The British Columbia Field Sampling Manual

Part B

Air and Air Emissions Testing

1 Introduction

Part B of the B.C. Field Sampling Manual (the ‘BCFSM’ or the ‘Manual’) provides guidance and instructions for *Air and Air Emissions Testing*. Part B of the BCFSM is divided into two sub-parts each of which covers a specific aspect of air testing. Part B1 deals with *Ambient Air Quality Monitoring* and was published in 2020 to provide consistency in the operation of ambient air monitoring stations and the data produced by those stations. Part B2 deals with *Stationary Air Emissions Testing*. Part B2 was initially published in 1999, underwent a comprehensive revision in 2001, and a minor revision in 2013.

1.1 Part B1

Part B1 provides guidance and instruction for operators of ambient air monitoring stations. The information contained in Part B1 is consistent with the information provided by the National Air Pollution Surveillance Program of Environment and Climate Change Canada. Ambient air monitoring stations that generate ambient air quality data for submission to provincial agencies are required to be designed, operated and maintained as specified in Part B1 of the B.C. Field Sampling Manual. Detailed information regarding ambient air monitoring methods is provided in Standard Operating Procedures (SOP) located in the Appendices section of this *Part* of the BCFSM. Additional specifications and requirements may be prescribed in Permits issued by the Province of British Columbia.

1.2 Part B2

The information and requirements contained in this ‘Part’ of the BCFSM are intended to supplement and update various stack sampling reference methods and clarify specific points as well as stating any requirements which may be unique to the Province. Part B2 provides a complete package of information including continuous emissions monitoring, calibration requirements and method specific reporting requirements. Detailed information, schematics and templated forms are provided in the appendices section of this *Part* of the BCFSM. Part B2 was reformatted in 2020 however the technical information and details provided in this Part have not been altered since it’s most recent revision in 2013.

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Ambient Air Quality Monitoring

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Part B1 – Ambient Air Quality Monitoring

1 Ambient Air Monitoring

1.1 Introduction

This Part (Part B1) of the B.C. Field Sampling Manual (the 'BCFSM' or the 'Manual') provides guidance and instructions for operators of ambient air monitoring stations. Ambient air monitoring stations that generate air quality data for submission to provincial agencies are required to be designed, operated and maintained as specified in this Part of the B.C. Field Sampling Manual. Detailed information regarding ambient air monitoring methods is provided in Standard Operating Procedures (SOP) located in the Appendices section of this *Part* of the BCFSM. Additional specifications and requirements may be prescribed in Permits issued by the Province of British Columbia.

The information presented in Part B1 of the BCFSM is derived in part from information published by the National Air Pollution Surveillance Program (NAPS), the United States (US) Environmental Protection Agency (EPA) 2013 *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*, and industry accepted best practices.

1.2 Purpose and Scope

The primary purpose of the guidance provided in this section of the British Columbia Field Sampling Manual is to support operators of ambient air quality monitoring stations within British Columbia to produce reliable and defensible data. The scope of this section includes all aspects of air quality data generation. Air quality data collected by the Province is used to inform health advisories, air shed capacity decisions, permit decisions and policy development. Due to these important data usages it is essential that the quality of the data meets or exceeds the requirements stipulated within this Part of the BCFSM. The information presented within this section has been developed to ensure that air quality data generated in all regions of British Columbia is collected and reported consistently and is truly representative of the region in which it is generated.

Data quality is affected by every aspect of air quality monitoring. Location and siting requirements ensure the air being sampled is representative and consistent with the stations monitoring objectives. The instrumentation deployed at a monitoring station will determine the accuracy and precision of measurements and station maintenance will ensure the instrumentation is functioning at an acceptable level of performance producing consistent and reliable data. Consistency in siting, installation, operation, maintenance, reporting and data management procedures help to ensure that data generated across the Province are sufficiently comparable, accurate, complete and representative. The purpose of this section of the BCFSM is to provide the guidance necessary to achieve those essential elements.

2 Monitoring Station Siting and Design

An instrument, or collection of instruments that are stationed at a single location to quantify the concentration of airborne pollutants is considered a monitoring station.

Planning the design of a monitoring station involves several critical aspects such as location, siting, power requirements and instrumentation. Monitoring stations can be installed in an existing permanent building, a ground-level enclosure or a rooftop. Design considerations for all of these aspects are driven by the station's *monitoring objectives*. The development and understanding of a monitoring station's objectives is crucial and forms the first step in designing an ambient air quality monitoring station.

2.1 General Considerations

Ambient air quality monitoring stations must meet the following conditions:

- Stations must meet the following Regulations and Codes:
    - Provincial requirements of Worksafe B.C.;
    - B.C. Safety Authority;
    - Canadian Standards Association (CSA); and,
    - Provincial electrical and applicable building codes.

If any of the information or conditions presented in this section contravenes or is interpreted to contravene or contradict applicable legislation, the applicable legislation takes precedence.

- Site location and access considerations:
    - Sites should be accessible and secure from unauthorized access;
    - Access to sites should not be impeded by snow or seasonal closures;
    - Ideally, access to sites should be available 24 hours a day for all 7 days of the week; and,
    - Sites and any external equipment (sample inlets, etc.) should be located where they can be protected as best as possible from vandalism.
- The shelter must protect the station's instrumentation from:
    - Precipitation and rodent impacts;
    - Fluctuations in internal temperature, pressure or humidity that may be caused by improperly sized air conditioning units, or intrusion of ambient air;
    - Excessive dust and dirt; and,
    - Environmental stress including temperature extremes, vibration, corrosive chemicals, intense light, or radiation pertinent to a manufacturer's specification.
- All monitoring in B.C. must be conducted using Pacific Standard Time. Analyzers, samplers and data loggers must not be adjusted for Daylight Savings Time. Sites sited locally in the Mountain Time Zone must still report in Pacific Time to maintain the consistency of the provincial data set.

2.2 Station Siting

General siting considerations should include the availability of communication's systems and power as well as the long term viability of the site. All new ambient air quality monitoring sites require approval. Sites operated as a requirement of a permit, order or other regulatory requirement need to be approved by the Ministry in consultation with the Air Quality Monitoring Program. Sites operated by the Ministry must be reviewed and approved by the Air Quality Monitoring Program's management team or designate(s).

Ministry siting approval will be granted based on an application of various criteria, including, but not limited to:

- NAPS, Environment Canada, and US EPA, siting criteria and quality assurance documents;
- Manufacturer's recommendations for siting / housing of equipment; and,
- Interpretation of local emission sources, climate patterns and rationale for monitoring (complaint resolution, impact to residential areas, traffic studies, etc.).

2.3 Installation Considerations

Instruments must be installed in a secure manner or as per manufacturer's direction. This includes designing housings, benches, outdoor enclosures, etc. to assure the instrument will stay secure and operate within the instrument manufacturer's specifications for criteria such as vibration, humidity and light intrusion. Gas cylinders must be properly secured within the station's enclosure to meet applicable safety regulations. Clear and unambiguous line tagging should be installed to help with station operation, particularly for monitoring stations equipped to monitor multiple parameters.

Outdoor or rooftop enclosures must be located at least 3 metres from the edge of a roof or significant elevation change to prevent non-representative sampling such as building influenced air currents. Rooftop enclosures must be sited and installed in accordance with WorkSafe BC regulations for fall protection to ensure worker safety.

2.4 Electrical Power Supply

Monitoring stations require a stable and reliable source of electrical power to help avoid unnecessary interruptions in monitoring and ensure that the instrumentation deployed at the station produces consistent, reliable data. A robust power source will reduce the potential for data gaps and prolong the life of the instrumentation providing that data. For these reasons the following aspects must be considered and addressed in the design of a monitoring station:

- The station should be powered by constant voltage transformers or regulators;
- Power distribution must comply with relevant electrical codes;
- Heaters, air conditioners, pumps and other inductive loads should be isolated from circuits supplying power to sensitive instrumentation such as data loggers;
- Line voltage supplies for each instrument should satisfy manufacturer's specifications; and,
- In areas where electrical supply interruptions are frequent or poor power conditions exist, the following options are available to help ensure data quality is not affected by transient power conditions:

- Data loggers, station computers, routers, modems and ancillary data handling equipment should be protected by an Uninterruptible Power Supply (UPS) of sufficient capacity and the ability to provide a controlled shut down of equipment during extended outage events.
- Monitoring stations in locations with known power issues can deploy UPS systems to keep gas analyzers, meteorological sensors and particulate monitor control units warm during short power interruptions and provide controlled shut downs during extended outages.
- It is not recommended that pumps be protected by UPS units when powered independently from the sampling instrument.

2.5 Internal Shelter Climate Control

Monitoring stations that house continuous monitoring equipment for particulate or gas analysis must be equipped with remote continuous monitoring of the station’s internal temperature. The internal temperature probe must be located in such a manner that it is representative of overall station conditions. Internal temperature data must be recorded at equivalent time periods as that of the continuous monitors operating within the station. All stations require a HVAC system capable of maintaining a year-round internal temperature range of 20 °C to 30 °C that is stable to within ± 2°C over a one hour period unless guidance provided by the instrument manufacturer indicates a greater tolerance. The ideal temperature range for monitoring stations is 20 °C to 25 °C.

Monitoring equipment housed in small outdoor enclosures (e.g. roof top installations) must have:

- Proper electrical connections and capacity, including a grounding wire installed by a professional electrician; and,
- Sufficient heating and cooling capacity to maintain a stable internal temperature that meets the instrument manufacturer’s specifications. This excludes shelters installed to house models of monitors, such as low flow rate samplers, which are specifically designed to operate at ambient temperature to maintain the integrity of the sample.

In situations where single analyzer cabinets (external or outdoor installations) are used to house monitoring equipment, those shelters must include electrical connections and capacity installed to code and include a grounding wire installed by a professional electrician.

2.6 Sample Inlet Placement

Sample inlets are provided by instrument manufacturers or they are designed and fabricated specifically for a monitoring station. The placement of the inlet is crucial to providing representative air samples and as such should be based on several factors including height, proximity to traffic corridors, traffic volumes, obstructions and distance between inlets.

The National Air Pollution Surveillance (NAPS) program’s *Monitoring and Quality Assurance/Quality Control Guidelines* specifies minimum separation distances between roadways and sample inlets based on traffic volumes. The NAPS specifications are provided in the following table.

Table 2.6.1: Minimum Separation Distances Between Sample Inlets and Roadways

Average Vehicles/Day	≤ 10,000	≤ 15,000	≤ 20,000	≤ 40,000	≤ 70,000	≤ 110,000
Distance to nearest traffic lane	≥ 10 m	20 m	30 m	50 m	100 m	≥ 250 m

Sample inlets for ground level monitoring stations deploying gas and particulate instrumentation must be installed at a minimum height of two metres above ground surface to a maximum of 15 metres above ground surface. To prevent non-representative sampling, inlets should not be placed near building ventilation ports, HVAC equipment, exhausts or stacks, or exposed soil or gravel staging areas that are frequently traversed. Inlets must be sufficiently tall in areas susceptible to snow accumulation. Inlets must also have adequate separation between other inlets and obstacles in situations as described in the following table.

Table 2.6.2: Inlet Separation Distances

Situational Trigger	Distance (m)	Distance to / Separation from
An obstacle to air flow	2 X obstacle height	The obstacle
PAH Samplers	1	Support structures
PAH and Particulate Samplers	2	Support structures
Flow rates ≤ 20 lpm	1	Other inlets
Flow rates > 20 lpm	2	Other inlets
Inlets of co-located instrumentation	4	Inlets of co-located instrumentation

2.7 Manifold Design

For monitoring stations that deploy multiple gas analyzers, a manifold and water trap are recommended and preferred to individual sample lines. Manifolds are not recommended for monitoring stations that deploy both continuous and integrated PM monitoring; in these situations, the instruments should be equipped with individual inlets connected to tubing that is vertically oriented.

Where horizontally mounted manifolds are used, they should be oriented with the ports facing upwards and water traps oriented vertically to reduce the risk of moisture entering an analyzer. Manifolds such as the “ARB style” must be mounted vertically. Regardless of the manifold type the monitoring station’s sampling inlet and manifold must meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program’s Monitoring and Quality Assurance/Quality Control Guidelines.

2.8 Particulate Matter Monitoring Considerations

Continuous PM monitors have specific siting requirements and inlet probe configurations that are outlined in the manufacturer’s manuals. Similarly, particulate samplers such as low flow samplers and high-volume samplers have specific siting considerations and clearance distances. Method specific considerations are summarized in method-specific SOPs located in the Appendices section of this Manual.

2.9 Passive Sampling Considerations

Passive samplers have a distinct set of siting criteria. It is important to establish applicable siting criteria and monitoring requirements prior to the installation of one or more passive samplers. Monitoring objectives should be discussed with the laboratory supplying the passive sampler/s to ensure the method is suitable and capable of achieving the objectives.

Passive sampler installations should conform to the following:

- The sampler housing shall be mounted to an adequate supporting structure in accordance with the manufacturer's specifications and in a configuration that does not produce a restriction to airflow.
- The sampler shall be deployed in a manner that prevents the diffusion barrier from becoming wet, protects the diffusion barrier from the precipitation of suspended particulates, and protects the diffusion barrier from high wind speeds (i.e. use a housing/rain shield).
- The sampler housing shall be placed so that the diffusion barrier of the sampler body is at a height of two meters (m) to four metres above ground surface.
- Co-located samplers should be positioned within a 4 m horizontal distance of each other.
- Passive samplers within a monitoring network should be positioned at the same sampling height.
- Higher objects such as trees and buildings should not exceed 30 degrees from a horizontal plane as viewed from the sampler body. This is shown in Figure 2.9.1.

