output channel, enter 65.000 on the line entitled "A/O Value." For a ±2 VDC input with 1 VDC applied to the channel, 50.000 would display for the analog input channel, indicating 50% of full scale.]

[Note: The potentiometers labeled TEMP and ALL GAIN should not be adjusted. They are preset at the factory.]

12.3.12 Set the "A/O Value" at 90.000 by entering < Edit > 90 < Enter > . This value causes the output on all installed analog output channels to be 90% of full scale. Monitor the multimeter for the proper readout while adjusting the appropriate GAIN ADJUSTMENT potentiometer for the analog output channel being calibrated.

12.3.13 Move the " + " lead of the meter to successive analog output channels; adjust the appropriate potentiometer if necessary. Be careful to note which channels are set for 2 VDC or 10 VDC output.

12.3.14 After the analog outputs are calibrated, set the "A/O Value" to 0.00. Then calibrate the analog input (A/D) section of the Analog Card by placing the " + " lead of the meter on the 0 test point of the analog outputs. Also, place the jumper from the 0 test point of analog outputs to the red 0 test point of the analog inputs.

12.3.15 Select analog input channel 0 on the Analog Calibration Screen by typing < Edit > 0 < Enter > when the cursor is on the line entitled "A/1 Chan." Enter a 90% of full scale output on the "A/O Value" line appropriate for the analog input channel being calibrated (either 90% of ±2 VDC or 90% of ±10 VDC). Monitor the meter to ensure that the proper voltage is being applied and look at the 4-line display to see what percentage of full scale the analog input is measuring. Adjust the appropriate potentiometer for the channel being calibrated to achieve the proper percentage of full scale.

12.3.16 Repeat Sections 12.3.10 through 12.3.15 for each analog input channel populated on the board. Remember to move the jumper to the new analog input channel.

12.3.17 Once the analog input calibration is complete, switch off the power to the instrument and replace all cables and connectors before restarting normal operation.

12.4 Flow Controller Calibration (Hardware)

[Note: R&P recommends that the analog calibration be performed prior to the mass flow controller (MFC) calibration. The procedure set forth in this Section specifies the use of a volumetric flow meter. If a non-volumetric flow meter (such as a mass flow meter) is used, convert the flow meter's indicated flow rate to a volumetric flow rate using the local temperature and pressure conditions at the flow meter. Follow the steps below to perform a hardware calibration of the main and auxiliary mass flow controllers in the TEOM® Control Unit. If the MFC's in the TEOM® Control Unit cannot be properly adjusted using the procedure below, refer to the Tylan FC-280 MFC Manual for more detailed troubleshooting, adjustment and repair techniques.]

12.4.1 Turn off the TEOM® Control Unit.

12.4.2 Disconnect the electric cable that links the control unit with the sensor unit.

12.4.3 Remove the top cover of the TEOM® Control Unit.

12.4.4 Remove the three-lobed knob that holds the hinged MFC mounting bracket to the chassis. Swing the bracket upward so that the MFC's are more easily accessed and place a support beneath the bracket.

12.4.5 Remove the wiring connectors from the tops of the MFC's. Then remove the silver-colored circuit board covers of the MFC's. Reinstall the wiring connectors.

12.4.6 Remove the Mounting Bracket with the in-line filters and flow lines from the back panel of the TEOM® Control Unit.

12.4.7 Turn on the TEOM® Control Unit.

12.4.8 Note the settings for Average Temperature and Average Pressure shown on the Set Tempa/Flows Screen. Press < Data Stop > to place the instrument in the Setup Mode. Then set the Average Temperature and Average Pressure to the current local conditions at the flow meter.

12.4.9 Reset the adjustment factors for both MFC's by changing the settings for "FAdjMain" and "FAdjAux" on the Set Tempa/Flows Screen to 1,000.

12.4.10 Perform the remaining steps of this procedure only after the TEOM® monitor has been run for at least 1 h.

12.4.11 Connect a reference volumetric flow meter (such as a piston meter, bubble meter, or dry gas meter) that has been recently calibrated to a primary standard to the port labeled-Sensor Flow (Bypass Flow for the auxiliary flow controller). Non-volumetric flow meters such as mass flow meters may also be used but must be corrected for ambient temperature and barometric pressure to equivalent volumetric readings. This reference flow meter should have a range of 0-5 L/min with an accuracy of better than $\pm$0.5%. If an auxiliary flow controller is incorporated in the TEOM® system, a reference should be used.

12.4.12 If a non-volumetric flow meter is used, calculate the readings on the reference flow meter that correspond to volumetric flow rates of 2.50, 5.00, 10.00 and 20.00 L/min using local temperature and barometric pressure.

12.4.13 With the Sample Pump line closed to the vacuum source (place a hose clamp on the vacuum line to ensure zero flow), adjust the ZERO potentiometer, R3, of the MFC until a reading of 0.00 $\pm$ 0.02 L/min is shown on the Set Temps/Flows Screen. The potentiometer R3 is located on the edge of the MFC circuit board closest to the base of the MFC.

12.4.14 Set the flow set point on the Set Temps/Flows Screen to the rated full scale flow of the test MFC. With the vacuum line open, adjust the GAIN pot, R9 (the potentiometer nearest the edge card connector on the MFC circuit board), until a full-scale reading (corresponding to 4.00 L/min or 20.0 L/min as computed in Section 12.4.11) is obtained on the reference flow meter to within $\pm$0.02 L/min (main flow) or $\pm$0.1 L/min (auxiliary flow).

12.4.15 Alternately close and open the vacuum source line while repeating the adjustments of steps 13 and 14 until both zero and full-scale readings are correct.

12.4.16 Set the flow set point on the Set Temps/Flows Screen to 50% of the full scale flow of the test MFC. Adjust the LINEARITY pot, R19, until a 50% full scale reading (corresponding to 2.5 L/min or 10.0 L/min as computed in step 11) is obtained on the reference flow meter to within $\pm$0.02 L/min (main flow) or $\pm$0.1 L/min (auxiliary flow).

12.4.17 Repeat a flow check at all three flows to confirm that correct final calibration values are within limits.

12.4.18 Repeat Sections 12.4.13 through 12.4.17 for the auxiliary MFC if one is present.

12.4.19 Reset the Average Temperature and Average Pressure on the Set Temps/Flows Screen to their original values as noted in Section 12.4.7 above through the Setup Routine. Exit the Setup Routine.

12.4.20 Turn off the TEOM® Control Unit.

12.4.21 Remove the wiring connectors from the tops of the MFC's. Replace the silver covers on the appropriate flow controllers, and reinstall the connectors.

12.4.22 Swing the MFC mounting bracket into its normal position. Lock it with the knob screw.

12.4.23 Remove the reference flow meter and reconnect the Mounting Bracket and flow lines to the TEOM® Control Unit. Replace the top cover of the TEOM® Control Unit.

12.4.24 Connect the electric cable that links the control unit with the sensor unit.

12.4.25 Turn on the TEOM® Control Unit.

12.4.26 Perform a system leak test.

12.5 Mass Transducer Calibration Verification

[Note: The calibration of the TEOM® mass transducer in the TEOM® Series 1400a monitor is determined by the mass transducer's physical mechanical properties. Under normal circumstances, the calibration does not change materially over the life of the instrument.

The TEOM® Series 1400a monitor is calibrated using entire TEOM® filter cartridges as calibration weights. Since the mass of the filter cartridge with particulate differs from the mass of a new filter cartridge by only a small fraction, calibrating the system with a calibration mass equivalent to the filter mass allows all measurements to be made at essentially the same operating point as the original calibration.]

12.5.1 Using a calibrated gravimetric balance, weigh five unused TEOM® filter cartridges to the nearest 0.1 mg. Keep each filter in a suitable storage container marked with its associated weight. If desired, these preweighed filters may be kept for future use.

[Note: It is not necessary to condition the filters to a constant temperature or relative humidity before this test since the filter material is relatively hydrophobic. Filter weights vary by less than 50 µg due to moisture content, out of a total filter weight of approximately 75 mg. Since the calibration constant error is proportional to the calibration weight error, the worst case K_o error is only 0.05/75 mg or 0.06%.]

12.5.2 Confirm that the Calibration Constant shown on the Set Hardware Screen is the same as that shown on the nameplate located on the left side of the mass transducer support cage.

12.5.3 Remove the PM_{10} sampling inlet. Replace the inlet with the Flow Audit Adapter (see Figure 14) that was supplied with the instrument. Open the valve of the Flow Audit Adapter and place the R&P-provided prefilter over the valve.

12.5.4 Disconnect the Bypass Flow Line where it connects to the Flow Splitter. Plug the exit of the Flow Splitter with the 3/8" Swagelok and cap supplied with the Flow Audit Adapter Kit.

12.5.5 Warm the TEOM® system with any filter cartridge that is not a calibration filter so that all temperatures are at their normal operating conditions for at least 1 h. The air flow through the system should be at its normal value during this period. Scroll through the Main Screen by pressing < 1 > and < 9 > until the Frequency is shown.

12.5.6 Open the mass transducer and remove the filter from the tip of the tapered element using the filter exchange procedure described earlier. Close the mass transducer and enclosure door. After the frequency has stabilized, record the frequency to within 0.001 Hz. Label this frequency FQ(1).

12.5.7 Open the mass transducer and place one of the preweighted filters on the tapered element using the filter exchange procedure earlier. Close the mass transducer and enclosure door. After the frequency has stabilized, record the frequency to within 0.001 Hz. Label this frequency F1(1).

12.5.8 Repeat Sections 12.5.6 and 12.5.7 for the remaining four filters. Use a consistent force in attaching all filters. Repeat the frequency measurement of F0 (no filter) each time to remove the effects of varying temperature from opening and closing the mass transducer.

12.5.9 For each of the 5 sets of data, calculate the K_o of the balance using the following formula:

$$K_o = (M_{filter})/[(1/f_1^2) - (1/f_o^2)]$$

where:

M_{filter} = gravimetric filter mass, g.
f_o = frequency without filter, Hz.
f_1 = frequency with filter, Hz.

12.5.10 Calculate the mean of the 5 values of K_o. Record this value.

12.5.11 Compute the standard deviation of the 5 values. Record this value both in gm-Hz and as a percentage of the mean. If the standard deviation is less than 1% of the mean, the mean value is the K_o of the instrument.

12.5.12 If the computed K_o differs by more than 2.5% from the K_o value shown on the nameplate located on the left side of the mass transducer support cage, contact R&P for further assistance. If this difference is less than 2.5%, do not change the Calibration Constant setting on the Set Hardware Screen.

12.5.13 Remove the Flow Audit Adapter and 3/8" Swagelok cap from the system and replace the PM_{10} sample inlet and Bypass Flow Line.

12.6 Flow Audit Procedure

[Note: This audit procedure for checking the flow rates in the TEOM® Series 1400a monitor is not difficult and can be done with minimal disturbance to the instrument's normal operating configuration.]

12.6.1 Reset the TEOM® Series 1400a monitor by pressing the < F1 > or < Run > keys on the front panel of the control unit. Please note that any data generated by the instrument during this audit procedure are invalid. Thus, a flow audit should be combined with a filter exchange.

12.6.2 Remove the PM_{10} sample inlet. Replace the inlet with the Flow Audit Adapter (see Figure 14) that was supplied with the instrument. Turn the valve of the Flow Audit Adapter to its open position to allow for air flow.

12.6.3 Scroll the Main Screen using < f > and < j > until the Main Flow and Auxiliary Flow appear on the four-line display. These data represent the actual volumetric flows as measured by the monitor's flow controllers. Confirm that these flows are within ± 2% of their set points (3.0 L/min for the main Flow and 16.7 L/min for the Main Flow plus Auxiliary Flow). Any greater deviation may indicate plugged in-line filters or other blockages in the system. If this is the case, correct the condition before proceeding.

12.6.4 Connect the Flow Audit Adapter to a suitable flow auditing device (such as a soap-bubble meter, dry gas meter, mass flow meter, etc.), capable of measuring 3.0 L/min and 16.7 L/min to an accuracy of ± 1% and having a pressure drop of less than 0.07 bar (1 psi). This flow meter should have been recently calibrated to a primary standard. Table 5 lists recommended transfer standards, their applicable flow ranges, references for transfer calibration procedures, and necessary equipment to perform calibrations. This table has been adopted from the EPA Quality Assurance Handbook for Air Pollution Measurement Systems [EPA 600/4-77-027A].

12.6.5 Read the total flow (nominally 16.7 L/min) on the audit flow meter. If a nonvolumetric flow meter is being used, make any corrections necessary to translate this reading to volumetric L/min at the current ambient temperature and barometric pressure. The volumetric flow measured by the audit flow meter must be 16.7 ± 1.0 L/min to be acceptable.

12.6.6 Disconnect the Bypass Flow Line where it connects to the Flow Splitter. Plug the exist of the Flow Splitter with the 3/8" Swagelok cap supplied with the Flow Audit Adapter Kit.

12.6.7 Read the main flow (nominally 3.0 L/min) on the audit flow meter. In a nonvolumetric audit flow meter is being used, translate this reading to volumetric L/min at the current ambient temperature and barometric pressure. The volumetric flow indicated by the audit flow meter must be 3.0 ± 0.2 L/min to be acceptable.

12.6.8 If either the Main or Auxiliary Flow is outside acceptable limits, the calibration procedures in Sections 12.2 and 12.4 must be performed.

12.6.9 Remove the cap from the exit of the Flow Splitter and replace the Bypass Flow Line.

12.6.10 To perform a system leak check, close the valve on the Flow Audit Adapter. Both the Main Flow and Auxiliary Flow should read less than 0.15 L/min on Main Screen. If one of the flows is greater than 0.15 L/min, the system is not leak tight. In this case, check hose fittings and other critical locations in the flow system for leaks.

12.6.11 Remove the Flow Audit Adaptor. Replace the PM_{10} inlet on the top of the Flow Splitter. The instrument is now back to its normal operating configuration.

12.6.12 Reset the TEOM® monitor by pressing < F1 > or < Run > . The instrument will automatically begin data collection after temperatures and flow rates have remained stable at their set points for ½ h.

13. Method Safety

This procedure may involve hazardous materials, operations, and equipment. This method does not purport to address all of the safety problems associated with its use. The user must establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to the implementation of this procedure. These activities should be part of the user's SOP manual.

14. Performance Criteria and Quality Assurance (QA)

Required quality assurance measures and guidance concerning performance criteria that should be activated within each laboratory are summarized and provided in the following section.

14.1 Standard Operating Procedures (SOPs)

14.1.1 SOPs should be generated by the users to describe and document the following activities in their laboratory:

- Assembly, calibration, leak check, and operation of the specific sampling system and equipment used;
- Preparation, storage, shipment, and handling of the sampler system;
- Purchase, certification, and transport of standard reference materials; and
- All aspects of data recording and processing, including lists of computer hardware and software used.

14.1.2 Specific instructions should be provided in the SOPs and should be readily available to and understood by the personnel conducting the monitoring work.

14.2 QA Program

The user should develop, implement, and maintain a quality assurance program to ensure that the sampling system is operating properly and collecting accurate data. Established calibration, operation, and maintenance procedures should be conducted regularly and should be part of the QA program. Calibration verification procedures provided in Section 13, operation procedures in Section 11, and the manufacturer's instruction manual should be followed and included in the QA program. Additional QA measures (e.g., trouble shooting) as well as further guidance in maintaining the sampling system are provided by the manufacturer. For detailed guidance in setting up a quality assurance program, the user is referred to the *Code of Federal Regulations* (see Section 15, Notation 18) and the *U. S. EPA Handbook on Quality Assurance* (see Section 15, Notation 19).

15. References

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2. Rupprecht & Patashnick, Co., Inc., *TEOM® Mass Monitoring Instrumentation: TEOM® Software Manual (TP3)*, Albany, NY, April 1988.

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17. Nagda, N. L., H. E. Rector, and M. D. Koontz, *Guidelines for Monitoring Indoor Air Quality*, Hemisphere Publishing Corporation, New York, NY, 1987.

18. 40 CFR, Part 58, Appendix A, B.

19. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II - Ambient Air Specific Methods (Interim Edition)*, EPA 600/R-94/038b.

TABLE 1. EXAMPLE OF MINIMUM SAMPLER SITING CRITERIA

Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
		Vertical	Horizontal[a]	
Micro	2 to 7	> 2	> 2	1. Should be > 20 meters from trees
Middle, neighborhood, urban, and regional scale	2 to 15	> 2	> 2	2. Distance from sampler to obstacle, such as buildings, must be twice the height that the obstacle protrudes above the sampler.
				3. Must have unrestricted airflow 270 degrees around the sampler inlet.
				4. No furnace or incineration flues should be nearby.[b]
				5. Spacing from roads varies with traffic (see (40 CFR 58, Appendix E).
				6. Sampler inlet is at least 2 m but not greater than 4 m from any collocated PM_{10} sampler. (See 40 CFR 58, Appendix E).

[a]When inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

[b]Distance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources. As a precautionary measure, the sampler should be placed at least 5 meters from the furnace or incinerator flue.

TABLE 2. EXPLANATION OF STATUS CONDITION CODES

Codes	Explanation
OK	No current exception conditions
M	Control unit is not receiving a frequency signal
T	Temperature(s) outside of operational bounds
F	Flow(s) outside of operational bounds
X	Filter nearing capacity-exchange filter. This status becomes active when the filter loading reaches 90%

TABLE 3. TEOM® OPERATING MODES

Mode	Operation
1	Mass values are not currently being computed because temperatures and flow rates are stabilizing. The temperatures and flow rates must remain within a very narrow band for ½ hr before the instrument enters mode 2. The system automatically enters mode 1 when it is turned on.
2	Data collection has begun, but the first total mass value has not yet been computed
3	The first total mass value has been computed, but mass concentration and mass rate are not yet available
4	Normal operation. All mass values are being computed.
S	Set Mode. Certain operating parameters such as temperatures and flow rates can only be changed in this mode because doing so during data collection (modes 1 and 4) would adversely affect the data from the instrument. Press < Dress Stop > to enter the Setup Mode from any other operating mode. To leave the Setup Mode and start data collection press either < F1 > or < Run > (monitor returns to mode 1). If the instrument remains in the Setup Mode for 5 min without any key being pressed on the keypad, the monitor automatically returns to mode 1.
X	Stop All Mode. This mode indicated that the normal operation of the instrument has been suspended, and that the monitor is "sleeping." In this mode, data collection ceases, the flow rates in the system drop to 0, and the output to the temperature circuits is turned off. This emergency state is activated by pressing < Stop All > on the instrument keypad. To leave this mode, press either < F1 > or < Run > to restart data collection (modes 1 to 4), or < Data Stop > to enter the Setup Mode.

TABLE 4. EXPLANATION OF DATA NOTATION

Data notation	Explanation
30-min MC	30-min average mass concentration. This value is updated every 30 min on the half hour (µg/m^3).
1-h MC	1-h average mass concentration. This value is updated every 60 min on the hour (µg/m^3).
8-h MC	8-h average mass concentration. This value is updated every 8 h (µg/m^3)
24-h MC	24-h average mass concentration. This value is updated every 60 min on the hour (µg/m^3).
Total mass	The amount of mass that has accumulated on the TEOM® filter cartridge since the most recent instrument reset < Run > (done by turning on the instrument, or pressing < F1 > or
Case temperature	Temperature of the TEOM® mass transducer (set point 50EC).
Air temperature	Temperature of the sample stream at the base of the heated air inlet (set point 50EC).
Cap temperature	Temperature of the upper part of the TEOM® mass transducer (set point 50EC).
Enclosure temperature	Temperature inside the sensor unit enclosure (set point 40EC).
Main flow	Actual volumetric flow rate through the main flow controller (set point 3 L/min), as measured by the main flow controller.
Auxiliary flow	Actual volumetric flow rate through the auxiliary flow controller (set point 13.67 L/min), as measured by the auxiliary flow controller.
Noise	Indication of how well the TOM mass transducer is performing. This figure should be less than 0.10 after the system has bene in operating mode 4 for at least ½ h.
Frequency	The oscillating frequency of the tapered tube in the TEOM® mass transducer. This figure varies from one Series 1400a monitor to another, but generally ranges between 150 and 400 Hz.

TABLE 5. EXAMPLE OF RECOMMENDED STANDARDS AND ASSOCIATED EQUIPMENT FOR FLOW RATE AUDITS

Transfer standard[a]	Optimum flow range Q_a	Equipment	Comments	Calibration equation[b,c]	Calibration of transfer standard reference
LFE (laminar flow element)	15.0-20.0 L/min	LFE Thermometer/barometer[d] Manometer[e], Filters, Adapter	Should have filtered air entering LFE. Subject to fluctuations due to temperature changes. Manometer must be used in its temperature range. Must equilibrate.	$(^{a}H_2O)(CF) = Q_{std}$	U. S. Environmental Protection Agency Procedures for Calibrating a Laminar Flow Element (LFE) against an NBS Calibrated LFE: Standard Operating Procedures EMSL/RTP SOP-QAD-003, November 1991
MFM (mass flow meter)	15.0-20.0 L/min	MFM Thermometer/barometer[d] Filters, Adapter	Recommended LCD display for outdoor use. Must equilibrate to ambient conditions.	$(Volts)(CF) = Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 21, EPA 600/4-77-027A, May 1977.
DGM L/rev (dry gas meter)	15.0-20.0 L/min	DGM Thermometer/barometer[d] Stopwatch,[f] Filters, Adapter	Should time through five revolutions. Repeat each timing 3 times.	$\frac{Volume}{time}(CF) \cdot Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 3.3 EPA 600/4-77-027B, August 1977.
Orifice	15.0-20.0 L/min	Orifice Thermometer/barometer,[d] Manometer,[e] Filters, Adapter	Good only in range $^{a}P < 8$ in.	$m\left[\left(H_2O\frac{P_a}{T_a}\right)^{1/2}\right] + b \cdot Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 2.2 EPA 600/4-77-027A. May 1977.

[a]Transfer standard should not cause more than 4.0" of H_2O flow resistance to the sampler flow.
[b]Traceable and referenced to EPA standard conditions:

$$Q_a = Q_{std}\left[\frac{T_a}{P_a}\right]\left[\frac{P_{std}}{T_{std}}\right]$$

[c]Calibration equations for determining flow rates may vary from those presented due to the transfer standard calibration relationship. CF = correction factor.
[d]Thermometer capable of measuring temperature to the nearest $\pm$1C. Barometer capable of accurately measuring barometric pressure to the nearest $\pm$1 mm Hg.
[e]The design or size of the LFE or orifice will determine the manometer range necessary and the resolution. The manometer resolution must be capable of detecting a flow change of 1% and represent a flow resistance less than 4.0" H_2O.
[f]Stopwatch or timer capable of accurately measuring time intervals of 30 s to several minutes to nearest 0.1 s.

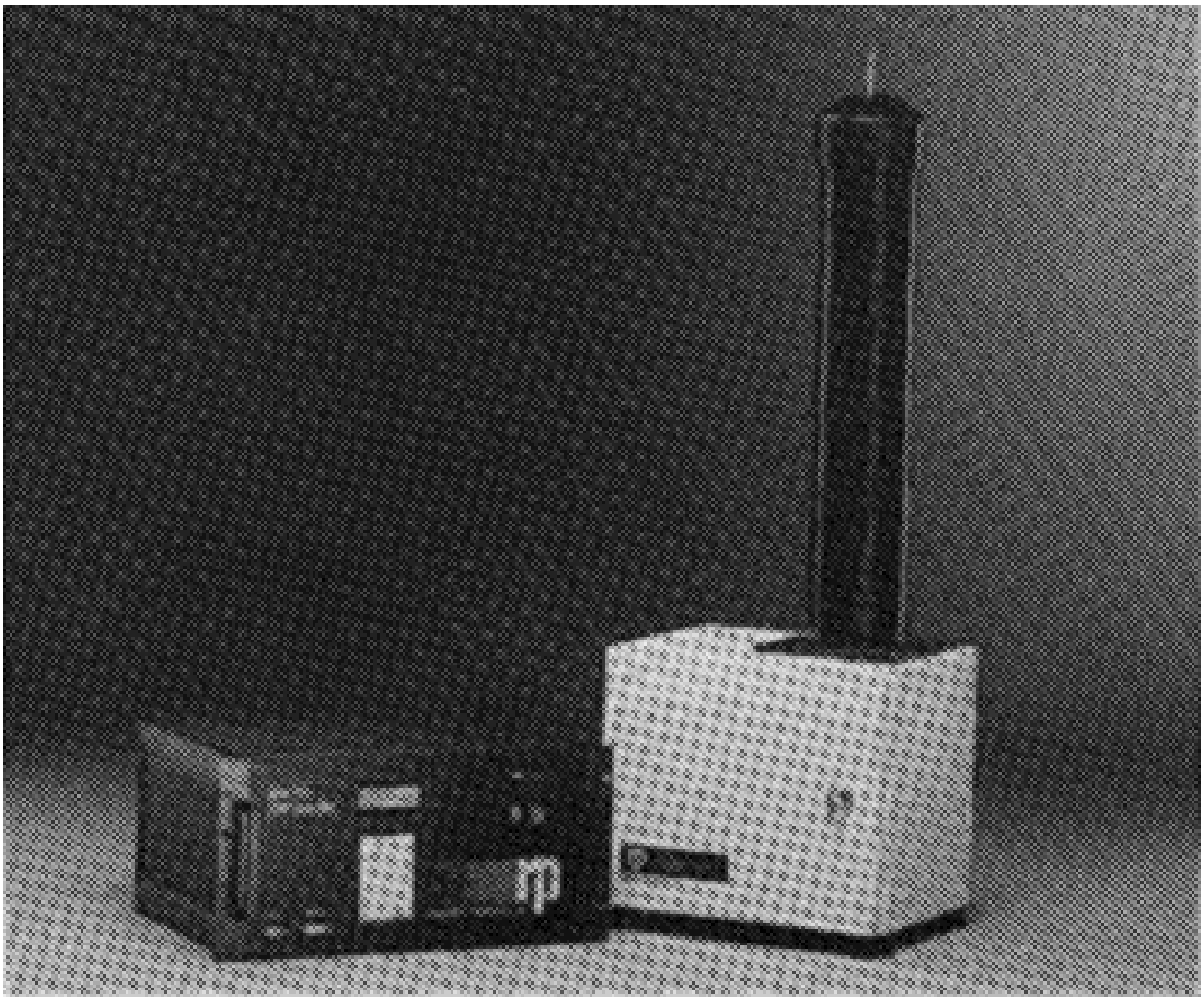

Figure 1. Example of TEOM® control and sensor unit.

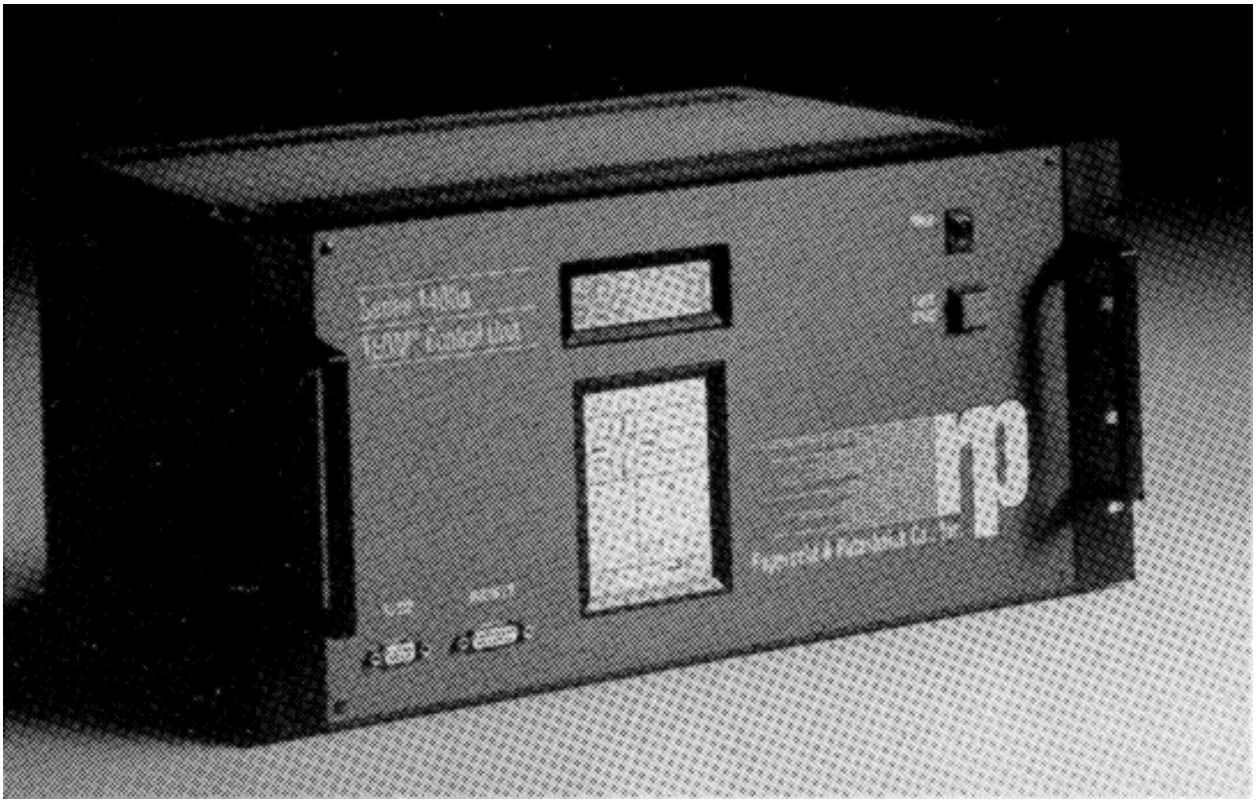

Figure 2. TEOM® control unit front panel.

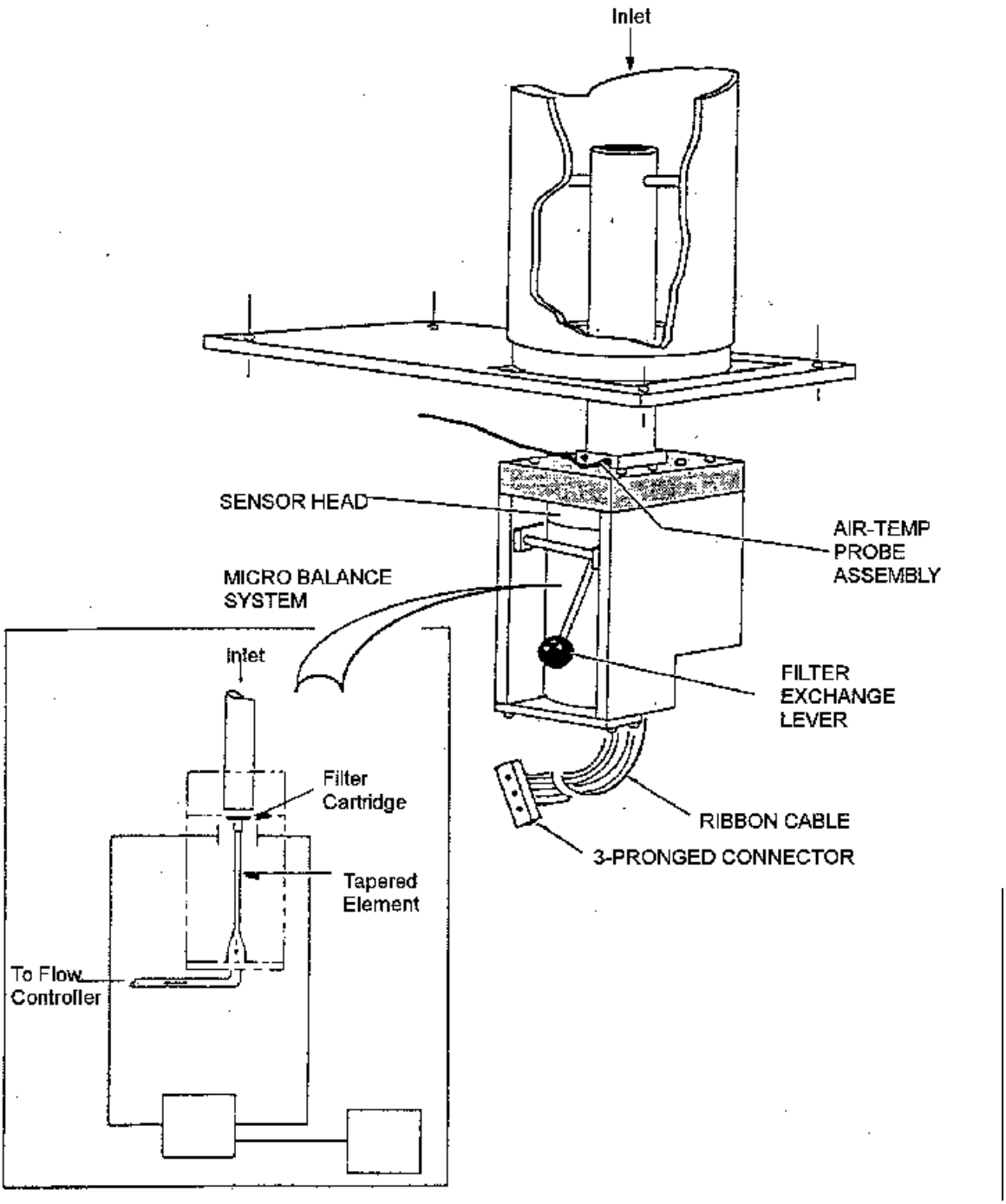

Figure 3. TEOM® sensor/preheater assembly.

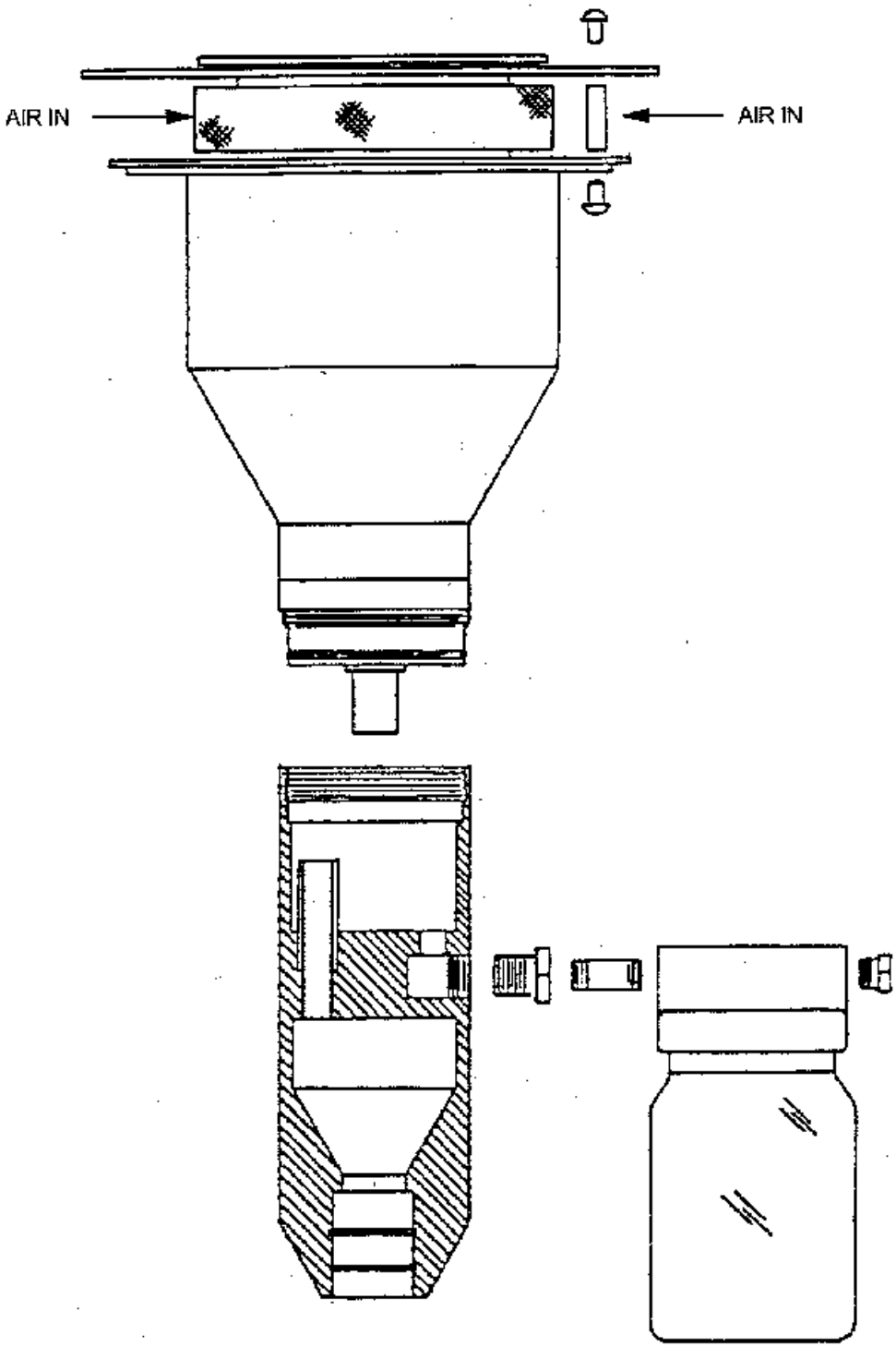

Figure 4. TEOM® PM_{10} inlet.