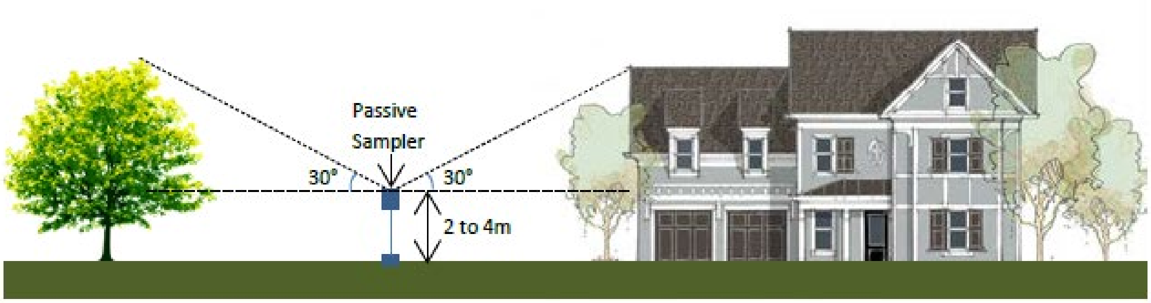


Figure 2.9.1 Passive Sampler Installation

Figure reference: Blair R. Irwin, ENV 2018

Detailed information regarding the siting and installation requirements for passive sampling instruments is provided in the Standard Operating Procedure (SOP) for the Passive Sample Method of Air Sample Collection (SOP 07) located in the Appendices of this Manual.

2.10 Rooftop Installations

When planning the design of a rooftop monitoring station, consideration should be given to applicable regulatory requirements of the Occupational Health and Safety Regulation (OHSR). Working at height, safe working zones, and roof access points must be considered and must comply with the applicable sections of the OHSR. In addition to provincial regulatory requirements, there may be regional, municipal, and agency requirements applicable to a site such as school or fire station roof tops. Preliminary planning must consider and assess the safety aspects listed in Table 2.10.1 and where applicable, develop commensurate safety control measures.

Table 2.10.1: Rooftop Installation Site Specific Health and Safety Considerations

Risk	Site Specific Considerations
Working at Height	› Review the OHSR to identify regulatory requirements and facility specific requirements, that may apply to the site; › Confirm that the load-bearing capacity of the roof can accommodate the instrumentation package and work crew; › Determine if fall protection is required; › Determine if a fall protection plan is required; › Determine if a control zone is required to establish a work area away from the elevated work surface; › Determine if it is necessary to work with a partner or in teams; › Identify rooftop hazards such as power lines; and, › Secure objects/tools to prevent items dropping or falling from the roof.
Access	› Ladder safety considerations such as three point contact, and; › Equipment transportation to monitoring location.
Weather Conditions	› Consider year-round weather conditions in terms of access and safety.

3 Continuous Monitoring and Sampling Methods

3.1 Methods and Performance Specifications

The information provided in this section of the Manual includes a summary of acceptable methods of ambient air monitoring within the provincial jurisdiction of British Columbia. The minimum performance specifications and operating ranges provided in this section are consistent with the *Monitoring and Quality Assurance/Quality Control Guidelines* published by the National Air Pollution Surveillance (NAPS) program.

Table 3.1.1 lists some of the commercially available analyzers, monitors, and samplers that are considered suitable for ambient air monitoring within the Provincial jurisdiction of British Columbia. This list is not an endorsement, nor does it exclude other commercially available instrumentation. In most instances, the Ministry will require that instruments are listed as a Federal Reference Method or Federal Equivalent Method (FEM) by the United States Environmental Protection Agency. However, some instruments designated as FEMs may not be suitable based on detection method and the dominant pollution source, such as some optical methods in the presence of woodsmoke.

All ambient air monitoring required by the Ministry or undertaken to generate data intended for decision making by the Province of British Columbia must only be initiated after discussion with, and the agreement of the Ministry regarding appropriate instrumentation. Similarly, this is required prior to the replacement of instrumentation at existing monitoring sites. Once agreement is reached approval will be indicated in writing by the Director. If operators purchase instrumentation without approval, it may be determined to be unsuitable, and the data not accepted at the cost of the site owner/operator. Instrumentation must also be compatible with existing data collection systems. Regardless of the equipment deployed all analyzers should meet the minimum performance specifications listed in Table 3.1.2.

Table 3.1.1: Continuous Ambient Air Equipment

Monitoring Parameter(s)	Operating Principle	Commercially Available Analyzers/Monitors/Samplers
CO	Non-dispersive Infrared Photometry with Gas Filter Correlation (GFC)	› Thermo Fisher Scientific Models 48i, 48Q. › Ecotech Serinus 30 Carbon Monoxide analyzer. › Teledyne API T300 analyzer.
H_2S/TRS	Ultraviolet fluorescence	› Thermo Fisher Scientific Models 450i, 450Q H_2S analyzers with applicable converter. › Teledyne API Models T101, T1021.
Oxides of Nitrogen (NO/NO_2/NOX)	Chemiluminescence	› Thermo Fisher Scientific Model 42i. › Teledyne API T200. › Ecotech Serinus 40.
O_3	Selective Absorption of Ultraviolet (UV) Photometry	› Thermo Fisher Scientific Model 42iQ. › Ecotech Serinus 10. › Teledyne API T400.

Monitoring Parameter(s)	Operating Principle	Commercially Available Analyzers/Monitors/Samplers
PM$_{10}$ and PM$_{2.5}$ Continuous Monitor	Beta Attenuation Monitor (BAM)	› Met One BAM-1020 with Smart Heater System › Thermo Fisher Scientific 5014i.
	Nephelometry and BAM	› Thermo Scientific SHARP Model 5030 and 5030i.
SO$_2$	Ultraviolet fluorescence	› Thermo Fisher Scientific Models 43i, 43iQ. › Teledyne API T200. › Ecotech EC9850T.
NH$_3$	Chemiluminescence	› Thermo Fisher Scientific Model 17i. › Teledyne API T201.
BTEX	Gas Chromatography (GC) with Detector	› Syntech Spectras Analyzer GC 955.
CH$_4$/NMHC	Gas Chromatography	› Thermo Fisher Scientific Direct Methane, Non-Methane Hydrocarbon Analyzer, Model 55i. › Synspec GC's Alpha 115.
Formaldehyde (CH$_2$O)	Adsorbent Cartridge	› Cartridge Sampler.
PM$_{10}$ and PM$_{2.5}$ Low Flow Sampler	Low Flow Rate Filter Collection and Gravimetric Mass Determination	› Thermo Fisher Scientific Partisol™ Various Models. › Tisch Environmental.
TSP and PM$_{10}$ High Flow Sampler	High Volume Filter Collection and Gravimetric Mass Determination	› Ecotech HiVol 3000 High Volume Air Sampler. › Tisch Environmental High Volume Air Sampler (Various models).
Various	Passive Sampler	› Available from laboratories

Additional information regarding the operating principles of instruments listed in Table 3.1.1 is provided within method-specific SOPs located in the Appendices section of this Manual.

Analyzers should meet the performance specifications described within Table 3.1.2. These specifications are largely adapted from the National Air Pollution Surveillance (NAPS) program. The performance specifications listed below are based on current technology and on manufacturer's information. It is recognized that technology continues to evolve in this area and therefore over time performance specifications may change as technologies typically improve.

Table 3.1.2: Minimum Performance Specifications for Continuous Ambient Air Equipment

Monitoring Parameter	Instrument Range	Operating Range in BC	Lower Detection Limit	Zero Noise	Zero Drift (24 hrs)	Span Drift (24 hrs)	Rise/Fall Time (max.)
CO	0 - 10 ppm	0 - 5 or 0 - 10 ppm	0.04 ppm	0.02 ppm RMS	< 0.1 ppm	< 1% full scale	60 sec
H$_2$S/TRS	0 - 200 ppb	0 - 200 ppb	Value not available	Value not available	Value not available	Value not available	-

Monitoring Parameter	Instrument Range	Operating Range in BC	Lower Detection Limit	Zero Noise	Zero Drift (24 hrs)	Span Drift (24 hrs)	Rise/Fall Time (max.)
Oxides of Nitrogen ($NO/NO_2/NO_X$)	0 - 500 ppb	0 - 500 ppb	0.4 ppb	0.2 ppb RMS	< 0.5 ppb	< 1% full scale	80 sec
O_3	0-500 ppb	0 - 500 ppb	1 ppb	0.3 ppb RMS	< 1 ppb	< 0.1% full scale	20 sec
PM_{10} and $PM_{2.5}$ Continuous Analyzer	0 – 1000 µg/m^3	0 – 200 µg/m^3 to 0 – 1000 µg/m^3	2 µg/m^3 (24 hour period)	n/a	n/a	n/a	n/a
SO_2	0 - 500 ppb	0 – 200 ppb or 0 - 500 ppb	0.1 ppb	< 0.06 ppb RMS	< 0.2 ppb	< 0.5% full scale	140 sec

4 Instrument Installation

4.1 Pre-Deployment Testing

Prior to installation and deployment, instruments should be tested within a controlled environment to ensure they are operating properly. Pre-deployment testing will help prevent on-site equipment issues following installation. Pre-deployment testing should follow the requirements specified in the manufacturer supplied equipment manuals.

4.2 Station Start-Up Records

A *Station Start-Up* record must be completed during the installation of each monitoring station. Start-up records should be maintained as part of the quality control process. A copy of the record should be forwarded to the B.C. ENV prior to operation. Details of significant changes to a station such as station relocation and changes to monitored pollutants should be recorded and kept on file with the original station start-up record.

In general station start-up records must include the following information:

- Station operator information;
- Station Name;
- Site Location with GPS Coordinates;
- Date and time that data polling commenced;
- Communication information (i.e. IP address, phone number)
- A description of the surrounding environment; and,
- Station equipment/instrumentation including phone number, IP address, etc. to enable data polling.

A station start-up form is provided in Appendix 1. Additional equipment-specific installation requirements are provided in SOPs located in the Appendices section of this manual.

5 Routine Operations

5.1 Operational and Quality Assurance Plans

It is recommended that a *Station Operational Plan* and or a Quality Assurance Plan (QAP) be produced for each monitoring station. A group or network of stations should have an Agency Quality Assurance Plan (AQAP). Station operational and quality assurance plans provide auditors and new station operators with information pertaining to the characteristics of the monitoring station and any special functions or operating conditions of the station. A station operational plan and any checklists included within the plan will assist station operators in identifying the requirements of routine operations and the frequency of scheduled inspections and planned maintenance routines. The station operational plan can also act as a record of the routine inspections, maintenance activities, calibrations and repairs carried out at the station. Information specific to AQAPs can be found in the most current version of the NAPS Monitoring and Quality Assurance/Quality Control Guidelines.

5.2 Inspections and Maintenance

The purpose of routine inspections is to check that monitoring equipment and associated environmental enclosures are operating and or functioning as designed. The frequency of routine inspections should be set to an interval that effectively mitigates the potential for data loss. The frequency of routine inspections will be a function of monitoring method/s, site constraints, and availability of remote diagnostic data.

The routine operation of a monitoring station's equipment is the responsibility of the monitoring station operator. In general, a monitoring station's routine operations include:

- Scheduled and non-scheduled inspections;
- Preventative and planned maintenance;
- Scheduled calibrations; and,
- Repairs and calibration.

Preventative maintenance undertaken during routine inspections can assist in reducing missing data; will provide more confidence in the monitoring results produced by the station and assist in identifying potential problems.

A general description of routine inspection and maintenance activities is provided in Table 5.1.1. Routine inspection and maintenance activities are divided into two categories: short term and long term. Short term checks can be undertaken weekly, every two-weeks, or monthly. Long term checks are conducted quarterly or semi-annually. Remote diagnostic testing and data analysis can be incorporated within the short term checks to assist in identifying potential problems. Quarterly/semi-annual inspections and maintenance should be undertaken by field trained technicians.

Table 5.1.1: Routine Inspection/Maintenance Summary

Short term - Weekly, Bi-Weekly, Monthly	Long Term - Quarterly/Semi-Annual
1. Check shelter integrity and security. 2. Check/test communications array. 3. Check/test Battery Backup system; clean filters as necessary.	1. Review operational requirements as per QAP/AQAP. 2. Inventory of all equipment onsite, compare against previous visit and update accordingly; this includes manufacturer's information and SOPs.

Short term - Weekly, Bi-Weekly, Monthly	Long Term - Quarterly/Semi-Annual
4. Inspect manifold apparatus and sample lines to the analyzers, clean if needed. 5. Check all equipment fans and filters. 6. Inspect equipment specific parameters (sample tape, inlet filter, water catch jars). 7. Inspect and replace drying equipment as necessary. 8. Check to ensure adequate supply of consumables (e.g., desiccant, filters, gloves, etc.). 9. As applicable, check station temperature is within designed operating range. 10. Review any instrument alarms, instrument issues and/or data issues identified since the last visit. 11. Verify that any maintenance undertaken on the last visit is still effective. 12. Check the fire extinguisher. 13. Verify instrument SOPs, manufacturer information and Routine operation plan/checklist is up-to-date. 14. Complete routine operation checklist.	3. Carry out short term checks. 4. If applicable check zero air supply system for each analyzer and change/correct if necessary. 5. Perform multi-point verification if applicable. 6. Perform flow verification if applicable. 7. Check time stamps in the local database and in all equipment data loggers. 8. Complete routine operation checklist. 9. Function checks for abnormal performance (e.g. excessive signal noise, unstable baseline, positive and/or negative drift, spiking, long response time, incorrect flow/pressure readings, warning light indicators, power or pump failure, etc.).

Details of routine inspections and maintenance must be recorded and maintained within the monitoring station. An *Inspection and Maintenance* template is provided in Appendix 1.

Additional operational requirements specific to monitoring methodologies are provided in Standard Operating Procedures (SOP) located in the Appendices of this Manual.

5.3 Non-Conformance and Corrective Action

For the purposes of this Manual, a non-conformance is defined as “the failure of an output, product or process to conform to the standards or specifications detailed in the equipment manufacturer’s specifications or any part of the B.C. Field Sampling Manual”. If a problem or a non-conformance issue is identified during routine inspections, the details of the problem or non-conformance must be recorded. For each non-conformance issue or incident, a root-cause analysis must be conducted to identify the source of the non-conformance. The information gleaned from the root-cause analysis must then be used to develop a corrective action plan. Root-cause analyses and corrective action plans should be commensurate with the non-conformance to avoid excessive and erroneous detail and resource expenditures. Details of both the root-cause analysis and the implementation of the corrective action must be recorded and maintained within the monitoring station (preferably within the *Station Operational Plan* or Quality Assurance Plan). An electronic copy of the corrective action record must be sent to the B.C. ENV.

A *Non-Conformance and Corrective Action* template is provided in Appendix 1.

6 Gas Analyzer Calibrations and Verifications

6.1 General Descriptions

General descriptions of the various categories of calibration checks are described below. Specific calibration instructions are provided in instrumentation manuals and SOPs located in the Appendices of this Manual.