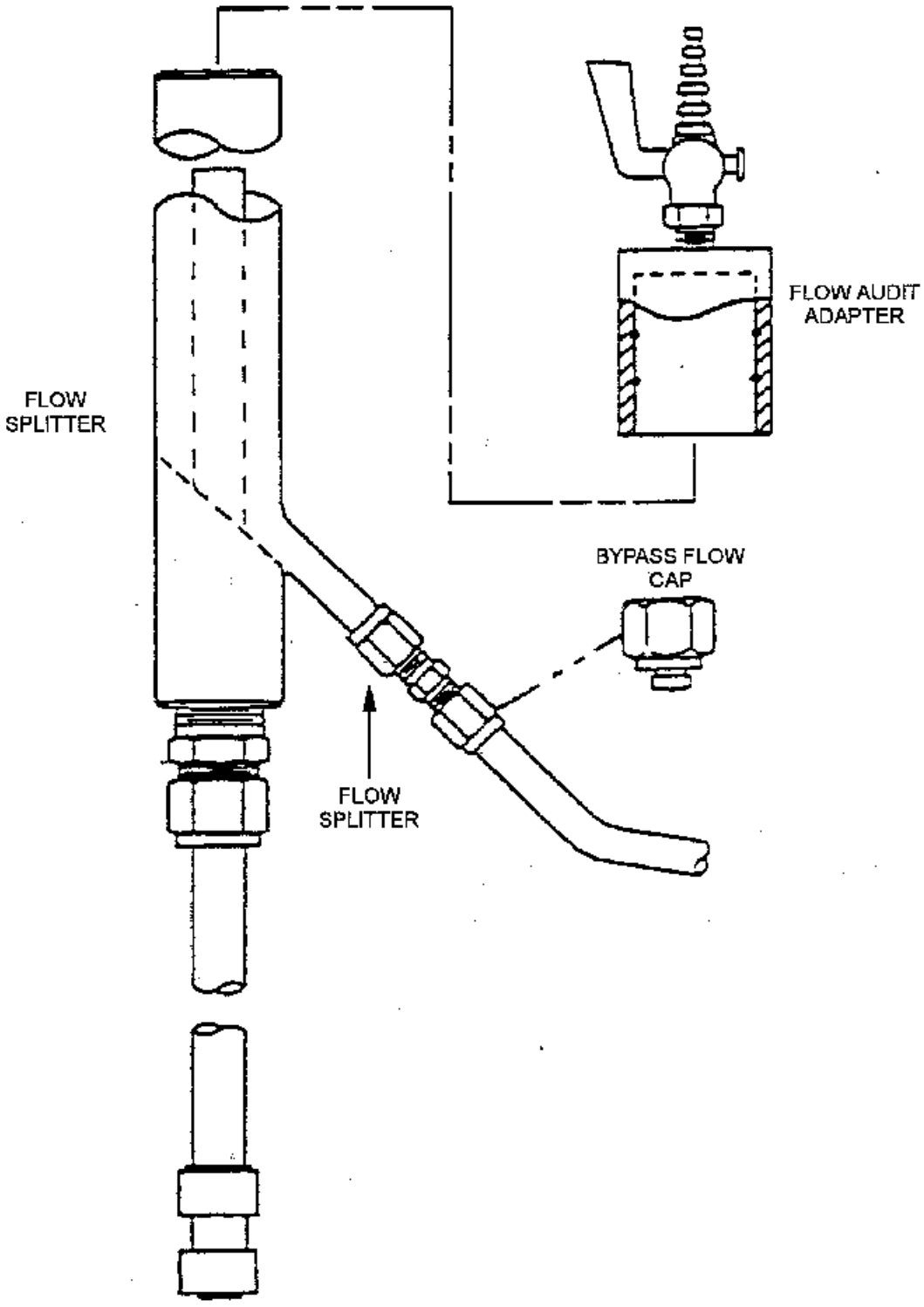

Figure 5. TEOM® flow splitter assembly.

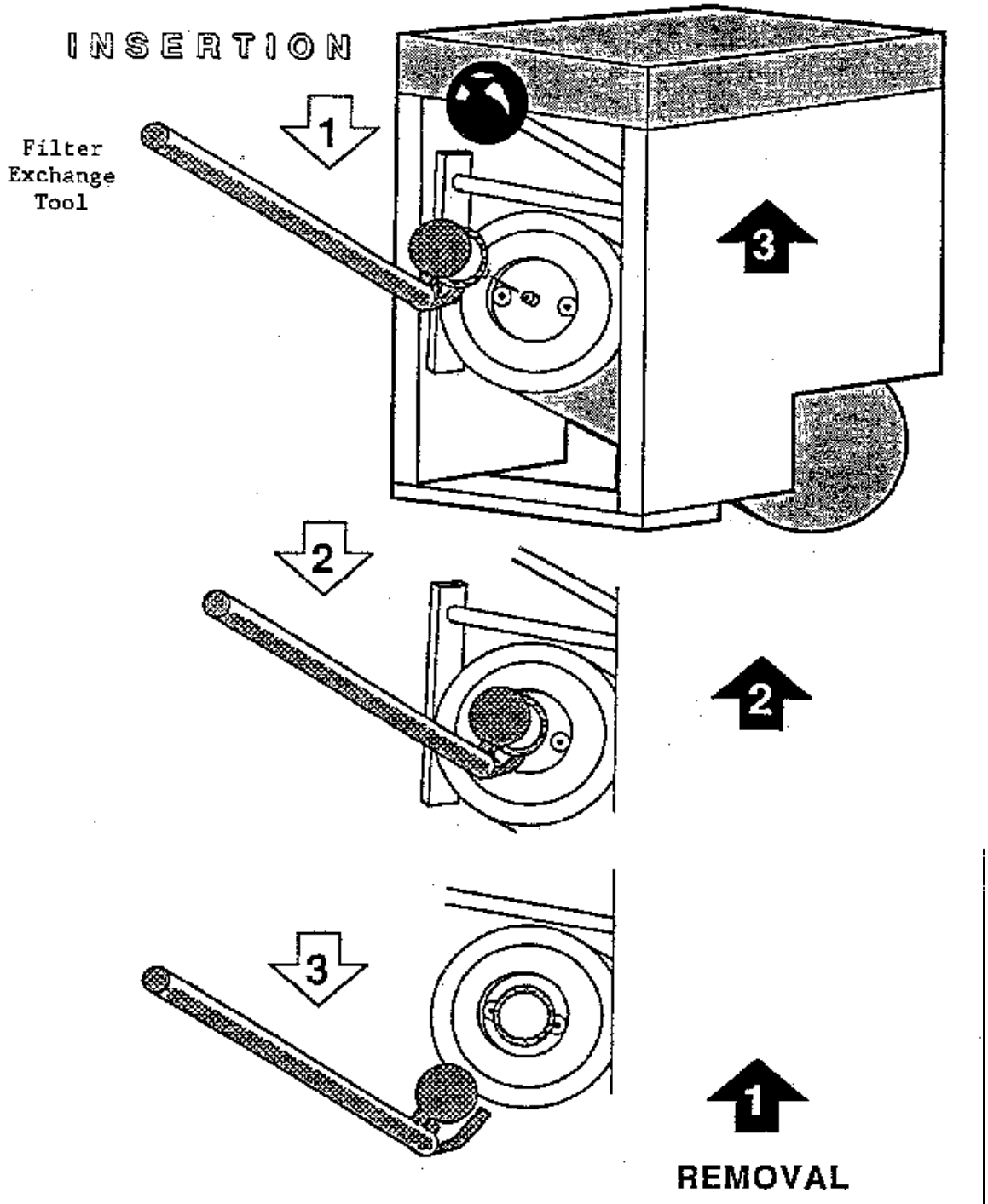

Figure 6. TEOM® filter cartridge assembly illustrating loading and removing filter.

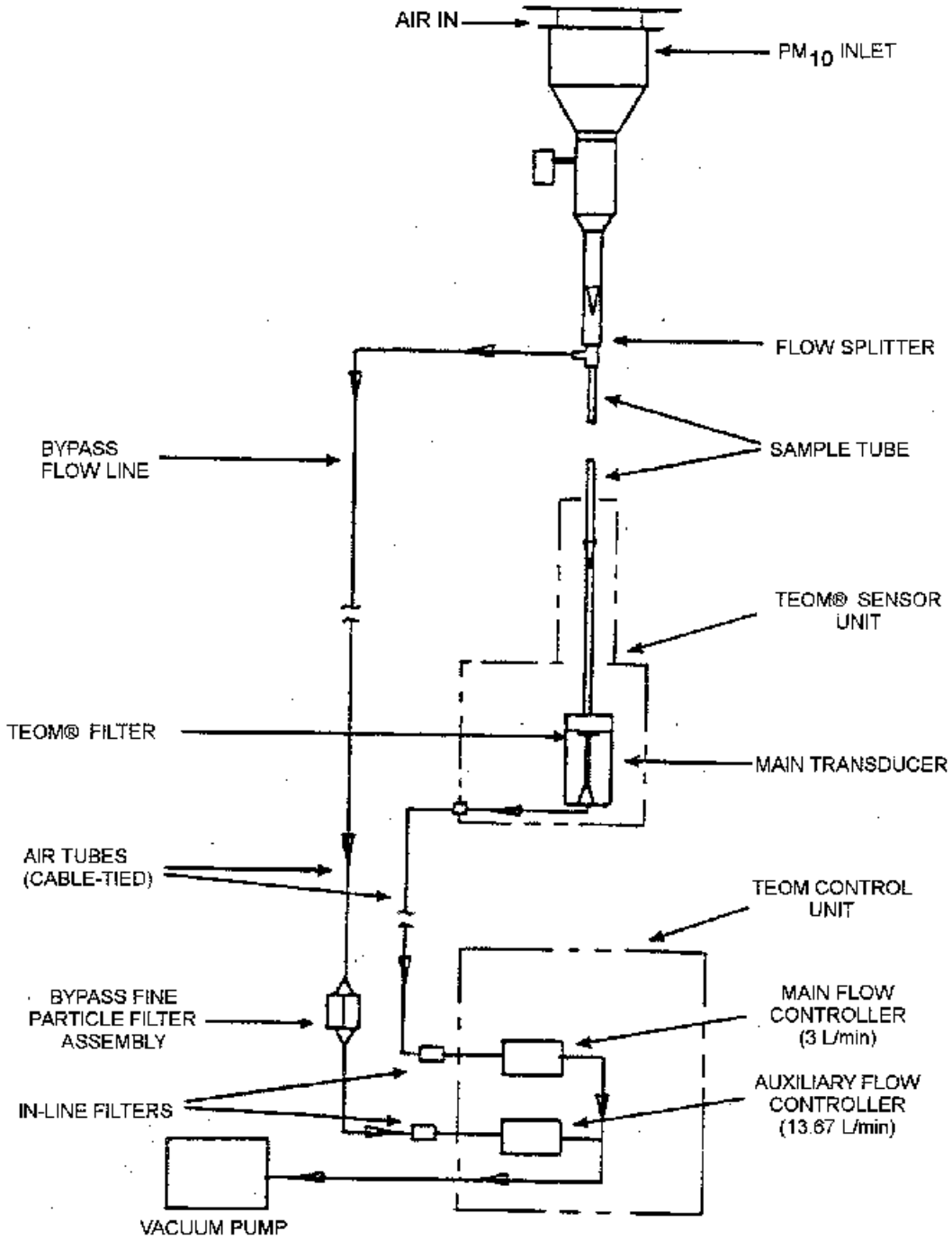

Figure 7. Schematic diagram of the assembled TEOM® monitor.

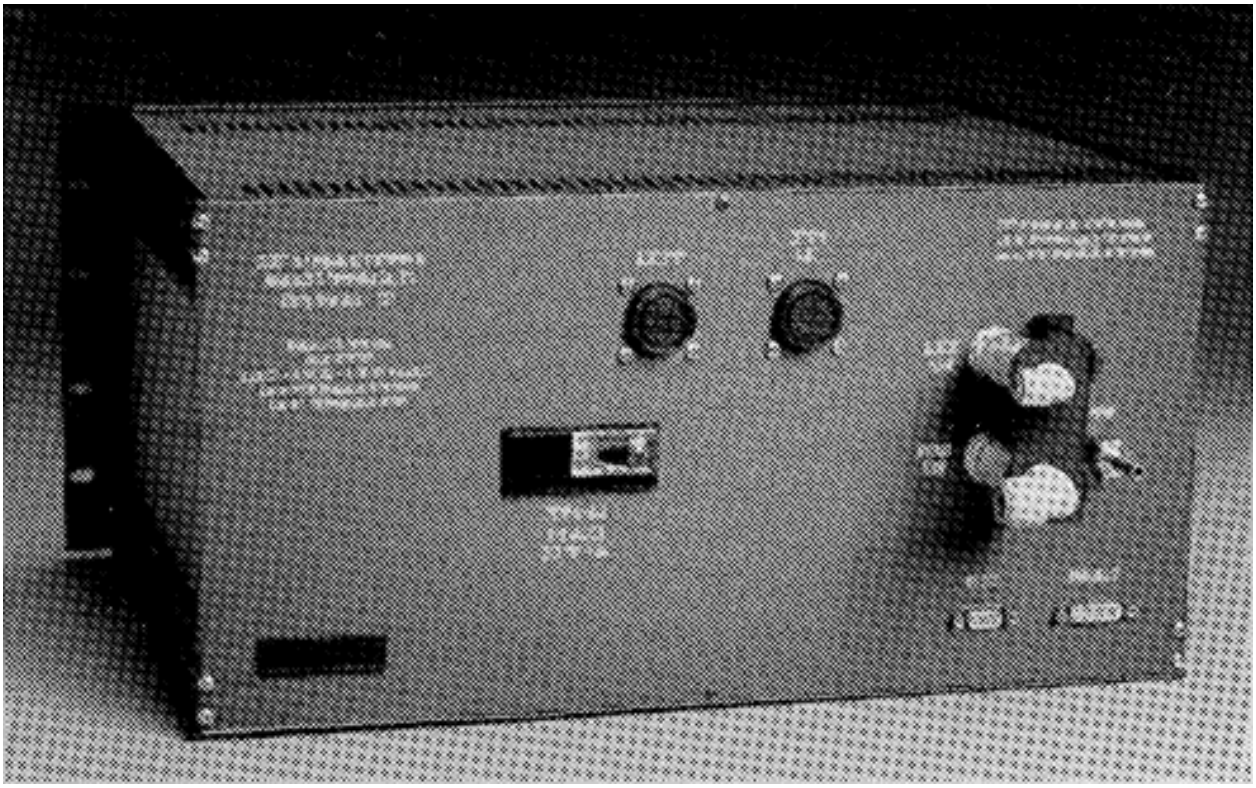

Figure 8. Back panel of TEOM® monitor.

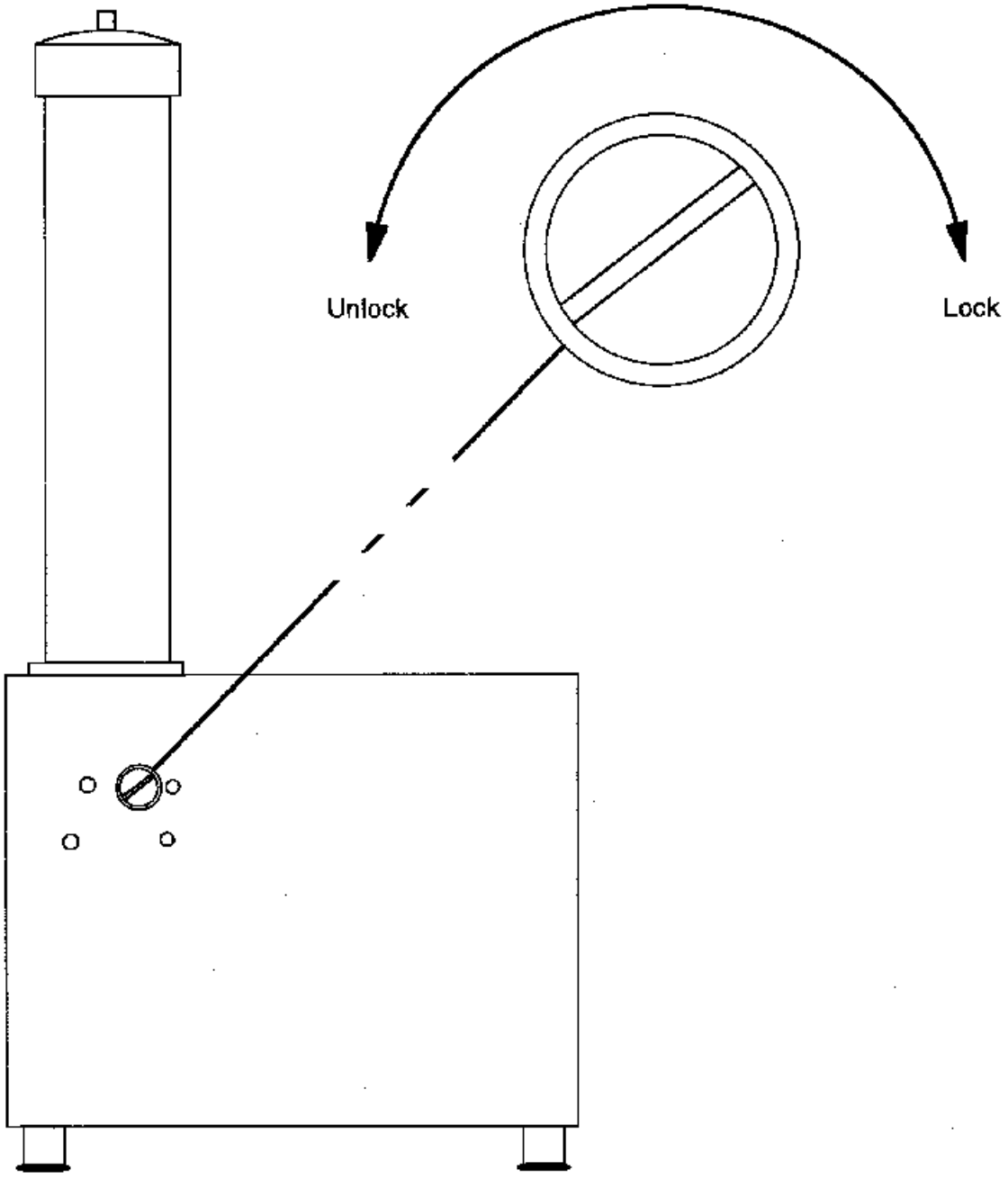

Figure 9. Location of shipping latch on back panel of the TEOM® monitor.

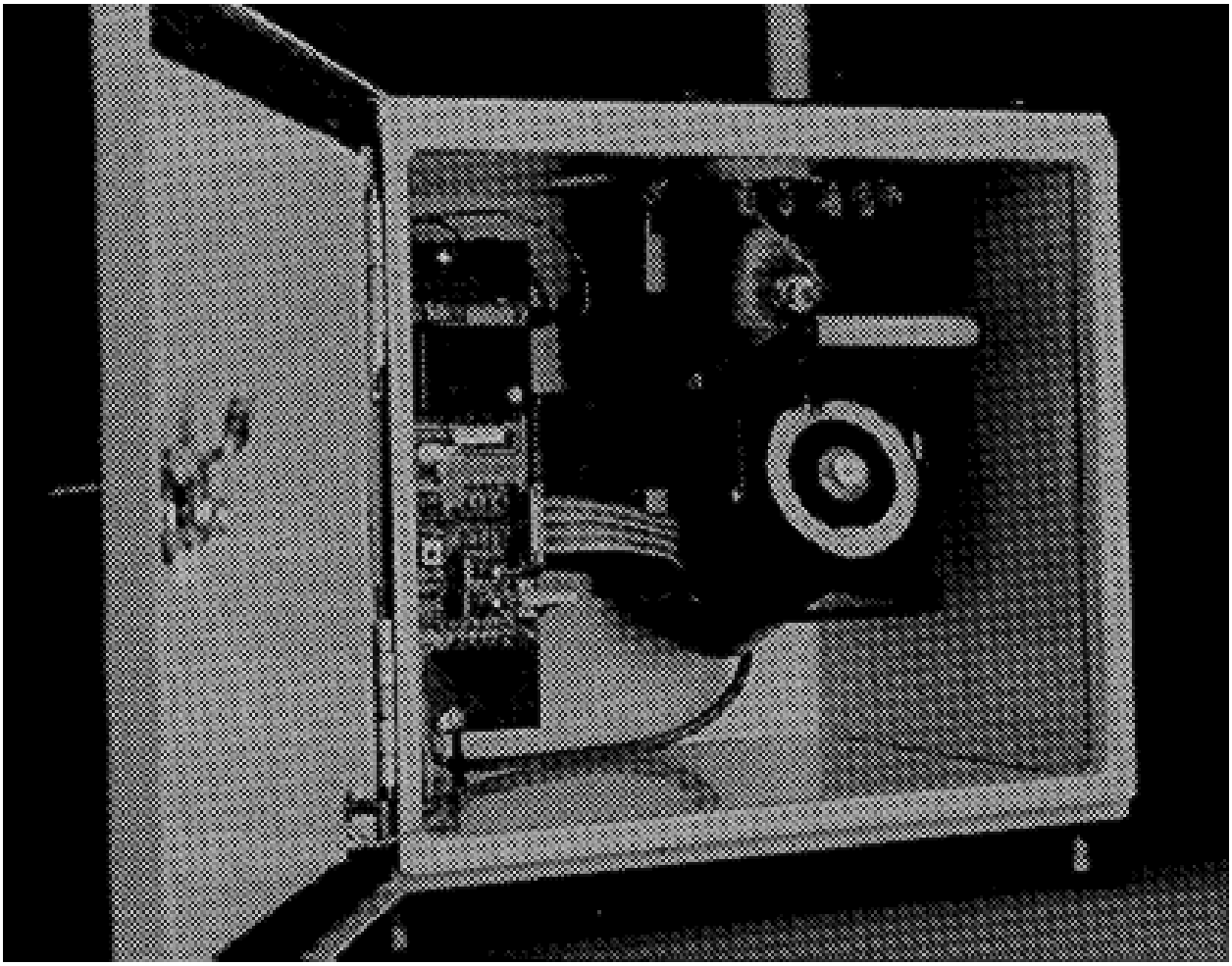

Figure 10. Inside view of TEOM® sensor unit.

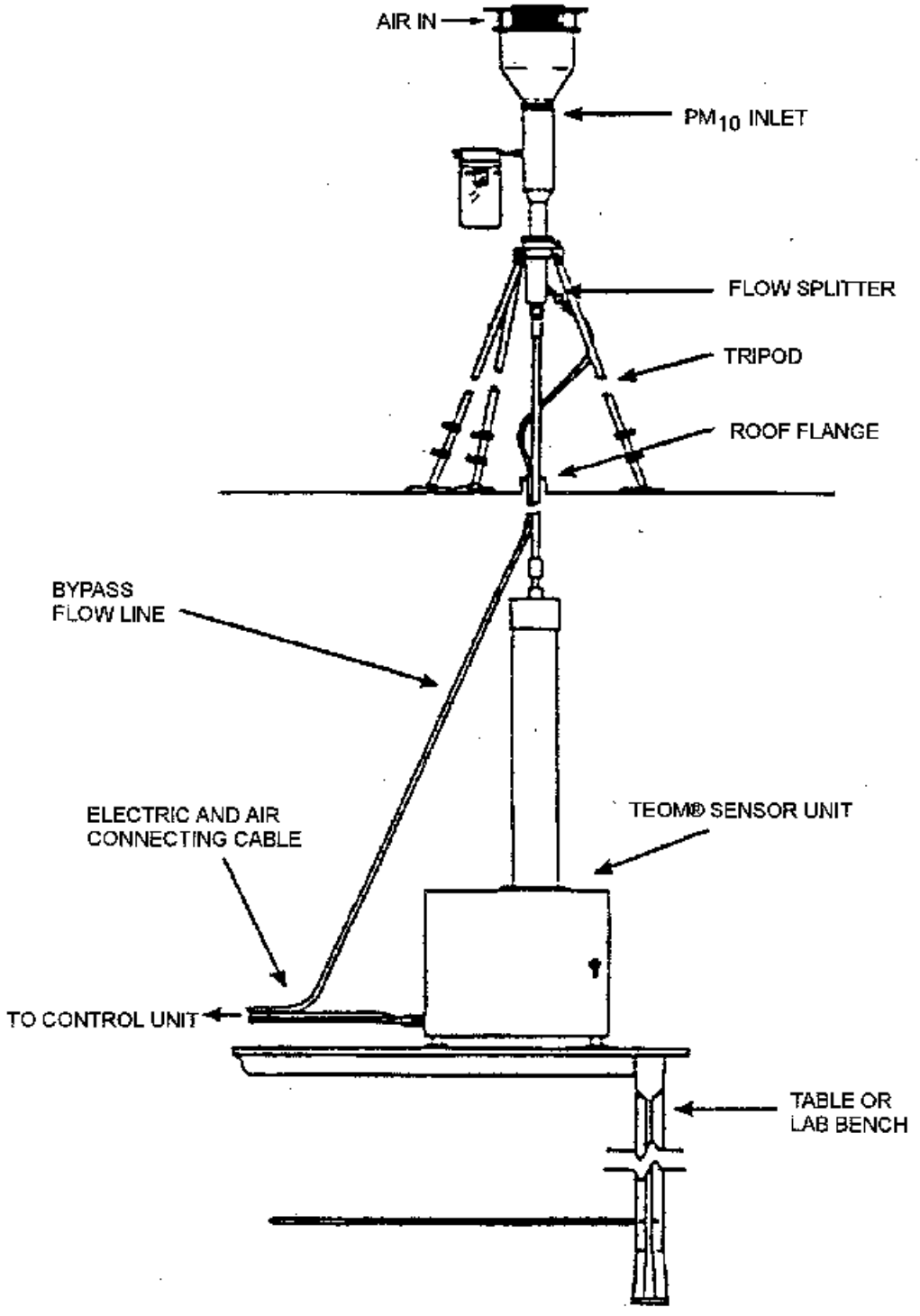

Figure 11. Schematic of typical TEOM® PM_{10} installation with flow splitter.

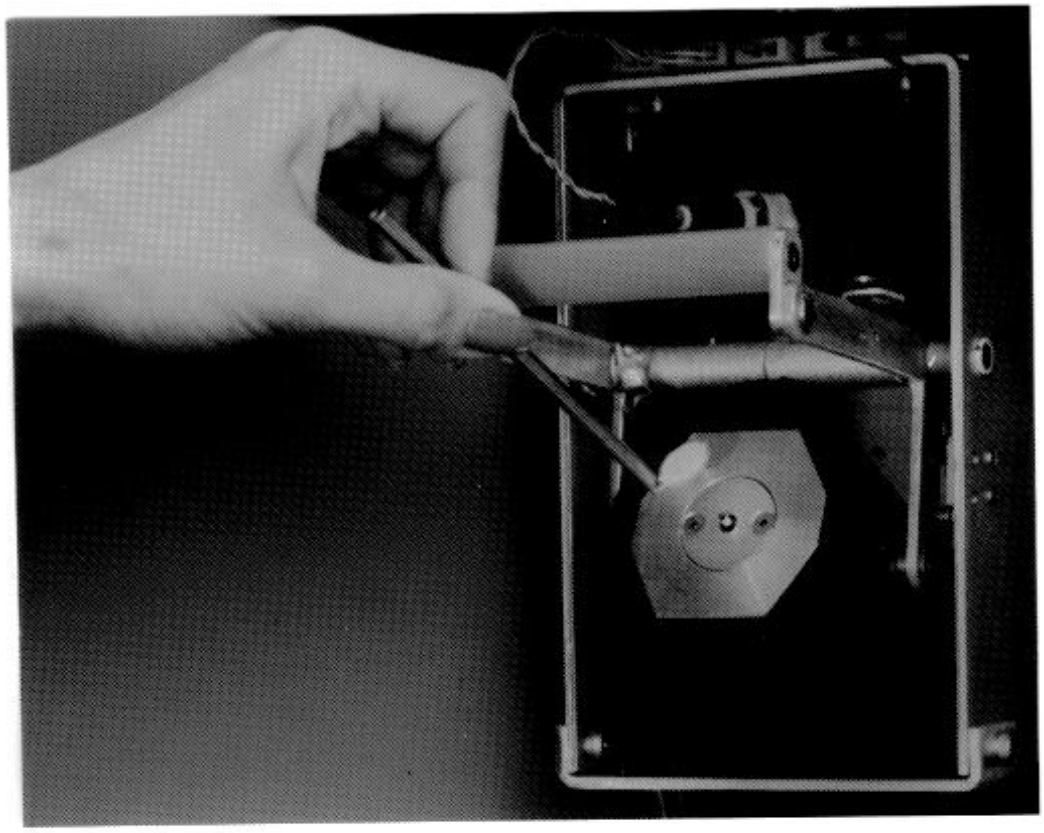

Figure 12. Replacing filter cartridge in sensor unit using filter exchange tool.

MAIN SCREEN (Screen 00)

Screen on Instrument			Description of Screen				
			Units	Edit in Modes	Default	Re-Init	Comments
OK 4 38% NU	09:39	6	N/A	N/A	N/A	N/A	Status Line
Mass Conc >	76.4	6	µg/m³	not editable	N/A	N/A	Short-term average
30-Min MC	72.3	6	µg/m³	not editable	N/A	N/A	Updated every 30 min
01-Hr MC	78.4	6	µg/m³	not editable	N/A	N/A	Updated every 1 hr
08-Hr MC	85.8	6	µg/m³	not editable	N/A	N/A	Updated every 1 hr
24-Hr MC	69.3	6	µg/m³	not editable	N/A	N/A	Updated every 1 hr
Tot Mass	974.38	6	µg	not editable	N/A	N/A	Mass since last reset
Case Temp	50.00	6	EC	not editable	50	50	Current temperature
Air Temp	50.01	6	EC	not editable	50	50	Current temperature
Cap Temp	49.98	6	EC	not editable	50	50	Current temperature
Encl Temp	40.00	6	EC	not editable	40	40	Current temperature
Main Flow	3.00	6	l/min	not editable	3	3	Current flow rate
Aux Flow	13.66	6	l/min	not editable	13.67	13.67	Current flow rate
----------		6	N/A	N/A	N/A	N/A	
Noise	0.034	6	µg	not editable	N/A	N/A	Diagnostic measure
Frequency	187.05738	6	hz	not editable	N/A	N/A	Mass transducer

To enter this screen press:	Next screen (using < Step Screen >):
< Main/Status > or 00 < Enter >	Menu Screen (Screen 02)

Figure 13. TEOM® main menu screens.

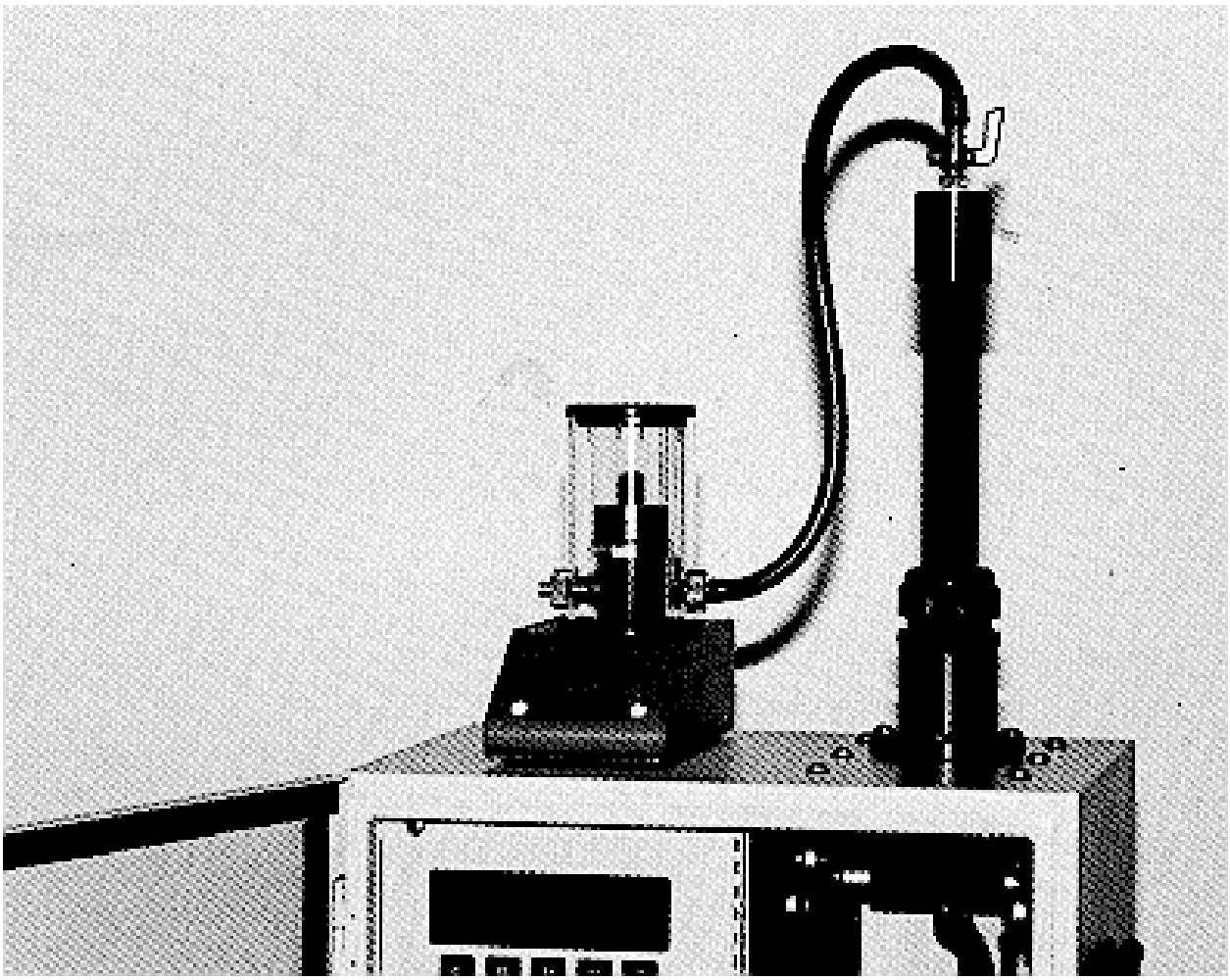

Figure 14. Auditing of the TEOM® flow control system.

TABLE 5. EXAMPLE OF RECOMMENDED STANDARDS AND ASSOCIATED EQUIPMENT FOR FLOW RATE AUDITS

Transfer standard[a]	Optimum flow range Q_a	Equipment	Comments	Calibration equation[b,c]	Calibration of transfer standard reference
LFE (laminar flow element)	15.0-20.0 L/min	LFE Thermometer/barometer[d] Manometer[e], Filters, Adapter	Should have filtered air entering LFE. Subject to fluctuations due to temperature changes. Manometer must be used in its temperature range. Must equilibrate.	$(^{a}H_2O)(CF) = Q_{std}$	U. S. Environmental Protection Agency Procedures for Calibrating a Laminar Flow Element (LFE) against an NBS Calibrated LFE: Standard Operating Procedures EMSL/RTP SOP-QAD-003, November 1991
MFM (mass flow meter)	15.0-20.0 L/min	MFM Thermometer/barometer[d] Filters, Adapter	Recommended LCD display for outdoor use. Must equilibrate to ambient conditions.	$(Volts)(CF) = Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 21, EPA 600/4-77-027A, May 1977.
DGM L/rev (dry gas meter)	15.0-20.0 L/min	DGM Thermometer/barometer[d] Stopwatch,[f] Filters, Adapter	Should time through five revolutions. Repeat each timing 3 times.	$\frac{Volume}{time}(CF) = Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 3.3 EPA 600/4-77-027B, August 1977.
Orifice	15.0-20.0 L/min	Orifice Thermometer/barometer,[d] Manometer,[e] Filters, Adapter	Good only in range $^{a}P < 8$ in.	$m\left[(H_2O)\frac{P_a}{T_a}\right]^{1/2} + b = Q_{std}$	Quality Assurance Handbook for Air Pollution Measurement Systems - Vol. II Ambient Air Specific Methods, Section 2.2 EPA 600/4-77-027A. May 1977.

[a]Transfer standard should not cause more than 4.0" of H_2O flow resistance to the sampler flow.

[b]Traceable and referenced to EPA standard conditions:

$$Q_a = Q_{std}\left[\frac{T_a}{P_a}\right]\left[\frac{P_{std}}{T_{std}}\right]$$

[c]Calibration equations for determining flow rates may vary from those presented due to the transfer standard calibration relationship. CF = correction factor.

[d]Thermometer capable of measuring temperature to the nearest $\pm$1C. Barometer capable of accurately measuring barometric pressure to the nearest $\pm$1 mm Hg.

[e]The design or size of the LFE or orifice will determine the manometer range necessary and the resolution. The manometer resolution must be capable of detecting a flow change of 1% and represent a flow resistance less than 4.0" H_2O.

[f]Stopwatch or timer capable of accurately measuring time intervals of 30 s to several minutes to nearest 0.1 s.

EPA/625/R-96/010b

Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air

Second Edition

Compendium Method TO-4A

Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using High Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

January 1999

Method TO-4A
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Method TO-4 was originally published in April of 1984 as one of a series of peer reviewed methods in *"Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air,"* EPA 600/4-89-018. In an effort to keep these methods consistent with current technology, Method TO-4 has been revised and updated as Method TO-4A in this Compendium to incorporate new or improved sampling and analytical technologies. In addition, this method incorporates ASTM Method D 4861-94, *Standard Practice for Sampling and Analysis of Pesticides and Polychlorinated Biphenyls in Air*.

This Method is the result of the efforts of many individuals. Gratitude goes to each person involved in the preparation and review of this methodology.

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DISCLAIMER

METHOD TO-4A

Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using High Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)

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METHOD TO-4A

Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using High Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)

1. Scope

1.1 This document describes a method for sampling and analysis of a variety of common pesticides and for polychlorinated biphenyls (PCBs) in ambient air. The procedure is based on the adsorption of chemicals from ambient air on polyurethane foam (PUF) using a high volume sampler.

1.2 The high volume PUF sampling procedure is applicable to multicomponent atmospheres containing common pesticide concentrations from 0.001 to 50 $\mu g/m^3$ over 4- to 24-hour sampling periods. The limits of detection will depend on the nature of the analyte and the length of the sampling period.

1.3 Specific compounds for which the method has been employed are listed in Table 1. The analytical methodology described in Compendium Method TO-4A is currently employed by laboratories throughout the U.S. The sampling methodology has been formulated to meet the needs of common pesticide and PCB sampling in ambient air.

1.4 Compendium Method TO-4 was originally published in 1989 (1). Further updates of the sampling protocol were published as part of Compendium Method TO-13 (2). The method was further modified for indoor air application in 1990 (3). In an effort to keep the method consistent with current technology, Compendium Method TO-4 has incorporated the sampling and analytical procedures in ASTM Method D4861-94 (4) and is published here as Compendium Method TO-4A.