Zero check: A zero check tests an instrument's response to pollutant-free air at concentrations below detection limits. The zero check generally involves exposing the instrument to pollutant free air from either a zero air supply or a zero air system (i.e. a scrubber). The zero check value is compared to the zero reference value established at the time of the multi-point check or calibration. If the zero value is outside of the tolerance level provided in Table 6.4.1, a zero adjustment must be performed.

Span check: A span check tests an instrument's response to a known concentration of a pollutant. The span gas, which is used as a surrogate for the pollutant, should be at a concentration that is higher than the expected monitoring values, and near the analyzer's calibration range. The span gas can be generated using a permeation device, a gas cylinder or dilution calibrator. The span check point is compared to a reference span value that is established at the time of a multi-point verification, calibration or when the span source is replaced. If the span is found to be outside of the tolerance level provided in Table 6.4.1, an "as-found" multi-point verification should be carried-out. For significant span value differences from reference span values a root-cause analysis should be conducted, and corrective actions undertaken. Additional information on span checks is provided in Section 6.3.

Two-point check: The two-point check tests an instrument's as found response at the 0% point and the 80% point of an instrument's calibration range.

Multi-point linearity verification: The multi-point linearity check tests an instruments accuracy and linear response to air pollutants at regular concentration intervals to verify data prior to instrument calibration. A multi-point verification is required prior to instrument calibration. The verification must include pre-zero, post-zero, 100%, 60% and 30% concentration intervals.

Calibration: Calibrations are conducted to adjust an instrument's response to a known concentration of gas. A calibration generally occurs when a multi-point check indicates that an instrument's response is outside of defined tolerance levels or acceptance criteria. Calibrations include both a zero and a highpoint (upper calibration limit) adjustment. Calibrations should follow the instrument manufacturer's instructions.

6.2 Calibration Frequency

The triggers for, and frequency of instrument checks and calibrations are summarized in Table 6.2.1. Note that the frequency of calibrations may be increased at the request of B.C. ENV.

Table 6.2.1: Gas Analyzer Calibration Frequency and Triggers

Zero and Span Check	Multi-point Check	Calibration
› Weekly minimum, Daily preferred (23 to 25 hours)	› After installation (or relocation); allow a 24 to 72 hour warm up period prior to; › Bi-annually if zero and span checks are conducted daily; › Quarterly if zero and span checks are conducted weekly; › Before and after analyzer repairs/maintenance that may affect instrument performance; › Prior to instrument calibration; › Prior to instrument shut-down; › When span drift exceeds 10%; › For new analyzers, after the first 3 months of operation; and, › When daily zero deviation is greater than ±2% of the range, and troubleshooting indicates that the analyzer is causing the deviation.	› Multi-point verification outside of tolerance limits

6.3 Zero and Span Checks

Continuous gas analyzers must perform weekly zero and span checks although daily checks (once per 24 hour period) are preferred. Preferable cycle durations are 23 hour or 25 hour to ensure that events specific to certain hours are captured over time. Alternate zero and span check cycles are approved on a case by case basis by B.C. ENV.

Generally quality control checks take place within a single hour (e.g. 11:00 to 12:00 PST rather than 11:30 to 12:30 PST), and need to allow for a sufficient period of time to purge the instrument with zero or span gas, and stabilize, prior to taking a reading. At the end of the cycle the instrument also needs a sufficient period of time to purge the instrument with sample gas before any data validation flags are removed. An example of a typical cycle is provided below:

- 0 - 20 m: introduce zero air; the recorded value is the average of the last 3 m.
- 20 - 40 m: introduce span gas; the recorded value is the average of the last 3 m.
- 40 - 45 m: purge with ambient air.
- 45 m: return instrument to sample mode.

Operators need to monitor the effectiveness of their zero/span cycles and may need to make adjustments based on instrument-specific responses.

Zero checks need to be recorded and logged, either electronically or within log books, each time a check is performed. Routine reviews of quality control checks will help identify changes in equipment operation or drift in calibration. An audit of an analyzer's response using a certified calibration standard and a zero air generator is the only way to confirm that routine zero and span checks are tracking the actual drift in an analyzers response when compared to the previous calibrated response.

If a monitoring station's zero-air-supply relies on equipment with consumables such as filters and scrubbers, the station operator should regularly confirm that the zero air supply is operating as expected.

With the exception of carbon monoxide (CO), BC ENV does not enable dynamic-zeroing functions on gas analyzers. In these cases, the zeroing frequency should be set to 6hours although a zeroing frequency of 24 hours is allowed.

6.4 Multi-point Verification and Calibration

Analyzer calibrations must include a zero adjustment and an upscale adjustment at the calibration range of the analyzer. A checklist outlining the general process for calibrating continuous gas monitors is provided in Appendix 1 of this Manual.

Table 6.4.1: Gas Analyzer Tolerance Levels and Acceptance Criteria

Analyzer	QC Check	Tolerance Levels	Acceptance Criteria
CO	Zero Check	± 0.1 ppm	≤ ± 2% of range
	Span Check	± 10% of reference value	≤ ± 10% of control value
	Multi-point Verification – Audit Protocol	≤ ± 2% of inst. range	≤ ± 10%
	Multi-point Verification – NAPS Guideline	± 4% of traceable std.	≤ ± 15%
SO2	Zero Check	± 1.0 ppb	N/A
	Span Check	± 10% of reference value	≤ ± 10% of control value
	Multi-point Verification – Audit Protocol	≤ ± 2% of inst. range	≤ ± 10%
	Multi-point Verification – NAPS Guideline	± 4% of traceable std.	≤ ± 15%
NOx	Zero Check	± 2.0 ppb	≤ ± 2%
	Span Check	± 10% of reference value	≤ ± 10% of control value
	Multi-point Verification – Audit Protocol	≤ ± 2% of inst. range	≤ ± 10%
	Multi-point Verification – NAPS Guideline	± 4% of traceable std.	≤ ± 15%
	Converter Efficiency	96 – 104%	≤ ± 15%
O3	Zero Check	± 2.0 ppb	≤ ± 1.5% of range
	Span Check	± 10% of reference value	N/A
	Multi-point Verification – Audit Protocol	≤ ± 1.5% of inst. range	≤ ± 7%
	Multi-point Verification – NAPS Guideline	± 4% of traceable std.	≤ ± 15%
H2S/TRS	Zero Check	± 1.0 ppb	≤ ± 2% of range
	Span Check	± 10% reference value	≤ ± 10% of control value
	Multi-point Verification – Audit Protocol	≤ ± 2% of inst. range	≤ ± 10%
	Multi-point Verification – NAPS Guideline	± 4% of traceable std.	≤ ± 15%

Requirements and specifications for zero and span gas air supplies and gas regulators are summarized in Table 6.4.2 below.

Table 6.4.2: Zero Air and Span Gas Supply and Regulator Requirements

Component & Aspect		CO	O_3	SO_2	NO_2
Zero Air Supply	Minimum Flow Rate (L/min)	To be free of contaminants that may cause a detectable response or that can react with either NO, O_3, or NO_2, that is commercially available or can otherwise be generated by the operator.			
	Pressure (psig)				
	Particulate filter efficiency				
Gas Regulator	Material	Brass or stainless steel	Stainless steel or Teflon	Stainless steel	Stainless steel
	Line	Clear Teflon® (FEP, PFA, PTFE)	Clear Teflon® (FEP, PFA, PTFE)	Clear Teflon® (FEP, PFA, PTFE)	Clear Teflon® (FEP, PFA, PTFE)
	Model	Two-stage design with non-reactive diaphragm and internal parts	Not specified	Two-stage design with non-reactive diaphragm and internal parts	Two-stage design with non-reactive diaphragm and internal parts
Span Gas	Mixture	CO in Nitrogen	Ozone generator	SO_2 in nitrogen or Permeation tubes	NO in nitrogen or Permeation tubes
	Concentration range	0 – 3 ppm	0 – 200 ppb	0 – 200 ppb	0 – 300 ppb

6.5 Parameter Specific Calibration Requirements

The following sub-sections provide additional information regarding gas specific calibration requirements.

6.5.1 Hydrogen Sulphide & Total Reduced Sulphur

This sub-section of the Manual provides calibration information that is specific to analyzers of hydrogen sulphide (H_2S) and total reduced sulphur (TRS).

- H2S/TRS analyzers are calibrated with a zero-air for a zero-offset reading; gas at 100% of the calibration range is used for span.
- Calibration gas can be generated from certified gas, gas dilution systems, or permeation methods..

6.5.2 Oxides of Nitrogen (NO_X)

For NO_X analyzer calibrations, the NO calibration regulator must be purged to remove all oxygen (O_2). The presence of O_2 results in the formation of NO_2, which produces a biased (increased) value.

6.5.3 Gas Phase Titration (GPT)

After NO and NO_X calibrations, a gas phase titration (GPT) of NO with ozone is employed to calibrate the analyzer for NO_2 and to determine converter efficiency. A brief outline of how to determine converter efficiency is provided below.

1. Generate a NO concentration at approximately 50% of full range for at least 10 minutes.
2. Generate O_3 at an approximate concentration of 50% of the NO concentration and wait until a stabilized reading has been achieved.
3. The converter loss is then calculated as follows:

$$\boldsymbol{Converter\ Efficiency} = \mathbf{100} \times \frac{[(\boldsymbol{final\ NO}\ - \boldsymbol{initial\ NO})\ - (\boldsymbol{final\ NO_X}\ - \boldsymbol{initial\ NO_X})]}{(\boldsymbol{final\ NO} - \boldsymbol{initial\ NO})}$$

   Replacement of the converter may be required if the calculated converter efficiency is outside of the 96 to 104% range.

4. Generate at least one additional NO2 audit point at a lower concentration.
5. Perform a zero and span check immediately following calibration.
6. Determine if span gas cylinders/permeation wafers need to be replaced based on the results of zero and span checks.

6.5.4 Ozone (O_3)

Ozone (O_3) analyzers must be calibrated using a calibrator with a UV photometer.

6.5.5 Sulphur dioxide (SO_2)

When conducting an SO_2 analyzer calibration, it is critically important to purge the SO_2 calibration regulator to remove all traces of H_2O, as even small amounts of H_2O will lead to stability problems. If the cylinder is suspected of containing moisture, the cylinder should be deemed as compromised and unusable.

6.5.6 Ammonia (NH_3)

Ammonia analyzers require a 3-stage calibration, which is unique among gas analyzers. The first stage of the calibration is typical of other continuous gas analyzer types and involves a serial dilution of a NO standard to verify analyzer NO and NO_X response.

In the second calibration stage, the analyzer's NO_2 response is verified by gas phase titration. This involves titrating the NO standard used in the first stage with a known concentration of ozone. The introduced ozone converts the equivalent amount of NO into NO_2, which is converted back into NO by the analyzer's converter oven and read as NO_X. To verify the linearity of the analyzer two levels of ozone are generated and calibrated in the gas phase titration. As the NO and NO_X channels were calibrated and verified in the first stage, the analyzer's response to the remaining NO, not converted by ozone, can be accepted as accurate. Comparison of the introduced ozone concentration with the analyzer's NO_X and NO response therefore allows for a determination of converter efficiency, and verification of the NO_2 channel.

In the third and final stage, a known concentration of NH_3 is used to verify the catalytic conversion process of the analyzer. Similar to the second stage of calibration, four different levels of NH_3 are generated to verify the linearity of the analyzer.

6.5.7 BTEX

To calibrate the gas chromatograph (GC) a BTEX calibration mixture is needed as well as zero air. The calibration is undertaken to determine the conversion factor that is used to calculate concentrations of BTEX compounds from the GC outputs. The calibration is undertaken in two sequential stages:

1. Measurement of calibration gas diluted to the desired concentrations; and,
2. Determination of the conversion factor.

6.5.8 Methane/Non-Methane Hydrocarbons

Calibration is undertaken to establish the relationship between the detectors output signal and the compound being measured. The detector's output signal can be affected by a number of different operational parameters, and as such requires calibration on a regular basis. If possible, a calibration gas standard with a similar composition to that expected in the actual sample should be used.

6.5.9 Calibration Gas Standards

Analyzers must be calibrated using certified calibration mixtures. For conventional analyzers, the mixtures should be certified to ± 2% accuracy by direct comparison to a Standard Reference Material (SRM) provided by organizations such as the Netherland's National Metrology Institute (VSL) and the U.S. National Institute of Standards and Technology (NIST). For trace level analyzers, the mixtures should be certified to ± 2% accuracy by comparison to a certified traceable reference standard.

All calibration standards must be verified against traceable standards every two years, or at the end of their stated certification period and at any time when there is found to be a significant discrepancy between station or operator equipment and audit standards.

In addition to gases, dilution calibrators and flow meters should undergo third party calibration annually or at the end of their certification period.

6.6 Method Specific Calibration Requirements

6.6.1 $PM_{2.5}$ Continuous Monitors and Filter Based PM Samplers

For continuous $PM_{2.5}$ monitors and filter-based PM samplers, several parameters require calibration including flow, temperature, ambient pressure, time and date. In general, the calibration procedure comprises the following sequential steps:

Step 1 – Leak checks;

Step 2 – Verification (as-is calibration) of flow, temperature and pressure;

Step 3 – Adjustments (calibration); and,

Step 4 – Verification.

In Step 1 a leak check is undertaken to ensure there are no leaks in the sample train before conducting the calibration. If leaks are detected during this step they must be addressed, and the flow re-verified.

The second step in the calibration process (Step 2 verification) is used to validate results obtained since the instruments last calibration. This is done by verifying that flow, temperature and pressure are still within acceptable tolerance levels. The verification step comprises checks against known standards. The flow verification check should be performed using a flow meter which has been calibrated or certified annually against a National Institute of Standards and Technology (NIST) traceable standard. Similarly, temperature and pressure verifications should be performed using a temperature and pressure standard which is calibrated or certified annually against a NIST traceable standard.

Tolerance levels (or 'pass criteria') for low flow rate and high volume samplers assessed are provided in the following table.

Table 6.6.1: Tolerance Levels for $PM_{2.5}$ Continuous Monitors and Filter Based PM Samplers

Parameter	Low Flow Rate Sampler	High Volume Sampler	Continuous $PM_{2.5}$ and Integrated PM
Flow	± 4% of 16.7 lpm (16.00 to 17.34 lpm)	Between 1.13 to 1.70 m^3/min with a correlation coefficient of 0.990 or better.	±4% of 16.7 lpm (16.00 to 17.34 lpm)
Temperature	±2 °C	As per instrument specifications	±2 °C
Ambient pressure	±10 mmHg	As per instrument specifications	±10 mmHg
Relative Humidity	N/A	N/A	±10%
Clock and date verification check	Clock should be within ±2 minutes of standard time, and the date should be correct.		
Leak check	As per instrument specifications	N/A	N/A

Parameters that do not meet the pass criteria specified in Table 6.6.1 above must be adjusted in Step 3. After adjustment a final verification (Step 4) is undertaken to confirm that the instrument's parameters are within the required criteria.

If the flow verification or leak check exceeds the acceptance criteria provided in Table 6.6.2, data obtained during the period since the instruments last successful calibration must be invalidated.

Table 6.6.2: Acceptance Criteria for $PM_{2.5}$ Continuous Monitors and Filter Based PM Samplers

Parameter	Low Flow Rate Sampler	High Volume Sampler	Continuous $PM_{2.5}$ and Integrated PM
Flow	±7%	±7%	±7%
Leak check	As per instrument manual.	As per instrument manual.	As per instrument manual.

6.7 Documentation

The minimum documentation required for the checks and calibrations discussed in this section are summarized in Table 6.7.1. Note that other documents such as permits may have additional documentation requirements. Templates for these and other records required for ambient air monitoring are provided in Appendix 1.

Table 6.7.1: Calibration Documentation

Zero check and Span Gases	Multi-point check	Calibration
› Record in logbook › Use routine maintenance record	› Record in logbook › Complete routine maintenance record	› Record in logbook › Complete gas calibration activity record

6.8 Measurement Uncertainty

The determination of measurement uncertainty in continuous air monitoring data is a function of many factors. During an instrument's calibration, there are uncertainties associated with instrument precision, calibration standards, and accuracy of the dilution process.

Instrument manufacturers specify instrument precision by various methods; typically, however, precision is specified as a value or as a percentage of an instrument's reading. Regardless of the method used to specify precision, calibration standards and the accuracy of the dilution process play a much larger role in determining an instrument's measurement accuracy and precision. The accuracy of the calibration gas and calibrator (dilution process) are certified against a respective standard.

Immediately following calibration, the linearity of the calibration will assist in estimating instrument uncertainty. Linearity specifications are often provided by the manufacturer as a percentage value of the calibration range. Pending any future, formal statistical calculation of uncertainty, concentrations of the target pollutant following calibration should not exceed 5% of the calibrated range. The measured uncertainty is expected to grow over time due to uncorrected drifts (span drifts) and or maintenance issues.

Another factor of measurement uncertainty stems from the variation of an instrument's performance over time. This uncertainty can be measured by undertaking a statistical analysis of the instruments zero and span check data. The uncertainty caused by instrument performance over time, is necessarily, calculated after the fact. The detailed statistical determination of an instrument's performance is beyond the scope of this manual however, method details are available in various documents such as ISO Standards, the US EPA 2013 QA Handbook for Pollution Measurement Systems, and Chapter 5 of the Alberta Government's 2014 Air Monitoring Directive.

Currently there is no requirement to determine or estimate measurement uncertainty for operators of Ambient Air Monitoring stations operating within ENV's jurisdiction.

7 Collection and Validation of Continuous Monitoring Data

7.1 Data Collection and Management

Data generated by Ambient Air Monitoring stations is collected and stored on Data Acquisition Systems (DAS) or "dataloggers". Data can be accessed from the data logger by manually connecting to the data logger, or via commercially available hardware and software packages using devices such as a telephone and modem, internet access, or satellite telemetry.

Data output options can be analog or digital. Digital data acquisition methods and instrumentation are subject to less noise which allows for greater sensitivity than analog systems. In addition, digital systems are capable of handling greater volumes of metadata. Based on these two advantages digital systems are typically the preferred method of data collection and storage.

Data should be stored with a minimum of 1-hour and 1-minute averaging periods. The 1-hour averaging period is required for reporting purposes; the 1-minute averaging period facilitates the validation process. Data loggers averaging 60 minute time intervals or greater should be configured to capture a minimum of 75% of the data from the shorter time interval. As an example, during a 60 minute time interval at least 45 minutes of 1-minute data is required.

Data should be reported using Pacific Standard Time to the ending hour (i.e. 8:00 covers data from 7:01 to 8:00).

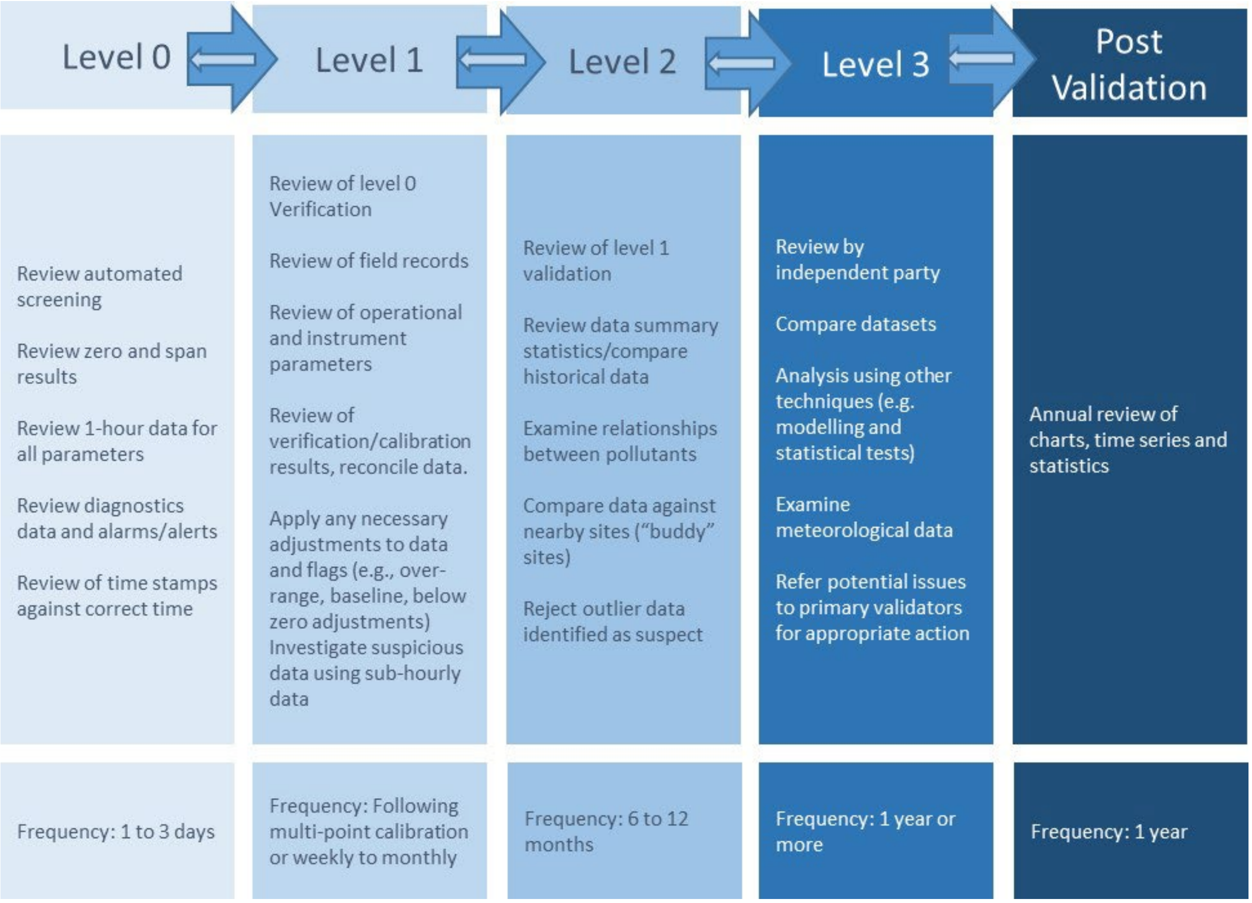
7.2 Data Validation Process

The data validation process involves actions and decisions which result in the transition of the *as-collected* data to a final dataset with an established level of data validity. Data validation is a progressive four step process which begins with preliminary verification activities at level 0 and concludes with an independent data review at level 3. Data validation responsibilities for the monitoring station's operator and field trained technician are limited to Level 0.

The data validation process prescribed for operators of ambient air monitoring stations within ENV's jurisdiction is generally consistent with that undertaken in the NAPS program, although recommendations specific to monitoring data collected within the ENV's jurisdiction do exist.

An overview of the validation process is shown in Figure 7.2.1. The validation process including frequency, and data review intervals is summarized in Table 7.2.2.

Figure 7.2.1: Overview of Data Validation Process



Level 0	Level 1	Level 2	Level 3	Post Validation
Review automated screening Review zero and span results Review 1-hour data for all parameters Review diagnostics data and alarms/alerts Review of time stamps against correct time	Review of level 0 Verification Review of field records Review of operational and instrument parameters Review of verification/calibration results, reconcile data. Apply any necessary adjustments to data and flags (e.g., over-range, baseline, below zero adjustments) Investigate suspicious data using sub-hourly data	Review of level 1 validation Review data summary statistics/compare historical data Examine relationships between pollutants Compare data against nearby sites (“buddy” sites) Reject outlier data identified as suspect	Review by independent party Compare datasets Analysis using other techniques (e.g. modelling and statistical tests) Examine meteorological data Refer potential issues to primary validators for appropriate action	Annual review of charts, time series and statistics
Frequency: 1 to 3 days	Frequency: Following multi-point calibration or weekly to monthly	Frequency: 6 to 12 months	Frequency: 1 year or more	Frequency: 1 year

Manual quality control assessments and corrections must be completed before monitoring data can be submitted as *validated data*. Data corrections for significant zero and span drifts that occur between zero and span tests do not need to occur in real time. Data corrections can be applied during routine data reviews, such as those following a full month of monitoring. If zero and span checks are controlled automatically, the data can be corrected at near real-time; however, until the corrections are applied the data must be identified as *preliminary*.

Table 7.2.1: Summary of Data Validation Requirements

Process Level	Level 0	Level 1	Level 2	Level 3
Data Description	Raw data	Level 0 Validated Data	Level 1 Validated Data	Level 2 Validated Data
Frequency	1 to 7 days (1 to 3 days preferred)	Following multi-point calibration Weekly or monthly	6 to 12 months	Annually
Period of Data Reviewed	1 to 6 days	1 to 6 months	6 to 12 months	1 or more years
		Review of level 0 Validation	**Review of level 1 Validation**	**Independent review**

Process Level	Level 0	Level 1	Level 2	Level 3
Summary of Requirements	**Review automated screening** › Review zero and span results › Review 1-hour data for all parameters › Review diagnostics data and alarms/alerts › Review of time stamps against correct time	› Review of field records › Review of operational and instrument parameters › Review of verification/calibration results, reconcile data › Apply necessary adjustments to data and flags (e.g., over-range, baseline, below zero adjustments) › Investigate suspicious data using sub-hourly data	› Review data summary statistics/compare historical data › Examine relationships between monitoring parameters › Compare data against nearby sites › Reject outlier data identified as suspect	› Compare datasets › Analysis using other techniques (e.g. modelling and statistical tests) › Examine meteorological data › Refer potential issues to primary validators for appropriate action

7.3 Data Flags & Logs

Data flags characterize individual data points as valid or invalid. These are activated during various levels of data validation. In Level 0, flags are activated either automatically based on instrument status to indicate daily zero/span checks and instrument failures, or manually by the station operator to conduct maintenance, calibration, instrument verification, replacement, and other activities. Whenever possible, station operators should make an electronic logbook entry to justify the automated and manually activated flags. Logbook entries are also made to document observations during site visits or events that may have an impact on instrument operations and data.

Dataloggers that are not capable of reporting flags must transmit invalid data as a null value or -9999. Logbook entries that justify these flags should be documented and submitted on a regular basis to the data polling centre (Central Polling System) as requirements of Level 0 validation.

Data flags are also activated during Level 1 and Level 2 validation as a result of data and instrument anomalies, audit failures, calibration issues, verification check failures, and other issues related to data, station, and instrument operations. Data flags can be modified during Level 1 and Level 2 validation. All adjustments to data, including baseline adjustments and flag corrections implemented during these validation activities are documented and stored in the Central Polling Station’s data validation log.

Validation logs should include, at minimum, the following information:

- Name of the person who performed the validation action;
- Date of validation action completed;
- Monitoring Parameter(s) affected;
- Description of any data adjustments and/or flag modifications;
- Brief description of any actions performed to address monitoring system/data issues;
- Identification of the validity of anomalous data or outliers; and,
- Justification for changes made after validation has been completed.

Monitoring data that has been invalidated through the validation process should be reported as a blank value. Note this is different from other jurisdictions such as NAPS which report invalid data as -9999.

7.4 Level 0 - Preliminary Validation

A Level 0 validation process usually involves both automatic and manual data screening and subsequent flagging; however, in some instances the level 0 validation process may be entirely automated. Recommended level 0 data validation activities are provided in the following table.

Table 7.4.1: Level 0 Verification Checklist

Check #	Activity	Comment
Automatic Checks		
1	Identify periods of missing data.	Possibly due to power/instrument/communication failure.
2	Identify data outside of instrument's monitoring range or expected range.	Outside of instrument operating range, negative values, or outside of an established historical expected range.
3	Review rate of change to assess if data changes too rapidly, or not at all.	Can be compared to predefined rate of change thresholds.
Manual Checks		
4	Review of 1-hour data for all parameters.	View in tables and graphs.
5	Review of 1-hour data for completeness and instrument performance.	
6	Review of automated screening flags.	(Typically checks #1-3 above), instrument diagnostics and alarms.
7	Verification that zero and span are within specifications.	
8	Verification of time stamps against correct time.	

Data that has been flagged for exclusion should be investigated. Investigations will assist in identifying the root cause of flagged data and help develop corrective actions where applicable. Corrective actions should be implemented as soon as possible to minimize data loss. Corrective actions must be recorded in the *validation log*.