2. Summary of Method

2.1 A high-volume (~8 cfm) sampler is used to collect common pesticides and PCBs on a sorbent cartridge containing PUF. Airborne particles may also be collected, but the sampling efficiency is not known (5). The sampler is operated for 24-hours, after which the sorbent is returned to the laboratory for analysis.

2.2 Pesticides and PCBs are extracted from the sorbent cartridge with 10 percent diethyl ether in hexane and determined by gas chromatography coupled with an electron capture detector (ECD), nitrogen-phosphorus detector (NPD), flame photometric detector (FPD), Hall electrolytic conductivity detector (HECD), or a mass spectrometer (MS). For common pesticides, high performance liquid chromatography (HPLC) coupled with an ultraviolet (UV) detector or electrochemical detector may be preferable.

2.3 Interferences resulting from analytes having similar retention times during GC analysis are resolved by improving the resolution or separation, such as by changing the chromatographic column or operating parameters, or by fractionating the sample by column chromatography.

3. Significance

3.1 Pesticide usage and environmental distribution are common to rural and urban areas of the United States. The application of pesticides can cause adverse health effects to humans by contaminating soil, water, air, plants, and animal life. PCBs are less widely used, due to extensive restrictions placed on their manufacturer. However, human exposure to PCBs continues to be a problem because of their presence in various electrical products.

3.2 Many pesticides and PCBs exhibit bioaccumulative, chronic health effects; therefore, monitoring the presence of these compounds in ambient air is of great importance.

3.3 The relatively low levels of such compounds in the environment requires the use of high volume sampling techniques to acquire sufficient sample for analysis. However, the volatility of these compounds prevents efficient collection on filter media. Consequently, Compendium Method TO-4A utilizes both a filter and a PUF backup cartridge which provides for efficient collection of most common pesticides, PCBs, and many other organics within the same volatility range.

3.4 Moreover, modifications to this method has been successfully applied to measurement of common pesticides and PCBs in outdoor air (6), indoor air (3) and for personal respiratory exposure monitoring (3).

4. Applicable Documents

4.1 ASTM Standards

- D1356 *Definition of Terms Relating to Atmospheric Sampling and Analysis*
- D4861-94 *Standard Practice for Sampling and Analysis of Pesticides and Polychlorinated Biphenyls in Air*
- E260 *Recommended Practice for General Gas Chromatography Procedures*
- E355 *Practice for Gas Chromatography Terms and Relationships*
- D3686 *Practice for Sampling Atmospheres to Collect Organic Compound Vapors (Activated Charcoal Tube Adsorption Method*
- D3687 *Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption*
- D4185 *Practice for Measurement of Metals in Workplace Atmosphere by Atomic Absorption Spectrophotometry*

4.2 EPA Documents

- *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air: Method TO-10, Second Supplement*, U. S. Environmental Protection Agency, EPA 600/4-89-018, March 1989.
- *Manual of Analytical Methods for Determination of Pesticides in Humans and Environmental Standards*, U. S. Environmental Protection Agency, EPA 600/8-80-038, June 1980.
- *Compendium of Methods for the Determination of Air Pollutants in Indoor Air: Method IP-8*, U. S. Environmental Protection Agency, EPA 600/4-90-010, May 1990.

4.3 Other Documents

- Code of Federal Regulations, Title 40, Part 136, Method 604

5. Definitions

[Note: Definitions used in this document and in any user-prepared Standard operating procedures (SOPs) should be consistent with ASTM D1356, E260, and E355. All abbreviations and symbols are defined within this document at point of use.]

5.1 Sampling efficiency (SE)-ability of the sampling medium to trap analytes of interest. The percentage of the analyte of interest collected and retained by the sampling medium when it is introduced as a vapor in air or nitrogen into the air sampler and the sampler is operated under normal conditions for a period of time equal to or greater than that required for the intended use is indicated by %SE.

5.2 Retention efficiency (RE)-ability of sampling medium to retain a compound added (spiked) to it in liquid solution.

5.3 Retention time (RT)-time to elute a specific chemical from a chromatographic column, for a specific carrier gas flow rate, measured from the time the chemical is injected into the gas stream until it appears at the detector.

5.4 Relative retention time (RRT)-a rate of RTs for two chemicals for the same chromatographic column and carrier gas flow rate, where the denominator represents a reference chemical.

5.5 Method detection limit (MDL)-the minimum concentration of a substance that can be measured and reported with confidence and that the value is above zero.

5.6 Kuderna-Danish apparatus-the Kuderna-Danish (K-D) apparatus is a system for concentrating materials dissolved in volatile solvents.

5.7 MS-SIM-the GC is coupled to a mass spectrometer where the instrument is programmed to acquire data for only the target compounds and to disregard all others, thus operating in the select ion monitoring mode (SIM). This is performed using SIM coupled to retention time discriminators. The SIM analysis procedure provides quantitative results.

5.8 Sublimation-the direct passage of a substance from the solid state to the gaseous state and back into the solid form without any time appearing in the liquid state. Also applied to the conversion of solid to vapor without the later return to solid state, and to a conversion directly from the vapor phase to the solid state.

5.9 Surrogate standard-a chemically compound (not expected to occur in the environmental sample) which is added to each sample, blank and matrix spiked sample before extraction and analysis. The recovery of the surrogate standard is used to monitor unusual matrix effects, gross sample processing errors, etc. Surrogate recovery is evaluated for acceptance by determining whether the measured concentration falls within acceptable limits.

6. Interferences

6.1 Any gas or liquid chromatographic separation of complex mixtures of organic chemicals is subject to serious interference problems due to coelution of two or more compounds. The use of capillary or microbore columns with superior resolution or two or more columns of different polarity will frequently eliminate these problems. In addition, selectivity may be further enhanced by use of a MS operated in the selected ion monitoring (SIM) mode as the GC detector. In this mode, co-eluting compounds can often be determined.

6.2 The ECD responds to a wide variety of organic compounds. It is likely that such compounds will be encountered as interferences during GC/ECD analysis. The NPD, FPD, and HECD detectors are element specific, but are still subject to interferences. UV detectors for HPLC are nearly universal, and the electrochemical detector may also respond to a variety of chemicals. Mass spectrometric analyses will generally provide positive identification of specific compounds.

6.3 PCBs and certain common pesticides (e.g., chlordane) are complex mixtures of individual compounds which can cause difficulty in accurately quantifying a particular formulation in a multiple component mixture. PCBs may interfere with the determination of pesticides.

6.4 Contamination of glassware and sampling apparatus with traces of pesticides or PCBs can be a major source of error, particularly at lower analyte concentrations. Careful attention to cleaning and handling procedures is required during all steps of sampling and analysis to minimize this source of error.

6.5 The general approaches listed below should be followed to minimize interferences.

6.5.1 Polar compounds, including certain pesticides (e.g., organophosphorus and carbamate classes) can be removed by column chromatography on alumina. Alumina clean-up will permit analysis of most common pesticides and PCBs (7).

6.5.2 PCBs may be separated from other common pesticides by column chromatography on silicic acid (8,9).

6.5.3 Many pesticides can be fractionated into groups by column chromatography on Florisil (9).

7. Safety

7.1 The toxicity or carcinogencity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of Occupational Safety and Health Administration (OSHA) regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified for the analyst (10-12).

7.2 PCBs have been classified as a known or suspected, human or mammalian carcinogen. Many of the other common pesticides have been classified as carcinogens. Care must be exercised when working with these substances. This method does not purport to address all safety problems associated with its use. It is the responsibility of whoever uses this method to consult and establish appropriate safety and health practices and

determine the applicability of regulatory limitations prior to use. The user should be thoroughly familiar with the chemical and physical properties of targeted substances.

7.3 Treat all target analytes as carcinogens. Neat compounds should be weighed in a glove box. Spent samples and unused standards are toxic waste and should be disposed according to regulations. Regularly check counter tops and equipment with "black light" for fluorescence as an indicator of contamination.

7.4 The collection efficiency for common pesticides and PCBs has been demonstrated to be greater than 95 percent for the sampling configuration described in the method (filter and backup adsorbent). Therefore, no field recovery evaluation will occur as part of this procedure.

8. Apparatus

[Note: This method was developed using the PS-1 semi-volatile sampler provided by General Metal Works, Village of Cleves, OH as a guideline. EPA has experience in use of this equipment during various field monitoring programs over the last several years. Other manufacturers' equipment should work as well. However, modifications to these procedures may be necessary if another commercially available sampler is selected.]

8.1 Sampling

8.1.1 High-volume sampler (see Figure 1). Capable of pulling ambient air through the filter/adsorbent cartridge at a flow rate of approximately 8 standard cubic feet per minute (scfm) (0.225 std m^3/min) to obtain a total sample volume of greater than 300 scm over a 24-hour period. Major manufacturers are:

- Tisch Environmental, Village of Cleves, OH
- Andersen Instruments Inc., 500 Technology Ct., Smyrna, GA
- Thermo Environmental Instruments, Inc., 8 West Forge Parkway, Franklin, MA

8.1.2 Sampling module (see Figure 2). Metal filter holder (Part 2) capable of holding a 102-mm circular particle filter supported by a 16-mesh stainless-steel screen and attaching to a metal cylinder (Part 1) capable of holding a 65-mm O.D. (60-mm I.D.) x 125-mm borosilicate glass sorbent cartridge containing PUF. The filter holder is equipped with inert sealing gaskets (e.g., polytetrafluorethylene) placed on either side of the filter. Likewise, inert, pliable gaskets (e.g., silicone rubber) are used to provide an air-tight seal at each end of the glass sorbent cartridge. The glass sorbent cartridge is indented 20 mm from the lower end to provide a support for a 16-mesh stainless-steel screen that holds the sorbent. The glass sorbent cartridge fits into Part 1, which is screwed onto Part 2 until the sorbent cartridge is sealed between the silicone gaskets. Major manufacturers are:

- Tisch Environmental, Village of Cleves, OH
- Andersen Instruments Inc., 500 Technology Ct., Smyrna, GA
- Thermo Environmental Instruments, Inc., 8 West Forge Parkway, Franklin, MA

A field portable unit has been developed by EPA (see Figure 3).

8.1.3 High-volume sampler calibrator. Capable of providing multipoint resistance for the high-volume sampler. Major manufacturers are:

- Tisch Environmental, Village of Cleves, OH
- Andersen Instruments Inc., 500 Technology Ct., Smyrna, GA
- Thermo Environmental Instruments, Inc., 8 West Forge Parkway, Franklin, MA

8.1.4 Ice chest. To hold samples at <4°C or below during shipment to the laboratory after collection.

8.1.5 Data sheets. For each sample for recording the location and sample time, duration of sample, starting time, and volume of air sampled.

8.2 Sample Clean-up and Concentration (see Figure 4).

8.2.1 Soxhlet apparatus extractor (see Figure 4a). Capable of extracting filter and adsorbent cartridges (2.3" x 5" length), 1,000 mL flask, and condenser, best source.

8.2.2 Pyrex glass tube furnace system. For activating silica gel at 180°C under purified nitrogen gas purge for an hour, with capability of raising temperature gradually, best source.

8.2.3 Glass vial. 40 mL, best source.

8.2.4 Erlenmeyer flask. 50 mL, best source.

[Note: Reuse of glassware should be minimized to avoid the risk of cross contamination. All glassware that is used, especially glassware that is reused, must be scrupulously cleaned as soon as possible after use. Rinse glassware with the last solvent used in it and then with high-purity acetone and hexane. Wash with hot water containing detergent. Rinse with copious amount of tap water and several portions of distilled water. Drain, dry, and heat in a muffle furnace at 400°C for 4 hours. Volumetric glassware must not be heated in a muffle furnace; rather, it should be rinsed with high-purity acetone and hexane. After the glassware is dry and cool, rinse it with hexane, and store it inverted or capped with solvent-rinsed aluminum foil in a clean environment.]

8.2.5 White cotton gloves. For handling cartridges and filters, best source.

8.2.6 Minivials. 2 mL, borosilicate glass, with conical reservoir and screw caps lined with Teflon®-faced silicone disks, and a vial holder, best source.

8.2.7 Teflon®-coated stainless steel spatulas and spoons. Best source.

8.2.8 Kuderna-Danish (K-D) apparatus (see Figure 4b). 500 mL evaporation flask (Kontes K-570001-500 or equivalent), 10 mL graduated concentrator tubes (Kontes K570050-1025 or equivalent) with ground-glass stoppers, and 3-ball macro Snyder Column (Kontes K-570010500, K-50300-0121, and K-569001-219, or equivalent), best source.

8.2.9 Adsorption column for column chromatography (see Figure 4c). 1-cm x 10-cm with stands.

8.2.10 Glove box. For working with extremely toxic standards and reagents with explosion-proof hood for venting fumes from solvents, reagents, etc.

8.2.11 Vacuum oven. Vacuum drying oven system capable of maintaining a vacuum at 240 torr (flushed with nitrogen) overnight.

8.2.12 Concentrator tubes and a nitrogen evaporation apparatus with variable flow rate. Best source.

8.2.13 Laboratory refrigerator. Best source.

8.2.14 Boiling chips. Solvent extracted, 10/40 mesh silicon carbide or equivalent, best source.

8.2.15 Water bath. Heated, with concentric ring cover, capable of ±5°C temperature control, best source.

8.2.16 Nitrogen evaporation apparatus. Best source.

8.2.17 Glass wool. High purity grade, best source.

8.3 Sample Analysis

8.3.1 Gas chromatograph (GC). The GC system should be equipped with appropriate detector(s) and either an isothermally controlled or temperature programmed heating oven. Improved detection limits may be obtained with a GC equipped with a cool on-column or splitless injector.

8.3.2 Gas chromatographic column. As an example, a 0.32-mm (I.D.) x 3-mm DB-5, DB-17, DB-608, DB-1701 are available. Other columns may also provide acceptable results.

8.3.3 HPLC column. As an example, a 4.6-mm x 25-cm Zorbax SIL or µBondpak C-18. Other columns may also provide acceptable results.

8.3.4 Microsyringes. 5 µL volume or other appropriate sizes.

8.3.5 Balance. Mettler balance or equivalent.

8.3.6 All required syringes, gases, and other pertinent supplies. To operate the GC/MS system.

8.3.7 Pipettes, micropipettes, syringes, burets, etc. To make calibration and spiking solutions, dilute samples if necessary, etc., including syringes for accurately measuring volumes such as 25 µL and 100 µL.

9. Equipment and Materials

9.1 Materials for Sample Collection (see Figure 5)

9.1.1 Quartz fiber filter. 102-millimeter bindless quartz microfiber filter, Whatman Inc., 6 Just Road, Fairfield, NJ 07004, Filter Type QMA-4.

9.1.2 Polyurethane foam (PUF) plugs (see Figure 5a). 3-inch thick sheet stock polyurethane type (density .022 g/cm^3). The PUF should be of the polyether type used for furniture upholstery, pillows, and mattresses. The PUF cylinders (plugs) should be slightly larger in diameter than the internal diameter of the cartridge. Sources of equipment are Tisch Environmental, Village of Cleves, OH; University Research Glassware, 116 S. Merritt Mill Road, Chapel Hill, NC; Thermo Environmental Instruments, Inc., 8 West Forge Parkway, Franklin, MA; Supelco, Supelco Park, Bellefonte, PA; and SKC Inc., 334 Valley View Road, Eighty Four, PA.

9.1.3 Teflon® end caps (see Figure 5a). For sample cartridge. Sources of equipment are Tisch Environmental, Village of Cleves, OH and University Research Glassware, Chapel Hill, NC.

9.1.4 Sample cartridge aluminum shipping containers (see Figure 5b). For sample cartridge shipping. Sources of equipment are Tisch Environmental, Village of Cleves, OH and University Research Glassware, Chapel Hill, NC.

9.1.5 Glass sample cartridge (see Figure 5a). For sample collection. Sources of equipment are Tisch Environmental, Village of Cleves, OH; Thermo Environmental Instruments, Inc., 8 West Forge Parkway, Franklin, MA; University Research Glassware, 116 S. Merritt Mill Road, Chapel Hill, NC; and Supelco, Supelco Park, Bellefonte, PA.

9.1.6 Aluminum foil. Best source.

9.1.7 Hexane, reagent grade. Best source.

9.2 Sample Extraction and Concentration

9.2.1 Methylene chloride. Chromatographic grade, glass-distilled, best source.

9.2.2 Sodium sulfate-anhydrous (ACS). Granular (purified by washing with methylene chloride followed by heating at 400°C for 4 hours in a shallow tray).

9.2.3 Boiling chips. Solvent extracted or heated in a muffle furnace at 450°C for 2 hours, approximately 10/40 mesh (silicon carbide or equivalent).

9.2.4 Nitrogen. High purity grade, best source.
9.2.5 Ether. Chromatographic grade, glass-distilled, best source.
9.2.6 Hexane. Chromatographic grade, glass-distilled, best source.
9.2.7 Dibromobiphenyl. Chromatographic grade, best source. Used for internal standard.
9.2.8 Decafluorobiphenyl. Chromatographic grade, best source. Used for internal standard.
9.2.9 Glass wool. Silanized, extracted with methylene chloride and hexane, and dried.
9.2.10 Diethyl ether. High purity, glass distilled.
9.2.11 Hexane. High purity, glass distilled.
9.2.12 Silica gel. High purity, type 60, 70-230 mesh.
9.2.13 Round bottom evaporative flask. 500 mL, T 24/40 joints, best source.
9.2.14 Capacity soxhlet extractors. 500 mL, with reflux condensers, best source.
9.2.15 Kuderna-Danish concentrator. 500 mL, with Snyder columns, best source.
9.2.16 Graduated concentrator tubes. 10 mL, with 19/22 stoppers, best source.
9.2.17 Graduated concentrator tubes. 1 mL, with 14/20 stoppers, best source.
9.2.18 TFE fluorocarbon tape. 1/2 in., best source.
9.2.19 Filter tubes. Size 40-mm (I.D.) x 80-mm.
9.2.20 Serum vials. 1 mL and 5 mL, fitted with caps lined with TFE fluorocarbon.
9.2.21 Pasteur pipetter. 9 in., best source.
9.2.22 Glass wool. Fired at 500°C, best source.
9.2.23 Alumina. Activity Grade IV, 100/200 mesh.
9.2.24 Glass chromatographic column. 2-mm I.D. x 15-cm long.
9.2.25 Vacuum oven. Connected to water aspirator, best source.
9.2.26 Die. Best source.
9.2.27 Ice chest. Best source.
9.2.28 Silicic Acid. Pesticide quality, best source.
9.2.29 Octachloronaphthalene (OCN). Research grade, best source.
9.2.30 Florisil. Pesticide quality, best source.

9.3 GC Sample Analysis

9.3.1 Gas cylinders of hydrogen, nitrogen, argon/methane, and helium. Ultra high purity, best source.
9.3.2 Combustion air. Ultra high purity, best source.
9.3.3 Zero air. Zero air may be obtained from a cylinder or zero-grade compressed air scrubbed with Drierite® or silica gel and 5A molecular sieve or activated charcoal, or by catalytic cleanup of ambient air. All zero air should be passed through a liquid argon cold trap for final cleanup.
9.3.4 Chromatographic-grade stainless steel tubing and stainless steel fitting. For interconnections, Alltech Applied Science, 2051 Waukegan Road, Deerfield, IL 60015, 312-948-8600, or equivalent.

[Note: All such materials in contact with the sample, analyte, or support gases prior to analysis should be stainless steel or other inert metal. Do not use plastic or Teflon® tubing or fittings.]

10. Preparation of PUF Sampling Cartridge

[Note: This method was developed using the PS-1 sample cartridge provider by General Metal Works, Village of Cleves, OH as a guideline. EPA has experience in use of this equipment during various field monitoring

programs over the last several years. Other manufacturers' equipment should work as well. However, modifications to these procedures may be necessary if another commercially available sampler is selected.]

10.1 Summary of Method

10.1.1 This part of Compendium Method TO-4A discusses pertinent information regarding the preparation and cleaning of the filter, adsorbent, and filter/adsorbent cartridge assembly. The separate batches of filters and adsorbents are extracted with the appropriate solvent.

10.1.2 At least one PUF cartridge assembly and one filter from each batch, or 10 percent of the batch, whichever is greater, should be tested and certified clean before the batch is considered for field use.

10.2 Preparation of Sampling Cartridge

10.2.1 Bake the Whatman QMA-4 quartz filters at 400°C for 5 hours before use.

10.2.2 Set aside the filters in a clean container for shipment to the field or prior to combining with the PUF glass cartridge assembly for certification prior to field deployment.

10.2.3 The PUF plugs are 6.0-cm diameter cylindrical plugs cut from 3-inch sheet stock and should fit, with slight compression, in the glass cartridge, supported by the wire screen (see Figure 2). During cutting, rotate the die at high speed (e.g., in a drill press) and continuously lubricate with deionized or distilled water. Pre-cleaned PUF plugs can be obtained from many of the commercial sources identified in Section 9.1.2.

10.2.4 For initial cleanup, place the PUF plugs in a Soxhlet apparatus and extract with acetone for 16 hours at approximately 4 cycles per hour. When cartridges are reused, use diethyl ether/hexane (10 percent volume/volume [v/v]) as the cleanup solvent.

[Note: A modified PUF cleanup procedure can be used to remove unknown interference components of the PUF blank. This method consists of rinsing 50 times with toluene, acetone, and diethyl ether/hexane (5 to 10 percent v/v), followed by Soxhlet extraction. The extracted PUF is placed in a vacuum oven connected to a water aspirator and dried at room temperature for approximately 2 to 4 hours (until no solvent odor is detected). Alternatively, they may be dried at room temperature in an air-tight container with circulating nitrogen (zero grade). Place the clean PUF plug into a labeled glass sampling cartridge using gloves and forceps. Wrap the cartridge with hexane-rinsed aluminum foil and placed in a jar fitted with TFE fluorocarbon-lined caps. The foil wrapping may also be marked for identification using a blunt probe. The extract from the Soxhlet extraction procedure from each batch may be analyzed to determine initial cleanliness prior to certification.]

10.2.5 Fit a nickel or stainless steel screen (mesh size 200/200) to the bottom of a hexane-rinsed glass sampling cartridge to retain the PUF adsorbents, as illustrated in Figure 2. Place the Soxhlet-extracted, vacuum-dried PUF (2.5-cm thick by 6.5-cm diameter) on top of the screen in the glass sampling cartridge using polyester gloves.

10.2.6 Wrap the sampling cartridge with hexane-rinsed aluminum foil, cap with the Teflon® end caps, place in a cleaned labeled aluminum shipping container, and seal with Teflon® tape. Analyze at least 1 PUF plug from each batch of PUF plugs using the procedure described in Section 10.3, before the batch is considered acceptable for field use. A blank level of <10 ng/plug and filter for single component compounds is considered to be acceptable. For multiple component mixtures (e.g., PCBs), the blank level should be <100 ng/plug and filter. Cartridges are considered clean for up to 30 days from date of certification when stored in their sealed containers.

10.3 Procedure for Certification of PUF Cartridge Assembly

10.3.1 Extract 1 filter and PUF adsorbent cartridge by Soxhlet extraction and concentrate using a Kuderna-Danish (K-D) evaporator for each lot of filters and cartridges sent to the field.

10.3.2 Assemble the Soxhlet apparatus. Charge the Soxhlet apparatus (see Figure 4a) with 300 mL of the extraction solvent [10 percent (v/v) diethyl ether/hexane] and reflux for 2 hours. Let the apparatus cool, disassemble it, and discard the used extraction solvent. Transfer the filter and PUF glass cartridge to the Soxhlet apparatus (the use of an extraction thimble is optional).

[Note: The filter and adsorbent assembly are extracted together in order to reach detection limits, to minimize cost and to prevent misinterpretation of the data. Separate analyses of the filter and PUF would not yield useful information about the physical state of most of the common pesticides and PCBs at the time of sampling due to evaporative losses of the analyte from the filter during sampling.]

10.3.3 Add between 300 and 350 mL of diethyl ether/hexane (10 percent v/v) to the Soxhlet apparatus. Reflux the sample for 18 hours at a rate of at least 3 cycles per hour. Allow to cool, then disassemble the apparatus.

10.3.4 Assemble a K-D concentrator (see Figure 4b) by attaching a 10-mL concentrator tube to a 500-mL evaporative flask.

10.3.5 Transfer the extract by pouring it through a drying column containing about 10 cm of anhydrous granular sodium sulfate (see Figure 4c) and collect the extract in the K-D concentrator. Rinse the Erlenmeyer flask and column with 20 to 30 mL of 10 percent diethyl ether/hexane to complete the quantitative transfer.

10.3.6 Add 1 or 2 clean boiling chips and attach a 3-ball Snyder column to the evaporative flask. Pre-wet the Snyder column by adding about 1 mL of the extraction solvent to the top of the column. Place the K-D apparatus on a hot water bath (50°C) so that the concentrator tube is partially immersed in the hot water, and the entire lower rounded surface of the flask is bathed with hot vapor. Adjust the vertical position of the apparatus and the water temperature as required to complete the concentration in one hour. At the proper rate of distillation, the balls of the column will actively chatter but the chambers will not flood with condensed solvent. When the apparent volume of liquid reaches approximately 5 mL, remove the K-D apparatus from the water bath and allow it to drain and cool for at least 5 minutes. Remove the Snyder column and rinse the flask and its lower joint into the concentrator tube with 5 mL of hexane. A 5-mL syringe is recommended for this operation.

[Note: The solvent may have to be exchanged to another solvent to meet the requirements of the analytical procedure selected for the target analytes.]

10.3.7 Concentrate the extract to 1 mL and analyze according to Section 13.

10.3.8 Acceptable levels of common pesticides must be less than 10 ng for each pair of filter and adsorbent assembly analyzed. For multiple component mixtures (e.g., PCBs), the blank level should be less than 100 ng for each pair of filter and adsorbent. Once certified clean, the cartridges can be shipped to the field without being chilled.

11. Assembly, Calibration and Collection Using High-Volume Sampling System

[Note: This method was developed using the PS-1 semi-volatile sampler provided by General Metal Works, Village of Cleves, OH as a guideline. EPA has experience in use of this equipment during various field monitoring programs over the last several years. Other manufacturers' equipment should work as well.

However, modifications to these procedures may be necessary if another commercially available sampler is selected.]

11.1 Description of Sampling Apparatus

The entire sampling system is diagrammed in Figure 1. This apparatus was developed to operate at a rate of 4 to 10 scfm (0.114 to 0.285 std m^3/min) and is used by EPA for high-volume sampling of ambient air. The method write-up presents the use of this device.

The sampling module (see Figure 2) consists of a filter and a glass sampling cartridge containing the PUF utilized to concentrate common pesticides and PCBs from the air. A field portable unit has been developed by EPA (see Figure 3).

11.2 Calibration of Sampling System

Each sampler should be calibrated (1) when new, (2) after major repairs or maintenance, (3) whenever any audit point deviates from the calibration curve by more than 7 percent, (4) before/after each sampling event, and (5) when a different sample collection media, other than that which the sampler was originally calibrated to, will be used for sampling.

11.2.1 Calibration of Orifice Transfer Standard. Calibrate the modified high volume air sampler in the field using a calibrated orifice flow rate transfer standard. Certify the orifice transfer standard in the laboratory against a positive displacement rootsmeter (see Figure 6). Once certified, the recertification is performed rather infrequently if the orifice is protected from damage. Recertify the orifice transfer standard performed once per year utilizing a set of five multiple resistance plates.

[Note: The set of five multihole resistance plates are used to change the flow through the orifice so that several points can be obtained for the orifice calibration curve. The following procedure outlines the steps to calibrate the orifice transfer standard in the laboratory.]

11.2.1.1 Record the room temperature (T_1 in °C) and barometric pressure (P_b in mm Hg) on the Orifice Calibration Data Sheet (see Figure 7). Calculate the room temperature in K (absolute temperature) and record on Orifice Calibration Data Sheet.

$$T_1 \text{ in K} = 273° + T_1 \text{ in } °C$$

11.2.1.2 Set up laboratory orifice calibration equipment as illustrated in Figure 6. Check the oil level of the rootsmeter prior to starting. There are 3 oil level indicators, 1 at the clear plastic end and 2 site glasses, 1 at each end of the measuring chamber.

11.2.1.3 Check for leaks by clamping both manometer lines, blocking the orifice with cellophane tape, turning on the high volume motor, and noting any change in the rootsmeter's reading. If the rootsmeter's reading changes, there is a leak in the system. Eliminate the leak before proceeding. If the rootsmeter's reading remains constant, turn off the hi-vol motor, remove the cellophane tape, and unclamp both manometer lines.

11.2.1.4 Install the 5-hole resistance plate between the orifice and the filter adapter.

11.2.1.5 Turn manometer tubing connectors 1 turn counter-clockwise. Make sure all connectors are open.

11.2.1.6 Adjust both manometer midpoints by sliding their movable scales until the zero point corresponds with the meniscus. Gently shake or tap to remove any air bubbles and/or liquid remaining on tubing connectors. (If additional liquid is required for the water manometer, remove tubing connector and add clean water.)

11.2.1.7 Turn on the high volume motor and let it run for 5 minutes to set the motor brushes. Turn the motor off. Insure manometers are set to zero. Turn the high volume motor on.

11.2.1.8 Record the time, in minutes, required to pass a known volume of air (approximately 200 to 300 ft^3 of air for each resistance plate) through the rootsmeter by using the rootsmeter's digital volume dial and a stopwatch.

11.2.1.9 Record both manometer readings-orifice water manometer ($\triangle H$) and rootsmeter mercury manometer ($\triangle P$) on Orifice Calibration Data Sheet (see Figure 7).

[Note: $\triangle H$ is the sum of the difference from zero (0) of the two column heights.]

11.2.1.10 Turn off the high volume motor.

11.2.1.11 Replace the 5-hole resistance plate with the 7-hole resistance plate.

11.2.1.12 Repeat Sections 11.2.1.3 through 11.2.1.11.

11.2.1.13 Repeat for each resistance plate. Note results on Orifice Calibration Data Sheet (see Figure 7). Only a minute is needed for warm-up of the motor. Be sure to tighten the orifice enough to eliminate any leaks. Also check the gaskets for cracks.

[Note: The placement of the orifice prior to the rootsmeter causes the pressure at the inlet of the rootsmeter to be reduced below atmospheric conditions, thus causing the measured volume to be incorrect. The volume measured by the rootsmeter must be corrected.]

11.2.1.14 Correct the measured volumes on the Orifice Calibration Data Sheet:

$$V_{std} = V_m \left(\frac{P_a - \triangle P}{P_{std}}\right)\left(\frac{T_{std}}{T_a}\right)$$

where:

V_{std} = standard volume, std m^3

V_m = actual volume measured by the rootsmeter, m^3

P_a = barometric pressure during calibration, mm Hg

$\triangle P$ = differential pressure at inlet to volume meter, mm Hg

P_{std} = 760 mm Hg

T_{std} = 273 + 25°C = 298 K

T_a = ambient temperature during calibration, K.

11.2.1.15 Record standard volume on Orifice Calibration Data Sheet.

11.2.1.16 The standard flow rate as measured by the rootsmeter can now be calculated using the following formula:

$$Q_{std} = \frac{V_{std}}{\theta}$$

where:

Q_{std} = standard volumetric flow rate, std m^3/min

θ = elapsed time, min

11.2.1.17 Record the standard flow rates to the nearest 0.01 std m^3/min.

11.2.1.18 Calculate and record $\sqrt{\triangle H\ (P_1/P_{std})(298/T_1)}$ value for each standard flow rate.

11.2.1.19 Plot each $\sqrt{\triangle H\ (P_1/P_{std})(298/T_1)}$ value (y-axis) versus its associated standard flow rate (x-axis) on arithmetic graph paper and draw a line of best fit between the individual plotted points.

[Note: This graph will be used in the field to determine standard flow rate.]

11.2.2 Calibration of the High Volume Sampling System Utilizing Calibrated Orifice Transfer Standard

For this calibration procedure, the following conditions are assumed in the field:

- The sampler is equipped with a valve to control sample flow rate.
- The sample flow rate is determined by measuring the orifice pressure differential, using a Magnehelic gauge.
- The sampler is designed to operate at a standardized volumetric flow rate of 8 ft^3/min (0.225 m^3/min), with an acceptable flow rate range within 10 percent of this value.
- The transfer standard for the flow rate calibration is an orifice device. The flow rate through the orifice is determined by the pressure drop caused by the orifice and is measured using a "U" tube water manometer or equivalent.
- The sampler and the orifice transfer standard are calibrated to standard volumetric flow rate units (scfm or scmm).
- An orifice transfer standard with calibration traceable to NIST is used.
- A "U" tube water manometer or equivalent, with a 0- to 16-inch range and a maximum scale division of 0.1 inch, will be used to measure the pressure in the orifice transfer standard.
- A Magnehelic gauge or equivalent, with a 9- to 100-inch range and a minimum scale division of 2 inches for measurements of the differential pressure across the sampler's orifice is used.
- A thermometer capable of measuring temperature over the range of 32° to 122°F (0° to 50°C) to ±2°F (±1°C) and referenced annually to a calibrated mercury thermometer is used.
- A portable aneroid barometer (or equivalent) capable of measuring ambient barometric pressure between 500 and 800 mm Hg (19.5 and 31.5 in. Hg) to the nearest mm Hg and referenced annually to a barometer of known accuracy is used.
- Miscellaneous handtools, calibration data sheets or station log book, and wide duct tape are available.

11.2.2.1 Set up the calibration system as illustrated in Figure 8. Monitor the airflow through the sampling system with a venturi/Magnehelic assembly, as illustrated in Figure 8. Audit the field sampling system once per quarter using a flow rate transfer standard, as described in the EPA *High Volume-Sampling Method, 40 CVR 50, Appendix B.* Perform a single-point calibration before and after each sample collection, using the procedures described in Section 11.2.3.

11.2.2.2 Prior to initial multi-point calibration, place an empty glass cartridge in the sampling head and activate the sampling motor. Fully open the flow control valve and adjust the voltage variator so that a sample flow rate corresponding to 110 percent of the desired flow rate (typically 0.20 to 0.28 m^3/min) is indicated on the Magnehelic gauge (based on the previously obtained multipoint calibration curve). Allow the motor to warm up for 10 minutes and then adjust the flow control valve to achieve the desire flow rate. Turn off the sampler. Record the ambient temperature and barometric pressure on the Field Calibration Data Sheet (see Figure 9).

11.2.2.3 Place the orifice transfer standard on the sampling head and attach a manometer to the tap on the transfer standard, as illustrated in Figure 8. Properly align the retaining rings with the filter holder and secure

by tightening the three screw clamps. Connect the orifice transfer standard by way of the pressure tap to a manometer using a length of tubing. Set the zero level of the manometer or Magnehelic. Attach the Magnehelic gauge to the sampler venturi quick release connections. Adjust the zero (if needed) using the zero adjust screw on face of the gauge.

11.2.2.4 To leak test, block the orifice with a rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler.

Caution: *Avoid running the sampler for too long a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the life of the motor*.

11.2.2.5 Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. A leak-free system will not produce an upscale response on the sampler's Magnehelic. Leaks are usually caused either by damaged or missing gaskets by cross-threading and/or not screwing sample cartridge together tightly. All leaks must be eliminated before proceeding with the calibration. When the sample is determined to be leak-free, turn off the sampler and unblock the orifice. Now remove the rubber stopper or plug from the calibrator orifice.

11.2.2.6 Turn the flow control valve to the fully open position and turn the sampler on. Adjust the flow control valve until a Magnehelic reading of approximately 70 in. is obtained. Allow the Magnehelic and manometer readings to stabilize and record these values on the orifice transfer Field Calibration Data Sheet (see Figure 9).

11.2.2.7 Record the manometer reading under Y1 and the Magnehelic reading under Y2 on the Field Calibration Data Sheet. For the first reading, the Magnehelic should still be at 70 inches as set above.

11.2.2.8 Set the Magnehelic to 60 inches by using the sampler's flow control valve. Record the manometer (Y1) and Magnehelic (Y2) readings on the Field Calibration Data Sheet (see Figure 9).

11.2.2.9 Repeat the above steps using Magnehelic settings of 50, 40, 30, 20, and 10 inches.

11.2.2.10 Turn the voltage variator to maximum power, open the flow control valve, and confirm that the Magnehelic reads at least 100 inches. Turn off the sampler and confirm that the Magnehelic reads zero.

11.2.2.11 Read and record the following parameters on the Field Calibration Data Sheet. Record the following on the calibration data sheet:

Data, job number, and operator's signature;

- Sampler serial number;
- Ambient barometric pressure; and
- Ambient temperature.

11.2.2.12 Remove the "dummy" cartridge and replace with a sample cartridge.

11.2.2.13 Obtain the Manufacturer High Volume Orifice Calibration Certificate.

11.2.2.14 If not performed by the manufacturer, calculate values for each calibrator orifice static pressure (Column 6, inches of water) on the manufacturer's calibration certificate using the following equation:

$$\sqrt{\triangle H(P_a/760)(298/[T_a + 273])}$$

where:

P_a = the barometric pressure (mm Hg) at time of manufacturer calibration, mm Hg

T_a = temperature at time of calibration, °C

11.2.2.15 Perform a linear regression analysis using the values in Column 7 of the manufacturer High Volume Orifice Calibration Certificate for flow rate (Q_{std}) as the "X" values and the calculated values as the Y

values. From this relationship, determine the correlation (CC1), intercept (B1), and slope (M1) for the Orifice Transfer Standard.