7.5 Level 1 - Primary Validation

Level 1 validation generally occurs between consecutive multi-point verifications, at an interval of 1 to 6 months, and after any instrument repairs or adjustments. Level 1 validation activities build on the data screening and flagging conducted during the Level 0 validation process. Level 1 validation activities provide a more thorough evaluation of available information and documentation. During Level 1 validation data should be flagged, issues identified, and corrective actions undertaken. Recommended level 1 data validation activities are provided in the following table.

Table 7.5.1: Level 1 Validation Checklist

<table>
<tr><th>Check #</th><th>Activity</th></tr>
<tr><td>1</td><td>Review of field records that were not available at the time of the level 0 checks. Review to identify issues or incidents with the potential to affect data quality. This information may be recorded in station logs, instrument maintenance records, multi-point verification and calibration records.</td></tr>
<tr><td>2</td><td>Review of operation and instrument parameters
The review considers any instrument specific conditions that may invalidate data. These parameters may be specified by the manufacturer or in SOPs. Examples include leak checks and environmental temperature and pressure controls.</td></tr>
<tr><td>3</td><td>Review of multi-point verification results
Compare zero and span check results with the multi-point verification results for consistency. If the results are inconsistent or the data has been invalidated or flagged, adjust the data based on the multi-point verification.
If the multi-point verification results are outside of ENV acceptance criteria provided in Table 6.4.1, the data should be invalidated to the most recent point in time where the data was verified as valid. If this action is not taken a sound justification must be developed and recorded. Where data has been invalidated, corrective actions should be developed and implemented. Corrective actions should specify a timeline to minimize data loss and identify the qualified person charged with implementing the corrective action.</td></tr>
<tr><td>4</td><td>Review of over-range values
There may be circumstances where an instrument monitors an unusually high reading. Where the high reading is triggered by a real event such as widespread woodstove use during a period of cold weather, it is termed as an over-range value. Over-range data points should be preserved in the dataset and flagged as reading(s) that are attributable to a direct event. Over-range flags that are kept should be noted in the validation log.</td></tr>
<tr><td>5</td><td>Review of automatic zero adjustments
If automatic zero adjustments are made automatically by an instrument the adjustments should be reviewed manually to verify the automated adjustment feature is functioning correctly.</td></tr>
<tr><td>6</td><td>Baseline adjustments
Changes to instrument response overtime, observable when the instrument is sampling zero air, is common. Instrument drift can be identified by reviewing zero checks using graphs and tables and confirmed during multi-point verification or by checking for a depletion of zero air consumables. Baseline drifts correction of data should be undertaken if tolerance levels provided in the following table are exceeded.
<table>
<tr><th>Pollutant</th><th>Zero Point Tolerance</th></tr>
<tr><td>CO</td><td>± 0.08 ppm</td></tr>
<tr><td>O_3</td><td>± 1.0 ppb</td></tr>
<tr><td>NO_X</td><td>± 1.0 ppb</td></tr>
<tr><td>SO_2</td><td>± 0.5 ppb</td></tr>
<tr><td>H_2S/TRS</td><td>± 0.5 ppb</td></tr>
</table>
Zero checks should be evaluated individually if they are used in data adjustment. The following points highlight additional considerations for corrections of drift:
› Excessive correction to hourly data increases uncertainty in short-term monitored data, although long term (annual) averages may be reasonably accurate.
› Frequent adjustment of the instrument zero results in higher data uncertainty and possible data invalidation.</td></tr>
</table>

<table>
<tr><th>Check #</th><th>Activity</th></tr>
<tr><td></td><td>

A rapid or excessive change in zero signals an instrument malfunction and possible data invalidation; not instrument drift which would be seen over days to weeks.
Corrections due to drifts in span results are not recommended by ENV and are not allowed by NAPS.

Baseline adjustments are made to the data by either: 1) adjusting the data by the verified drift amount and applying that adjustment to all data during the period between consecutive compliant zero checks; or 2) interpolating zero adjustments between consecutive zero checks to gradually adjust the baseline.
</td></tr>
<tr><td>7</td><td>
Below zero adjustments
Instruments are subject to zero noise, which is a measure of the deviations from zero while sampling zero air.
Care should be taken to distinguish zero noise data from operational issues, since operational issue data should be invalidated. Zero noise corrections should be made on valid hourly data where readings less than zero should be adjusted to zero. The following table summarizes the zero adjustment criteria.
<table>
<tr><th>Averaging Interval</th><th>Parameter</th><th>Validation Criteria</th></tr>
<tr><td>Sub Hourly</td><td>All parameters</td><td>All negative values determined valid shall remain negative</td></tr>
<tr><td rowspan="2">1-hour</td><td>PM$_{2.5}$ (ug/m^3)</td><td>PM$_{2.5}$ value ≥ -3 and < 0 adjusted to 0
PM$_{2.5}$ value < -3 are flagged as invalid</td></tr>
<tr><td>All gases</td><td>Below zero values determined valid are adjusted to zero (values < -3 should be further investigated prior to setting to zero)</td></tr>
</table>
</td></tr>
<tr><td>8</td><td>
Derived parameter relationships
Some instruments do not directly measure a substance but instead provide a measurement is based on an established relationship. During validation, checks are made to ensure the relationship is preserved during the monitoring period.
For example NO$_2$ is typically not a direct measurement of NO$_2$, rather it is calculated as the difference between NO$_x$ and NO in the sample. If adjustments are made to NO, NO$_X$ or NO$_2$ it may be necessary to apply these adjustments to all parameters to preserve the relationship. Since NO and NO$_X$ are often not measured simultaneously a tolerance level of ±2 ppb difference is allowed for the summation of the three compounds.
</td></tr>
</table>

7.6 Level 2 - Final Validation

Level 2 validation, which is performed every 6 to 12 months, reviews the past 6 to 12 months' worth of hourly data. The objectives of the Level 2 validation are to:

- Verify zero inconsistencies between related data, measured at the station;
- Verify zero inconsistencies between regional data (if applicable); and,
- Provide contextualization of monitoring data to time and place.

All suspect data should be investigated. An investigation can include reviewing level 1 checks and supporting documentation to ensure any flags and adjustments are applied correctly. Additionally, investigations may result in the identification of missed data that should be flagged and invalidated due to instrument malfunction or other issues.

Recommended level 2 data validation activities are provided in the following table.

Table 7.6.1: Level 2 Validation Checklist

Check #	Activity
1	**Data summaries and statistics** Plot data summaries and statistical analysis to assist in identifying outliers.
2	**Meteorological data** Review relevant meteorological data using wind rose and pollutant roses to assist in identifying anomalous data.
3	**Data time series plots** Plot multiple station parameters together if available to identify relationships/trends are as expected, for example O_3 and NO_2 are often inversely correlated. This may include plotting diurnal trends. For example, in urban areas concentrations of NO_2 would be expected to correlate to times of peak traffic. O_3 typically exhibits a diurnal and seasonal trend.
4	**Independent Data** Compare station data to data from nearby monitoring stations to assess the validity of suspect data. For example, large pollutant events that would have regional air quality effects would likely be evident in the data from a number of monitoring stations.

Data should be considered valid unless substantial evidence demonstrates that it is inconsistent with dependant (related) and independent data or is not representative of the time or place monitored. Justifications for inclusion or exclusion of outlier or anomalous data validity should be documented.

7.7 Level 3 - Independent Data Review

The level 3 independent data review is not meant to replicate or replace Level 1 or Level 2 reviews. The level 3 review should be undertaken by an individual independent from the field operator and previous validator. The reviewer should be a suitably qualified person whose knowledge of air pollutants and meteorological and basic site conditions will help ensure that the data is subjected to a robust and dependable level of review.

A level 3 review is generally performed annually on a full years-worth of data. The review focuses on the identification and assessment of trends that would most likely not be apparent in the shorter (e.g. monthly) data. In addition to trend analysis of data, the review should include comparisons to regional and other relevant datasets. Suspect data should be flagged, and the previous reviewers and validators of that data should be notified. Appropriate investigations and modification should be undertaken, and justifications noted and logged.

7.8 Post Validation

Despite the best efforts of station operators, reviewers and independent validators, errors and omissions may still exist in the validated data.

Charts, time series, and annual statistics (minimum and maximum) should be reviewed annually, as a minimum. If errors and omissions are identified or suspected the data review periods may be re-evaluated. If changes are required, the edited data should undergo re-submittal and re-validation.

8 Collection and Validation of Non-Continuous Monitoring Data

Air monitoring measurements by non-continuous or sampler collection methods often require subsequent laboratory analysis to complete the measurement. This process includes methods such as passive sampling, low flow rate sampling and high volume sampling. The data validation function for these sampling methods is performed by the laboratory and is therefore not covered in detail in this document. This type of monitoring does however involve important data validation aspects such as flow rate, leak rate, and appropriate filter media that must be considered and addressed at the sample collection stage. In addition to the information provided in the following two subsections, detailed information on sample collection is provided in method-specific SOPs located in the Appendices section of this Manual.

8.1 Preparatory Considerations

Prior to the data collection stage, a laboratory will typically be involved in the preparation/preconditioning of the sample media such as filters, cartridges or passive sampler cartridges. As a best practice, sample media should be used within 30 days of conditioning by the laboratory. The appropriate sample media should be selected in consideration of the monitoring objectives and the subsequent laboratory analysis required. For example, if metals analysis of a filter is required then this may require a different sample media to be used. Samples are transported to the sampling location, installed, left for the sampling period and then retrieved and transported back to the laboratory for analysis.

During the data collection period, the following information should be recorded as a minimum:

- Monitoring location/ID
- Date/time of sample installation and retrieval
- Sample ID
- Sample media ID
- Sample type (field blank, travel blank, duplicate/s)
- Complete chain of custody and any other documentation required by the laboratory
- Other operational parameters specific to a sample collection method (see method specific SOPs within the Appendices for more information)
- Information on sample validity, for example:
    - Sample media damage
    - Note if sample tampering is suspected
    - Sampler equipment errors/malfunctions
    - Unusual weather conditions
    - Potential interference during sampling (e.g. vegetation clearing activities occurred during the sampling period)

During the data collection period, appropriate laboratory blanks should be used. A minimum of one blank sample media should be used for every media shipment. The blank should be returned to the laboratory with the same batch of sample media it was received with. It is recommended that samplers confirm the process for collecting blanks as well as the number of blanks required with the analysing laboratory.

Sample media should be retrieved and shipped to the laboratory as soon as practical following the sampling period. Some sampling methods provide recommended retrieval times (e.g., within 5 days) and maximum handling times depending on the required laboratory analysis.

8.2 High-Volume Sampling for Trace Metals

Detailed data collection information for high-volume samplers is provided in SOP-05d located in the Appendices section of this Manual. This section of the Manual provides additional information on the use of high-volume sampling to collect data to assess chronic hazards associated with the presence of trace metals in particulate matter.

8.2.1 Background

Requirements of the High-Volume sampling method include:

- The analysis of 5 blank filters prior to the use/implementation of new filter types.
- A trip blank must be provided for every 5 samples collected.
- Unless otherwise required by permit or site-specific monitoring objectives High Volume samplers should draw a sample over a full 7 day period per filter, and the 7 day sampling intervals should be contiguous (one interval following immediately after another) over the course of a full year.
- The sampling site must meet Ministry standards for particulate sampling.
- Analytical reports must include QA/QC data and information for all reported parameters.

These requirements maximize the amount of information obtained from the sampling equipment and laboratory methodologies. Information produced by this method facilitates a calculation of chronic exposure hazards with the greatest accuracy and reliability without significantly increasing the costs of sample collection and analysis.

An assessment of the chronic impact of trace metals involves calculating the average metal concentration found in a sequence of samples. The high-volume sampling method involves drawing particulate onto a filter. Laboratory analysis of the sample will determine the combination of metals in the sample and metals in the filter.

In calculating an averaged ambient metal concentration, the averaged metal content of the filters must be subtracted from the averaged total (sample and filter) of the metal measured. The greatest source of uncertainty in calculating ambient metals concentrations is generally due to the variability in the metal composition of the filter.

8.2.2 Quality Control

Because metals are often present in concentrations which border on the threshold of detection:

- A proper understanding of the uncertainties and statistical distribution of the amounts of metals in the analyzed sample (filter plus collected particulate) is required, as is;
- A proper understanding of the uncertainties and statistical distribution of the amounts of metals in blank filters.

Under no circumstance should data be censored at a detection limit as this destroys the statistical profile.

Analytical reports provided from laboratories must include quality control information. Quality control information is used to separate bias and precision from overall uncertainties so that averaged quantities can be accorded an appropriate uncertainty. This also allows for the incorporation of information obtained from a variety of analytic sources (laboratories) and methodologies, into a statistical analysis, adjusting for bias and precision as required.

To mitigate the costs associated with quality control, samples can be processed in batches. However, to build a base of quality control information, a given batch should not contain more than 5 samples.

As quality control reference samples, containing known concentrations of metals, which match those found in a typical field sample become available, at least one reference sample must be included with every sample batch analyzed.

Because of the volume of information, all data from the laboratory analysis must be available electronically in a form that can be easily incorporated into Ministry databases. Laboratories that seek to provide analytical services must receive approval from the Ministry for data delivery formats prior to submission.

8.2.3 Analysis of Blank Filters

A statistical base of information must be generated for every filter type used in the collection of ambient metals samples. This can be accomplished whenever a new filter type is introduced by having the lab provide an analysis of the metallic composition of 5 filters prior to circulation and use. At present, only the Pallflex Teflon TX40HI20WW has been approved for metals analysis sampling. Other filter types must receive approval from the Ministry before being used.

The contamination associated with the field analysis can be determined by analyzing trip blanks. A trip blank is a blank filter that is delivered to the field site, placed on the high-volume sampler, removed immediately without activating the sampler, and then repackaged and shipped to the lab for analysis. To develop a base of information, trip blanks must accompany every 5 samples collected in the field. This will allow tracking of contamination and variations between filter batches.

Should a significant trend be noted in the trip blanks it may be necessary to re-analyze a sequence of blanks (not trip blanks). This step is taken to ensure that the filter composition has not shifted. If, after this step, it is determined that the composition of the filter has not changed, the sampling methodology should be re-examined to ensure that contamination is being minimized.

8.2.4 Sampling

The uncertainty introduced by the metal composition of a filter can be reduced if the amount of sample per filter is increased. This can be accomplished by running the high-volume sampler for a period exceeding 24 hours per filter.