11.2.2.16 Record these values on the Field Calibration Data Sheet (see Figure 9).

11.2.2.17 Using the Field Calibration Data Sheet values (see Figure 9), calculate the Orifice Manometer Calculated Values (Y3) for each orifice manometer reading using the following equation:

Y3 Calculation

$$Y3 = [Y1(P_a/760)(298/\{T_a + 273\})]^{½}$$

11.2.2.18 Record the values obtained in Column Y3 on the Field Calibration Data Sheet (see Figure 9).

11.2.2.19 Calculate the Sampler Magnehelic Calculate Values (Y4) using the following equation:

Y4 Calculation

$$Y4 = [Y2(P_a/760)(298/\{T_a + 273\})]^{½}$$

11.2.2.20 Record the value obtained in Column Y4 on the Field Calibration Data Sheet (see Figure 9).

11.2.2.21 Calculate the Orifice Flow Rate (X1) in scm, using the following equation:

X1 Calculation

$$X1 = \frac{Y3 - B1}{M1}$$

11.2.2.22 Record the values obtained in Column X1, on the Field Calibration Data Sheet (see Figure 9).

11.2.2.23 Perform a linear regression of the values in Column X1 (as X) and the values in Column Y4 (as Y). Record the relationship for correlation (CC2), intercept (B2), and slope (M2) on the Field Calibration Data Sheet.

11.2.2.24 Using the following equation, calculate a set point (SP) for the manometer to represent a desired flow rate:

$$\text{Set point (SP)} = [(\text{Expected } P_a)/(\text{Expected } T_a)(T_{std}/P_{std})][M2\ (\text{Desired flow rate}) + B2]^2$$

where:

P_a = Expected atmospheric pressure (P_a), mm Hg
T_a = Expected atmospheric temperature (T_a), °C
M2 = Slope of developed relationship
B2 = Intercept of developed relationship
T_{std} = Temperature standard, 25°C
P_{std} = Pressure standard, 760 mm Hg

11.2.2.25 During monitoring, calculate a flow rate from the observed Magnehelic reading using the following equations:

$$Y5 = [\text{Average Magnehelic Reading } (\triangle H)\ (P_a/T_a)(T_{std}/P_{std})]^{1/2}$$

$$X2 = \frac{Y5 - B2}{M2}$$

where:

Y5 = Corrected Magnehelic reading
X2 = Instant calculated flow rate, scm

11.2.2.26 The relationship in calibration of a sampling system between Orifice Transfer Standard and flow rate through the sampler is illustrated in Figure 10.

11.2.3 Single-Point Audit of the High Volume Sampling System Utilizing Calibrated Orifice Transfer Standard

Single point calibration checks are required as follows:

- Prior to the start of each 24-hour test period.
- After each 24-hour test period. The post-test calibration check may serve as the pre-test calibration check for the next sampling period if the sampler is not moved.
- Prior to sampling after a sample is moved.

For samplers, perform a calibration check for the operational flow rate before each 24-hour sampling event and when required as outlined in the user quality assurance program. The purpose of this check is to track the sampler's calibration stability. Maintain a control chart presenting the percentage difference between a sampler's indicated and measured flow rates. This chart provides a quick reference of sampler flow-rate drift problems and is useful for tracking the performance of the sampler. Either the sampler log book or a data sheet will be used to document flowcheck information. This information includes, but is not limited to, sampler and orifice transfer standard serial number, ambient temperature, pressure conditions, and collected flow-check data.

In this subsection, the following is assumed:

- The flow rate through a sampler is indicated by the orifice differential pressure;
- Samplers are designed to operate at an actual flow rate of 8 scfm, with a maximum acceptable flow-rate fluctuation range of ±10 percent of this value;
- The transfer standard will be an orifice device equipped with a pressure tap. The pressure is measured using a manometer; and
- The orifice transfer standard's calibration relationship is in terms of standard volumetric flow rate (Q_{std}).

11.2.3.1 Perform a single point flow audit check before and after each sampling period utilizing the Calibrated Orifice Transfer Standard (see Section 11.2.1).

11.2.3.2 Prior to single point audit, place a "dummy" glass cartridge in the sampling head and activate the sampling motor. Fully open the flow control valve and adjust the voltage variator so that a sample flow rate corresponding to 110 percent of the desired flow rate (typically 0.19 to 0.28 m^3/min) is indicated on the Magnehelic gauge (based on the previously obtained multipoint calibration curve). Allow the motor to warm up for 10 minutes and then adjust the flow control valve to achieve the desired flow rate. Turn off the sampler. Record the ambient temperature and barometric pressure on the Field Test Data Sheet (see Figure 11).

11.2.3.3 Place the flow rate transfer standard on the sampling head.

11.2.3.4 Properly align the retaining rings with the filter holder and secure by tightening the 3 screw clamps. Connect the flow rate transfer standard to the manometer using a length of tubing.

11.2.3.5 Using tubing, attach 1 manometer connector to the pressure tap of the transfer standard. Leave the other connector open to the atmosphere.

11.2.3.6 Adjust the manometer midpoint by sliding the movable scale until the zero point corresponds with the water meniscus. Gently shake or tap to remove any air bubbles and/or liquid remaining on tubing connectors. (If additional liquid is required, remove tubing connector and add clean water.)

11.2.3.7 Turn on high-volume motor and let run for 5 minutes.

11.2.3.8 Record the pressure differential indicated, $\triangle H$, in inches of water, on the Field Test Data Sheet. Be sure stable $\triangle H$ has been established.

11.2.3.9 Record the observed Magnahelic gauge reading, in inches of water, on the Field Test Data Sheet. Be sure stable $\triangle M$ has been established.

11.2.3.10 Using previous established Orifice Transfer Standard curve, calculate Q_{xs} (see Section 11.2.2.23).

11.2.3.11 This flow should be within ±10 percent of the sampler set point, normally, 8 ft^3. If not, perform a new multipoint calibration of the sampler.

11.2.3.12 Remove flow rate transfer standard and dummy adsorbent cartridge.

11.3 Sample Collection

11.3.1 General Requirements

11.3.1.1 The sampler should be located in an unobstructed area, at least 2 meters from any obstacle to air flow. The exhaust hose should be stretched out in the downwind direction to prevent recycling of air into the sample head.

11.3.1.2 All cleaning and sample module loading and unloading should be conducted in a controlled environment, to minimize any chance of potential contamination.

11.3.1.3 When new or when using the sampler at a different location, all sample contact areas need to be cleared. Use triple rinses of reagent grade hexane contained in Teflon® rinse bottles. Allow the solvent to evaporate before loading the PUF modules.

11.3.2 Preparing Cartridge for Sampling

11.3.2.1 Detach the lower chamber of the cleaned sample head. While wearing disposable, clean, lint-free nylon, or powder-free surgical gloves, remove a clean glass adsorbent module from its shipping container. Remove the Teflon® end caps. Replace the end caps in the sample container to be reused after the sample has been collected.

11.3.2.2 Insert the glass module into the lower chamber and tightly reattach the lower chambers to the module.

11.3.2.3 Using clean rinsed (with hexane) Teflon-tipped forceps, carefully place a clean conditioned fiber filter atop the filter holder and secure in place by clamping the filter holder ring over the filter. Place the aluminum protective cover on top of the cartridge head. Tighten the 3 screw clamps. Ensure that all module connections are tightly assembled. Place a small piece of aluminum foil on the ball-joint of the sample cartridge to protect from back-diffusion of semi-volatile into the cartridge during transporting to the site.

[Note: Failure to do so could result in air flow leaks at poorly sealed locations which could affect sample representativeness.]

11.3.2.4 Place in a carrying bag to take to the sampler.

11.3.3 Collection

11.3.3.1 After the sampling system has been assembled, perform a single point flow check as described in Sections 11.2.3.

11.3.3.2 With the empty sample module removed from the sampler, rinse all sample contact areas using reagent grade hexane in a Teflon® squeeze bottle. Allow the hexane to evaporate from the module before loading the samples.

11.3.3.3 With the sample cartridge removed from the sampler and the flow control valve fully open, turn the pump on and allow it to warm-up for approximately 5 minutes.

11.3.3.4 Attach a "dummy" sampling cartridge loaded with the exact same type of filter and PUF media to be used for sample collection.

11.3.3.5 Turn the sampler on and adjust the flow control valve to the desired flow as indicated by the Magnehelic gauge reading determined in Section 11.2.2.24. Once the flow is properly adjusted, take extreme care not to inadvertently alter its setting.

11.3.3.6 Turn the sampler off and remove the "dummy" module. The sampler is now ready for field use.

11.3.3.7 Check the zero reading of the sampler Magnehelic. Record the ambient temperature, barometric pressure, elapsed time meter setting, sampler serial number, filter number, and PUF cartridge number on the Field Test Data Sheet (see Figure 11). Attach the loaded sampler cartridge to the sampler.

11.3.3.8 Place the voltage variator and flow control valve at the settings used in Section 11.3.2, and the power switch. Activate the elapsed time meter and record the start time. Adjust the flow (Magnehelic setting), if necessary, using the flow control valve.

11.3.3.9 Record the Magnehelic reading every 6 hours during the sampling period. Use the calibration factors (see Section 11.2.2.24) to calculate the desired flow rate. Record the ambient temperature, barometric pressure, and Magnehelic reading at the beginning and during sampling period.

11.3.4 Sample Recovery

11.3.4.1 At the end of the desired sampling period, turn the power off. Carefully remove the sampling head containing the filter and adsorbent cartridge. Place the protective "plate" over the filter to protect cartridge during transport to clean recovery area. Also, place a piece of aluminum foil around the bottom of adsorbent sampler head.

11.3.4.2 Perform a final calculated sampler flow check using the calibration orifice, as described in Section 11.3.2. If calibration deviates by more than 10 percent from initial reading, mark the flow data for that sample as suspect and inspect and/or remove from service, record results on Field Test Data Sheet, Figure 11.

11.3.4.3 Transport adsorbent sampler head to a clean recovery area.

11.3.4.4 While wearing disposable lint free nylon or powder-free surgical gloves, remove the PUF cartridge from the lower module chamber and lay it on the retained aluminum foil in which the sample was originally wrapped.

11.3.4.5 Carefully remove the glass fiber filter from the upper chamber using clean Teflon®-tipped forceps.

11.3.4.6 Fold the filter in half twice (sample side inward) and place it in the glass cartridge atop the PUF.

11.3.4.7 Wrap the combined samples in the original hexane rinsed aluminum foil, attached Teflon® end caps and place them in their *original* aluminum sample container. Complete a sample label and affix it to the aluminum shipping container.

11.3.4.8 Chain-of-custody should be maintained for all samples. Store the containers under dry ice and protect from UV light to prevent possibly photo-decomposition of collected analytes. If the time span between sample collection and laboratory analysis is to exceed 24 hours, refrigerate sample at 4°C.

11.3.4.9 Return at least 1 field filter/PUF blank to the laboratory with each group of samples. Treat a field blank exactly as the sample except that no air is drawn through the filter/adsorbent cartridge assembly.

11.3.4.10 Ship and store field samples chilled (<4°) (blue ice is acceptable) until receipt at the analytical laboratory, after which they should be refrigerated at less than or equal to 4°C. Extraction must be performed within 7 days of sampling and analysis within 40 days of extraction.

12. Sample Extraction Procedure

[Note: Sample extraction should be performed under a properly ventilated hood.]

12.1 Sample Extraction

12.1.1 All samples should be extracted within 1 week after collection. All samples should be stored at <4°C until extracted.

12.1.2 All glassware should be washed with a suitable detergent; rinsed with deionized water, acetone, and hexane; rinsed again with deionized water; and fired in an oven (500°C).

12.1.3 Prepare a spiking solution for determination of extraction efficiency. The spiking solution should contain one or more surrogate compounds that have chemical structures and properties similar to those of the analytes of interest. Octachloronaphthalene (OCN) and dibutylchlorendate have been used as surrogates for determination of organochlorine pesticides by GC with an ECD. Tetrachloro-m-xylene and decachlorobiphenyl can also be used together to insure recovery of early and late eluting compounds. For organophosphate pesticides, tributylphosphate or triphenylphosphate may be employed as surrogates. The surrogate solution should be prepared so that addition of 100 μL into the PUF plug results in an extract containing the surrogate compound at the high end of the instrument's calibration range. As an example, the spiking solution for OCN is prepared by dissolving 10 mg of OCN in 10 mL of 10% acetone in n-hexane, followed by serial dilution n-hexane to achieve a final spiking solution of OCN is 1 μg/mL.

[Note: Use the recoveries of the surrogate compounds to monitor for unusual matrix effects and gross sample processing errors. Evaluate surrogate recovery for acceptance by determining whether the measured concentration falls within the acceptance limits of 60-120 percent.]

12.1.4 The extracting solution (10% diethyl ether/hexane) is prepared by mixing 1800 mL of freshly opened hexane and 200 mL of freshly opened diethyl ether (preserved with ethanol) to a flask.

12.1.5 All clean glassware, forceps, and other equipment to be used should be rinsed with 10% diethyl ether/ hexane and placed on rinsed (10% diethyl ether/hexane) aluminum foil until use. The condensing towers should also be rinsed with 10% diethyl ether/hexane. Then add 700 mL of 10% diethyl ether/hexane to the 1,000 mL round bottom flask and add up to three boiling granules.

12.1.6 Using precleaned (i.e., 10% diethyl ether/hexane Soxhlet extracted) cotton gloves, the filter/PUF cartridge is removed from the sealed container, the PUF removed from the glass cartridge, and the filter/PUF together are placed into the 300 mL Soxhlet extractor using prerinsed forceps.

12.1.7 Before extraction begins, add 100 µL of the OCN solution directly to the top of the PUF plug.

[Note: Incorporating a known concentration of the solution onto the sample provides a quality assurance check to determine recovery efficiency of the extraction and analytical processes.]

12.1.8 Connect the Soxhlet extractor to the 1,000 mL boiling flask and condenser. Wet the glass joints with 10% diethyl ether/hexane to ensure a tight seal between the fittings. If necessary, the PUF plug can be adjusted

using forceps to wedge it midway along the length of the siphon. The above procedure should be followed for all samples, with the inclusion of a blank control sample.

12.1.9 The water flow to the condenser towers of the Soxhlet extraction assembly should be checked and the heating unit turned on. As the samples boil, the Soxhlet extractors should be inspected to ensure that they are filling and siphoning properly (4 to 6 cycles/hour). Samples should cycle for a minimum of 16 hours.

12.1.10 At the end of the extracting process (minimum of 16 hours), the heating unit is turned off and the sample cooled to room temperature.

12.1.11 The extracts are then concentrated to 5 mL using a Kuderna-Danish (K-D) apparatus. The K-D is set up, assembled with concentrator tubes, and rinsed. The lower end of the filter tube is packed with glass wool and filled with sodium sulfate to a depth of 40 mm. The filter tube is then placed in the neck of the K-D. The Soxhlet extractors and boiling flasks are carefully removed from the condenser towers and the remaining solvent is drained into each boiling flask. Sample extract is carefully poured through the filter tube into the K-D. Each boiling flask is rinsed three times by swirling hexane along the sides. Once the sample has drained, the filter tube is rinsed down with hexane. Each Snyder column is attached to the K-D and rinsed to wet the joint for a tight seal. The complete K-D apparatus is placed on a steam bath and the sample is evaporated to approximately 5 mL.

[Note: Do not allow samples to evaporate to dryness.]

Remove sample from the steam bath, rinse the Snyder column with a minimum of hexane, and allow to cool. Adjust sample volume to 10 mL in a concentrator tube, close with a glass stopper, and seal with TFE fluorocarbon tape. Alternatively, the sample may be quantitatively transferred (with concentrator tube rinsing) to prescored vials and brought up to final volume. Concentrated extracts are stored at <4°C until analyzed. Analysis should occur no later than 40 days after sample extraction.

12.2 Sample Cleanup

12.2.1 If only polar compounds are sought, an alumina cleanup procedure is appropriate. Before cleanup, the sample extract is carefully reduced to 1 mL using a gentle stream of clean nitrogen.

12.2.2 A glass chromatographic column (2-mm I.D. x 15-cm long) is packed with alumina (7), activity grade IV, and rinsed with approximately 20 mL of n-hexane. The concentrated sample extract is placed on the column and eluted with 10 mL of n-hexane at a rate of 0.5 mL/minute. The eluate volume is adjusted to exactly 10 mL and analyzed as per Section 13.

12.2.3 If both PCBs and common pesticides are sought, alternate cleanup procedures (8,9) may be required (i.e., silicic acid).

12.2.4 Finally, class separation and improved specificity can be achieved by column clean-up and separation on Florisil (9).

13. Analytical Procedure

13.1 Analysis of Organochlorine Pesticides by Capillary Gas Chromatography with Electron Capture Detector (GC/ECD)

[Note: Organochlorine pesticides, PCBs and many nonchlorinated pesticides are responsive to electron capture detection (see Table 1). Most of these compounds can be analyzed at concentration of 1 to 50 ng/mL by GC/ECD. The following procedure is appropriate. Sampling and analytical methods that have been used to determine pesticides and PCBs collected from air using a modification of this methodology have been published (14-22).]

13.1.1 Select GC column (e.g., 0.3-mm by 30-m DB-5 column) and appropriate GC conditions to separate the target analytes. Typical operating parameters for this column with splitless injection are: Carrier gas-chromatography grade helium at a flow rate of 1 to 2 mL/min and a column head pressure of 7 to 9 psi (48 to 60 kPa); injector temperature of 250°C; detector temperature of 350°C; initial oven temperature of 50°C held for 2.0 min., ramped at 15°C/min to 150°C for 8 min, ramped at 10°C/min to 295°C then held for 5 min; purge time of 1.0 min. A typical injection volume is 2 to 3 μL.

13.1.2 Remove sample extract from refrigerator and allow to warm to room temperature.

13.1.3 Prepare standard solution from reference materials of known purity. Analytically pure standards of organochlorine pesticides and PCBs are available from several commercial sources.

13.1.4 Use the standard solutions of the various compounds of interest to determine relative retention times (RRTs) to an internal standard such as p,p'-DDE, aldrin or octachloronaphthalene. Use 1 to 3-μL injections or other appropriate volumes.

13.1.5 Determine detector linearity by injecting standard solutions of three different concentrations (amounts) that bracket the range of analyses. The calibration is considered linear if the relative standard deviation (RSD) of the three response factors for the three standards is 20 percent or less.

13.1.6 Calibrate the system with a minimum of three levels of calibration standards in the linear range. The low standard should be near the analytical method detection limit. The calibration is considered linear if the relative standard deviation (RSD) of the three response factors for the three standards is 20 percent or less. The initial calibration should be verified by the analysis of a standard from an independent source. Recovery of 85 to 115 percent is acceptable. The initial calibration curve should be verified at the begining of each day and after every ten samples by the analysis of the midpoint standard; an RPD of 15% or less is acceptable for continuing use of the initial calibration curve.

13.1.7 Inject 1 to 3 μL of sample extract. Record volume injected to the nearest 0.05 μL.

13.1.8 A typical ECD response for a mixture of single component pesticides using a capillary column is illustrated in Figure 12. If the response (peak height or area) exceeds the calibration range, dilute the extract and reanalyze.

13.1.9 Quantify PCB mixtures by comparison of the total heights or areas of GC peaks (minimum of five) with the corresponding peaks in the best-matching standard. Use Aroclor 1242 for early-eluting PCBs and either Aroclor 1254 or Aroclor 1260 as appropriate for late-eluting PCBs.

13.1.10 If both PCBs and organochlorine pesticides are present in the same sample, use column chromatographic separation on silicic acid (8,9) prior to GC analysis.

13.1.11 If polar compounds are present that interfere with GC/ECD analysis, use column chromatographic cleanup or alumina (7), activity grade IV, in accordance with Section 12.2.

13.1.12 For confirmation use a second GC column such as DB-608. All GC procedures except GC/MS require second column confirmation.

13.1.13 For improved resolution use a capillary column such as an 0.25-mm I.D. x 30-m DB-5 with 0.25 μm film thickness. The following conditions are appropriate.

- Helium carrier gas at 1 mL/min.
- Column temperature program, 90°C (4 min)/16°C/min to 154°C/4°C/min to 270°C.
- Detector, ^{63}Ni ECD at 350°C.
- Make up gas, nitrogen, or 5% methane/95% argon at 60 mL/min.
- Splitless injection, 2 μL maximum.
- Injector temperature, 220°C.

13.1.14 Class separation and improved specificity can be achieved by column chromatographic separation on Florisil (9).

13.1.15 A Hall electrolytic conductivity detector (HECD) operated in the reductive mode may be substituted for the ECD for improved specificity. Sensitivity, however, will be reduced by at least an order of magnitude.

13.2 Analysis of Organophosphorus Pesticides by Capillary Gas Chromatography with Flame Photometric or Nitrogen-Phosphorus Detectors (GC/FPD/NPD)

[Note: Organophosphorus pesticides are responsive to flame photometric and nitrogen-phosphorus (alkali flame ionization) detection. Most of these compounds can be analyzed at concentrations of 50 to 500 ng/mL using either of these detectors.]

13.2.1 Procedures given in Section 13.1.1 through 13.1.9 and Section 13.1.13 through 13.1.14 apply, except for the selection of surrogates.

13.2.2 Use tributylphosphate, triphenylphosphate, or other suitable compound(s) as surrogates to verify extraction efficiency and to determine RRTs.

13.3 Analysis of Carbamate and Urea Pesticides by Capillary Gas Chromatography with Nitrogen-Phosphorus Detector

13.3.1 Trazine, carbamate, and urea pesticides may be determined by capillary GC (DB-5, DB-17, or DB-1701 stationary phase) using nitrogen-phosphorus detection or MS-SIM with detection limits in the 0.05 to 0.2 μL/mL range. Procedures given in Section 13.1.1 through 13.1.9 and Section 13.1.13 through 13.1.14 apply, except for the selection of surrogates, detector, and make up gas.

13.3.2 Thermal degradation may be minimized by reducing the injector temperature to 200°C. HPLC may also be used, but detection limits will be higher (1 to 5 μg/mL).

13.3.3 N-methyl carbamates may be determined using reverse-phase high performance liquid chromatography (HPLC) (C-18) (Section 13.4) and post-column derivization with o-phthaldehyde and fluorescence detection (EPA Method 531). Detection limits of 0.01 to 0.1 μg/mL can be achieved.

13.4 Analysis of Carbamate, Urea, Pyrethroid, and Phenolic Pesticides by High Performance Liquid Chromatography (HPLC)

[Note: Many carbamate pesticides, urea pesticides, pyrethrins, phenols, and other polar pesticides may be analyzed by high HPLC with fixed or variable wavelength UV detection. Either reversed-phase or normal phase chromatography may be used. Detection limits are 0.2 to 10 μg/mL of extract.]

13.4.1 Select HPLC column (i.e., Zorbax-SIL, 46-mm I.D. x 25-cm, or μ-Bondapak C18, 3.9-mm x 30-cm, or equivalent).

13.4.2 Select solvent system (i.e., mixtures of methanol or acetonitrile with water or mixtures of heptane or hexane with isopropanol).

13.4.3 Follow analytical procedures given in Sections 13.1.2 through 13.1.9.

13.4.4 If interferences are present, adjust the HPLC solvent system composition or use column chromatographic clean-up with silica gel, alumina, or Florisil (9).

13.4.5 An electrochemical detector may be used to improve sensitivity for some ureas, carbonates, and phenolics. Much more care is required in using this detector, particularly in removing dissolved oxygen from the mobile phase and sample extracts.

13.4.6 Chlorophenol (di- through penta-) may be analyzed by GC/ECD or GC/MS after derivatization with pentafluorobenzylbromide (EPA Method 604).

13.4.7 Chlorinated phenoxyacetic acid herbicides and pentachlorophenol can be analyzed by GC/ECD or GC/MS after derivatization with diazomethane (EPA Method 515). DB-5 and DBJ-1701 columns (0.25-mm I.D. x 30-m) at 60 to 300°C/4°C per min have been found to perform well.

13.5 Analysis of Pesticides and PCBs by Gas Chromatography with Mass Spectrometry Detection (GC/MS)

[Note: A mass spectrometer operating in the selected ion monitoring mode is useful for confirmation and identification of pesticides.]

13.5.1 A mass spectrometer operating in select ion monitoring (SIM) mode can be used as a sensitive detector for multi-residue determination of a wide variety of pesticides. Mass spectrometers are now available that provide detection limits comparable to nitrogen-phosphorus and electron capture detectors.

13.5.2 Most of the pesticides shown in Table 1 have been successfully determined by GC/MS-SIM. Typical GC operating parameters are as described in Section 13.1.1.

13.5.3 The mass spectrometer is typically operated using positive ion electron impact ionization (70 eV). Other instrumental parameters are instrument specific.

13.5.4 p-Terphenyl-d_{14} is commonly used as a surrogate for GC/MS analysis.

13.5.5 Quantification is typically performed using an internal standard method. 1,4-Dichlorobenzene, naphthalene-d_8, acenaphthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12} and perylene-d_{12} are commonly used as internal standards. Procedures given in Section 13.1.1 through 13.1.9 and Section 13.1.13 through 13.1.14 apply, except for the selection of surrogates, detector, and make up gas.

13.5.6 See ASTM Practice D 3687 for injection technique, determination of relative retention times, and other procedures pertinent to GC and HPLC analyses.

13.6 Sample Concentration

13.6.1 If concentrations are too low to detect by the analytical procedure of choice, the extract may be concentrated to 1 mL or 0.5 mL by carefully controlled evaporation under an inert atmosphere. The following procedure is appropriate.

13.6.2 Place K-D concentrator tube in a water bath and analytical evaporator (nitrogen blow-down) apparatus. The water bath temperature should be from 25°C to 50°C.

13.6.3 Adjust nitrogen flow through hypodermic needle to provide a gentle stream.

13.6.4 Carefully lower hypodermic needle into the concentrator tube to a distance of about 1 cm above the liquid level.

13.6.5 Continue to adjust needle placement as liquid level decreases.

13.6.6 Reduce volume to slightly below desired level.

13.6.7 Adjust to final volume by carefully rinsing needle tip and concentrator tube well with solvent (usually n-hexane).

14. Calculations

14.1 Determination of Concentration

14.1.1 The concentration of the analyte in the extract solution can be taken from a standard curve where peak height or area is plotted linearly against concentration in nanograms per milliliter (ng/mL). If the detector response is known to be linear, a single point is used as a calculation constant.

14.1.2 From the standard curve, determine the nanograms of analyte standard equivalent to the peak height or area for a particular compound.

14.1.3 Ascertain whether the field blank is contaminated. Blank levels should not exceed 10 ng/sample for organochlorine pesticides or 100 ng/sample for PCBs and other pesticides. If the blank has been contaminated, the sampling series must be held suspect.

14.2 Equations

14.2.1 Quantity of the compound in the sample (A) is calculated using the following equation:

$$A = 1000 \left(\frac{A_s \times V_e}{V_i} \right)$$

where:

A = total amount of analyte in the sample, ng.

A_s = calculated amount of material injected onto the chromatograph based on calibration curve for injected standards, ng.

V_e = final volume of extract, mL.

V_i = volume of extract injected, μL.

1000 = factor for converting microliters to milliliters.

14.2.2 The extraction efficiency (EE) is determined from the recovery of surrogate spike as follows:

$$EE(\%) = \left|\frac{S}{S_a}\right| [100]$$

where:

EE = extraction efficiency, %

S = amount of spike recovered, ng.

S_a = amount of spike added to plug, ng.

The extraction efficiency (surrogate recovery) must fall between 60-120% to be acceptable.

14.2.3 The total volume of air sampled under ambient conditions is determined using the following equation:

$$V_a = \frac{\sum_{i=1}^{n} (T_i \times F_i)}{1000 \text{ L/m}^3}$$

where:

V_a = total volume of air sampled, m^3.

T_i = length of sampling segment between flow checks, min.

F_i = average flow during sampling segment, L/min.

14.2.4 The air volume is corrected to EPA standard temperature (25°C) and standard pressure (760 mm Hg) as follows:

$$V_s = V_a \left(\frac{P_b - P_w}{760 \text{ mm Hg}}\right) \left(\frac{298K}{t_A}\right)$$

where:

V_s = volume of air at standard conditions (25°C and 760 mm Hg), std. m^3.

V_a = total volume of air sampled, m^3.

P_b = average ambient barometric pressure, mm Hg.

P_w = vapor pressure of water at calibration temperature, mm Hg.

t_A = average ambient temperature, °C + 273.

14.2.5 If the proper criteria for a sample have been met, concentration of the compound in a standard cubic meter of air sampled is calculated as follows:

$$C_a(\text{ng/std. m}^3) = \left[\frac{(A)}{(V_s)}\right]$$

If it is desired to convert the air concentration value to parts per trillion (ppt) in dry air at standard temperature and pressure (STP), the following conversion is used:

$$ppt = 0.844\ (C_a)$$

The air concentration can be converted to parts per trillion (v/v) in air at STP as follows:

$$pptv = \left[\frac{(24.45)\ (C_a)}{(MW)}\right]$$

where:

MW = molecular weight of the compound of interest, g/g-mole.

14.2.6 If quantification is performed using an internal standard, a relative response factor (RRF) is calculated by the equation:

$$RRF = \left[\frac{(I_s)(C_{is})}{(I_{is})(C_s)}\right]$$

where:

I_s = integrated area of the target analyte peak, counts.
I_{is} = integrated area of the internal standard peak, counts.
C_{is} = concentration of the internal standard, ng/μL.
C_s = concentration of the analyte, ng/µL.

14.2.7 The concentration of the analyte (C_a) in the sample is then calculated as follows:

$$C_a = \frac{(I_s)(C_{is})}{(RRF)(I_{is})}$$

where:

I_s = integrated area of the target analyte peak, counts.
RRF = relative response factor (see Section 14.2.7).

15. Performance Criteria and Quality Assurance

[Note: This section summarizes required quality assurance (QA) measures and provides guidance concerning performance criteria that should be achieved within each laboratory.]

15.1 Standard Operating Procedures (SOPs)

15.1.1 Users should generate SOPs describing the following activities accomplished in their laboratory: (1) assembly, calibration, and operation of the sampling system, with make and model of equipment used; (2) preparation, purification, storage, and handling of sampling cartridges, (3) assembly, calibration, and operation of the analytical system, with make and model of equipment used; and (4) all aspects of data recording and processing, including lists of computer hardware and software used.

15.1.2 SOPs should provide specific stepwise instructions and should be readily available to, and understood by, the laboratory personnel conducting the work.

15.2 Process, Field, and Solvent Blanks

15.2.1 One filter/PUF cartridge from each batch of approximately twenty should be analyzed, without shipment to the field, for the compounds of interest to serve as a process blank.

15.2.2 During each sampling episode, at least one filter/PUF cartridge should be shipped to the field and returned, without drawing air through the sampler, to serve as a field blank.

15.2.3 Before each sampling episode, one PUF plug from each batch of approximately twenty should be spiked with a known amount of the standard solution. The spiked plug will remain in a sealed container and will not be used during the sampling period. The spiked plug is extracted and analyzed with the other samples. This field spike acts as a quality assurance check to determine matrix spike recoveries and to indicate sample degradation.

15.2.4 During the analysis of each batch of samples, at least one solvent process blank (all steps conducted but no filter/PUF cartridge included) should be carried through the procedure and analyzed.

15.2.5 Levels for process, field and solvent blanks should not exceed 10 ng/sample for single components or 100 ng/sample for multiple component mixtures (i.e., for organochlorine pesticides and PCBs).

15.3 Method Precision and Bias

15.3.1 Precision and bias in this type of analytical procedure are dependent upon the precision and bias of the analytical procedure for each compound of concern, and the precision and bias of the sampling process.

15.3.2 Several different parameters involved in both the sampling and analysis steps of this method collectively determine the precision and bias with which each compound is detected. As the volume of air sampled is increased, the sensitivity of detection increases proportionately within limits set by: (a) the retention efficiency for each specific component trapped on the polyurethane foam plug, and (b) the background interference associated with the analysis of each specific component at a given site sampled. The sensitivity of detection of samples recovered by extraction depends on: (a) the inherent response of the particular GC detector used in the determinative step, and (b) the extent to which the sample is concentrated for analysis. It is the responsibility of the analyst(s) performing the sampling and analysis steps to adjust parameters so that the required detection limits can be obtained.

15.3.3 The reproducibility of this method for most compounds for which it has been evaluated has been determined to range from ±5 to ±30% (measured as the relative standard deviation) when replicate sampling cartridges are used (N>5). Sample recoveries for individual compounds generally fall within the range of 90 to 110%, but recoveries ranging from 65 to 125% are considered acceptable.

15.4 Method Safety

15.4.1 This procedure may involve hazardous materials, operations, and equipment. This method does not purport to address all of the safety problems associated with its use.

15.4.2 It is the users responsibility to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to the implementation of this procedure. This should be part of the users SOP manual.

16. References

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TABLE 1. COMPOUNDS FOR WHICH PROCEDURE HAS BEEN TESTED[1]

Compound	Recommended Analysis[2]	Compound	Recommended Analysis
Alachlor	GC/ECD	Folpet	GC/ECD
Aldrin	GC/ECD	Heptachlor	GC/ECD
Allethrin	HPLC/UV	Heptachlor epoxide	GC/ECD
Aroclor 1242	GC/ECD	Hexachlorobenzene	GC/ECD
Aroclor 1254	GC/ECD	Lindane (γ-BHC)	GC/ECD
Aroclor 1260	GC/ECD	Linuron	HPLC/UV
Atrazine	GC/NPD	Malathion	GC/NPD or FPD
Bendiocarb	HPLC/UV	Methyl parathion	GC/NPD or FPD
BHC (α- and β-Hexachlorocyclohexanes)	GC/ECD	Methoxychlor	GC/FCD
Captan	GC/ECD	Metolachlor	GC/ECD
Carbaryl	HPLC/UV	Mexacarbate	GC/FCD
Carbofuran	HPLC/UV	Mirex	GC/ECD
Chlordane, technical	GC/ECD	Monuron	HPLC/UV
Chlorothalonil	GC/ECD	Trans-nonachlor	GC/ECD
Chlorotoluron	HPLC/UV	Oxychlordane	GC/ECD
Chlorpyritos	GC/ECD	Pentachlorobenzene	GC/ECD
2,4-D esters and salts	GC/ECD	Pentachlophenol	GC/ECD
Dacthal	GC/ECD	Permethrin (cis and trans)	HPLC/UV
ρ,ρ-'DDT	GC/ECD	o-Phenylphenol	HPLC/UV
ρ,ρ-'DDE	GC/ECD	Phorate	GC/NPD or FPD
Diazinon	GC/NPD or FPD	Propazine	GC/NPD
Dicloran	GC/ECD	Propoxur (Baygon)	HPLC/UV
Dieldrin	GC/ECD	Pyrethrin	HPLC/UV
Dicofol	GC/ECD	Resmethrin	HPLC/UV
Dicrotophos	HPLC/UV	Ronnel	GC/ECD
Diuron	HPLC/UV	Simazine	HPLC/UV
Ethyl parathion	GC/NPD or FPD	Terbuthiuron	HPLC/UV
Fenvalerate	HPLC/UV	Trifluralin	GC/ECD
Fluometuron	HPLC/UV		

[1] The following recommendations are specific for that analyte for maximum sensitivity.
[2] GC = gas chromatography; ECD = electron capture detector, FPD = flame photometric detector; HPLC = high performance liquid chromatography; NPD = nitrogen-phosphorus detector; UV = ultraviolet absorption detector; GC/MS = gas chromatography/mass spectrometry may also be used.

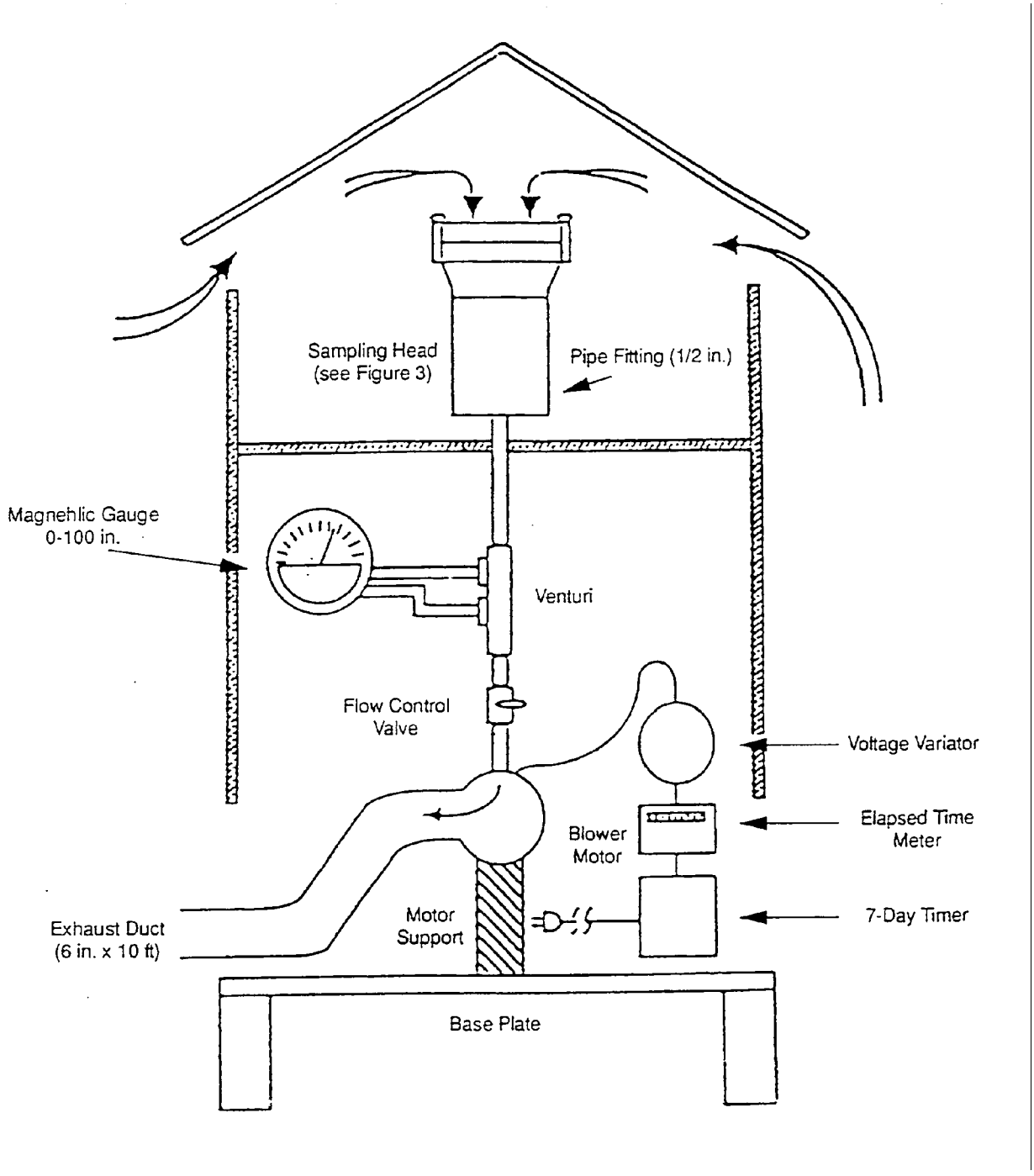

Figure 1. Typical high volume air sampler for monitoring common pesticides and PCBs.

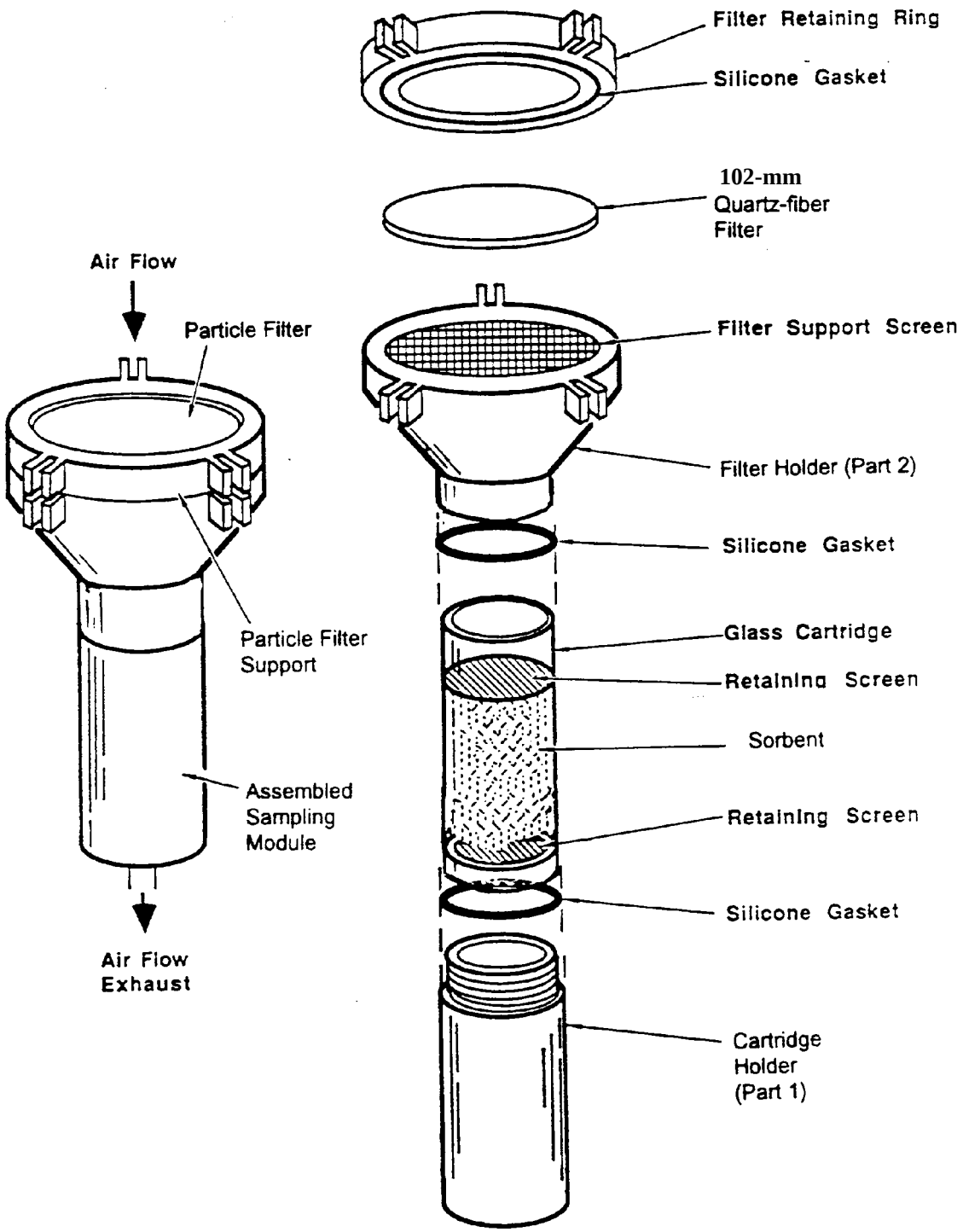

Figure 2. Typical absorbent cartridge assembly for sampling common pesticides and PCBs.

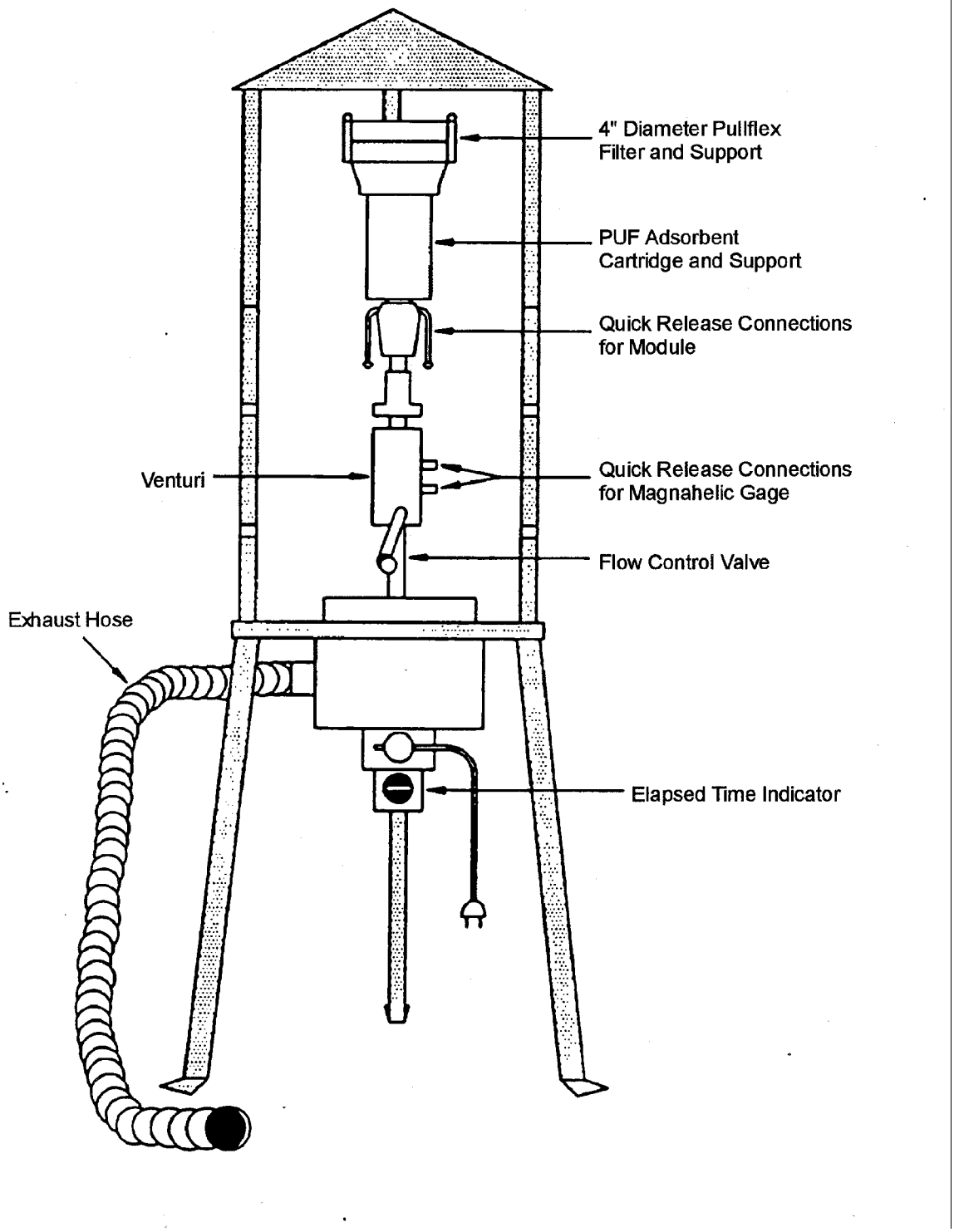

Figure 3. Portable high volume air sampler developed by EPA.

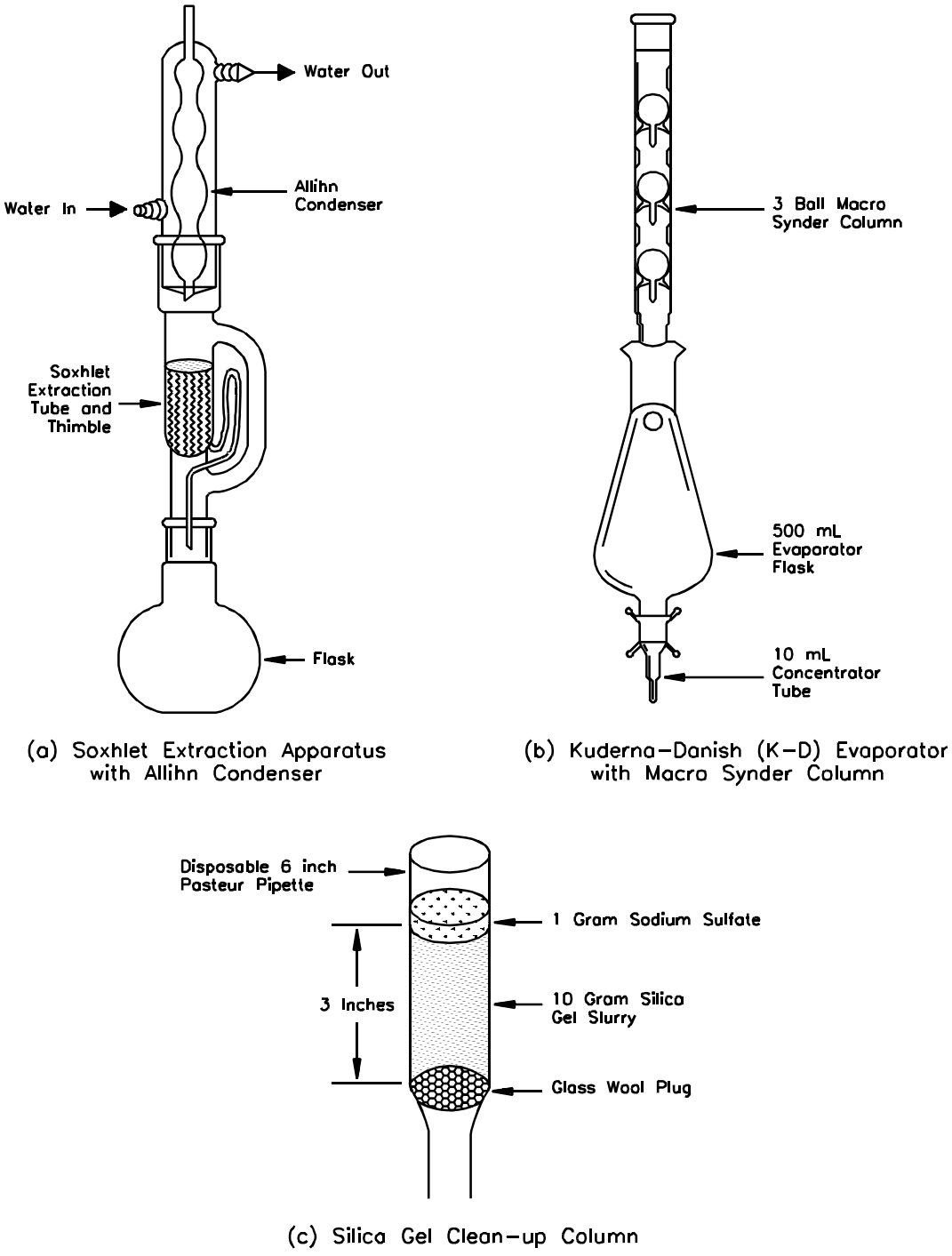

Figure 4. Apparatus used for sample clean-up and extraction.

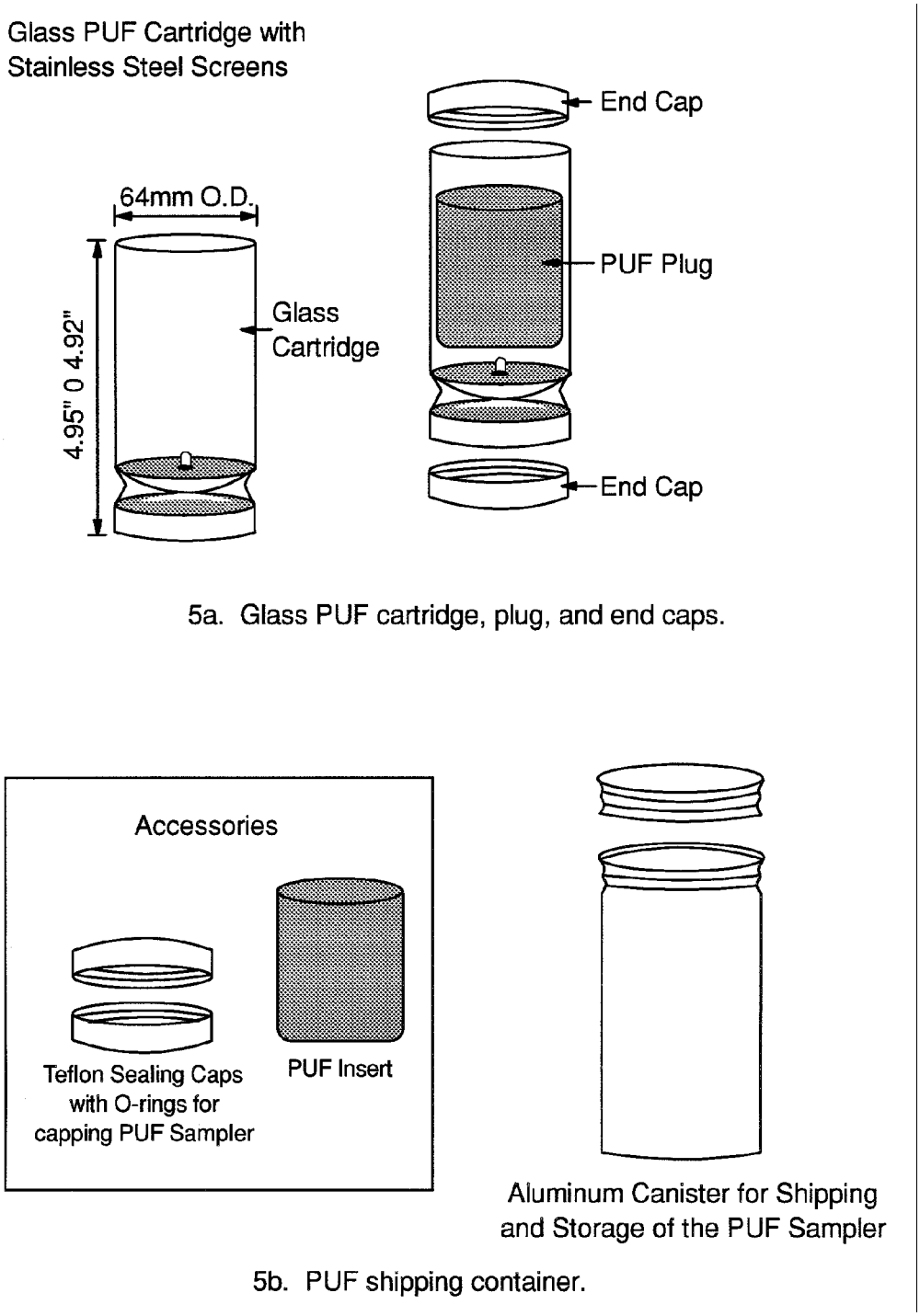

Figure 5. Glass PUF cartridge (5a) and shipping container (5b) for use with high-volume sampling systems.

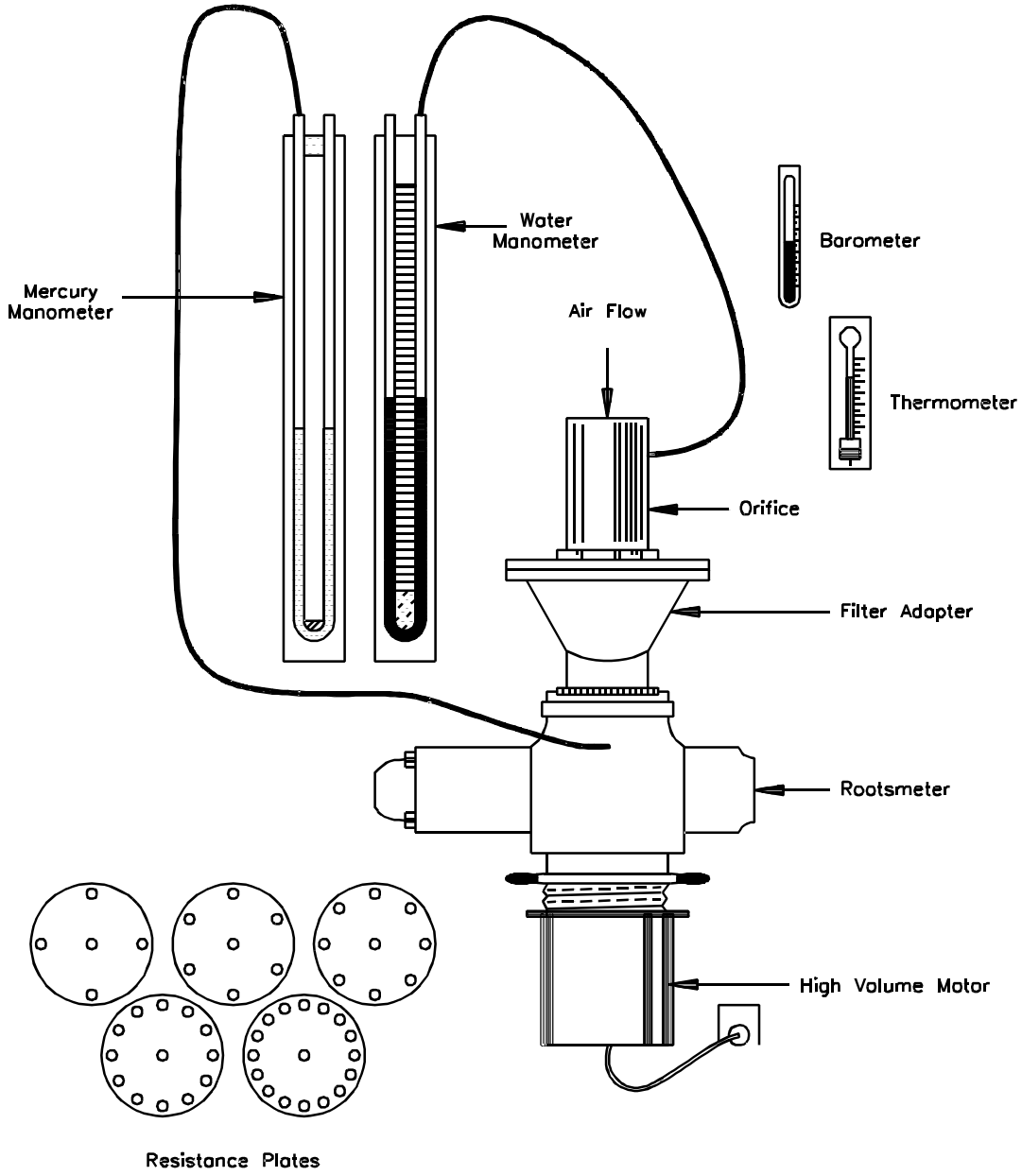

Figure 6. Positive displacement rootsmeter used to calibrate orifice transfer standard.

COMPENDIUM METHOD TO-4A
ORIFICE CALIBRATION DATA SHEET

T_1 _____ Name _____

P_1 _____ mmHg Date _____

Orifice No. _____

Rootsmeter No. _____

Resistance Plants (No. of holes)	Air Volume Measured by Rootsmeter V_m (R^3)	(m^3)	Standard Volume, V_{std} (std m^3)	Time for Air Volume to Pass Through Rootsmeter, θ (min)	Rootsmeter Pressure Differential, ΔP (mm Hg)	Pressure Drop Across Orifice, ΔH (in. H_2O)	x-Axis Standard Flowrate, Q_{std} (std m^3/min)	Y - axis $\sqrt{\Delta H(P_1/P_{std})(298/T_1)}$ value
5	200	5.66						
7	200	5.66						
10	300	8.50						
13	300	8.50						
18	300	8.50						

Factors: $(R^3)(0.02832\ \frac{m^3}{R^3}) = m^3$ and (in. Hg) $25.4\ (\frac{mm\ Hg}{in.\ Hg})$ = mm Hg

Calculation Equations:

1. $V_{std} = V_m\ (\frac{P_1 - \Delta P}{P_{std}})(\frac{T_{std}}{T_1})$

where:

$T_{std} = 296°K$

$P_{std} = 760.0$ mm Hg

2. $Q_{std} = \frac{V_{std}}{\theta}$

Figure 7. Orifice calibration data sheet.

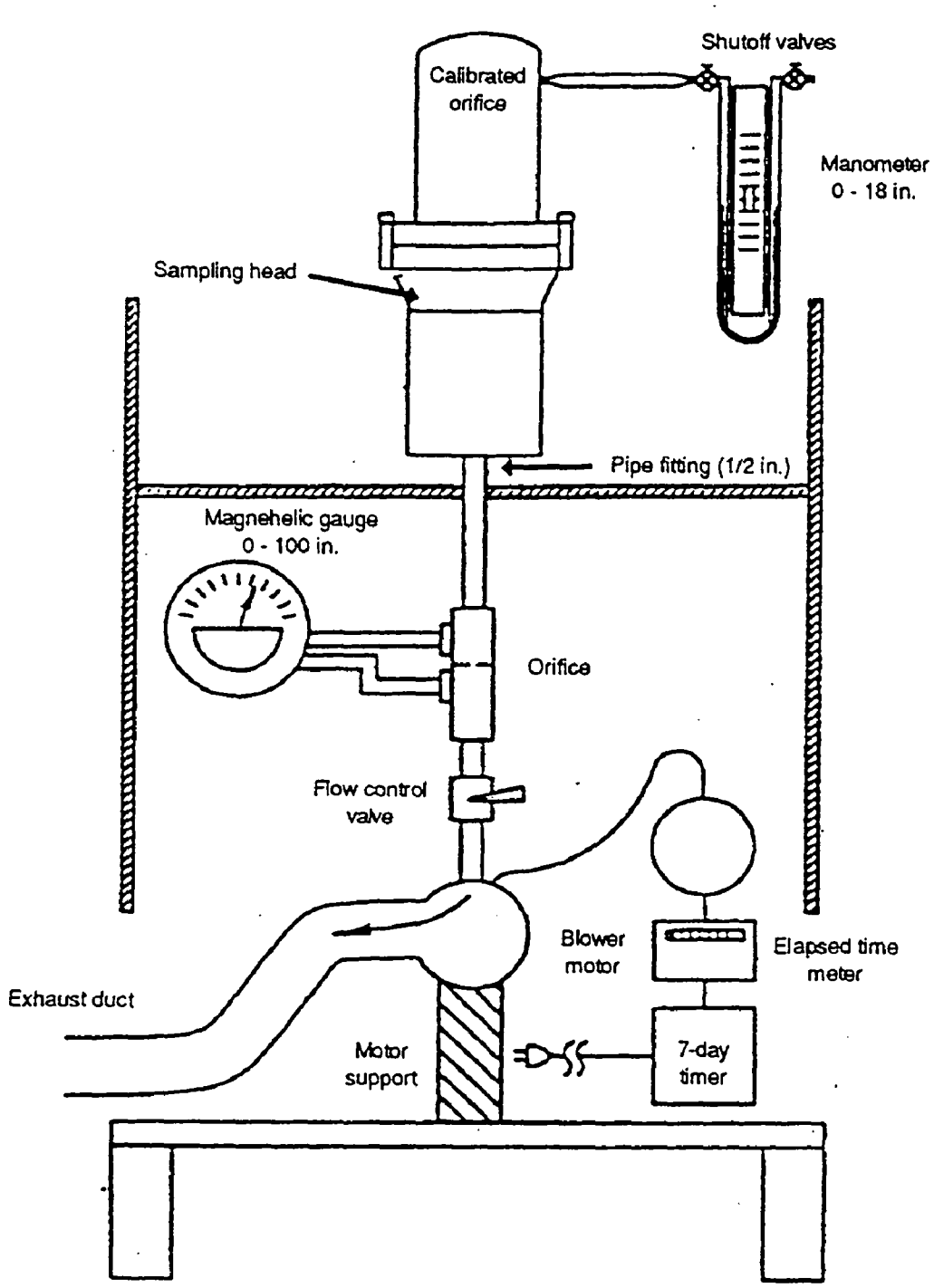

Figure 8. Field calibration configuration of the high-volume sampler for common pesticides and PCBs.

COMPENDIUM METHOD TO-4A
FIELD CALIBRATION DATA SHEET FOR SAMPLER CALIBRATION

Sampler ID: Calibration Orifice ID:

Sampler Location: Job No.:

High Volume Transfer Orifice Data:

Correlation Coefficient (CC1): Slope (M1):
(CC2): (M2):

Intercept (B1):
(B2):

Calibration Date: ___ Time:
Calibration Ambient Temperature: ___°F ___°C CALIBRATOR'S SIGNATURE
Calibration Ambient Barometric Pressure: ___ "Hg ___ mm Hg
Calibration set point (SP): _____

SAMPLER CALIBRATION

Actual values from calibration		Calibrated values		
Orifice manometer, inches (Y1)	Monitor Magnehelic, inches (Y2)	Orifice manometer (Y3)	Monitor Magnehelic (Y4)	Calculated value orifice flow, scm (X1)
	70			
	60			
	50			
	40			
	30			
	20			
	10			

Definitions

Y1 = Calibration orifice reading, in. H_2O

Y2 = Monitor Magnehelic reading, in. H_2O

P_a = Barometric pressure actual, mm Hg

B1 = Manfacturer's Calibration orifice Intercept

M1 = Manufacturer's Calibration orifice manometer slope

Y3 = Calculated value for orifice manometer
= $[Y1(Pa/760)(298/\{Ta + 273\})]^{½}$

Y4 = Calculated value for Magnehelic
= $[Y2(Pa/760)(298/\{Ta + 273\})]^{½}$

X1 = Calculated value orifice flow, scm
= $\frac{Y3 - B1}{M1}$

P_{std} = Barometric pressure standard, 760 mm Hg

T_a = Temperature actual, °C

T_{std} = Temperature standard, 25°C

Figure 9. Orifice transfer standard field calibration data sheet.

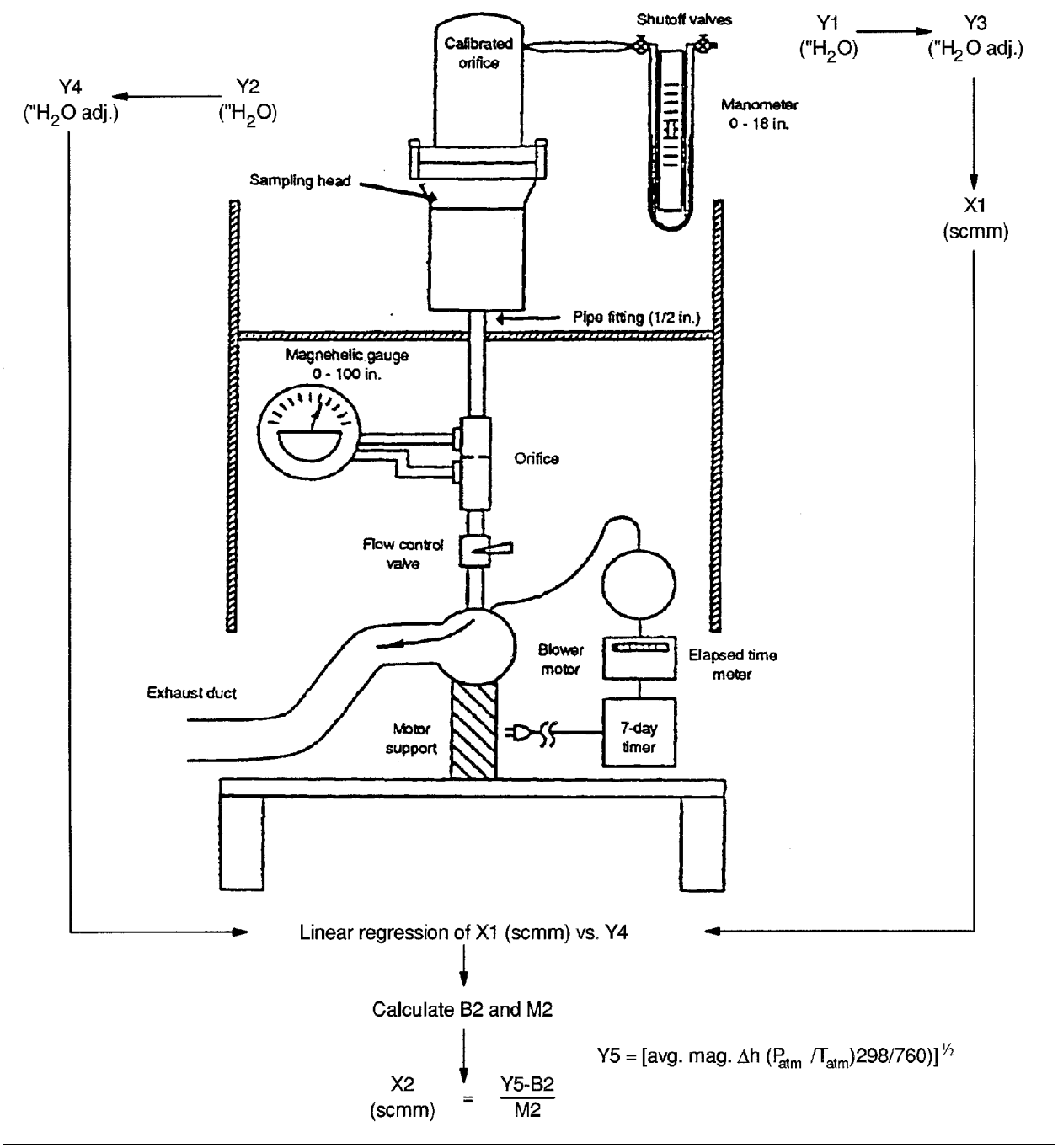

Figure 10. Relationship between orifice transfer standard and flow rate through sampler.

COMPENDIUM METHOD TO-4A
FIELD TEST DATA SHEET
GENERAL INFORMATION

Sampler I.D. No.: _____
Lab PUF Sample No.: _____
Sample location: _____
_____
_____

Operator: _____
Other: _____
_____
_____

PUF Cartridge Certification Date: _____
Date/Time PUF Cartridge Installed: _____
Elapsed Timer: _____
Start _____
Stop _____
Diff. _____
Sampling

M1 _____ **B1** _____
M2 _____ **B2** _____

	Start	Stop
Barometric pressure ("Hg)	_____	_____
Ambient Temperature (°F)	_____	_____
Rain	**Yes** _____	**Yes** _____
	No _____	**No** _____

Sampling time
Start _____
Stop _____
Diff. _____

Audit flow check within ±10 of set point
_____ **Yes**
_____ **No**

TIME	TEMP	BAROMETRIC PRESSURE	MAGNEHELIC READING	CALCULATED FLOW RATE (scmm)	READ BY
Avg.					

Comments

_____
_____
_____

Figure 11. Field test data sheet.

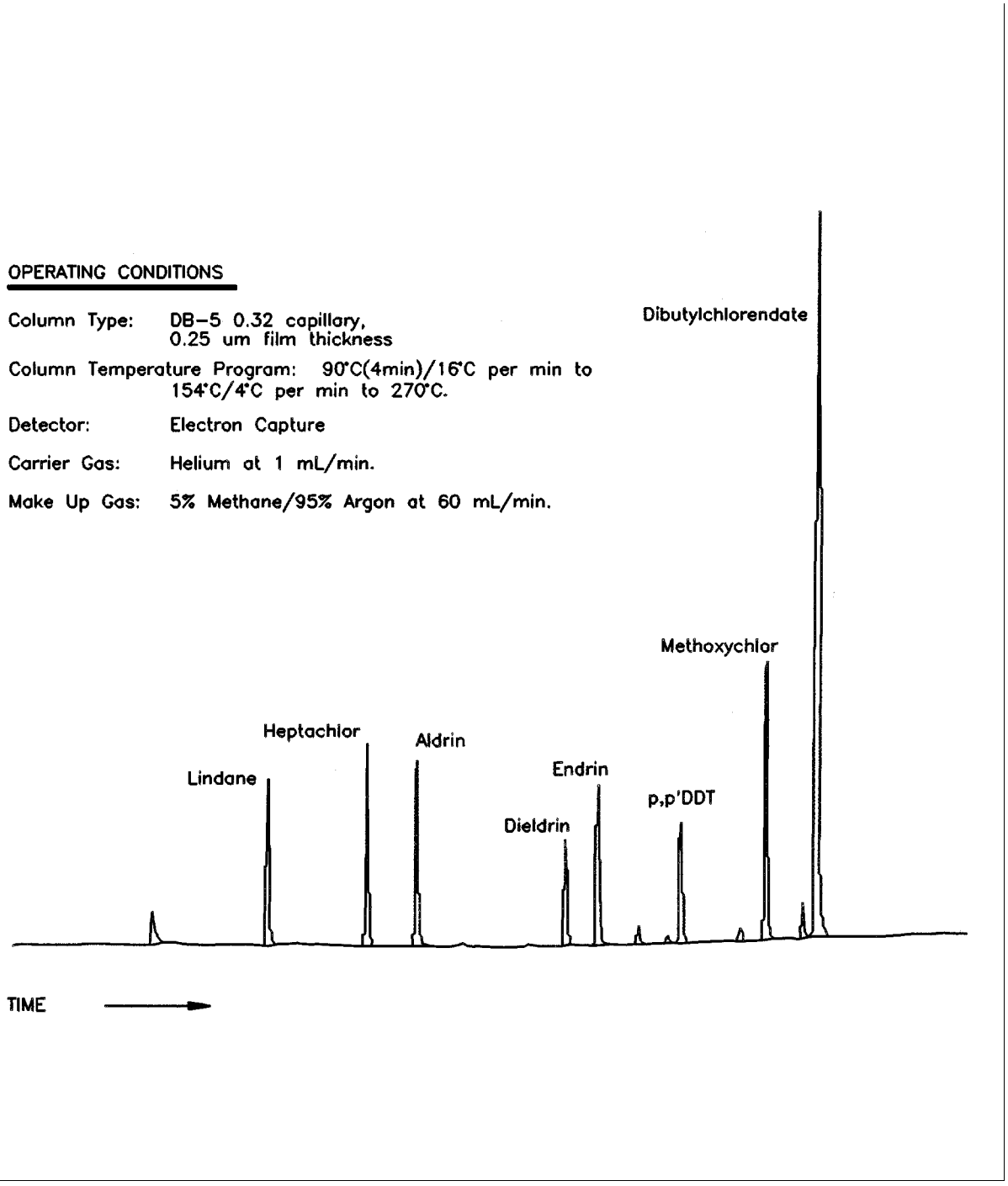

Figure 12. Chromatogram showing a mixture of single component pesticides determined by GC/ECD using a capillary column.

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ARIZONA INSTRUMENT LLC

JEROME® 431-X

MERCURY VAPOR ANALYZER

OPERATION MANUAL

April 2009

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JEROME® 431-X
Mercury Vapor Analyzer
Operation Manual

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Table of Contents

1. FOR THOSE WHO CAN'T READ THE WHOLE MANUAL NOW

This manual contains details that will optimize the results and the life of your instrument. Read and refer to the manual for complete details on operation, maintenance and troubleshooting, special voltage inputs and data output.

The Jerome® 431-X is easy to operate and ready for use upon receipt from the factory.

- Remove the instrument from the packing material.

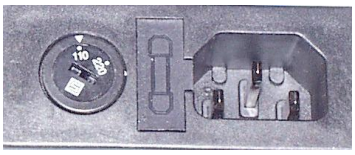
Retain all packaging materials for any future shipment of the instrument.
If the instrument is returned to AZI for any reason, it must be placed in the original packaging materials that have been tested and proven to be effective protection during shipment.

- Call AZI Customer Service at 800-528-7411 or 602-470-1414 for Return Material Authorization (RMA) information prior to returning a unit.
- For all shipments, boxes and packing materials are available from AZI.
- Pack the Jerome® instrument only in a Jerome® shipping container.

AZI WILL NOT BE RESPONSIBLE FOR SHIPPING DAMAGE.
IF YOU RETURN THE INSTRUMENT IMPROPERLY PACKAGED OR SHIPPED,
YOU SHOULD INSURE IT FOR FULL VALUE.

- Check for any damage and confirm receipt of all parts on your packing list. Contact Arizona Instrument Customer Service at (800) 528-7411 or (602) 470-1414 if you have any questions.
- Press the ON button. The display should read 000 in less than one second.
  - A LO BAT message appears briefly in the upper left corner.
  - If the LO BAT message persists, recharge the battery. See page 17.

- Check the voltage setting (110 or 220 VAC) on the back of the instrument. Ensure that it is set to the correct voltage. If the pointer is not aligned to the local voltage, turn the selector to point to the correct voltage.