Sampling period durations are limited by the build-up of particulate matter on the filter. At a certain concentration the particulate matter will block the air flow pathways through the filter which results in an alteration of its screening properties. The suppliers of filters generally do not provide or specify maximum load limits.

A rough estimate of acceptable loading can be obtained using maximum loading limits of historic/past measurements in British Columbia. For TSP, the maximum load was 1.3 grams (ambient concentration of 787 ug/m^3 collected over 24 hours). For PM$_{10}$ the maximum load was 0.7 g (ambient concentration of 419 ug/m^3 collected over 24 hours). No failure of equipment was noted for such loadings over the 24 hour sampling period.

Actual loading limits will depend on the density and size of particulate collected. As a guide however, filters should generally not become overloaded when operated for 7 days in an environment where the ambient concentration rarely exceeds 100 ug/m^3. The 7 day sampling duration is provided as an initial guideline to coincide with a normal work week schedule. Additionally, the 7 day sampling duration is long enough that the relative uncertainty associated with the metallic composition of the Teflon filters (Pallflex EMFAB TX40H120WW) is less than levels set by current ambient objectives.

The duration of the sampling period can be extended beyond 7 days if it is demonstrated that this will not overload the HiVol sampler. The number of days can be reduced if filters of greater metallic purity (less trace metal composition, or more uniform metallic composition) are used. At present only the Pallflex Teflon TX40HI20WW has been approved for metals analysis sampling, and as such the sampling period must not be reduced without prior consultation with and approval from the Ministry.

For quality assurance, the flow rate of the high-volume sampler must be measured at the beginning and end of the sampling interval, although an instrument model that continuously monitors and records the flow rate throughout the sampling period is preferred. Flow rate information must be available for incorporation into Ministry databases.

Sampling must be conducted over contiguous intervals (the next sample started as soon as the previous sample is finished) so that statistical artifacts associated with high, or low concentration episodes can be minimized.

Equipment downtime is tolerable as long as samples are collected over at least 85% of the time for each calendar month.

9 Training

Personnel who operate ambient air monitoring stations within the provincial jurisdiction of British Columbia as well as persons conducting maintenance on those stations and the instrumentation deployed at the stations must be appropriately trained to carry out those tasks. In addition to mentoring and on-the-job training, formal training is available through several agencies such as the Air and Waste Management Association (AWMA), vendors. Training should be ongoing through refresher courses and continual improvement to remain current with technological developments and to better understand the specific operational characteristics and requirements of each monitoring station. Training records must be maintained and available for review.

In addition to training required for monitoring station operation and maintenance, personnel must have formal training as required to conduct activities included in the British Columbia Occupational Health and Safety Regulation (OHSR).

Training in the following areas should be taken where warranted:

- First Aid;
- Workplace Hazardous Material Information System (WHMIS);
- Transportation of Dangerous Goods;
- Working at Height and Ladder Safety; and,
- Safe Driving Techniques.

10 Documentation and Record Keeping

Ambient air monitoring stations must maintain records that are relevant to the operation of the station, the maintenance and deployment of instrumentation and issues and incidents with the potential to affect data validity. Accurate and organized record keeping will help identify substantial issues before they arise, identify potential trends and demonstrate the proficiency of a station's operation.

In particular ambient air monitoring stations must maintain the following records:

- Station Start-Up Record;
- Inspection and Maintenance Records;
- Verification and Calibration Records;
- Non-Conformance and Corrective Action Records;
- Level 0 Data Verification Log; and,
- Audit Evaluations.

11 Audits

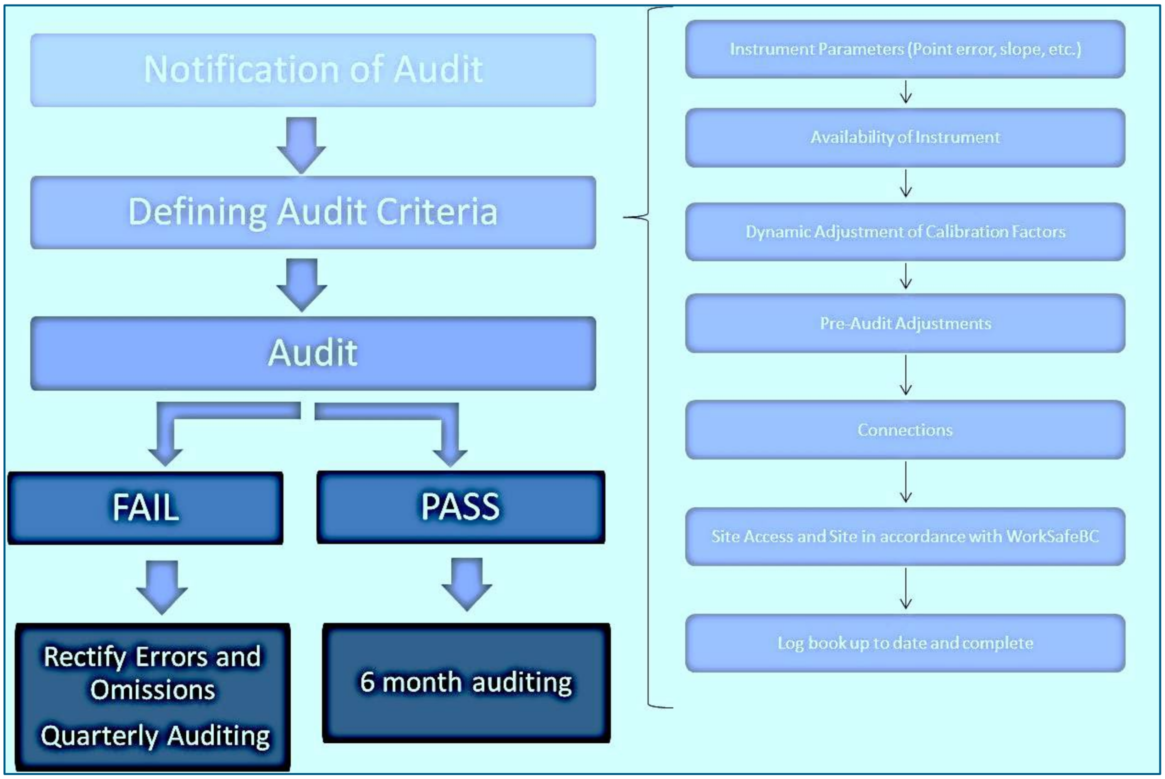
The objective of an audit is to ensure that the data generated by ambient air monitoring stations is produced at an acceptable level of quality and in a consistent manner across all regions of the province. This ensures that monitoring results from each station are comparable to one another and reliable for their intended monitoring objectives. ENV's detailed audit processes are described in the Standard Auditing Procedure for Continuous Emission Monitors and Ambient Air Monitoring Instruments (B.C. ENV 2009).

The B.C. Ministry of Environment and Climate Change Strategy conducts audits on all ambient air monitoring stations within their jurisdiction. Generally, an audit consists of:

- An audit notice;
- The audit process which includes:
    - Instrument performance verification;
    - Calibrator verification;
    - Housing inspection; and,
    - Site accessibility.
- Post-audit corrective actions if required.

A flow chart of the audit process is provided in Figure 11.1 below.

Figure 11.1: Auditing Procedure



11.1 Audit Process

Ambient air monitoring station operators can expect to receive an audit notice from ENV one to two weeks prior to an audit event. The notice will provide an overview of the audit's intent and activities. The station operator will work with the ENV auditor in the completion of the audit. General audit criteria include the verification of instrument performance, checking of support equipment and review of the station logbook. Audits are completed in accordance with the procedures outlined in the *Standard Auditing Procedure for Continuous Emission Monitors and Ambient Air Monitoring Instruments* (the Standard Auditing Procedure).

11.2 Audit Results

At the end of the audit process the station will be assigned a pass or fail in accordance with the criteria listed in the Standard Auditing Procedure. Stations that pass their audit will continue to be audited bi-annually. If a stations instrument does not achieve its audit criteria the auditor will typically debrief the station operator explaining the rationale for their finding. The station operator must then investigate the failure, identify the root cause of the failure and develop and implement corrective actions to mitigate the potential of a reoccurrence. The station operator must ensure that the corrective actions are implemented in order to restore the ambient air monitoring station to an acceptable state. An instrument that fails an audit may be scheduled for additional audits on a quarterly basis until the station has passed two consecutive audits.

11.3 Audit Follow-Up

Within one month of an audit's completion the ENV auditor will provide the station operator with the audit certificates and an email summarizing the audit results. The summary and certificates will provide the following information:

- Audit date and site name;
- Audit team members;
- Equipment used to conduct the audit;
- Audit findings;
- A link to the *Standard Auditing Procedure*; and,
- The results of any additional investigations that were completed following an audit failure.

The audit event must be recorded in the station's log along with any follow up maintenance or work that has been undertaken as a result of the audit.

12 References

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13 Revision History

May 01, 2020	This ‘Part’ (Part B1 – Ambient Air Monitoring) initial publication.
November 1996:	Initial publication of the British Columbia Field Sampling Manual.

Appendix 1

Forms and Checklists

Step No.	Analyzer Calibration Checklist		
1	☐		Turn the calibrator on and allow it to warm up to operating temperature.
2	☐		Record data acquisition system channel and flag into calibration.
3	☐		Connect a two-stage pressure regulator to a certified calibration standard cylinder and purge regulator.
	a	☐	Turn the pump on
	b	☐	Open the regulator valve and purge for 60 seconds
	c	☐	While keeping the pump on, close the regulator valve and slowly open the cylinder valve to fill the regulator with calibration gas
	d	☐	Close cylinder valve and open regulator valve to evacuate regulator
	e	☐	Repeat the previous two steps twice
	f	☐	Close the regulator valve
	g	☐	Connect an 1/8 inch stainless steel line from the purged regulator to the gas inlet of the calibrator
	h	☐	Slowly open the cylinder valve and verify that the regulator out pressure is within the calibrator’s specifications
	i	☐	Slowly open regulator valve
4	☐		Connect a vent line to vent excess air from the calibrator to the atmosphere. This can be achieved by connecting a transfer line to one of the calibrator manifold ports using a reducer or for calibrators without a manifold connect, by using a stainless steel Tee to the calibrator. The length to diameter ratio must be at least 10:1 to prevent ambient air entrainment.
5	☐		Plug any unused manifold ports.
6	☐		For all points measure the flow by connecting a flow meter to the calibration gas outlet on the calibrator. Record the flow value. Flow values are calculated as the average of ten flow measurements from a certified primary flow meter.
7	☐		Perform an as found zero by setting the calibrator to produce zero air. Monitor analyzer zero readings, verify reading stability for at least 10 minutes.
8	☐		Perform an as found upper point by setting the calibrator to generate a concentration at 80% of the instrument’s range. Monitor the analyzer’s readings to verify reading stability for at least 10 minutes then set the instrument to read the generated concentration.
9	☐		Install an inline particulate filter to the analyzers inlet and connect a transfer line from the calibration port/Tee to the filter inlet OR replace the calibrator inter filter (whichever is applicable).
10	☐		Set the calibrator to produce zero air. Monitor the analyzers zero reading to verify reading stability for at least 10 minutes then set the reading to zero. For all points measure the flow by connecting a flow meter to the calibration gas outlet on the calibrator. Record the flow value. Flow values are calculated as the average of ten flow measurements from a certified primary flow meter.

Step No.		Analyzer Calibration Checklist
11	☐	Set the calibrator to generate a concentration at 80% of the instrument's range. Monitor the analyzers readings, verify reading stability for at least 10 minutes then set the instrument to read the generated concentration. Check that the reading is stable and within ±1% of the set concentration value.
12	☐	Set calibrator to produce zero gas again to verify zero reading. If necessary re-adjust zero.
13	☐	Using the calibrator introduce gas at concentrations of 80%, followed by 60%, 40% and 20% of the instruments range. Verify stability for at least 10 minutes at each point. Alternative ranges can be used with approval from the ENV.
14	☐	Reconfigure the analyzer for normal operation.
15	☐	Perform a zero and span check and record these values as part of the calibration report. The zero and span check values will be used as the control values until the next calibration. Reset the data logger flagging to normal operation mode.
16	☐	Reset the datalogger's flagging to normal operation mode
17	☐	Document all calibration results, and calibration procedures in sufficient detail in the equipment's log book and in the calibration report.
18	☐	Plot the calibration curves from the instrument against the calibrators zero and four upscale points (80%, 60%, 40% and 20%) and calculate the slope and intercept. The calibration curves can be used to correct subsequent monitoring data.
19	☐	Mark up the data acquisition channel.
20	☐	Attach a visible label to the instrument identifying the date of calibration.

Placeholder for

Inspection & Maintenance Form

Placeholder for

Non-Conformance & Corrective Action Form

Appendix 2

Standard Operating Procedures

Monitoring Parameter: **Carbon Monoxide (CO)**	**Standard Operating Procedure for the Continuous Measurement of Ambient CO**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-01** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instruction for the continuous ambient monitoring of Carbon Monoxide (CO) within the provincial jurisdiction of British Columbia (BC).

This SOP forms part of the British Columbia Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a CO analyzer within the provincial jurisdiction of BC must be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Nondispersive Infrared Photometry with Gas Filter Correlation (GFC)

The principle detection and quantification method deployed for ambient concentrations of Carbon Monoxide (CO) involves selective infrared (IR) absorption by CO in a sample of ambient air. To compensate for interfering compounds that may be present within gas samples the analyzer passes IR light through a gas filter wheel to the sample cell, and finally to the detector. The gas filter wheel has two rotating chambers; One of the chambers is filled with a high concentration of CO, the second chamber contains nitrogen. The chamber filled with CO provides a reference beam that cannot be further altered by the CO in the sample cell and as such, functions as a reference absorption point. The chamber filled with nitrogen has no impact on the IR radiation since nitrogen gas does not absorb IR, and therefore this chamber provides a measurement beam that can be absorbed by CO in the sample cell. The amount of IR absorption by the CO in the sample cell is proportional to its concentration within the sample. The concentration of CO within the ambient air sample is determined by the ratio of intensities between the rays that pass through the two chambers using the Beer-Lambert law.

A more detailed discussion on the CO measurement principle is typically provided within the manufacturer's operation manual.