- Perform a sensor regeneration by following these steps:
  - Connect the line cord between the connector on the back of the 431-X and an AC power outlet.
  - Press the ON switch and then press the REGEN button.
    - The instrument will begin a 10 minute regeneration cycle, indicated by .H.H.H flashing on the display. **Do not interrupt this cycle.** For a complete description of this process, see page 12.
    - If any error message, such as .P.P.P, appears on the display, see the "Troubleshooting" section beginning on page 24.
- When regeneration is complete, zero the sensor by pressing the ZERO button and turning the zero adjust screw, located under the handle, until the display reads 0.
- The instrument is now ready to sample.
- To ensure the input to the instrument contains no Mercury Vapor or mercaptans, use a Zero Air Filter, AZI P/N Z2600 3905. The Zero Air Filter cleans the air sample and should produce sample readings of less than 0.003 mg/m^3. Therefore, use the filter to:
  - Equilibrate the instrument to temperatures that are higher or lower than the instrument. Sample with filter installed until the reading is below 0.003 mg/m^3.
  - Identify contamination within the unit.
  - Confirm the presence of Mercury Vapor when readings are elevated. Install filter and verify that the readings go down with filter installed.
- When the instrument measures Mercury Vapor, the zero display will be replaced with a value.

CAUTION

Do not adjust the ZERO after the instrument has measured Mercury Vapor or before the next regeneration. (Occasionally the display may drop to .L.L.L (indicating low) between the initial zeroing and the first sample. It is OK to readjust the ZERO if the instrument has not measured Mercury Vapor.)

- The instrument is designed for ambient air monitoring. **DO NOT allow the probe or the instrument's intake to be exposed to <u>any</u> liquid.**
- The instrument is not explosion proof.
- Press the SAMPLE button to start a 12 second sampling cycle.
- Perform sensor regeneration after each day's testing.
- Perform another sensor regeneration and re-zero the instrument before each day's use.
- Perform sensor regeneration after 30 days of storage or inactivity.

Call AZI Customer Service, at (800) 528-7411 from the United States and Canada or (602) 470-1414 if you have any questions. If you prefer, you may send e-mail to support@azic.com

2. INTRODUCTION

The Jerome® 431-X Mercury Vapor Analyzer is an ambient air analyzer with a range of 0.001 to .999 milligrams of mercury vapor per cubic meter (mg/m^3 Hg).

CAUTION:

The Jerome® 431-X is for vapor use only.
DO NOT allow the probe or the instrument's intake to be exposed to any liquid, dust or other foreign material.

The 431-X is designed to be easy to operate for quick and accurate analysis of mercury vapor levels. It has few maintenance requirements. However, please take a moment to read this manual before attempting operation. If you have any questions about your application or operation, please call AZI Customer Service at (800) 528-7411 or (602) 470-1414 or e-mail support@azic.com for assistance.

431-X Features

- Automatic sensor regeneration when equipped with the communications option and used with the Jerome® Communication Software (JCS) program and the Jerome® data logger.
- Regulated film heat voltage during sensor regeneration. This allows the sensor to clean properly with voltages from 100-130 VAC (or 200-260 VAC).
- Survey mode can be locked in.
- DIP switch setting can change the digital meter readings from mg/m^3 Hg to nanograms (ng) of Hg (see page 22).
- The Jerome® 431-X can be operated from 100-130 or 200-260 VAC. To change the default voltage range, refer to Setting the Input Voltage, page 21.

Accessories and Maintenance Parts

The Accessories and optional items available to support the 431-X are listed and pictured beginning on page 30.

Applications

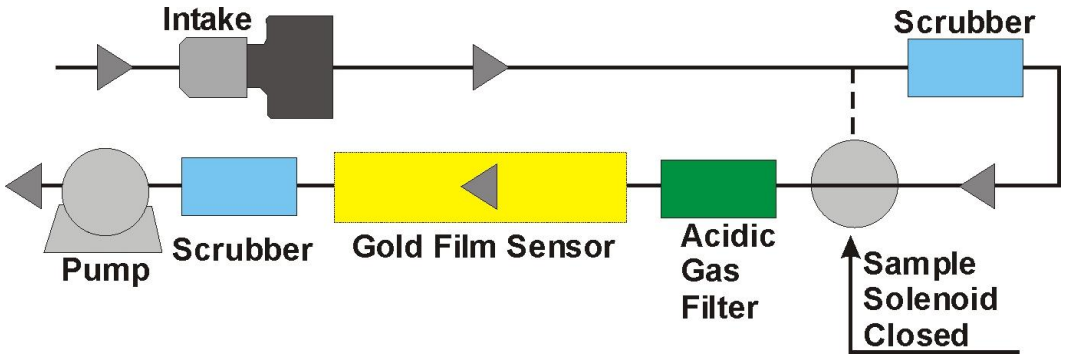
- Ambient air analysis
- Regulatory compliance
- Quality control
- Scrubber efficiency testing
- Accuracy check for other Mercury Vapor monitors and control systems
- Mercury Vapor source detection
- Leak detection
- Portable Mercury Vapor detection

The Jerome® 431-X can be operated from 100-120 or 200-240 VAC. To change the default voltage range, See "Setting the Input Voltage" on page 21.

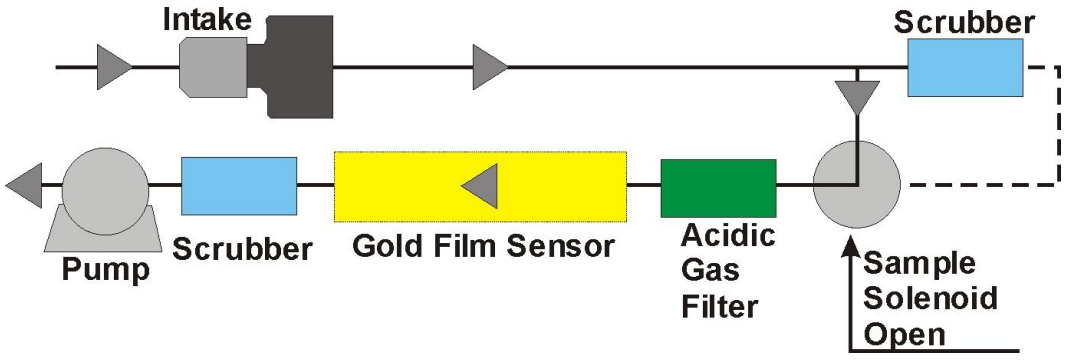
3. PRINCIPLE OF OPERATION

A thin gold film, in the presence of Mercury Vapor, undergoes an increase in electrical resistance proportional to the mass of Mercury Vapor in the sample.

When the SAMPLE button is pressed, an internal pump pulls ambient air through a scrubber filter and into the flow system.



After 2 seconds, the sample solenoid bypass opens, closing off the scrubber filter from the flow system.



The sample air passes through a filter (removing any acidic gases which interfere with the sensor's response to mercury) and is drawn over the gold film sensor. The sensor absorbs the Mercury Vapor. Nine seconds after starting, the sample solenoid bypass closes and the remainder of the sample is drawn through the scrubber filter and the flow system. The instrument determines the amount absorbed and displays the measured concentration on the digital meter in milligrams per cubic meter (mg/m^3) of mercury. An internal DIP switch can be used to change the digital meter display from mg/m^3 to nanograms of mercury (see page 22).

The instrument's microprocessor automatically re-zeroes the digital meter at the start of each sample cycle and freezes the meter reading until the next sample cycle is activated, thus eliminating drift between samples.

During the sample mode cycle, bars on the LCD represent the percentage of sensor saturation. Depending on the concentrations, approximately sixty-five samples containing 0.1 mg/m^3 Hg may be taken before the sensor reaches saturation. After absorbing approximately 500 nanograms of mercury, the sensor becomes saturated and needs to be cleaned. This is accomplished by a manually activated 10-minute heat cycle, or sensor regeneration that burns the mercury from the sensor. This mercury is absorbed on internal filters to prevent any external contamination. The solenoid bypass closes during the sensor regeneration cycle, causing the air to pass through the scrubber filter, providing clean air for the regeneration process. The flow system's final scrubber prevents contamination to the atmosphere from the desorbed mercury.

The heat generated during the regeneration may cause some low level thermal drift. To ensure maximum sample accuracy, wait 30 minutes after regeneration before zeroing and using the instrument.

Zero Air Filter

The Zero Air Filter removes mercury vapor, mercaptans, and hydrogen sulfide from the air sample. Readings with the filter installed should be near zero.

Because air that is cooler than the instrument will cause low readings and warmer air will cause higher readings, the Zero Air Filter should be used to equilibrate the unit to ambient air. Continuous sampling with clean air will not cause saturation of the gold film sensor but will equalize temperatures faster to allow accurate analysis to begin sooner.

The Zero Air Filter can also be used to identify contamination within the instrument. If the readings do not reduce to near zero with the filter installed, contamination should be suspected. If the readings do drop to near zero with the filter installed but elevate with the filter removed, the presence of Mercury Vapor at the sampled location is confirmed.

For more information on the use of the Zero Air Filter, contact customer service at 1-800-528-7411, 1-602-470-1414, or visit our web site at http://www.azic.com.

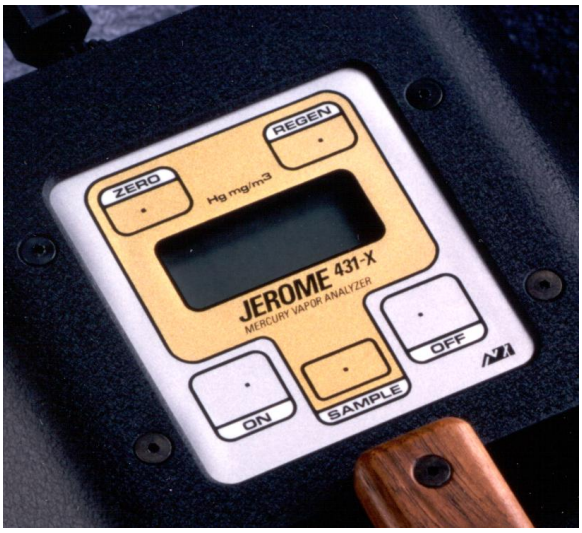
4. INSTRUMENT OPERATION

LCD Codes

LCD CODE	EXPLANATION
000	Ready to sample
.000	No Mercury Vapor reading
00.0	No Mercury Vapor reading, display in nanograms
.8.8.8	Sensor saturated-regeneration needed (refer to page 12)
.H.H.H	Sensor regeneration in progress (.H.H.H flashes)
.L.L.L	Re-zero needed (refer to page 13)
.P.P.P	Power cord required or low line power, <100 VAC (or 200 VAC) (see pages 16 and 17, Changing the Fuse, if .P.P.P remains on after the cord is connected.)
.H.L.P	High line power, greater than 130 VAC in 110 operation or 260 VAC in 220 operation
.LO BAT	Recharge batteries (refer to page 17)
.E.E.E	Same as LO BAT, automatically shuts off
.HL	Very high concentration has been detected. Refer to your safety policy for additional direction to confirm the concentrations."
DURING SAMPLING	
.-	0-25% sensor saturation
.--	25-50% sensor saturation
.---	50-75% sensor saturation
-.---	75-100% sensor saturation
DURING SAMPLING, USING SURVEY MODE	
-	Survey sampling (minus sign flashes continuously)
WHEN ZERO IS DEPRESSED	**Adjust to 0 <u>only</u> after sensor regeneration. It is normal for the display to read H after sampling has started.**
0	Zero, ready to sample
H	High, turn Zero potentiometer counterclockwise
L	Low, turn Zero potentiometer clockwise

Daily Operations

Before each day's use of the Jerome® 431-X, perform the following steps to verify proper instrument operation:



- Press the power ON button.
  - ➢ The digital meter displays 000.
    - ♦ (Disregard the digital meter's initial momentary reading.)
    - ♦ Recharge or replace the battery pack if the LO BAT indicator REMAINS ON. Refer to "Charging Batteries" on page 17 and/or "Replacing the Battery Pack" on page 21.
    - ♦ To ensure the instrument's electronics have stabilized, allow a 1-minute warm up before beginning the next step.
- Use the Zero Air Filter to equilibrate the instrument to ambient air temperature.
  - ➢ Install the Zero Air Filter in the instrument's intake.
  - ➢ Sample continuously until the readings stabilize.
- Perform sensor regeneration. Refer to page 12 for the procedure.
- Thirty minutes after sensor regeneration is complete, zero the instrument.

> **NOTE:** For maximum accuracy, such as when testing with the Functional Test Kit, wait 30 minutes after the sensor regeneration cycle to re-zero the unit. For immediate use, the unit can be re-zeroed immediately after sensor regeneration.

- Press the SAMPLE button.
  - ➢ During the sample cycle, the digital meter displays bars (-, --, or ---) to indicate the amount of sensor saturation.
- At the end of the sampling cycle, read the digital meter.
  - ➢ The number shown on the digital meter is the Mercury Vapor concentration in mg/m3.
  - ➢ This value remains on the display until the next sample is taken.
  - ➢ The digital meter automatically zeroes at the start of each sample.
- At the end of each day's use, perform sensor regeneration as described in the next section.

DO NOT ALLOW MERCURY VAPOR TO STAY ON THE GOLD FILM SENSOR OVERNIGHT.

Sensor Regeneration

Sensor regeneration is needed to clear the 431-X sensor of any accumulated Mercury Vapor and to prolong the life of the sensor. This simple procedure should be done:

- At the beginning of the day on which the instrument is to be used.
- During the day when the sensor becomes saturated.
- At the end of the day before storing the instrument.
- At a minimum of 30 day intervals while the instrument is in storage.

CAUTION:

Ensure the voltage selector on the back of the instrument, near the power cord inlet connector, points to the local AC power value. See "Setting the Input Voltage" on page 21.

To clean and protect the sensor, the supplied AC power must be 100 to 120 VAC or 220 to 240 VAC, depending on the available power source.

Once sensor regeneration is initiated, DO NOT interrupt the cycle.

- Attach the power cord to the 431-X and plug it into AC power. AC power is required to thermally regenerate the sensor.
- Press the power ON button.
- Press the REGEN button.
  - The digital meter flashes .H.H.H for the duration of the 10-minute cycle and displays .0.0.0 when the cycle is completed.

DO NOT INTERRUPT THIS CYCLE.
Wait until the cycle is completed before continuing with the next step.

- **A minimum 30-minute wait after the sensor regeneration cycle is complete ensures maximum sample accuracy. However, the unit can be used immediately following the sensor regeneration if necessary. When the sensor regeneration is complete, press ZERO and adjust the ZERO ADJUST pot until 0 appears on the display. Install the zero air filter in the intake and take several samples or lock the instrument into survey mode (see page 15). After approximately one minute, stop sampling and check the ZERO. Adjust to 0. Repeat sampling through the zero air filter until reading remains on 0.**

NOTE: The digital meter will read .P.P.P after REGEN is activated if the power cord is not plugged in or if the instrument's fuse needs to be replaced. Connect the power cord, or if necessary, replace the fuse. See "Changing the Fuse" on page 22.

Zero Adjust

- To ensure air entering the instrument is clean, install the zero air filter in the instrument's intake and sample until the readings stabilize.
- While pressing the ZERO button, turn the ZERO ADJUST potentiometer (shown at right) using the trimmer tool until the digital meter reads 0.
  - If the LCD reads H, turn the ZERO ADJUST counter-clockwise;
  - If the LCD reads L, turn the ZERO ADJUST clockwise.

NOTE: A minimum 30-minute wait after the sensor regeneration cycle is complete ensures maximum sample accuracy. The unit can be used immediately following the sensor regeneration if necessary. When the sensor regeneration is complete, press ZERO and adjust the ZERO ADJUST pot until 0 appears on the display. Install the zero air filter in the intake and take several samples or lock the instrument into survey mode (see page 15). After approximately one minute, stop sampling and check the ZERO. Adjust to 0 if necessary. Repeat sampling through the zero air filter until sensor remains on 0.

NOTE: When ZERO is pressed, and depending upon internal configuration, a number between 00 and 100 may appear on the display instead of H, L, or O. If the instrument is configured with an Option Bard, see APPENDIX E - JEROME® 431-X OPTION BOARD beginning on page 58.

CAUTION:
Do not turn the ZERO ADJUST potentiometer between samples.

Turn the ZERO ADJUST only after a sensor regeneration cycle otherwise invalid readings will result.

- Press the power OFF button and disconnect the power cord.
- The Jerome® 431-X is ready for sampling.

CAUTION:
The Jerome® 431-X is intended for vapor use only. DO NOT allow the probe or the instrument's intake to be exposed to liquids, dust or other foreign material. Moisture or liquids drawn into the instrument can damage the sensor and flow system.

Sample Mode

This mode, used for standard operation, produces optimum accuracy (±5% at 0.100 mg/m^3 Hg) with the Jerome® 431-X.

- Press the power ON button.
  - The digital meter displays 000. If the unit is set to display in ng, the digital meter displays 00.0. (Disregard the digital meter's initial momentary readings.) Recharge or replace the battery pack if the LO BAT indicator REMAINS ON. Refer to pages 17 and/or 21 for the procedure.
- To ensure the instrument's electronics have stabilized, allow a 1 minute warm up before beginning the next step.
- Press the SAMPLE button.
  - During the sampling cycle, the bar (or bars) shown on the digital display indicate the current percentage of sensor saturation. (Refer to Meter Display Codes, page 10, for code descriptions.)
  - The bar (or bars) flash after 2 seconds and again after an additional 7 seconds. This flashing signals the opening and closing of the solenoid sample bypass. (See the Principles of Operation on page 8 for details.)
- At the end of the 12 second cycle, read the digital meter.
  - The number shown on the digital meter is the mercury concentration in mg/m^3 (or ng). This value remains displayed until the next sample is taken. The digital meter automatically zeroes at the start of each sample.
- When the sensor is completely saturated, the digital meter displays .8.8.8 instead of a value. No further operation is possible until a sensor regeneration is performed. (Refer to page 12 for the Sensor Regeneration procedure.)
- Press the power OFF button when not in use. Install the zero air filter in the instrument intake during storage.

Sampling Notes

The Jerome® 431-X is intended for vapor use only. **DO NOT** allow the probe or the instrument's intake to come in contact with liquids, dust or other foreign material. Moisture or liquids drawn into the instrument can damage the sensor and flow system.

The Jerome® 431-X operates a minimum of 6 hours on a fully charged battery.

Use the probe (AZI P/N1400-2002) to locate mercury vapor in hard to reach places. Plug the probe directly into the instrument's intake.

Survey Mode

The survey mode takes samples every 3 seconds automatically. Use this mode to locate mercury spills or to assess areas of potentially high mercury concentrations. Sampling in the survey mode is not as accurate. Due to the decreased sample volume, the accuracy of the instrument is reduced to ± 20% @ .100 mg/m^3.

- Press the power ON button.
  - The digital meter displays 000. If the unit is set to display in ng, the digital meter displays 00.0. (Disregard the digital meter's initial momentary readings.) Recharge or replace the battery pack if the LO BAT indicator REMAINS ON. Refer to pages 17 and/or 21 for the procedure.
  - To ensure the instrument's electronics have stabilized, allow a 1 minute warm up before beginning the next step.
- Press and **hold** the SAMPLE button.
  - The instrument takes a normal 12 second sample, displays the concentration at the end of the cycle and then goes into the survey mode sampling every 3 seconds. The display flashes the measured concentrations at the end of each 3 second sample cycle.
- When you are finished surveying, **release** the SAMPLE button.
  - The final survey value remains displayed until the next sample is taken.

NOTE: Approximately 65 samples at .1 mg/m^3 may be taken before a sensor regeneration is required.

- To lock the instrument in a survey mode:
  - Hold the SAMPLE button down until the sensor status indicator bar(s) "_" begins flashing on the display.
  - Press the ZERO button, then release the SAMPLE button.
  - The pump should continue to run and the display should update every 3 seconds.
  - The instrument remains in the survey mode until one of the following occurs:
    - The sensor is saturated
    - A LO BAT (low battery) signal is encountered
    - An HL (high mercury level) is encountered
    - The instrument is turned OFF.

Press the power OFF button when not in use.

Operating on AC Power or Generator

- For stationary use, the 431-X may be operated on AC power.
  - Operating the instrument on AC power at all times eliminates the need for the battery pack and its necessary maintenance.
  - The battery may be unplugged or removed completely whenever the instrument is operating on AC power.

- When a generator is used to power the Jerome® 431-X, a high quality line conditioner or voltage regulator is required to ensure a pure sine wave and regulated voltage is applied to the instrument. The gold film sensor may be damaged by voltage that varies in amplitude or by surges, spikes, and/or noise on the power line. **This is especially true during the sensor regeneration.**

Operating on Internal Battery Power

For portable use, the 431-X may be operated on Battery power.

- When you operate the instrument on battery power, please be aware of the following:
  - A fully charged battery pack, AZI P/N Z4000-0907, provides power for a minimum of six (6) hours of operation.
  - For operating more than six (6) hours, an extra fully charged battery pack is needed.
  - Complete battery recharging takes 14 hours. Refer to Charging Batteries on page 17.
  - The 431-X uses a rechargeable Nickel Cadmium (NiCad) battery. Dispose of worn-out batteries properly when you are replacing the battery pack.

External battery power

A special version of the Jerome® 431-X and a DC Power Kit are available to operate the instrument from a secondary DC source. The source may be a car/truck battery or a storage cell used in conjunction with solar panels.

Call AZI Customer Service at 800-528-7411, 602-470-1414, or e-mail support@azic.com for additional information.

Charging Batteries

- Press the power OFF button.
- Connect the AC power cord between the 431-X power receptacle and an AC power source.
  - Complete battery recharging takes 14 hours.
  - The 431-X contains a trickle charger so it may be continually plugged into an AC power source without damaging the battery pack.
- The battery pack may be charged outside the instrument with an optional AZI IDC Battery Charger. (AZI P/N 4000-1011, for 115 VAC, P/N 4000-1012, for 230 VAC)

Obtaining Maximum Battery Life

There are certain inherent limitations to NiCad batteries. The primary limitation is a memory effect that occurs when the batteries are partially discharged and then recharged, repeatedly. This memory leads to a drastic reduction in the usable battery life. To prevent this memory effect, periodically allow the battery pack to discharge completely, and then recharge the battery pack.

- To obtain maximum battery life, follow these three (3) steps:
  - At least once a month wait until LO BAT appears on the digital meter before recharging the battery pack.
  - Charge the battery pack when the LO BAT indicator comes on. Excessive discharge can damage the battery pack.
  - Before storing the instrument verify the power is OFF.

- When the batteries fail to hold a charge, the battery pack should be replaced.
  - Battery life under normal usage is approximately 1 year, depending on the number of charge and discharge cycles.

5. MAINTENANCE

Preventive Maintenance Calendar

To keep the Jerome® 431-X operating at peak performance, follow the maintenance schedule below as a guide. Since maintenance is more a function of application and amount of use rather than time, your requirements may be different from the listed schedule. Call AZI Customer Service at 800-528-7411, 602-470-1414, or e-mail support@azic.com for additional guidance for your environment and operation.

PART/COMPONENT	MAINTENANCE CYCLE	REFER TO PAGE
Charge batteries	At least once per month, after 1 month's storage, or when LO BAT appears	Page 17
Change .25 inch fritware	Weekly or as needed	Page 19
Change internal filters and tubing[1]	After 6 months of use or as needed	Page 20
Replace zero air filter[2]	Annually	
Factory calibration	Annually	Page 23
Calibration check	Monthly or as needed	Appendix A, Page 37
Replace batteries	Annually or as needed. The battery pack contains NiCad batteries. Dispose of properly.	Page 21

NOTE: Install the zero air filter into the instrument's intake during storage.

[1] C/M filters contain Sofnolime ™. For safety information see the supplier's Material Safety Data Sheet (MSDS) or call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com for a copy. Dispose of all filters properly.

[2] Zero air filters and scrubber filters contain Resisorb®. For safety information see the supplier's Material Safety Data Sheet (MSDS) or call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com for a copy. Dispose of all filters properly.

Flow System

The Jerome® 431-X's flow system is the crucial link between the sensor and the sample. For the instrument to perform correctly, the flow system must be properly maintained. The user maintainable components of this system are the intake filter (.25 inch fritware), a C/M Filter, two scrubber filters and connecting tubing.

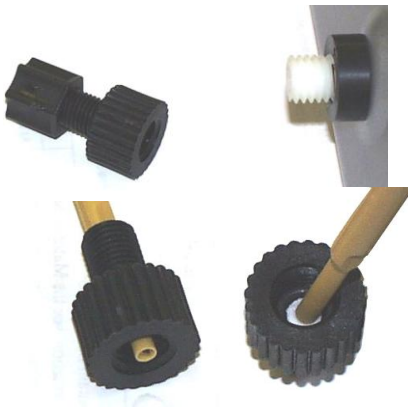
Check the Preventive Maintenance Calendar on page 18, for a suggested schedule for changing fritware and scrubber filters. The Tygon™ tubing in the system must be free of crimps for proper flow.

Part	Part Number
Scrubber Filter	Z2600 3930
C/M Filter	Z2600 3928
.25 inch Fritware Filter	2600 3039
Tygon™ Tubing - 1/8" I.D. (1')	2500 3001

.25 inch Fritware Filter

Replace the .25 inch fritware filter once each week or as needed. In dusty environments, the fritware filter may need to be replaced as often as once a day. Replacement .25-inch fritware filters are available from AZI, Consumable Sales at 800-528-7411 or 602-470-1414.

- Unscrew and remove the intake.



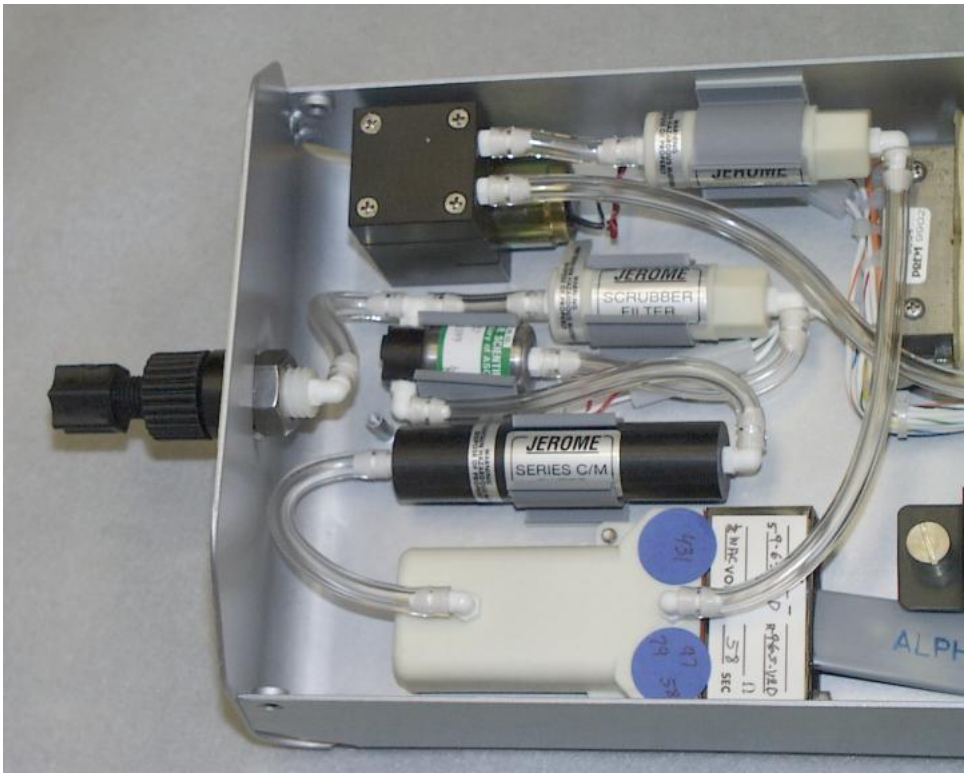
- Push the old fritware filter disc out of the intake with your trimmer tool.
- Avoid touching the new fritware disc with fingers. Use tweezers to insert the new fritware.
- Use the blunt end of the trimmer tool to seat the fritware disc firmly against the inner ledge of the intake.
- Screw the intake back on the Jerome® 431-X.

CAUTION:

The stem coming from the instrument onto which the outer intake housing is attached must be securely held in place. If loose, the tubing inside the instrument can become twisted when the intake housing is replaced. It may be necessary to open the instrument and tighten the hold-down nuts inside the instrument. Call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com if you have any questions

Internal Filters

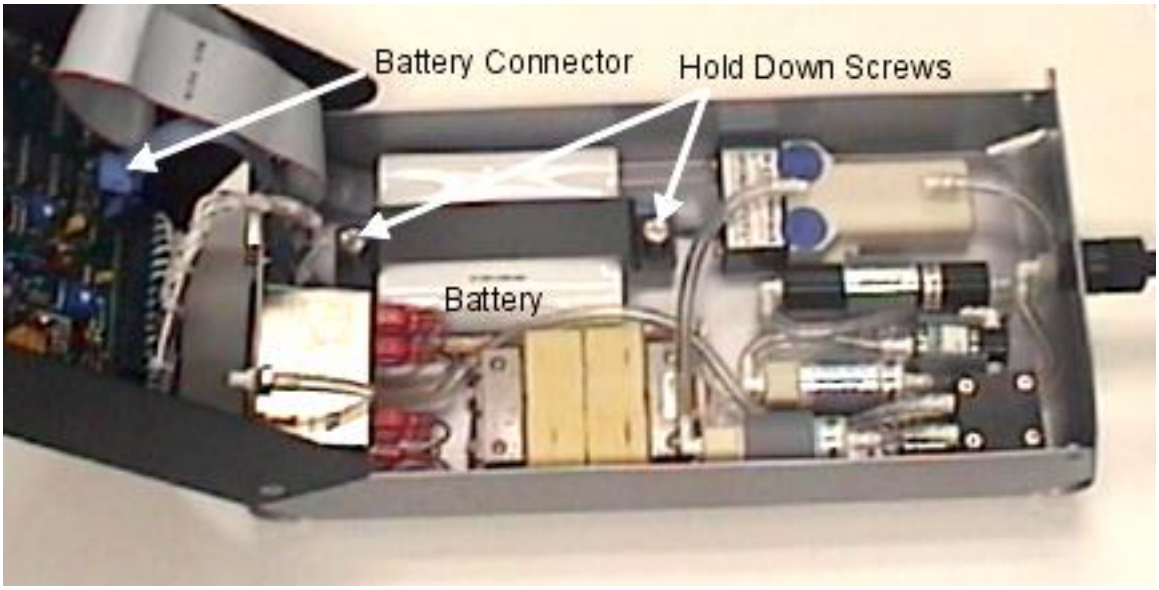
- Replace the internal filters after six (6) months of use, or as needed.
- Press the power OFF button and unplug the power cord.
- Remove the two (2) side screws from the intake end of the instrument and open the case.
- Carefully disconnect the Tygon tubing from both ends of the filters and discard the old filters.



CAUTION:
Filters contain either Sofnolime™ or Resisorb®. Used filters will contain trace amounts of Mercury also. Use proper methods when disposing of used filters. Call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com for a copy of the Resisorb® or Sofnolime™ MSDS or for other questions.

- Connect the new filters to the Tygon tubing, ensuring all straight hose barbs point toward the intake/pump corner of the case and elbow hose barbs point toward the sensor housing as shown in the illustration.
  - Push the Tygon as far as it will go onto the filter fittings.
- Push the filters into the mounting clips.
- Remove any crimps or twists in the tubing and ensure that tubing connections are secure. If the tubing is loose, readings may not be accurate. Replace any tubing that has deteriorated due to heat and/or age.
- Close the case and replace the screws.
- Dispose of all filters in accordance with state and federal environmental regulations.

Replacing the Battery Pack

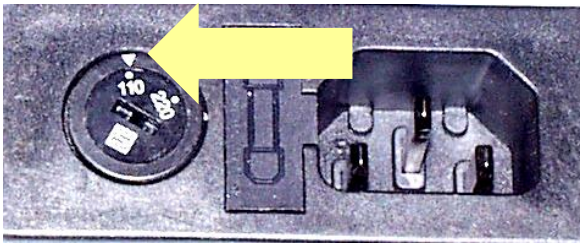


- Press the power OFF button.
- Unplug the power cord.
- Remove the two (2) side screws from the intake end of the instrument and open the case lid.
- Disconnect the battery connector from the board.
- Loosen the two (2) captive screws holding the battery bracket and remove the bracket.
- Remove the old battery pack and replace with a new battery pack.
- Replace the battery bracket and tighten the captive screws.
- Connect the new battery connector to the board.
- Close the case and replace the two (2) side screws.
- Dispose of the old NiCad battery in accordance with state and federal regulations.

Setting the Input Voltage and Frequency

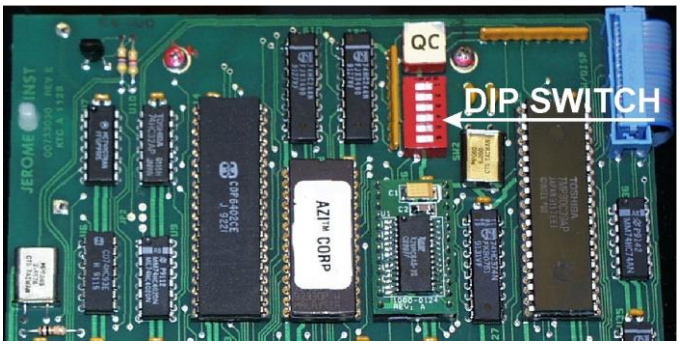
Instruments are factory set and calibrated to use the power setting requested on the order. However, the voltage setting is easily changed to use either 110 or 220 VAC.

- Ensure the instrument is turned OFF and unplugged.
- Locate the voltage selector on the rear of the instrument.
- Insert a small screwdriver in the voltage selector slot and turn the selector until the arrow points toward your setting choice and a click is heard.



- Remove the two screws toward the front of the instrument and open the lid.
- Locate the DIP Switch SW2 at the top of the main circuit board. This is the red on illustrated at right
- Set SW2 position #1 and #6 as follows.

	60Hz	50Hz
Position #1	OFF	OFF
Position #6	OFF	ON



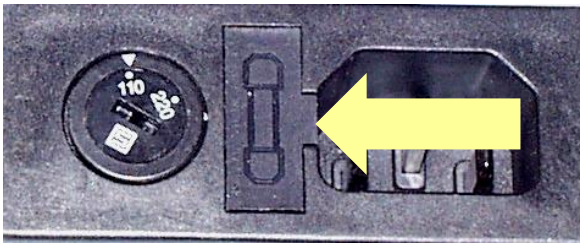
Display Nanograms or Milligrams Per Cubic Meter

The instrument is factory set to display mg/m^3 (milligrams per cubic meter) of mercury (.XXX). For some applications, including dosimeter analysis, the instrument's display can be converted to nanograms.

- Ensure the instrument is turned OFF.
- Remove the two screws near the front of the instrument and open the lid.
- Locate DIP Switch SW2 at the top of the main circuit board.
- Place Position #2 to OFF for nanograms display.
- Return Position #2 to ON for the normal milligram display.

Changing the Fuse

If the instrument display reads .P.P.P when the instrument is connected to AC power or when REGEN is pressed, or if the battery will not charge, the fuse may need to be replaced. The AC line power could also be less than 100 VAC (220 VAC). Check the fuse with an ohmmeter and the AC line power with a voltage meter.



- Locate the power receptacle on the rear of the instrument.
- Insert a small screwdriver in the slot, located in the power receptacle, and gently slide the fuse compartment out.
- If the fuse in the open-sided clip is open, remove and discard it.
- Replace the discarded fuse with the spare fuse located in the slide-out spare fuse compartment.
- Replace the fuse compartment in the power receptacle.
  - ➢ As soon as possible, replace the spare fuse with another 1A, 250V, time delay fuse, AZI P/N 5100 1012).

6. CALIBRATION

The Jerome® 431-X's gold film sensor is inherently stable and does not require frequent calibration. The interval between calibrations depends upon the application and frequency of use; however, the recommended interval is every 12 months.

The Jerome® 431-X has been factory calibrated using laboratory equipment containing NIST traceable permeation tubes. These permeation tubes have a rated accuracy of ± 2%. In order to calibrate the Jerome® 431-X, a sophisticated calibration system is required that ensures stability of the calibration gas source, eliminates any pressure in the calibration gas stream, and controls the temperature of the calibration environment.

We strongly recommend you take advantage of our calibration and maintenance service at Arizona Instrument. Call Customer Service at (800) 528-7411 or (602) 470-1414 to arrange re-calibration. A certificate of calibration is issued from AZI when your instrument is factory calibrated.

Verification of Functionality and Quality Control

The Functional Test Kit (FTK), AZI P/N Y431 0902, is used to determine if your instrument is functioning correctly between recommended annual factory calibrations. It allows you to have complete confidence in the sample results. This test verifies proper instrument operation through the introduction of a known concentration of Mercury Vapor into the Jerome® analyzer.

THIS IS A FIELD CHECK OF THE FUNCTIONALITY OF THE INSTRUMENT.

THIS TEST DOES NOT CALIBRATE THE INSTRUMENT.

If your application requires frequent verification of instrument function, this test demonstrates the unit's operation and function. Recording FTK results in an instrument log provides a quality control/quality assurance record of instrument function between regular calibrations. If test results fall within the expected range, you may assume the instrument is functioning correctly.

See APPENDIX A - 431-X FUNCTIONAL TEST KIT on page 37 for more information about the FTK procedures. Complete instructions for use are supplied with the test kit, AZI P/N Y431 0902.

To order the FTK, contact your AZI Sales Representative at (800) 528-7411 or (602) 470-1414.

7. 431-X TROUBLESHOOTING

Symptom	Possible Cause	Solution
Power Problems		
Unit does not turn ON. Unit turns on when power cord is plugged in. LCD displays 000 when instrument is operating on AC power.	Discharged battery or Dead battery.	Recharge battery for a minimum of 14 hours. Refer to page 17. Replace battery. Refer to page 21.
Unit does not turn on when connected to AC power cord.	Open fuse. Insufficient power. Internal component failure.	Replace fuse. Refer to page 22. Use a voltmeter to verify there is power to the AC outlet. Call AZI Customer Service for information at 800-528-7411 or 602-470-1414.
Regeneration & Zero Problems		
LCD displays .8.8.8.	Sensor saturated.	Do not attempt to adjust zero pot. The sensor must be regenerated. Refer to page 12 for information.
LCD displays .L.L.L when taking first sample.	Changes in temperature.	Readjust zero pot. See page 13 for information.
LCD displays H at finish of sensor regeneration when zero is pressed.	Internal contamination may redeposit Mercury Vapor from flow system onto gold film sensor.	Remove and replace fritware filter, intake filter disk, scrubber filters and Tygon tubing. Refer to "Flow System" on Page 19. Check tubing for kinks or crimps. Repeat regeneration cycle. Refer to page 12.
Zero adjust pot cannot be adjusted to 0.	Pot not turned sufficiently. Sensor may be ruptured or pot may be broken.	1. Turn zero adjust up to 20 times to reach the end. Pot will "click" softly. 2. If no "0", turn pot slowly in opposite direction until display reads "0". 3. If still unchanged, call AZI Customer Service at (800) 528-7411 or 602-470-1414.

Sampling Problems		
Airflow is restricted during the sensor regeneration cycle, causing possible permanent damage.	Kinks and crimps in the Tygon tubing.	Periodically check the Tygon tubing inside the instrument. Refer to page 20.
High erratic results.	Internal Mercury Vapor contamination.	1. Install zero air filter in intake and tighten intake nut. Press SAMPLE button. After three samples, if readings are over 0.003 mg/m^3, replace fritware filter and Tygon tubing. Refer to page 19. 2. Perform sensor regeneration with the zero air filter in intake. Refer to page 12. Retest if necessary. Replace scrubber filters and Tygon™ tubing. Refer to page 20.
High/erratic results	Intake and internal filters may become clogged and need replacement when sampling in a dusty or humid area.	1. Open instrument and check for pinched, crimped or disconnected internal tubing. 2. In extreme conditions, an additional particle filter may be installed on the intake.
High/erratic results Readings vary more than 0.05 mg/m3 when in survey mode.	Loose connections to gold film sensor.	Place a zero air filter into the intake. Place the instrument in survey mode. Move the unit as samples are being taken. Call AZI Customer Service at 800-528-7411 or 602-470-1414 for assistance.
Low response or erratic readings after a long period of non-use.	May need a second regeneration cycle.	1. Wait 30 minutes and perform another sensor regeneration. 2. Test with FTK. Refer to page 37. 3. If still unresponsive, call AZI Customer Service at 800-528-7411 or 602-470-1414 for assistance.

False readings, may go to .8.8.8 or .L.L.L.	Extremely cold or extremely warm air sampled into unit.	If sampling under these conditions, install zero air filter in intake. Sample until display reads 0.003 mg/m3 or less. This equilibrates sensor temperature with the temperature of the sample air stream. Remove filter and take samples.
Miscellaneous Problems		
Display reads .P.P.P when regeneration is attempted.	Power cord not attached.	Check power cord for connection
	Blown fuse.	Replace fuse. Refer to page 22.
	Line voltage less than 100 VAC (or less than 200 VAC for 220V units).	Check line voltage settings. Refer to page 21.
	Cycles dipswitch set incorrectly.	Check input cycle settings. Refer to 55.
		If fuse and line voltage are OK, it may be circuit board adjustment or component failure. Call AZI Customer Service at 800-528-7411 or 602 470-1414.
Display reads .E.E.E	Very low battery.	Recharge battery. Refer to page 17. Replace battery. Refer to page 21.

8. JEROME® 431-X TECHNICAL SPECIFICATIONS

Range	0.001 to 0.999 mg/m^3
Sensitivity	0.003 mg/m^3 Hg
Precision	5% relative standard deviation at 0.100 mg/m^3 Hg
Accuracy	±5% at 0.100 mg/m^3 Hg
Response time-sample mode	12 seconds
Response time-survey mode	3 seconds
Flow rate	750cc/min (0.75 liters/min)
Power requirements	100-120 VAC, 50/60 Hz, 1 A, or 220-240 VAC, 50/60 Hz, 1 A
Fuse	F1A 250V, 5mm X 20mm
Internal battery pack	Rechargeable Nickel Cadmium
Operating environment	0º to 40 ºC, non-condensing, non-explosive
Case construction	Aluminum alloy
Dimensions – standard model	33 cm L x 15 cm W x 10 cm H (13" L x 6" W x 4" H)
Dimensions – XE model	35 cm L x 18 cm W x 18 cm H (14” L x 7” W x 7” H)
Weight – standard model	3.18 kilos (7 pounds)
Weight – XE model	3.5 kilos (8 pounds)
Digital meter display	Liquid crystal display (LCD)
Certification	CE mark on 220-240 V~, 431-XE model only.

Optional Communications Capability

Alarm output	30V DC, 100mA
Dosimeter power output	For dosimeter analysis and regeneration
Data output	1. RS-232 Serial, Baud Rate 1200 for use with data logger, and/or Jerome® communication program. 2. RS-232 Serial data format with 0 & 20mA current logic levels; Baud Rate 1200 (special industrial applications) and Analog 20 mA output.
"With Option Board" - See APPENDIX E - JEROME® 431-X OPTION BOARD on page 58.	
Analog output	0 to 2V or 4 to 20 mA
Auto sample interval	5, 15, 30, or 60 minutes
Auto regeneration interval	6, 12 or 24 hours

Instrument I/O Interface

The 431-X I/O port (25 pin D-sub) provides the following functions:

- Serial data communication
  - Interface type: RS-232C full duplex, DCE
  - Parameters: 1200 Baud, 1 start bit, 8 data bits, 2 stop bits, no parity
  - Pin assignments:

Pin 1	Protective ground
Pin 2	Data in
Pin 3	Data out
Pin 7	Data ground

- Serial current loop
  - Interface type: 20mA current loop, full duplex
  - Parameters - 1200 Baud, 1 start bit, 8 data bits, 2 stop bits, no parity
  - Pin assignments:

Pin 1	Protective ground
Pin 4	Data out (+)
Pin 5	Data in (+)
Pin 14	Data out (-)
Pin 16	Data in (-)

- Alarm output
  - Maximum voltage 30 VDC
  - Maximum current 100mAmp
  - Pin assignments:

Pin 9	Switched battery (+)
Pin 10	Alarm output (open collector, active low)
Pin 7	Battery ground (-)
Pin 23	Battery ground (-)

- Dosimeter Power
  - Pin Assignments:

Pin 22	Dosimeter Enable – 24 to 28 Volts AC
Pin 23	Battery Ground
Pins 12 & 24 Tied – Dosimeter Power	
Pins 13 & 25 Tied – Dosimeter Power	

- Switched battery connection for data logger
  - Pin assignments:

Pin 9	Battery (+)
Pin 7	Battery ground (-)
Pin 23	Battery ground (-)

- Unswitched battery connection for external battery pack pin assignments
  - Pin assignments:

Pin 15	Battery (+)
Pin 19	Battery (+)
Pin 7	Battery ground (-)
Pin 23	Battery ground (-)

NOTE: Pins 6, 8, 11, 17, 18, 20 and 21 are non-standard and should not be connected.

Potential Interferences

Potential interferences to the Jerome® mercury vapor analyzers are rare and most of these can be eliminated with proper maintenance procedures. However, erroneously high readings can sometimes occur. Here are a few things to be aware of when using the instrument:

The gold film sensors used in the Jerome® mercury vapor analyzers do not respond to the following compounds:

- Hydrocarbons
- CO, CO_2, and SO_2
- Water vapor (Note that water vapor condensation on the gold film can cause irreparable harm to the sensor and must be avoided.)

The C/M filter (AZI P/N: Z2600 3928), an acidic gas filter contained in the internal filter system, removes the following compounds that cause the gold film sensor to respond:

- Chlorine
- NO_2
- Hydrogen Sulfide (H_2S)
- Most mercaptans (organic sulfur compounds or "thiols")

In areas containing these highly volatile compounds, the filter can quickly become saturated. In such situations, it is recommended that these gases be allowed to dissipate before sampling for the less volatile, more persistent mercury vapor. In addition, a special filter designed to remove chlorine gas from the sample stream is available from Arizona Instrument and may be ordered as Chlorine Filter, AZI P/N Z2600-3940. Collection of air samples with Jerome® gold coil dosimeters for analysis by the Jerome® mercury vapor analyzers will also eliminate interferences.

Ammonia in very high concentrations can cause an off-gassing of accumulated acidic fumes from the internal acidic gas filter, resulting in positive readings on the instrument. In these cases, the ammonia odors are very strong. A special filter designed to remove ammonia gas from the sample stream is available from Arizona Instrument and may be ordered as Ammonia Filter, AZI P/N 990-0193. Again, either allow the vapors to dissipate, use the ammonia filter, or use the dosimeters. Filter replacement at regular intervals, or when unexpectedly high readings are encountered in areas of these potential interferences, may resolve these problems.

Visit the "Tech Notes" section at www.azic.com for more information concerning the chlorine and ammonia filters.

Volatile mercury compounds in general will cause the gold film to respond. Alkyl organic mercuries such as methyl mercury (and other "straight chained" compounds) are typically extremely volatile and change the electrical resistance of the gold film sensor. Any such responses should be considered "qualitative," **not** quantitative. The instruments are designed and calibrated to elemental mercury vapor only.

Inorganic mercury salts such as mercuric chloride are not very volatile. They may, however, generate some minute level of elemental mercury vapor to which the instruments will respond. This response, again, should be considered a qualitative response only.

9. ACCESSORIES & MAINTENANCE PARTS

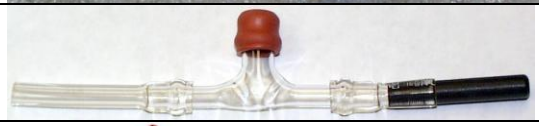
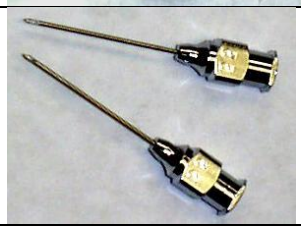
PART #	ITEM DESCRIPTION
Y431 0901	**431 Accessory Kit (See pictures beginning on page 32)**
1400 2002	Probe
1400 3010	Tubing Adapter, 1/4" to 1/8"
2300 0001	Trimmer Tool
2600 3039	.25 Fritware
6000 4003	Line Cord, 115 VAC - USA and Canada
Alt. 200-0003	Line Cord, 220-240 VAC - England
Alt. 200-0008	Line Cord, 220-240 VAC - Europe
Z2600 3905	Zero Air Filter
Y431 0902	**431 Functional Test Kit (See pictures beginning on page 32)**
A2600 0902	Stopper Assembly
A2600 0903	Syringe Assembly
A2600 0904	Mercury Vial
2600 0022	Syringe Needles, 22 Ga. Reusable
2600 0030	Calibration Vessel, Thermos
3200 0011	Septa (20)
Z2600 3905	Zero Air Filter
Z2600 3914	Septum Holder
Y431 0903 or	**431 Maintenance Kit (110 VAC) (See pictures beginning on page 32)**
Y431 0904	**431 Maintenance Kit (220 VAC) (See pictures beginning on page 32)**
2500 3001	1' of 1/8" Tygon tubing
2600 3039	.25 inch fritware
Z2600 3905	Zero Air Filter
Z2600 3928	C/M Filter
Z2600 3930	Scrubber Filter
Z4000 0907	Battery Pack Assembly
Y990-0175 or	**Dosimeter Analysis Kit (110 VAC applications)**
Y990-0176	**Dosimeter Analysis Kit (220 VAC applications)**
990-0177	Pocket Pump, calibrated to 5 ml/min
990-0159	Converter, 220VAC to 110VAC, 200 WATT (supplied with Y990-0176 for locations using 220 VAC power)
X412 0901	Personal Mercury Dosimeter (2)
2500 3001	2' of 1/8" Tygon tubing
2500 3010	1' of 3/16" Tygon tubing
2100 6017	Dosimeter Lead Set
1300 0031	3/16" to 1/8" Reducer
Z2600 3905	Zero Air Filter

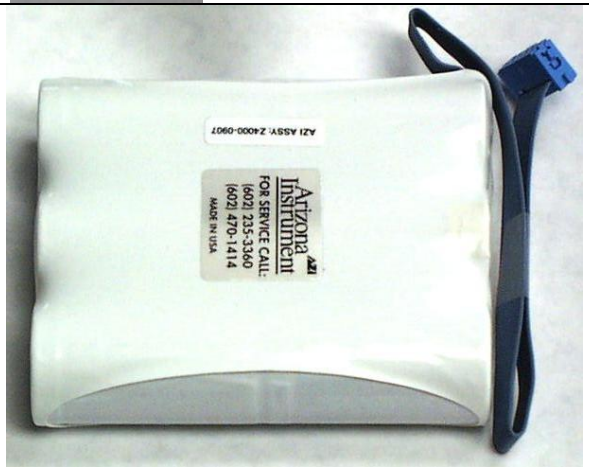
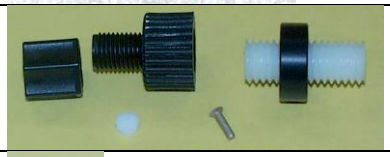
Y990-0169	**Jerome® Data Logger** Includes the Jerome® Data Logger and JCS Software Kit.	
Y990-0175 (110 VAC) or Y990-0176 (220 VAC)	**Personal Dosimeter Kit** Includes the Pocket Pump, two mercury dosimeters, zero air filter, regeneration cable, connecting tubing and adaptor.	
Y990-0168 (with cable) Y990-0170 (without cable)	**Jerome® Communication Software Kit (JCS)**	
Y411 0904	**Hard Side Carry Case** Includes a molded case with die cut foam rubber inserts to hold the Jerome® 431-X and accessories.	

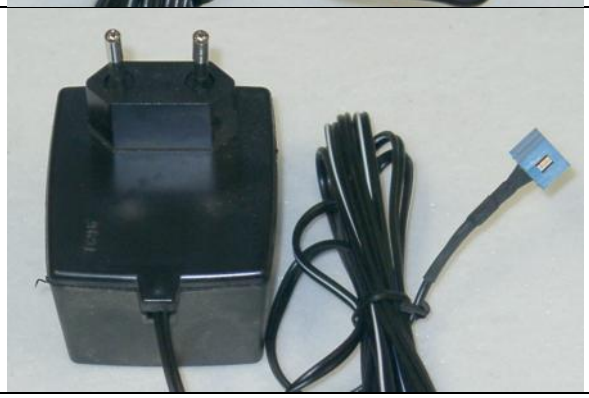
Soft Field Carrying Case

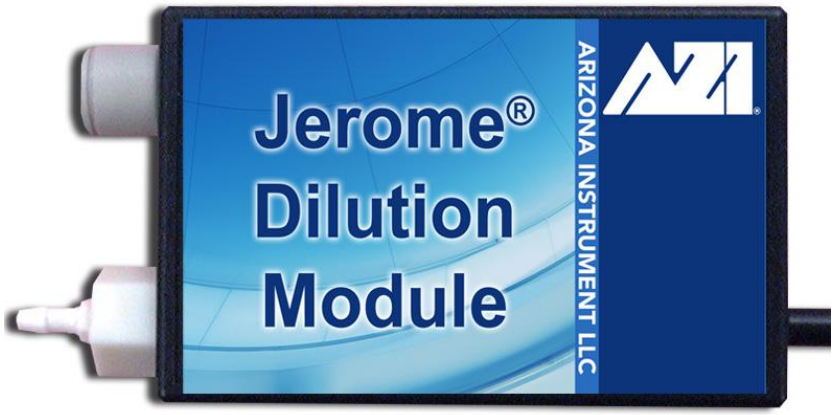
1400 0052 Hand/shoulder case with pockets for accessories.

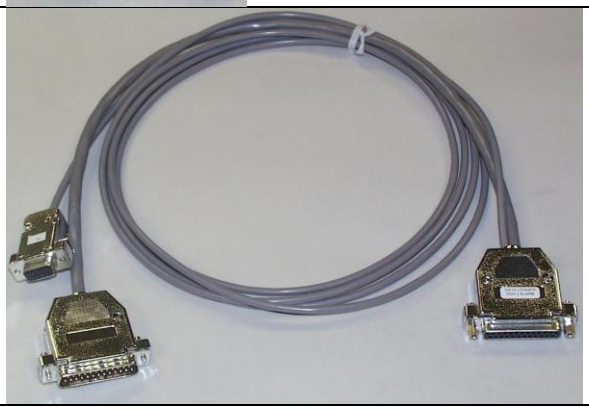
Spare Parts

X412 0901	Personal Mercury Dosimeter	
A2600 0902	Stopper Assembly	
Z2600 3914	Septum Holder	
3200 0011	Septa	
A2600 0903	Syringe Assembly	
2600 0022	Syringe Needles, 22 Ga.	

1400 2002	Probe	
2300 0001	Trimmer	
1300 0031	1/8 x 3/16 reducer	
Z4000 0907 Z4000 0908	Battery Pack Assembly (115V) Battery Pack Assembly (230V)	
Z2600 3905	Zero air filter	
Z2600 3928	C/M filter	
Z2600 3930	Scrubber filter	
Z2600 3940	Chlorine Filter	
990-0193	Ammonia Filter	
1400 3010	Tubing adapter	
Y2600 3945	Intake Kit	 Includes mounting hardware
PS-151	Tube Nut	

2600 3039	.25 inch fritware	
2500 3001	Tygon tubing 1/8" I.D. (1 foot)	
2500 3002	Tygon tubing 1/16" I.D. (1 foot)	
4000 1011	115 VAC IDC battery charger (Used to charge an uninstalled battery)	
4000 1012	230 VAC IDC battery charger (Used to charge an uninstalled battery)	

6000 4003	100-120 VAC Line Cord	
Alternate – 200-0003	220-240 VAC Line Cord for England	
Alternate – 200-0008	220-240 VAC Line Cord for Europe	
990-0225	10 to 1 Dilution Module	

5100 1012 Spare Fuse	
6000 1055 Jerome® Communication Cable	

For current prices and delivery information, call AZI Customer Service at (800) 528-7411 or (602) 470-1414.

10. Factory Calibration Service

Service includes filter replacement, component testing, and instrument calibration to NIST traceable standards.

For scheduling and shipping authorization, call AZI Customer Service at (800) 528-7411 or (602) 470-1414.

11. APPENDIX A - 431-X FUNCTIONAL TEST KIT

If your application requires frequent verification of instrument functionality, this test will benefit you. If the test results fall within the expected range, you may assume the instrument is functioning properly.

THIS IS A FIELD CHECK OF THE FUNCTIONALITY OF THE INSTRUMENT.

THIS TEST DOES NOT CALIBRATE THE INSTRUMENT.

NOTE: Perform the functional test ONLY after a sensor regeneration.

The 431-X Functional Test Kit contains all accessories necessary to perform the functional test. See the complete list on page 30 and verify that all the parts to the kit are present.

CAUTION:

The vial and thermometer contain liquid mercury and are possible sources of mercury contamination. Follow the instructions for handling or transferring the mercury into the Functional Test Kit Vessel carefully.
For safety information, see the supplier's Material Safety Data Sheets (MSDS) or call AZI Customer Service at 1-800-528-7411 or 1-602-470-1414 for assistance in obtaining the MSDS.

Preparation

- Carefully unpack and inspect the parts of the kit.
- ENSURE that the mercury shipping container and mercury filled thermometer are not broken.
- In a ventilated area, preferably under a fume hood, remove the mercury vial from its shipping container.
- Place the functional test kit vessel and the mercury vial close to each other and open the mercury vial.

CAUTION:

The edge between the plastic case and the glass inner vessel of the functional test kit vessel are not sealed tight enough to prevent mercury from entering the area between the inner and outer vessels. ENSURE the mercury, transferred in the next step, does not contact the seal where the glass and plastic portions join.

NOTE: The vessel may be disassembled to transfer the mercury and better prevent contamination of the outer portion of the vessel. Instructions to disassemble the vessel can be found on page 38.

Mercury Transfer

- CAREFULLY pour the mercury into the center of the functional test kit vessel's opening.
  - ENSURE that no mercury residue is on the outside of the vessel. See the supplier's Material Safety Data Sheets (MSDS) or call AZI Customer Service at 1-800-528-7411 or 1-602-470-1414 for clean-up instructions.
- INSTALL the stopper assembly into the functional test kit vessel carefully, to prevent breakage of the thermometer.
  - PRESS the stopper assembly into the vessel to achieve a good seal.
- USE the 431-X instrument to verify that the outside of the vessel is not contaminated and the mercury vapor emission level, if any, is below the OSHA TLV for mercury.
- ALLOW the kit to adjust to room temperature for at least two (2) hours before using.
  - The temperature range for the test is 18-22 °C. Avoid temperature fluctuations.

CAUTION:
Do not use the calibration vessel as a portable container. If the calibration vessel is upset or greatly agitated, mercury droplets will cling to the thermometer stem, the rubber stopper, the mouth of the calibration vessel and the needle guide.

Vessel Disassembly

CAUTION:
The inner portion of the vessel is made of glass. Handle the vessel carefully to prevent breakage.

- LOOSEN, BUT DO NOT REMOVE the base of the vessel. The base unscrews from the body.
- SET the vessel on a firm surface.
- HOLD the base stationary and unscrew the body from the base.
- HOLD the base and the inner glass vessel with one hand while removing the body and gasket with the other hand.
- After the mercury is transferred into the glass inner vessel, reassemble in the reverse order.

Replacing Mercury

An oxide coating will form on the drop of mercury and will cause lower readings in your testing. Gently swirl the vessel to disturb the outer oxidized surface of the droplet. If this does not restore higher readings, it may be necessary to replace the mercury.

- Carefully remove the stopper assembly from the calibration vessel.

CAUTION:
BE SURE NEEDLE GUIDE IS FREE OF LIQUID MERCURY.

- Carefully pour the mercury into a disposal vessel. Refer to Vessel Disassembly Instructions on page 38.
  - Mercury can become trapped between the plastic calibration vessel and the glass inner-liner.
- Replace the oxidized mercury with approximately ½ cc fresh mercury. (AZI P/N A2600-0904)
  - Do NOT use the syringe for measuring liquid mercury. Dispose of oxidized mercury properly.
- Reassemble the calibration vessel.
- Reinstall the stopper assembly.

Functional Test Procedure

NOTE: Perform the functional test ONLY after sensor regeneration.

- Allow the calibration vessel to remain stable at room temperature for at least 2 hours.
  - The temperature range for the test is 18º - 22ºC.
  - Temperature fluctuations during the test procedure will produce erratic results.
- Replace the .25mm fritware.
  - Refer to page 19 for instructions.
- Replace the septum on the septum holder assembly.
- Plug the tubing adapter end of the septum assembly into the instrument's intake and tighten the intake tube nut.

NOTE: To check for a tight seal, gently pull on the septum holder assembly. If it comes out of the intake, it may be necessary to remove the intake tube from the instrument and firmly press the tubing adapter through the intake. Tighten the intake tube firmly to the intake stem.

- Attach a zero air filter to the septum assembly.
- Press power ON.
- Take 3 samples.

- If the average meter reading is greater than .005, stop here. The instrument may be contaminated. See 431-X TROUBLESHOOTING on page 24.
- If the average meter reading is less than .005, continue to the next step.

- Note the temperature of the calibration vessel.
- Press the SAMPLE button, wait 2 seconds and **when the display flashes**, inject 1 cc of mercury vapor according to the syringe technique described on page 41. Be sure all mercury vapor has been injected before the solenoid closes (second click and display flash).

CAUTION:
Carefully follow these instructions to minimize error.

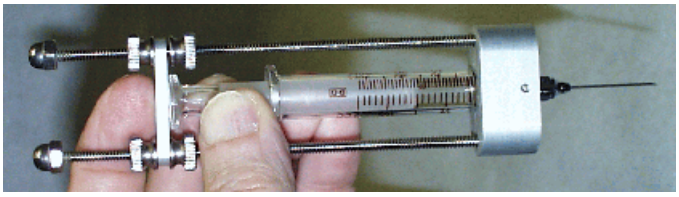
- Record the meter reading.
- Repeat the instructions for mercury injection three more times.
  - The readings obtained for the last three 1cc injections should be within ± 5% of each other.
- Refer to the Temperature Conversion Chart, page 42, for the acceptable range.
  - The average of the last three readings should fall within the range shown on the chart.

If the average is within range, the JEROME® 431-X is functioning properly.

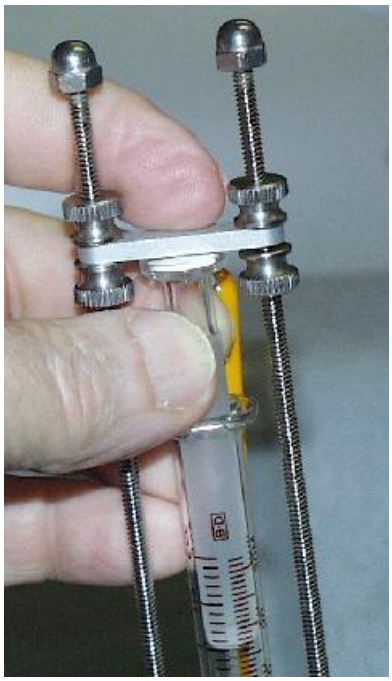
- If the last three readings are not within ±5% of each other,
  - Perform sensor regeneration. Press ZERO and turn the ZERO ADJUST (refer to page 12 and 13 for the complete sensor regeneration procedure).
  - Wait 1 hour before proceeding to the next step.
  - Repeat the mercury injection test procedure.
  - If the average of the last three readings is still not within range, refer to the section on Functional Test Troubleshooting below.

Syringe Technique

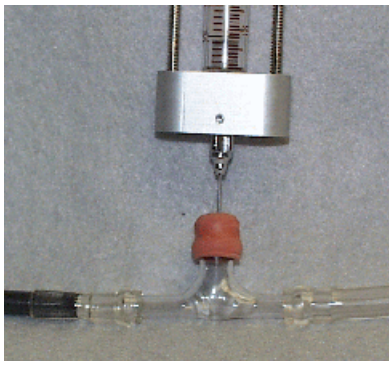
- Pull and hold the syringe plunger against the bar-stop.
- Verify that the black mark on the syringe plunger aligns with the 1cc mark on the syringe barrel.
  - If it does not, the holder assembly must be adjusted. Call AZI customer service at 602-281-1745 or 800-528-7411 for assistance.
- Insert the needle into the needle-guide of the bottle stopper.



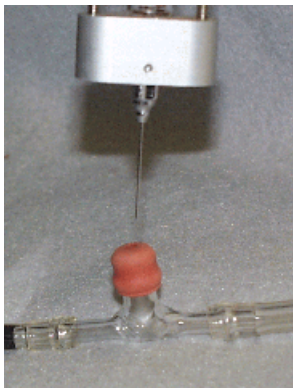
- Operate the plunger two or three times to pump mercury vapor into the syringe. On the final stroke, pull and hold the plunger against the bar-stop.
- Holding the plunger against the bar-stop, remove the syringe from the bottle and move it to the septum attached to the instrument intake.



- Continue to hold the plunger against the bar-stop and insert the syringe needle into the septum.
- Press “SAMPLE” on the instrument.



- When the display flashes, release the plunger and allow gravity to feed the mercury vapor into the airstream. If the plunger stops, gently press it completely closed.
- Remove the syringe needle from the septum.



431-X Temperature Conversion Chart

Temperature in °C	Digital Meter Response
16	.091 to .123
17	.100 to .135
18	.108 to .146
19	.118 to .159
20	.129 to .174
21	.138 to .187
22	.151 to .204
23	.164 to .222
24	.177 to .240

Functional Test Troubleshooting

If you don't achieve good results with the functional test procedure, check the following:

Results	Solution
Typically too high	Ensure the calibration vessel temperature is stable.
Too Low	Be sure to inject the Hg vapor ONLY after the display flashes (approximately 2 seconds after SAMPLE is pressed).
	Ensure there is no oxidation on the mercury drop in the calibration vessel. Gently swirl the mercury drop in the calibration vessel. Replace if necessary.
	Ensure the instrument's intake is not blocked with foreign matter. Check flow with a flow meter.
	Ensure syringe is calibrated to 1cc. Use a new syringe needle. Straighten or replace crimped or blocked internal tubing.

If you find the above does not solve your problem, please call AZI Customer Service at 800-528-7411 or 602-470-1414.

12. APPENDIX B - PERSONAL MERCURY DOSIMETER

The gold coil personal mercury dosimeter is a unique collection device for mercury vapor. The Jerome® 431-X Gold Film Mercury Vapor Analyzer and the Personal Mercury Dosimeter determine personal exposure levels and ambient air concentrations, as well as low levels of mercury in natural and stack gases. The dosimeters are not compatible with the 431-XE model.

For personal sample collection, the dosimeter is worn as close to the wearer's breathing zone as possible and is connected by tubing to a pump usually worn on a belt. The dosimeter can also be used for multiple point area monitoring by placing a dosimeter, with pump attached, in various strategic locations.

We recommend a pump flow rate of 5 cc/minute for the most accurate results when sampling in an atmosphere that for eight hours may contain an average of .025 mg/m^3 Hg. If you are considering using any other flow rate, see page 48, Non-Standard Flow Rates and Dilution Modules .

After sample collection is completed, the dosimeter is inserted in the Jerome® 431-X's intake. A dosimeter lead set is connected between the dosimeter and the DB-25 connector on the back of specially equipped instruments. The instrument supplies power to volatilize the accumulated mercury from the dosimeter to the gold film sensor. The Jerome® 431-X determines the mass of mercury collected by the dosimeter in a 17 second analysis. The dosimeter is ready for immediate re-use after a mercury measurement has been performed.

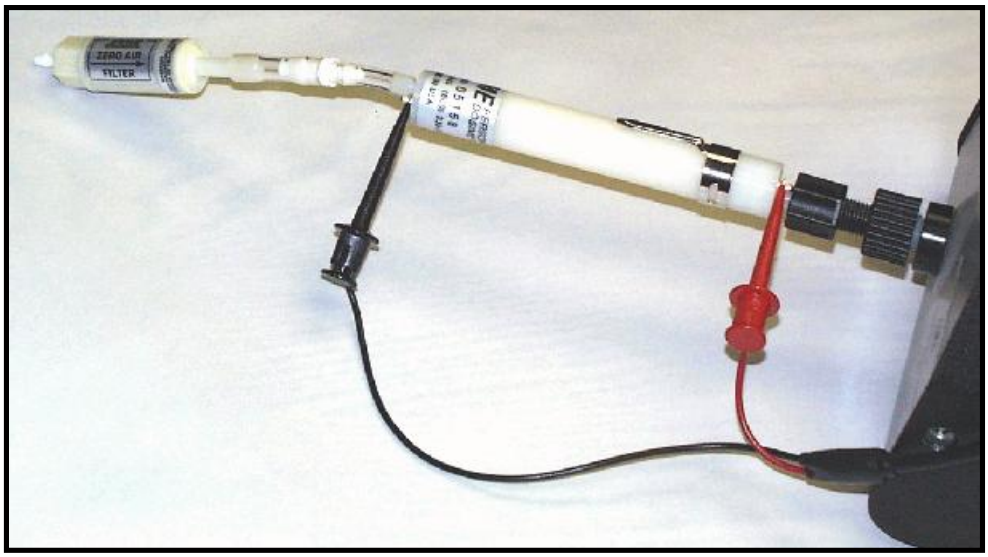
Dosimeter Technical Specifications

Sensitivity	Less than 0.5 nanograms of mercury
Precision	15% RSD @ 0.100 mg/m^3 Hg
Accuracy	15% @ 0.100 mg/m^3 Hg
Recommended flow rate	5 cc/min (0.005 liters/min) for atmospheres up to 0.025 mg/m^3
Construction	Nylon and glass housing a gold film coil
Weight	1.5 ounces
Dimensions	0.5" dia. x 4.5"
Capacity	1000 nanograms of mercury
Analysis Time	Less than two 2 minutes

Before Sampling with the Dosimeter

The personal mercury dosimeter adsorbs mercury vapor over a set period of time. Therefore, before each day's use it is necessary to ensure the dosimeter is mercury free. Perform the following steps to remove any accumulated mercury.

- Connect the system as shown.
  - Insert the dosimeter's large end in the 431-X's intake and gently tighten the intake tube nut to ensure an airtight seal.
  - Connect the Dosimeter Lead Set clips as shown, Short red lead to the rear and long black lead to the far end.



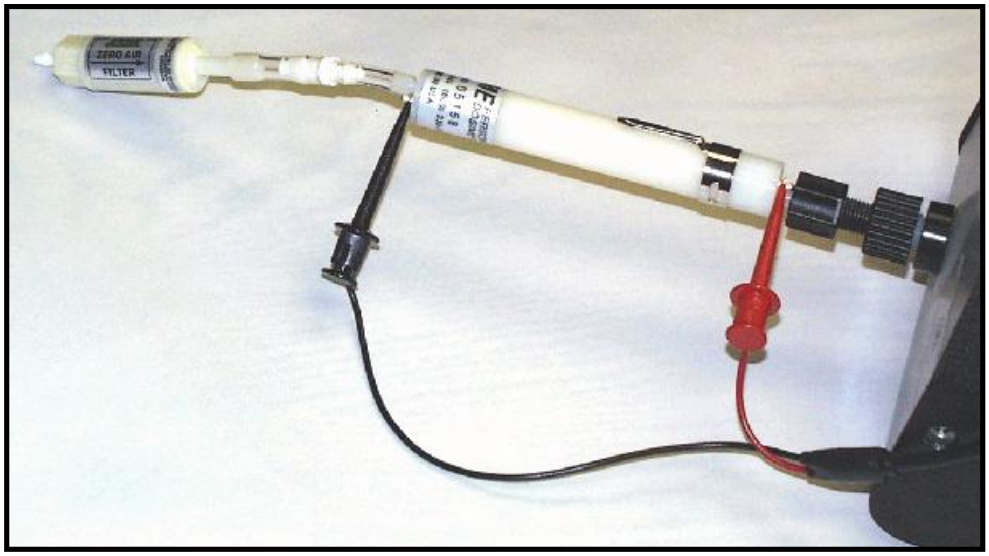
- Attach the power cord to the 431-X and plug it into AC power. AC power is required to heat the dosimeter.
- Attach the Dosimeter Lead Set 25 pin connector to the respective 25 pin communications port.
- Press the instrument's power ON button.
- Press the instrument's SAMPLE button.
  - The digital meter reading will appear in 15 seconds.
- Wait 60 seconds and press the SAMPLE button again.
  - The digital meter should display less than 0.005, verifying all mercury has been removed from the dosimeter coil.
- Wait 2 minutes to cool sensor to prevent false positive response.
- The dosimeter is ready for sample collection.

NOTE: For best results, dosimeter analysis should be performed immediately after collection. If analysis cannot take place immediately, place the red end caps on the dosimeter. For accurate results, perform dosimeter analysis no later than five days after sampling.

Dosimeter Analysis

NOTE: Wait a minimum of 30 minutes after a sensor regeneration before continuing.

- Connect the system as shown.
  - Insert the dosimeter's large end in the 431-X's intake and gently tighten the intake tube nut to ensure an airtight seal.
  - Connect the Dosimeter Lead Set clips as shown, Short red lead to the rear and long black lead to the far end.



- Attach the power cord to the 431-X and plug it into AC power. AC power is required to heat the dosimeter.
- Attach the Dosimeter Lead Set 25 pin connector to the respective 25 pin communications port.
- Press the instrument's power ON button
- Reading the dosimeter (dosimeter desorption)
  - Press the SAMPLE button.
    - The digital meter reading appears in 15 seconds.
  - Record the digital meter reading (include the decimal point).
  - Wait 30 seconds.
  - Press SAMPLE again and record this digital meter reading. Repeating the heating/reading process ensures complete release of mercury from the dosimeter coil.
- Add the two digital meter readings together. The sum of the two digital meter readings is the figure you will use in your calculations and is referred to as the meter response (MR).

NOTE: A third dosimeter desorption (pressing the SAMPLE button) should give a reading of .005 mg/m^3 or less.

Perform the following calculation to obtain the mercury concentration in mg/m^3 based on a time weighted average; **or alternately, DIP switch #2 can be set to OFF** and the digital meter will display nanograms Hg directly (refer to diagram, page 55).

Working Formula and Units of Measure

$$\frac{\text{Meter Response X Conversion Factor}}{\text{Pump Flow Rate X Sampling Time}} = \text{Sample Concentraton}$$

Where:

Meter Response	=	Total of the two digital meter readings in mg/m^3
Conversion Factor	=	87.5 $ng/mg/m^3$ (a constant which changes the meter response to nanograms of Hg)
Pump flow rate	=	5.0cc per minute (calibrated value of the supplied SKC Pocket Pump)
Sampling time	=	Duration of the sample in minutes
Sample concentration	=	In ng/cc mg/m^3

EXAMPLE: To calculate a time weighted average during an 8 hour period using the following values:

Meter response	=	0.600 mg/m^3 (sum of the two meter response readings)
Conversion factor	=	87.5 $ng/mg/m^3$ (constant)
Pump flow rate	=	5 cc/min
Sampling time	=	8 hours (480 min)

- Convert the meter response (the total of the two digital meter readings) to nanograms of mercury.
  - 0.600 x 87.5 = 52.5 nanograms of Hg

- Determine the total volume of air sampled.
  - 5 cc/min x 60 min/hr x 8 hr = 2400 cc
- Determine the Hg concentration (time weighted average) of the dosimeter.

$$\frac{52.5\text{ng}}{2400\text{cc}} = 0.022\text{ ng / cc of Hg} = 0.022\text{ mg/m}^3\text{ of Hg}$$

Check the sensor status after each dosimeter analysis.

IMPORTANT:
To prevent the loss of a sample,
perform sensor regeneration as soon as the display shows "- - - -" (four bars).
This indicates that the sensor is 75-100 percent saturated.

- Seal the dosimeter with caps after analysis to prevent mercury contamination during storage.
- If your readings exceed 75 nanograms or more, try the recommendations described next or call AZI Customer Service at 800-528-7411 or 602-470-1414 for assistance.

Non-Standard Flow Rates and Dilution Modules

You may use a pump with a flow rate up to 50 cc/min, but be aware that there are certain limitations. If your pump flow rate exceeds 5 cc/min and your average dosimeter analysis produces nanogram levels of 75 or more, it may be easy to collect enough mercury to saturate the 431-X sensor. You thus risk over ranging your instrument and losing your collection data. Higher flow rates may also impair the capture efficiency of the dosimeter.