4. Interferences

H_2O and CO_2

As discussed in Section 3 *Principles of the Measurement Method*, CO analyzers use selective absorption in the IR spectra. Species such as CO_2 and H_2O are known to absorb a portion of the same IR spectra as that used in the measurement of CO. Although some reports claim that the absorption of IR radiation by CO_2 and H_2O does not change the ratio of intensities between the reference beam and the measurement beam, and hence does not interfere with the CO measurement, a permeation dryer must be used to minimize any potential interference from H_20.

Particulate Matter

The presence of particulate matter in air samples is known to interfere with CO measurement. Interference by particulate matter can be minimized by using a particle filter at the sample inlet (for analyzers that do not have an internal filter).

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of a sensor can be checked by performing calibrations against a certified carbon monoxide calibration standard mixture (See sections 11 and 12). Accuracy can also be confirmed through periodic span checks and multipoint verifications/calibrations.

6. Recommended Equipment and Apparatus

The following models are commercially available CO analyzers suitable for use within the provincial jurisdiction of B.C.:

- Latest model of the Thermo Fisher Scientific Environmental Instruments (TEI) trace-level model 48 instrument (e.g., 48i-TLE).
- Ecotech Serinus 30 Carbon Monoxide analyzer.
- Latest model of the Teledyne trace-level model 300 instrument (e.g., T300U).

This list does not necessarily exclude other commercially available CO analyzers, and analyzers recognized by the United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. Indeed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is recommended, however, that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy CO analyzers not listed above. Regardless of the equipment deployed all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available CO analyzers operating in B.C. are configured to an operating range of no more than a 0 ppm to 10 ppm (generally 0 ppm to 5 ppm), with a 0 ppm to 3 ppm calibration range. The detection limit is determined by instrument type but is generally specified at 0.04 ppm.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of the stations intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type of the monitoring location (residential, commercial, industrial).

Refer to Section 2 of Part B1 of the B.C. Field Sampling Manual for further information on site selection.

Installation Requirements

Follow analyzer specific installation requirements provided in the analyzer manufacturer's manual.
The installation should also conform to the following:

- The monitoring station’s sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program’s *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- All connection tubing, connectors and fittings from the manifold to the analyzer inlet must be made of Teflon or a material of equivalent chemical inertness.
- A Teflon particulate filter meeting the instrument manufacturer’s pore-size specifications unless the analyzer is equipped with a similar internal filter. The filter holder must be constructed of an inert material (e.g. Teflon, stainless steel).
- To reduce the risk of moisture entering the analyzer it is recommended that horizontally mounted manifolds be oriented with the ports facing upwards (with the exception of manifolds such as the “ARB style” which must be mounted vertically); ensure any water traps are oriented vertically.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20°C to 30°C but must ultimately be capable of maintaining the operating temperature range specified by the manufacturer. Enclosure temperatures should not deviate by more than 2 °C over a one hour period.
- A data acquisition system (DAS) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The DAS must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a temperature controlled, temperature stable enclosure. The enclosure’s temperature must be maintained between 20 °C to 30 °C.
- A permeation dryer should be placed in the sampling line upstream of the analyzer.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated CO analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. ▪ Operating range should be 0 ppm to 5 ppm; Calibration range 0 ppm - 3 ppm.	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) following a 24 hour to 72 hour warm up period; ▪ After analyzer repairs/maintenance that may have affected the performance of the instrument; ▪ When zero check exceeds ± 0.1 ppm; ▪ When span drift is ≥ ± 10% of reference value; ▪ For new analyzers, after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold above is reached (whichever happens first).	▪ As per Section 11 of this SOP	▪ Record in logbook

Zero and Span Verification	- Daily. Auto-zeroing is permitted for trace-level CO analyzers. Frequency is at the discretion of the regulating agency (e.g. every 4 – 12 hours).	- As per manufacturers operation manual	- Record in logbook
Verify Operational Parameters	- Each station visit.	- As per manufacturers operation manual	
Inlet Filter Change	- Inspect monthly, change as required.	- As per manufacturers operation manual	
Analyzer Maintenance	- As recommended by manufacturer or as required.	- As per manufacturers operation manual	- Record in logbook
Sample Path Inspection (Probe to Analyzer)	- Monthly. May be conducted at a lesser frequency with approval from ENV.	- Where necessary replace with new lines, tighten loose connections, clean manifold as required	- Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify the analyzers performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer's manual.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

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Ecotech Environmental Monitoring Solutions 2013. *Serinus 30 Carbon Monoxide Analyzer User Manual*.

Environment Canada (EC) 2010. *Continuous Measurement of Carbon Monoxide (CO) in Ambient Air by Nondispersive Infrared Photometry with Gas Filter Correlation (GFC)*. EC National Air Pollution Surveillance (NAPS) Operations Unit.

EC 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Teledyne Advanced Pollution Instrumentation 2012. *Operation Manual Model T300/T300M Carbon Monoxide Analyzer*.

Thermo Fisher Scientific 2007. *Model 48i Trace Level-Enhanced Instruction Manual Gas Filter Correlation CO Analyzer*.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Hydrogen Sulphide (H_2S) and Total Reduced Sulphur (TRS)**	**Standard Operating Procedure for the Continuous Measurement of Ambient H_2S and TRS**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-02** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Hydrogen Sulphide (H_2S) and Total Reduced Sulphur within the provincial jurisdiction of British Columbia (BC).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of an H_2S/TRS analyzer within the provincial jurisdiction of B.C. must be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

Note: Due to similarities in the monitoring methods for H_2S and TRS, the operating guidelines and instructions for both parameters are presented in this document as a single SOP.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Ultraviolet fluorescence

The principle detection and quantification method deployed for ambient concentrations of H_2S and TRS involves ultraviolet (UV) fluorescence and a photomultiplier tube.

For reference, compounds found in Total Reduced Sulphur (TRS) are comprised of a variety of sulphur containing compounds such as Carbonyl Sulphide (COS), Carbon Disulphide (CS_2) and Methyl Mercaptan (CH_3SH). Similar to H_2S, TRS molecules become oxidized to SO_2 in the presence of Oxygen and heat. With two notable exceptions the method deployed for ambient concentrations of H_2S and TRS is identical to that deployed for Sulphur Dioxide (SO_2). Although both analyzers use ultraviolet fluorescence (UV) and operate on the same principle, analyzers used to monitor H_2S and TRS deploy scrubbers and a conversion chamber.

The scrubbers are used to remove SO_2 and hydrocarbons from the ambient air sample stream. The sample is then passed through a converter oven which, in the presence of oxygen (O_2), converts H_2S and/or TRS compounds into SO_2. To convert H_2S to SO_2, the ambient sample is oxidized in a chamber heated to at least 320 °C. By comparison, the conversion of TRS takes place at a chamber temperature of at least 800 °C; effectively converting all reduced sulphur compounds to SO_2.

The concentration of SO_2 in the sample is quantified through ultraviolet (UV) fluorescence. SO_2 molecules absorb UV rays at a wavelength of 214 nm. The absorption of UV rays causes the SO_2 molecules to transition to an excited state. As the excited state SO_2 molecules return to their normal state they release energy by emitting UV light at a wavelength of 330 nm. The analyzer measures the amount of UV light present at a wavelength of 330 nm using a photo multiplier tube. The measurement of 330 nm UV rays is then used to quantify the concentration of SO_2.

A more detailed discussion on the H_2S/TRS measurement principle is typically provided within the manufacturer's operation manual. Additional information describing SO_2 quantification is provided in SOP-06 located in Appendix 1 of the BCFSM.

4. Interferences

UV Light

H2S/TRS analyzers measure ultraviolet light emitted by SO_2 molecules to quantify hydrogen sulfide or total reduced sulphur and for this reason compounds that emit ultraviolet light at similar wavelengths may potentially introduce interference. Compounds such as hydrocarbons and nitric oxide (NO) may introduce interference. To minimize the interference from hydrocarbons, the analyzer should be equipped with a hydrocarbon scrubber. If typical ambient NO levels are significant when compared to SO_2 levels, particularly for trace level analyzers, it is recommended that the analyzer be tested for it's degree of sensitivity to NO using span gas in the range of 600 ppb to 800 ppb NO.

Particulate Matter

The presence of particulate matter in air samples can interfere with the SO_2 measurement. The potential for this interference can be minimized by using a particle filter of 5 µm pore size made of inert material such as Teflon, at the sample inlet (for analyzers that do not have an internal filter).

Scrubbers

The performance of the SO_2 scrubber should be checked routinely, since residual SO_2 not removed by the scrubber can interfere with the measurement of both H_2S and TRS.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of the sensor can be checked by performing a calibration against a certified H_2S/TRS calibration standard mixture (see sections 10 and 11). Accuracy can also be confirmed through span checks and calibrations.

6. Recommended Equipment and Apparatus

The following are commercially available H_2S/TRS analyzers suitable for use within the B.C. ENV's jurisdiction:

- Thermo Environmental Instruments (TEI) Models 45A, 45C, 450i H_2S analyzers with converter model numbers 340 for H_2S and CDN 101 for TRS; operating in single channel mode.
- Teledyne Advanced Pollution Instrumentation Models 101E (H_2S), 102E (TRS), 101/101A (H_2S) 102/102A (TRS)

This list does not necessarily exclude the use of other commercially available H_2S/TRS analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended, however, that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy a H_2S/TRS analyzers not listed above.

Regardless of the equipment deployed all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available H_2S/TRS analyzers operating in B.C. are configured to a 0 ppb - 200 ppb operating range. Detection limits are determined by instrument type but are generally specified at 0.5 ppb.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type of the monitoring location (residential, commercial, industrial).

Refer to Section 2 of Part B1 of the Field Sampling Manual for further information on site selection method.

9. Installation Requirements

Follow analyzer specific installation requirements provided in the manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- All connection tubing, connectors and fittings from the manifold to the analyzer inlet must be made of Teflon or a material of equivalent chemical inertness.
- A Teflon particulate filter capable of removing at least 99% of 1 µm diameter and larger particles must be placed in the sampling line upstream of the analyzer, unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel).
- A data acquisition system (data logger) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a temperature controlled, temperature stable enclosure. The enclosure's temperature must be maintained at a range of 20 °C to 30 °C.
- Remove any sources of solvents and volatile hydrocarbons from the vicinity of the station.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated H_2S/TRS analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. Monitoring range should be 0 ppb to 200 ppb	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) following a 24 h warm up period; ▪ After analyzer repairs/maintenance that may affect performance of the instrument; ▪ When zero check exceeds ± 1.0 ppb; ▪ When span drift ≥, ± 10% of reference value; ▪ For new analyzers, after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold above is reached (whichever happens first).	▪ As per Section 11 of this SOP	▪ Record in logbook
Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual	▪ Record in logbook
Verify Operational Parameters	▪ Each monitor station visit	▪ As per manufacturers operation manual	
Inlet Filter Change	▪ Inspect monthly, change as required	▪ As per manufacturers operation manual	
Analyzer Maintenance	▪ As recommended by manufacturer or as required	▪ As per manufacturers operation manual	▪ Record in logbook
Sample Path Inspection (Probe to Analyzer)	▪ Monthly	▪ Where necessary replace with new lines, tighten loose connections, clean manifold if required	▪ Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify the analyzers performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer's manual.

12. Calibration

Calibration should be performed in accordance with Section 6 of the B.C. Field Sampling Manual and the manufacturer's manual.

13. References

Environment Canada 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Alberta Environment 2011. *Standard Operating Procedure for Hydrogen Sulphide (H_2S) and Total Reduced Sulphur (TRS) Detectors*. AENV Air Monitoring and Audit Centre.

Teledyne 2016. *User Manual – Model T101 UV Fluorescence H_2S Analyzer*.

Teledyne 2012. *User Manual – Model T102 Total Reduced Sulfur Analyzer with Model 501 TRS Thermal Converter*.

Thermo Fisher Scientific 2015. *Model 450i Instruction Manual Pulsed Fluorescence SO_2-H_2S-CS Analyzer*.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Oxides of Nitrogen (NOx)**	**Standard Operating Procedure for the Continuous Measurement of Ambient NO_x**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-03** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Oxides of Nitrogen (NOx) including Nitrogen Dioxide (NO_2), within the provincial jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of NO_x analyzers within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.
This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Chemiluminescence

The principle detection and quantification method deployed for ambient concentrations of NO_2 is chemiluminescence. Chemiluminescence uses a photomultiplier tube to measure the light emitted by the chemical reaction of nitric oxide (NO) and ozone (O_3).

$$NO + O_3 \rightarrow NO_2 + O_2 + hv$$

The concentration of NO_2 in an air sample is determined by two measurement processes. The first process measures the amount of NO in ambient air. The second process measures the amount of NO_X in ambient air. The NO_2 concentration is then calculated as the difference between these two measurements.

In the first process, NO concentration is determined by passing an ambient air sample through an Ozone (O_3) rich reaction chamber. Ozone is continuously generated within the analyzer at a concentration that far exceeds that of ambient NO levels. When exposed to O_3, NO is readily oxidized to NO_2 in a 1:1 relationship. As excited NO_2 molecules decay to a lower energy state they release infrared light at an intensity that is linearly proportional to the amount of NO present. The light emitted during this chemical reaction is measured using a photomultiplier tube. The infrared light measurement is used to determine the concentration of NO.

In the second process, the concentration of NO_X is determined by passing the ambient air sample through a molybdenum catalysis oven that is heated to approximately 325°C which converts NO_x to NO. A valve then directs the sample to the reaction chamber used in the first process, where total NO_x is measured as NO.

Atmospheric concentrations of NOx species, other than NO_2 and NO, are typically so low that they are considered negligible and as such the concentration of NO_2 is determined as the difference between concentrations of NO and NO_X.

$$NO_2 = NO_X(catalyst\ converted\ NO_2\ and\ NO) - NO$$

A more detailed discussion on the NO_2 measurement principle is typically provided within the manufacturer's operation manual.

4. Interferences

Nitrogen Based Compounds

The presence of nitrogen based compounds in ambient air may interfere with NO_x measurement. These compounds are known to erroneously increase analyzer response as they can undergo chemical reaction within the catalysis oven or reaction chamber resulting in an inaccurate analyzer response. Some of the compounds known to interfere with NO_2 measurement include, H_2O, ammonia (NH_3) and oxides of sulphur (SO_x). If high concentrations of NH_3 are present then steps must be taken to remove this contaminant from the sample stream.