We recommend that you drop your flow rate or use a dilution module* (AZI P/N 990-0225). Lowering the flow rate to decrease the sample volume provides the greatest accuracy. Using a dilution module introduces an additional 15% inaccuracy to your analysis. As an alternative to the dilution module, sample for shorter time periods.

Dilution Module Specifications

Accuracy	± 15% of 10:1 ratio
Dimensions	6.1 cm w x 14.0 cm l x 2.5 cm h (2.4" w x 5.5" l x 1" h)
Weight	61.4 g (2.2 oz)

The dilution module is factory set to a 10:1 ratio. The mass of mercury entering the dilution module is reduced by 90%, leaving a 10% (X10 dilution) concentration to be introduced into the Jerome® 431-X. Since this ratio can change slightly with use, it is important to occasionally determine the current dilution module ratio to ensure accurate results. For normal applications a X8 to X12 ratio is recommended. The 431-X Functional Test Kit contains all accessories necessary to determine the current dilution module ratio.

Call Customer Service at 800-528-7411 or 602-470-1414 if you have questions about flow rates or applications.

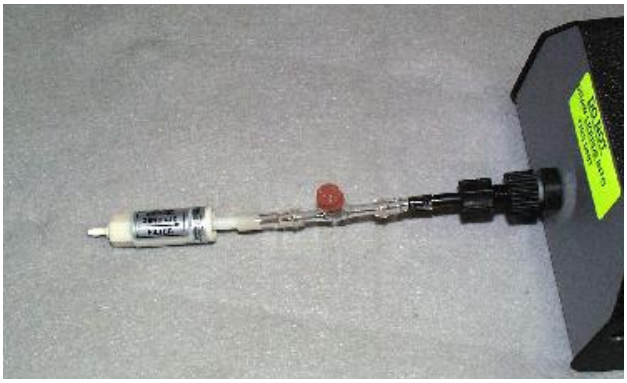
*The dilution module contains Resisorb®, mercury vapor adsorbent. For safety information, see the supplier's Material Safety Data Sheets (MSDS) or call AZI Customer Service at 1-800-528-7411 or 1-602-470-1414 for assistance in obtaining the MSDS.

Dilution Module Ratio Check

The 10:1 dilution module was manufactured and calibrated to produce a 10:1 ratio in the sample delivered to the instrument. Over time the ratio may change slightly. To accurately determine the exact dilution offered by the 10:1 dilution module, perform the following tests and calculate the exact dilution ratio. The calculated ratio can then be used in all final calculations where the dilution module is used.

NOTE: Wait a minimum of 30 minutes after sensor regeneration before starting this procedure.

Direct 431-X Readings:



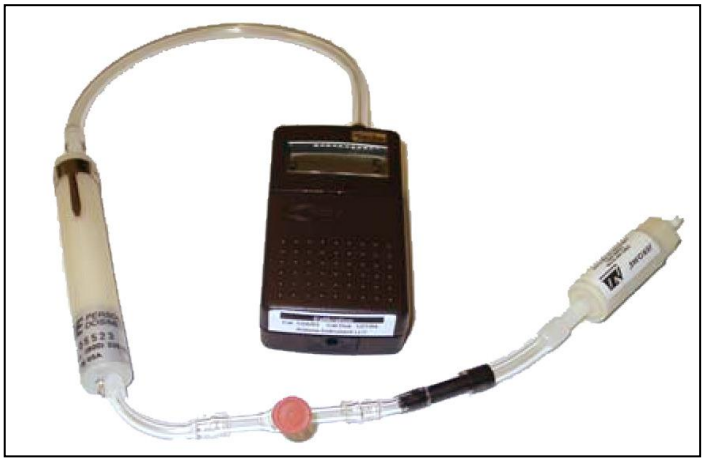
- Connect the instrument, septum holder assembly and zero air filter, with arrow pointing to the instrument, as shown.
- Press the Jerome® 431-X power ON button.
- Inject 1 cc of mercury saturated vapor into the septum, according to the Syringe Technique described on page 37, Appendix A.
- Make 3 additional 1 cc injections sample readings and record the displayed values (include the decimal points).
- Average the results of the last 3 injections.
- Remove the septum assembly and zero air filter from the instrument.
- Connect the 10:1 dilution module to the instrument, connect the septum assembly and zero air filter to the dilution module.
- Inject 1 cc of mercury vapor as above into the septum.
- Make three additional injections and average the three readings.
  - ➢ Divide this result into the average from the three direct injections.
- Use the result as the dilution module ratio in your dosimeter analysis.

Most Accurate Method

Perform the above test, however attach the dosimeter, septum holder assembly and zero air filter to the sampling pump that will be used. The technique is described in the next section. Collection efficiencies should be approximately 100%.

Loading the Dosimeter

- Connect your pump, dosimeter, septum holder assembly and zero air filter together with 1/8" and 3/16" Tygon™ tubing as shown to the right.
- Turn on the pump.
- Inject 10 cc's of Hg into the septum, 1 cc at a time.
  - A total of ten, 1cc injections, one after another.



- Wait 30 seconds after the last injection then turn off the pump.
- Remove the dosimeter, septum assembly and zero air filter from the pump.
- Connect the instrument, dilution module, dosimeter, zero air filter and dosimeter lead set as shown.

- Attach the power cord to the 431-X and plug it into AC power.
  - AC power is required to heat the dosimeter.
- Press the Jerome® 431-X Power ON button and then press the SAMPLE button.
  - The digital meter reading appears in approximately 15 seconds.
- Record the digital meter reading (include decimal point). Wait 60 seconds, then press SAMPLE again and record this reading.
- Repeating the heating process ensures complete release of mercury from the dosimeter coil.
- Add the two digital meter readings together.
  - The sum of the two digital meter readings is the figure you will use in your calculations and is referred to as the meter response (MR).
- Repeat this procedure two more times.
- Average the three meter responses you obtained in this section.

Dilution Module Ratio Calculations

- Multiply the average obtained for **Direct 431-X Readings** by 10 (the number of 1 cc injections).
  - Divide this result by the average obtained in the section "Loading the Dosimeter" on page 50.
- Use the result as the dilution module ratio in your dosimeter analysis.

EXAMPLE:

Direct 431-X readings

0.102 mg/m^3
0.103 mg/m^3
0.104 mg/m^3
0.103 mg/m^3 average

Loading the dosimeter

0.120 mg/m^3
0.113 mg/m^3
0.100 mg/m^3
0.111 mg/m^3

Step 1 (above)
0.103 mg/m^3 x 10 = 1.030 mg/m^3

Step 2 (above)
(1.030 mg/m^3) / (0.111 mg/m^3 = 9.4
Dilution module ratio 9.4:1

NOTE: For normal applications a X8 to X12 ratio is recommended. If your ratio is not within this range, call Customer Service at 800-528-7411 for assistance.

Analysis with a Dilution Module

NOTE: Wait a minimum of 30 minutes after sensor regeneration before starting this procedure.

- Connect the system as shown in the figures below.

- Attach the power cord to the 431-X and plug it into AC power.
  - ➢ AC power is required to heat the dosimeter.
- Press the Jerome® 431-X power ON button and then press SAMPLE button. The digital meter reading appears in 12 seconds.
- Record the digital meter reading (include the decimal point). Wait 30 seconds, then press SAMPLE button again and record this reading.
  - ➢ Repeating the heating process ensures complete release of mercury from the dosimeter coil.
- Add the two digital meter readings together.
  - ➢ The sum of the two digital meter readings is the figure you will use in your calculations and is referred to as the meter response.
- The following calculations will provide the mercury concentration in mg/m^3 based on a time weighted average.

$$(\text{Meter Response converted to nanograms (Ng) of mercury}) \text{ X } \frac{\text{Dilution Module Ratio}}{\text{Sample Volume}} = \text{Sample Concentration}$$

- Alternately, DIP switch #2 can be set to OFF and the digital meter will display nanograms Hg directly.

MR (meter response)	total of the two digital meter readings in mg/m^3
87.5 $ng/mg/m^3$	conversion factor, a constant which changes the meter response to nanograms of Hg
DM dilution module ratio	the ratio determined on page 51
SV (sample volume)	pump flow rate (in cc/min) multiplied by sample time (in minutes)
Sample concentration	$ng/cc = mg/m^3$

EXAMPLE:
Assume the following values.

Meter Response (MR)	0.600 mg/m^3 (sum of the two meter response readings)
Conversion Factor	87.5 $ng/mg/m^3$ (constant)
Dilution Module Rate	9.4
Pump Flow Rate	5 cc/min
Sampling time	8 hours = 480 min
Sample volume	5 cc/min X 480 min = 2400cc

A time weighted average during an 8 hour period is calculated by:

$$\frac{\left(0.600\ mg/m^3\right) X \left(87.5\ ng/mg/m^3\right)}{2400\ cc} = 0.021875\ ng/cc$$

- Convert the meter response (the total of the two digital meter readings) to nanograms of mercury.
  - The MR (0.600) multiplied by the conversion factor (87.5) equals nanograms of mercury
  - 0.600 x 87.5 = 52.5 nanograms of Hg
- Determine the actual mass of Hg collected by the dosimeter.
  - Nanograms of mercury multiplied by the dilution module ratio.
  - 52.5 nanograms x 9.4 = 493.5 nanograms
- Determine the total volume of air sampled.
  - The pump flow rate multiplied by 60 min/hr multiplied by 8 hours.
  - 5 cc/min x 60 min/hr x 8 hr = 2400 cc
- Determine the Hg concentration (time weighted average) of the dosimeter.
  - The mass of Hg collected by the dosimeter divided by the total volume of air sampled.
  - 493.5 nanograms divided by 2400 cc = 0.205625 ng/cc of Hg = 0.205625 mg/m^3 of Hg
- Check the sensor status after each dosimeter analysis.
- Seal the dosimeter with tubing after analysis to prevent excessive mercury contamination during storage.

IMPORTANT:
Perform a sensor regeneration as soon as the meter display shows "- - - -" (four bars) to prevent the loss of sample.

Dosimeter Reference Chart 431-X

Expected concentration, related to sample volume and meter response

= Indicates the optimum meter response for that concentration with the corresponding volume

		431-X reading in mg/m^3									
Estimated concentration in mg/m^3	0.5	0.429	0.857	HL	HL	HL	HL	HL	HL	HL	HL
	0.1	0.086	0.171	0.343	0.686	HL	HL	HL	HL	HL	HL
	0.05	0.043	0.086	0.171	0.343	0.686	HL	HL	HL	HL	HL
	0.025	0.021	0.043	0.086	0.171	0.343	0.686	HL	HL	HL	HL
	0.005	0.004	0.009	0.017	0.034	0.069	0.137	0.274	0.549	HL	HL
	0.001	LOW	LOW	0.003	0.007	0.014	0.027	0.055	0.110	0.219	0.439
Volume at 5ml/min		75	150	300	600	1200	2400	4800	9600	19200	38400
Hours collected		0.25	0.5	1	2	4	8	16	32	64	128

Use the following formula for calculating the concentration of mercury in air:

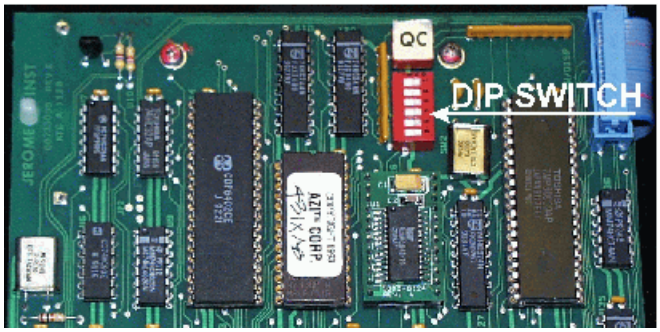
$$\frac{(\text{Meter Response}) \text{ X } 87.5}{(\text{Flow Rate of Sampling Pump}) \text{ X Time}} = \text{Concentration } (mg/m^3)$$

The following table shows the relation of flow rate and time to total volume collected.

cc/min	Total volume collected in cc							
100	6000	12000	24000	48000	72000	144000	288000	432000
60	3600	7200	14400	28800	43200	86400	172800	259200
20	1200	2400	4800	9600	14400	28800	57600	86400
10	600	1200	2400	4800	7200	14400	28800	43200
5	300	600	1200	2400	3600	7200	14400	21600
	1	2	4	8	12	24	48	72
	HOURS							

13. APPENDIX C - INTERNAL DIP SWITCH SETTINGS

Main circuit board RED DIP switches (SW2)



This is the red DIP switch box located at the top, center of the instrument's main circuit board.

The 431-X provides regulated film heat at both 50 Hz and 60 Hz line frequencies. This also provides two ranges of preset but unregulated film heat (100-120/200-240 volt and 110-130/220-260 volt ranges). The two ranges are available to reduce the effects of chronic low or high line voltage.

Note: The ranges are doubled when the AC line selector switch is set to the 220V position. The DIP switch positions 1 and 6 must be properly set.

DIP 1	DIP 6	Function
OFF	OFF	60 Hz regulated film heat (100-130/200-260 VAC)
OFF	ON	50 Hz regulated film heat (102-130/205-260 VAC)
ON	OFF	50/60 Hz preset film heat (110-130/220-260 VAC)
ON	ON	50/60 Hz preset film heat (100-120/200-240 VAC)

Regulated film heat should normally be used (DIP 1 OFF) except in the few cases where extremely dirty line voltage conditions may exist. These conditions might be found where large motors are being controlled or other situations may exist where the voltage may vary outside the 100-130 VAC range with regularity. In those cases the two preset heat ranges will allow some degree of satisfactory operation.

Switch Number	Normal Position	Action
2	ON	Nanograms mode
3	ON	Displays relative (not true)voltage during regen (0-255)
4	OFF	Display L-O-H when "zero" button pressed
	ON	Display 00-99 when "zero" button pressed
5	ON	Locks into 0-10mg/m^3 range (survey mode)

14. APPENDIX D - JEROME® COMMUNICATIONS SOFTWARE

The Jerome® Communications Software (JCS) is used with 431-X Mercury Vapor Analyzers that feature the communications configuration option.

- The JCS allows the user to program the instrument for unattended monitoring and to download recorded data stored in the Jerome® data logger.
- Automatic sampling can be initiated every one (1) to sixty (60) minutes with programmable audible alarm levels.

The Jerome® Communications Software (JCS) operates with the Jerome® 431-X Mercury Vapor and Jerome® 631-X Hydrogen Sulfide Analyzers that have the "Communications Configuration" option installed. The software can control instrument sampling for unattended continuous operation, collect data, graph this data in real time and perform statistical analysis.

The software can also program the Jerome® Data Logger, AZI P/N 6100-0010. This optional accessory enables data storage during manual sampling or portable automatic sampling without being attached to a computer. The data logger initiates automatic sampling, triggers alarms and stores data. The logged data may then be downloaded to the computer when it is convenient. The data logger stores up to 1,000 data points.

The JCS is menu-driven and easy to use. Each display screen is designed for clarity with self-explanatory menu options, such as "Operate Instrument" or "Display Stored Data." Select menu options using either a mouse or a track ball pointing device or a standard keyboard. The user creates records, or files, for computer storage of collected data. Data is easily retrieved for later viewing, graphing, printing or editing with spreadsheet or word processing software, (not provided). Data can be used for ongoing record keeping or for fulfilling local regulatory requirements.

Before using this software, familiarization with the operation of the Jerome® Hydrogen Sulfide Analyzer or Mercury Vapor Analyzer is important. Also, prior to installation of this software you should be familiar with the personal computer and operating system you are using. If you have any questions about how to proceed, call AZI Customer Service at (800) 528-7411 or (602) 470-1414 or send an e-mail to support@azic.com for assistance.

JCS Kit Contents

- Jerome® Communication Software on CD-ROM with security key
- Jerome® Communication Cable, AZI P/N 6000 1055
- User's manual

System Requirements

Jerome® 431-X with the "Communications Option."
Windows 98 Second Edition, ME, NT, 2000 or XP
At least one free serial port
One free USB port

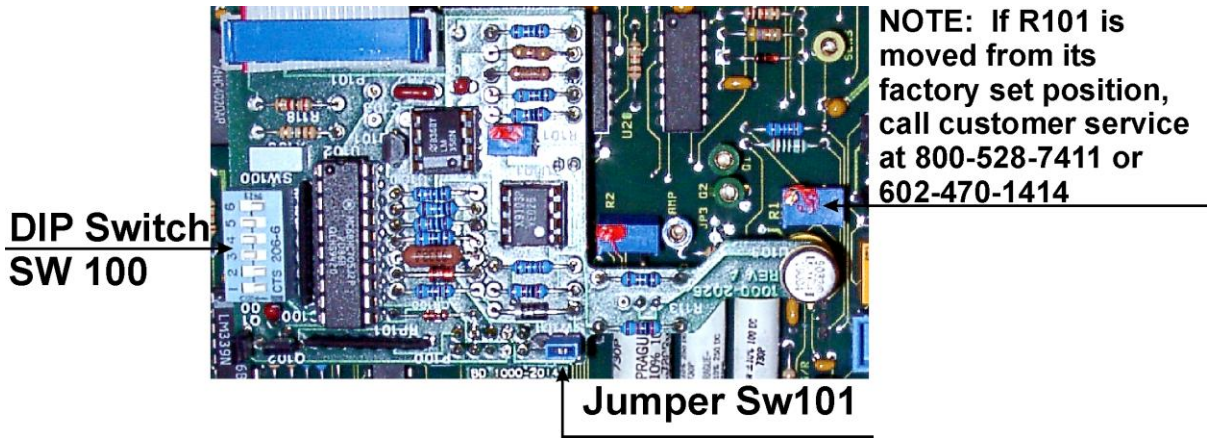
Optional equipment:
Jerome® Data Logger, AZI P/N 6100-0010 (to capture data without a computer nearby)

Data Logger Option

The software can also program the Jerome® Data Logger (AZI P/N 6100 0010) used with the Jerome® analyzer. The computer programs the data logger that then attaches to the DB-25 connector on the rear of the instrument. The data logger initiates automatic sampling, triggers alarms and stores data. This optional accessory enables portable automatic sampling without a dedicated computer.

15. APPENDIX E - JEROME® 431-X OPTION BOARD

Proper use of this board requires that the base instrument be fully functional and set correctly for the intended operation.



Auto-Zero

With the option board installed, the 431-X has a limited auto-zero function. This function cannot be disabled and is transparent to the user. The instrument can be manually zeroed as described in "Zero Adjust" on page 13. However, if the instrument is to be operated by personnel not familiar with the procedure or if it is operated unattended, the auto-zero function should satisfactorily zero the unit after each sensor regeneration.

Instrument Zeroing

The Jerome® 431-X has essentially three ways to zero the sensor reading before samples are taken if the option board is installed.

- The instrument automatically re-zeroes between samples so that each sample is a unique reading. To take a sample, simply press the SAMPLE button.
- The manually adjusted zero, using the switch on the top of the 431-X, is used to re-establish a baseline between the reference and sensor gold films **only after a sensor regeneration**. This zero is manually adjusted by pressing the ZERO button and turning the potentiometer on the top of the instrument until the display reads 0. **Adjust only after sensor regeneration;** it is normal for H to be displayed after sampling.
- The 431-X option board provides an auto-zero feature following regeneration that is invisible to the user.

- In some cases, the instrument cannot resume sampling after regeneration. .L.L.L appears on the display when the ZERO button is pressed and the error message "manual bridge adjust needed" is added to the notes column of the JCS text file when the JCS is used. If this problem persists, it may be necessary to re-set the auto-zero.
- When necessary to re-adjust the auto-zero point:
  - Turn the instrument off.
  - Make a note of the original DIP switch settings of SW100 on the option board.
  - On red DIP switch on the control board, SW2, turn DIP switch 4 to ON.
  - Set the switches on the option board's blue DIP box, SW100, to 1,2,6 OFF; 3,4,5 ON.
  - Turn the instrument ON.
  - Press the Zero button and adjust the potentiometer on top of the instrument until the numbers read between 5 and 7.
  - Switch option board DIP #1 from OFF to ON three times leaving it set to ON. (i.e. starting from OFF, switch it ON, OFF, ON, OFF, ON).
  - While pressing the ZERO button, turn the potentiometer on the option board until the numbers read between 5 and 7. Note the display will flicker one digit.
  - Return all switches to their original position.

NOTE: The higher the auto-zero number, the lower the sensor capacity and the more sensor regenerations are needed.

Timed Regeneration

If the unit is to be operated unattended for extended periods, AZI recommends that the sensor be regenerated regularly. Operation under JCS or data logger control automatically regenerates saturated sensors. The option board can control regeneration on a regular basis, every 6, 12 or 24 hours.

The regeneration intervals are set through a combination of switch settings as shown in the following table:

------- SW100---------		REGENERATION
Switch #1	Switch #2	Interval (Hrs.)
OFF	OFF	OFF
ON	OFF	6
OFF	ON	12
ON	ON	24

Auto-Sample

If a data logger is either not connected or is operating in the manual sampling mode, the following automatic sampling rates may be selected with option board's SW100 dip switch settings:

Dip switch settings			Sampling frequency
3	4	5	
ON	ON	ON	No automatic sampling
OFF	ON	ON	5 minutes
OFF	OFF	ON	15 minutes
OFF	ON	OFF	30 minutes
OFF	OFF	OFF	1 hour

The switches have no effect if a data logger is connected and operating in automatic sampler mode as programmed through the JCS.

4-20 mA Analog Output

The analog output signal at pin 18 of the 25 pin connector can be configured to provide the instrument's native mode 0-2 Volt output or the optional 4-20 mA output by setting the option board jumper (SW101) to the "V" position for voltage, or the "I" position for current. (Pin 23 is the ground pin for the analog output function. Pin 18 is positive with respect to the ground pin).

- The 0-2 Volt output circuit can drive loads of 10 k ohms or higher.
- The 4-20 mA output is a passive transmitter and requires the connected receiver to supply between 10 and 28 volts of excitation potential.

The analog output signal is based on the entire range (0-.999 mg/m3).

Note that neither analog output circuit is floating. The negative terminals of both circuits are connected to the instrument's common ground buss.

SW101 Functions:

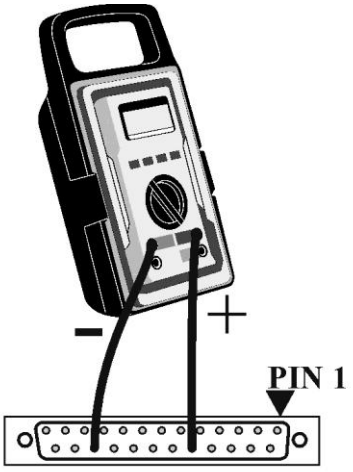
V =	0-2V analog output
I =	4-20 ma analog output

Jerome® 431-X instruments shipped after early 1995 are capable of providing 0-2 volts analog output. Instruments shipped before that time can be upgraded by a firmware update and adjustment.

Instruments that are capable of 0-2 volt output can be upgraded to the 4-20 mA output with the addition of an option board upgrade. This must be installed at the factory.

Connection and Setup:

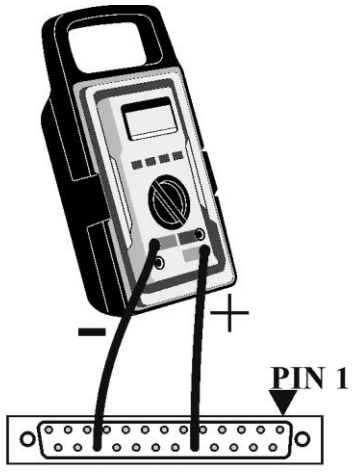
- 0-2 volt devices connect as shown in Figure 1. If the instrument includes an option board, be sure its analog jumper (SW101) is set to the "V" position.



REAR OF CONNECTOR, CONNECT PINS 18 AND 23 FOR 0-2 VOLT OUTPUT. JUMPER ON BOARD IS AT "V"
Figure 1

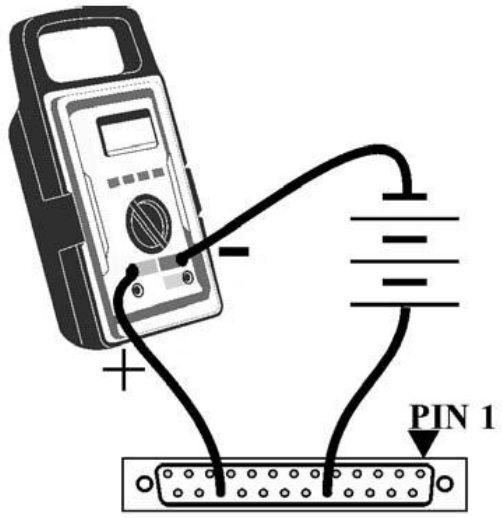
- The 4-20 mA active receivers connect as shown in Figure 2. The active receiver contains a voltage source to power the loop current. The receiver must have an isolated input circuit. That is, it must not be connected to ground or to a voltage source referenced to ground. Be sure that jumper SW101 is set to the "I" position before power is applied.
- 431X reading Current
  0.000mg/m3 4mA
  1.000mg/m3 20mA
- The 431X current formula is:
  16mA ∗ Display Reading + 4mA = (Current)

  Example:
  A reading of .100mg/m^3 would produce an output current of:
  16mA ∗ 0.1 +4mA = 5.6mA



REAR OF CONNECTOR, CONNECT PINS 18 AND 23 FOR 4-20 mA OUTPUT. JUMPER ON BOARD IS AT "I"
Figure 2

- The 4-20 mA passive receivers do not contain a voltage source to power the loop current. They require the addition of a separate isolated power supply. Typically a supply that delivers 15 to 20 volts DC at 50 mA is sufficient. Wire these as in Figure 3. Note that some 12-volt DC wall transformers (as used on portable equipment) may deliver 15 to 20 volts when they are lightly loaded. The Digi-Key T509-P1P-ND is a commonly available example of a 12 volt 200mA supply that will deliver around 18 volts nominal when loaded below 20 mA.
- Be sure that both the power supply used and the passive receiver are floating (not connected to earth ground). If either is not floating, the circuit will not work and damage may occur.
- Ensure that jumper SW101 is set to the "I" position before power-up.



REAR OF CONNECTOR, CONNECT PINS 18 AND 23 FOR 4-20 mA OUTPUT. JUMPER ON BOARD IS AT "I"

Figure 3

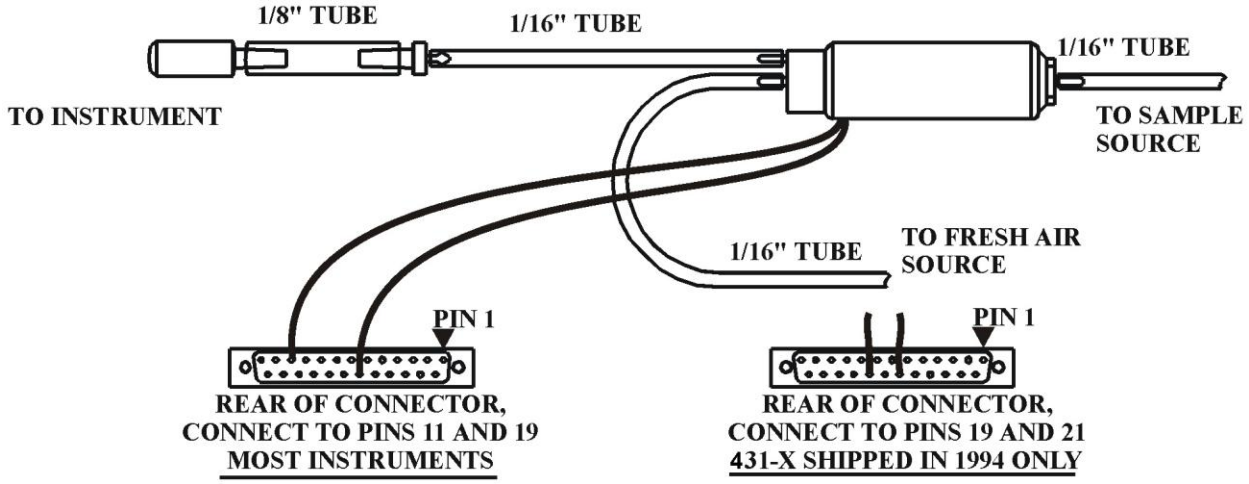
Fresh Air Solenoid

An external three-way solenoid can be used to provide fresh air or conditioned air during sensor regeneration. This may be necessary if the sample stream lacks molecular oxygen. A low current six volt DC solenoid, connected between pins 19 and 11 of the 25 pin rear panel connector, will be energized during the regeneration cycle if the option board SW100 switch 6 is placed in the OFF position.

If needed, the circuit may be built from the following components and configured as shown in the following diagram. It will only function if the option board is installed in the 431-X instrument.

Required Parts:	**Suggested Part**	**Similar AZI P/N**
1 solenoid, 6volt 3way	Angar P/N 407569	1300 1004
1/8" to 1/16" tubing adaptor	Any	1300 0025
1/2" clamp, adhesive mount	Any	6000 0013
1/8" tube to instrument adaptor	Any	1400 3010
3" 1/8" tubing	Tygon Formula R3603	2500 3001
A/R 1/16" tubing	Tygon Formula R3603	2500 3002
1 25 pin male DB-25 connector Solder-cup style	AMP 747912-2	None *
1 connector hood	AMP 749626-2	None *

* These are types not stocked by AZI, but should be available overnight from many AMP stocking distributors such as Digi-Key Corporation. There are multiple suitable alternatives such as Radio Shack's 276-1547 and 276-1549.



DC Power Operation

Instruments with the 431-X option board modification can be used with any +12 VDC source for continuous operation, if the AZI Power Inverter Kit, P/N Y031 0902 is installed along with the option board. To preserve the life of the DC power source, usually a car or truck battery, the power inverter will switch on automatically to supply the AC necessary for regeneration only. The external switch on the inverter should always be OFF to preserve battery life during normal sampling.

To work with the power inverter kit, place option board SW100 DIP Switch #6 to the ON position.

When the instrument starts a regeneration with option board SW100 DIP Switch #6 ON, the instrument sends a signal to close the relay on the DC Power Adaptor, AZI P/N 1000 0089, mounted between the data logger and the instrument. This switches the power inverter ON using the inverter's internal switch.

NOTE: When this mode is enabled, the instrument does NOT check for 115 VAC for the regeneration. If there is no AC power to the instrument, and a regeneration is initiated, the instrument will flash .H.H.H (rather than .P.P.P), however the sensor will not heat, nor will the sensor be cleaned.

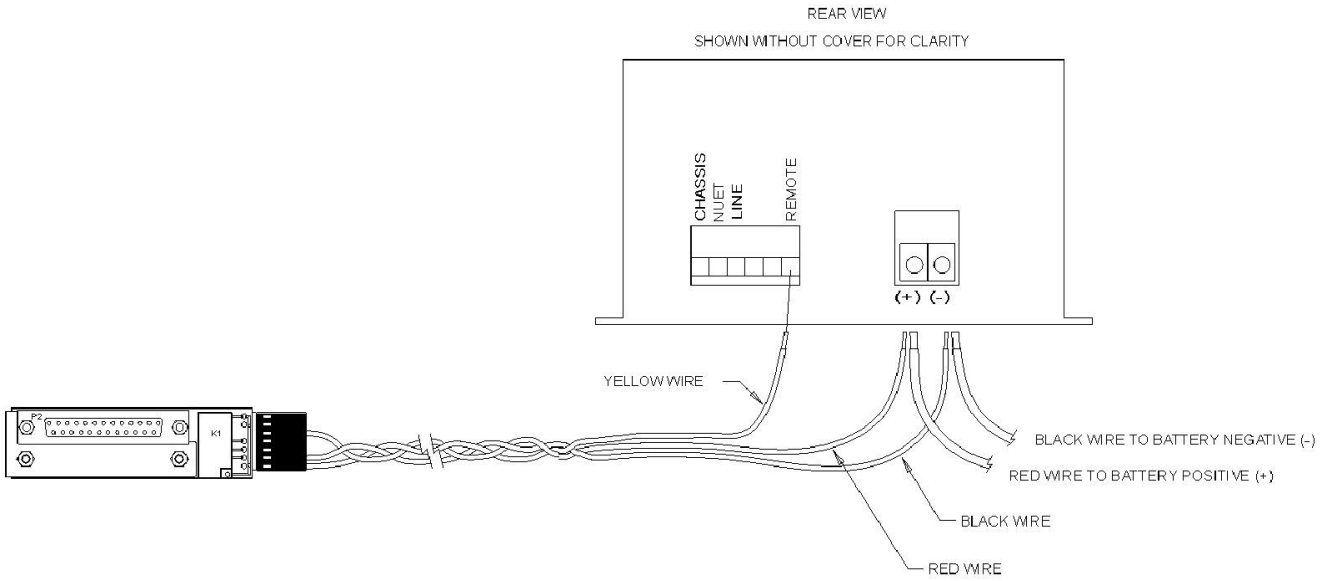
DC Power Adaptor Kit, AZI P/N Y031 0902

- The DC power adaptor kit consists of:
  - DC Power Adaptor, P/N 1000 0089
  - DC Power Inverter, P/N 4000 1021
  - DC Power Cable Assembly, P/N 6000 1093

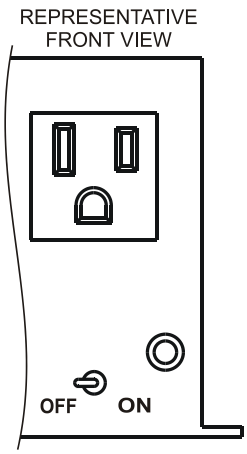
Installation

- Ensure that the instrument's option board switches are set correctly for the intended operation with the option board's SW100 DIP Switch #6 set to "ON" for DC operation.
- Mount the interface board to the rear of the instrument. Tighten the mounting screws.
- Place or mount the DC/AC power inverter in a secure position near the instrument.
- Connect the cable from the DC/AC power inverter to the matching connecter on the interface board. Note that the connectors are keyed to prevent improper connection.
- Plug the instrument's AC power cord into the power inverter and connect it to the instrument.

Ensure that the inverter's power switch is in the "OFF" position. LEAVE the power switch in the "OFF" position at all times. The interface board will activate the inverter when necessary. If the inverter power switch is placed in the "ON" position, it will cause a continuous drain on the external 12-volt power system.



- Remove the screws from the rear cover of the inverter and remove the cover.
- Place the wires from the external DC source (battery) and the wires from the DC power cable through the holes in the end plate.
- Connect cables from the external 12-volt power source and the DC power cable assembly to the appropriate positive (+) and negative (-) terminals on the back of the inverter and tighten the hold down screws.
- Connect the yellow wire from the DC power cable to the "REMOTE" terminal on the power inverter and tighten the hold down screw.
- Reinstall the cover.
- If the external 12volt lines are not powered, power them now. (Connect them to the battery)
- Connect the instrument's AC power cord between the instrument and the front of the power inverter.
- Turn the instrument "ON."
- Press the "REGEN" switch on the instrument. Inverter operation can be verified in either of two ways:
  - Immediately after pressing "REGEN" the inverter will intermittently "sing." This tone slowly becomes nearly continuous and then ends after 64 seconds.
  - If the area is noisy, use a voltmeter or test lamp to verify that approximately 115 volts is present for about 64 seconds, starting when the "REGEN" switch is pressed.
- Allow the instrument to complete its regeneration before turning it off.
- With the instrument turned off, complete the installation (i.e. connect data logger, communications cables, or other devices and ensure that the DIP switches for the instrument and option board are set correctly.



16. WARRANTY

Arizona Instrument LLC (seller) warrants to buyer that Jerome® products delivered pursuant to this agreement shall, at the time of delivery, and for a period of one (1) year. Thereafter (the Internal Battery Pack, where applicable, is warranted for a period of ninety [90] days only), to be free from defects in material or workmanship and shall conform to seller's specifications or such other specifications as seller has agreed to in writing. Seller's obligations with respect to claims under this warranty shall be limited, at seller's option, either to the replacement of defective or non-conforming product or to an appropriate credit for the purchase price thereof subject to the provisions of seller's Warranty Policy as amended from time to time, said Policy being incorporated herein by reference.

Returned products under warranty claims will be shipped to seller's plant by buyer at buyer's expense and shall be accompanied by a statement of the reason for the return and an approved Return Material Authorization Number issued by seller. Buyer remains responsible for payment for products not accepted for warranty adjustment, handling costs, and freight costs associated therewith.

Notwithstanding the foregoing, no warranty shall be enforceable in the event that product has been subjected to environmental or stress testing by buyer or any third party without written approval of seller prior to such testing. Further, no warranty shall be enforceable if the alleged defect is found to have occurred because of misuse, neglect, improper installation, repair, alteration, accident, or improper return handling procedure by buyer.

Discontinued product is warranted only for a credit or replacement at seller's option.

THE EXPRESS WARRANTIES GRANTED ABOVE SHALL EXTEND DIRECTLY TO BUYER AND NOT TO BUYER'S CUSTOMERS, AGENTS, OR REPRESENTATIVES AND, EXCEPT FOR WARRANTY OF TITLE, IS IN LIEU OF ALL OTHER WARRANTIES, WHETHER EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE AND MERCHANTABILITY, SUCH OTHER WARRANTIES BEING SPECIFICALLY DISCLAIMED BY SELLER. IN NO EVENT SHALL EITHER PARTY'S LIABILITY FOR ANY BREACH OR ALLEGED BREACH OF THIS AGREEMENT EXCEED THE TOTAL EXTENDED PRICE OR PRICES SHOWN ON UNFILLED ORDERS, NOR SHALL EITHER PARTY BE LIABLE FOR ANY SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM BREACH OR ALLEGED BREACH.

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The foregoing state the entire liability of seller in connection with products supplied hereunder.

TRADEMARK AND COPYRIGHT PROTECTION

Arizona Instrument LLC
Jerome® 431-X Mercury Vapor Analyzer Operation Manual
Part Number 700-0046-C
April 2009

If you have any questions regarding the operation of this instrument, please call our toll free number (800) 528-7411. Internationally, call (602) 470-1414 or fax (480) 804-0656.