H_2O and CO_2

Water and high levels of carbon dioxide (>0.5%) have the potential to interfere with the measurement of Oxides of Nitrogen. Analyzers situated in areas of high humidity may require a gas dryer to reduce moisture. The gas dryer should be positioned in the sample line upstream of the analyzer.

Particulate Matter

Particulate matter in ambient air is known to reduce analyzer response by absorbing and scattering light. Interference by particulate matter can be minimized by installing a particle filter at the sample inlet (for analyzers that do not have an internal filter). The particle filter must have a pore size of 5 µm in diameter and be made of an inert material such as Teflon.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy. The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of the sensor can be checked by performing analyzer calibrations against a certified standard gas mixture (see sections 10 and 11). This is typically an NO standard converted to NO2 on site within an ozone generator-equiped calibrator. Accuracy can also be evaluated through periodic span checks.

6. Recommended Equipment and Apparatus

The following are common commercially available NO_2 analyzers suitable for use within the jurisdiction of B.C.:

- Thermo Environmental Instruments (TEI) Models 42, 42C, & 42i NO_X
- Teledyne API T200
- Serinus 40

This list does not necessarily exclude the use of other commercially available NO_x analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. Indeed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C.

Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy NO_2 analyzers not listed above. Regardless of the equipment deployed all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available NOx and NO_2 analyzers operating in B.C. are configured to a 0 ppb - 500 ppb operating range, with a 0 to 300 ppb calibration range. Detection limits are determined by instrument type, but are generally around 0.4 ppb.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the monitoring location.

Refer to Section 2 of Part B1 of the Field Sampling Manual for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements provided in the analyzer manufacturer’s manual. Installation should also conform to the following:

- The monitoring station’s sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program’s *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- The ¼ inch diameter connection tubing from the manifold to the analyzer inlet must be made of Teflon or equivalent material for chemical inertness.
- A Teflon particulate filter meeting the instrument manufacturer’s pore-size specifications unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel).
- To reduce the risk of moisture entering the analyzer it is recommended that horizontally mounted manifolds be oriented with the ports facing upwards (with the exception of manifolds such as the “ARB style” which must be mounted vertically); ensure any water traps are oriented vertically.
- A data acquisition system (data logger) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a temperature controlled, temperature stable enclosure. The enclosure’s temperature must be maintained between 20 °C and 30 °C.
- Remove any sources of solvents and volatile hydrocarbons from the vicinity of the station.
- A permeation dryer should be placed in the sampling line upstream of the analyzer.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated NO_x analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ Monitoring range should be 0 ppb to 500 ppb.	▪ Record in logbook

Multipoint Verification	▪ After installation (or relocation) following a 24 h to 72 h warm up period; ▪ After analyzer repairs/maintenance that may have affected the performance of the instrument; ▪ When zero check exceeds ± 2.0 ppb; ▪ When span drift is ≥, ± 10% of reference value; ▪ For new analyzers, after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold above is reached (whichever happens first).	▪ As per Section 6 of Part B1 of the BCFSM.	▪ Record in logbook
Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual	▪ Record in logbook
Verify Operational Parameters	▪ Each monitor station visit	▪ As per manufacturers operation manual	
Inlet Filter Change	▪ Inspect monthly, change as required	▪ As per manufacturers operation manual. A filter change can affect flow and pressure so a verification or full calibration is required.	
Analyzer Maintenance	▪ As recommended by manufacturer or as required	▪ As per manufacturers operation manual	▪ Record in logbook
Sample Path Inspection (Probe to Analyzer)	▪ Monthly	▪ Where necessary replace with new lines, tighten loose connections, clean manifold if required. Flow and pressure may significantly affect the analyzer response for NO2 analyzers. Any alteration to the sample pathway should be accompanied by	▪ Record in logbook

		verification or full calibration.	

11. Zero and Span Checks

Zero and span checks are required to verify analyzer performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer's manual. Certain specifics of the NOx/NO_2 analyzer calibration are as follows:

Calibrations of NO-NOx-NO2 analyzers are unique when compared to other analyzer types. As both NOx and NO are measured, a 2-stage calibration is required. The first stage is typical of other analyzer types and involves serial dilution of an NO standard to calibrate and verify analyzer NO/NO_x response. Following this, NOx-NO_2 response is calibrated/verified by Gas Phase Titration (GPT) for two points. This involves titrating the NO standard used in the first stage with a known concentration of ozone. The introduced ozone converts the equivalent amount of NO into NO_2, which is converted back into NO by the analyzer's converter oven and read as NOx. As the NO channel was calibrated and verified in the first stage, the analyzer's response to the remaining NO, not converted by ozone, can be accepted as accurate. Comparison of the introduced ozone concentration with the analyzer's NOx and NO response therefore allows for a determination of converter efficiency, and calibration of the NOx-NO_2 channel.

Acceptance criteria for gas phase titration is ≥ 95% converter efficiency at each point.

13. References

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Measurement of Oxides of Nitrogen in by Chemiluminescence*. AENV Air Monitoring and Audit Centre.

AENV 2011. *Standard Operating Procedure for Dilution Calibrations*. AENV Air Monitoring and Audit Centre.

Environment Canada (EC) 2010. *Continuous Measurement of Nitrogen Dioxide (NO_2) in Ambient Air by Chemiluminescence*. ECCC National Air Pollution Surveillance (NAPS) Operations Unit.

EC 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Thermo Fisher Scientific 2015. *Model 42i Instruction Manual Chemiluminescence NO-NO2-NO_X Analyzer*.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Ozone (O_3)**	**Standard Operating Procedure for the Continuous Measurement of Ambient O_3**
Revision No: Original Revision Date: 05 May, 2020	**Reference No: SOP-04 Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Ozone (O_3) within the jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of an O_3 analyzer within the provincial jurisdiction of B.C. must be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Method

Selective Absorption of Ultraviolet (UV) Photometry

The principle detection and quantification method deployed for ambient concentrations of Ozone (O_3) is selective UV absorption (at a wavelength of 254 nm) by O_3. The concentration of O_3 is determined using two steps of UV photometry, and the application of the Beer-Lambert Law.

In the first step ozone is removed from the sample stream as it passes through an O_3 scrubber. The intensity of the UV rays in the ozone free environment is measured by the analyzer's stabilized photo detector to provide a reference value. In the second step, the sample air bypasses the O_3 scrubber. Ozone present in the sample air absorbs UV in the 254 nm range and this reduction in UV rays is represented in the UV measurement provided by the photo detector. The Beer-Lambert Law shows that UV light absorption is proportional to the ray's travel path, and the concentration of O_3. Using this relationship the concentration of ozone in the air sample can be determined.

A more detailed discussion on the O3 measurement principle is typically provided within the manufacturer's operation manual.

4. Interferences

NO_2, SO_2, and VOCs

Nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and volatile organic compounds (VOCs) are known to influence O_3 measurement, however, in a typical urban environment the interference effect is reported to be negligible.

H_2O, NO, Hg, and PAHs

Other compounds that affect the measurement of O_3 are water (H_2O), Nitric Oxide (NO), and Polycyclic Aromatic Hydrocarbons (PAHs). Mercury vapour is a strong absorber of UV radiation at the 254 nm range and therefore O_3 cannot be measured using this method in the presence of mercury vapour. Similarly, PAHs are a strong absorber of UV radiation at the 254 nm range, and at high concentrations, PAHs may interfere with the measurement of O_3.

Particulate Matter

The presence of particulate matter in an air sample is known to interfere with the measurement of Ozone. Particulate matter if present will absorb and scatter UV radiation. This can be minimized by installing a particle filter at the sample inlet (for analyzers that do not have an internal filter).

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and multipoint verifications.

The accuracy of the sensor is generally considered a measure of the 'deviation from true'. The accuracy of the sensor can be checked by performing a verification check against a certified reference standard photometer (see section 10 and 11). Accuracy can also be confirmed through span checks and calibrations.

6. Recommended Equipment and Apparatus

The following are commercially available O_3 analyzers suitable for use within the provincial jurisdiction of B.C.:

- Thermo Environmental Instruments (TEI) Models 49, 49C, 49i
- Serinus 10
- Teledyne API T400

This list does not necessarily exclude other commercially available O_3 analyzers, and analyzers recognized by the United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy O_3 analyzers not listed above. Regardless of the equipment deployed all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available O_3 analyzers can operate at a user selectable range of 0 ppb to 1000 ppb; for B.C. ENV monitoring purposes analyzers should be set to a range of 0 ppb to 500 ppb. Detection limits are determined by instrument type but are generally around 1 ppb.

Multipoint verifications and calibration should be conducted across a range of 2 ppb to 200 ppb.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and monitoring location zone type (residential, commercial, industrial).

Refer to Section 2 of Part B1 of the Field Sampling Manual for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements provided in the analyzer manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- The ¼ inch diameter connection tubing from the manifold to the analyzer inlet must be made of Teflon or equivalent material for chemical inertness.
- All connectors and fittings in the sampling systems must be Teflon or stainless steel (connections should be Teflon-to-Teflon or steel-to-steel – no mixing of fittings at any connection point).
- A Teflon particulate filter meeting the instrument manufacturer's pore-size specifications unless the analyzer is equipped with a similar internal filter. The filter holder must be constructed of an inert material (e.g. Teflon, stainless steel).
- A data acquisition system (DAS) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a temperature controlled, temperature stable enclosure. The enclosures temperature must be maintained between 20 °C to 30 °C.
- Remove any sources of solvents and volatile hydrocarbons from the vicinity of the station.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated O_3 analyzer.

Action	Time/Frequency	Description	Record
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. Monitoring range should be 0 ppb to 1000 ppb	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) after a 24 h to 72 h warm up period; ▪ After analyzer repairs/maintenance that may affect performance of the instrument; ▪ When zero check exceeds ± 2.0 ppb; ▪ When span drift is ≥, ± 10% of reference value; ▪ For new analyzers, after the first 3 months of operation ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold	▪ As per Section 11 of this SOP	▪ Record in logbook

	above is reached (whichever happens first).		
▪ Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual	▪ Record in logbook
▪ Verify Operational Parameters	▪ Each station visit	▪ As per manufacturers operation manual	
▪ Inlet Filter Change	▪ Inspect monthly, change as required	▪ As per manufacturers operation manual	
▪ Analyzer Maintenance	▪ As recommended by manufacturer or as required	▪ As per manufacturers operation manual	▪ Record in logbook
▪ Sample Path Inspection (Manifold to Analyzer)	▪ Monthly	▪ Where necessary replace with new lines, tighten loose connections, clean manifold if required	▪ Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify the analyzers performance between calibrations. These checks should be performed in accordance with Section 6 of the B.C. Field Sampling Manual and the manufacturer's manual.

12. Multi-Point Verification and Calibration

Calibration should be performed in accordance with Section 6 of the B.C. Field Sampling Manual and the manufacturer's manual.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Measurement of Ozone in Ambient Air by Ultraviolet (UV) Photometry*. AENV Air Monitoring and Audit Centre.

Environment Canada (EC) 2010. *Continuous Measurement of Ozone in Ambient Air by Ultraviolet (UV) Photometry.* EC National Air Pollution Surveillance (NAPS) Operations Unit.

EC 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Thermo Fisher Scientific 2011. *Model 49i Instruction Manual UV Photometric* O_3 *Analyzer*.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Particulate Matter (PM)**	**Standard Operating Procedure for the Continuous Measurement of Ambient PM using a Beta Attenuation Monitor**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-05a** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Particulate Matter (PM) within the provincial jurisdiction of British Columbia (B.C.).

These guidelines and instructions have been written specifically for particulate matter that is 10 µm or less in aerodynamic diameter (PM_{10}) and particulate matter that is 2.5 µm or less in aerodynamic diameter ($PM_{2.5}$). This SOP describes particulate matter measurements using Beta Attenuation Monitors (BAM). Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs 5b through 5e.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a BAM PM analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer’s manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Beta Attenuation Monitor

The principle detection and quantification method deployed by Beta Attenuation Monitors (BAM) is beta radiation attenuation. Monitors are set to a particulate size fraction of interest, typically 10 µm (PM_{10}) or 2.5 µm ($PM_{2.5}$), by attaching a size-selective inlet to the analyzer. Regardless of inlet size ambient air is drawn through the analyzer at a rate of 16.7 litres per minute ($l\ min^{-1}$).

Met One BAM-1020 analyzers use a stepwise monitoring cycle: a radioactive source within the analyzer emits beta radiation that passes through a glass fibre sample tape. The beta radiation is emitted at a constant rate and measured by a scintillation detector. At the beginning of each sample cycle, the beta rays pass through an unexposed glass fibre filter tape to determine background attenuation levels. During the sampling period, air is drawn into the analyzer, where the glass fibre tape is exposed to particulate matter that may be present in the air sample. Particulate matter present on the glass fibre tape attenuates the beta rays. Beta ray attenuation is proportional to the mass of particulate matter which is inversely reported by the scintillation counter. The mass of particulate matter measured is combined with the flow rate calculated during the sampling period, to produce an ambient mass concentration.

Instrumentation such as the Thermo 5014i do not deploy a stepwise monitoring cycle however the principle is the same.

A more detailed description of the PM measurement principle is typically provided within the manufacturer's operation manual.

4. Interferences

Particulate matter measurements by BAM instruments can be interfered with by the presence of moisture, extremely cold temperatures, inlet and sample tube loss, and by system leaks.

Moisture

Conditions in which the relative humidity (RH) exceeds 45% may result in an accumulation of water vapour on the filter tape. This results in a mismeasurement of PM as the water vapour attenuates beta rays. This interference is minimized by using an internal RH probe to measure sample stream humidity and an inlet heater to control the relative humidity (RH Threshold 35% and 45%). RH set-points must be set as per USEPA FEM requirements which are usually stipulated in the instrument manual.

For instruments not referenced refer to instrument manuals, and consult with the Ministry to confirm required thresholds.

Temperature

Instruments have an absolute low-temperature limit which must be considered prior to acquisition and installation. This can be variable depending on the ambient sensor selected (e.g., BAM-1020 has an optional lower temperature sensor). Ensure the instrument selected can operate within the full range of the site's weather conditions.

Inlet and Sample Tube Loss

The particle size-selective inlet has a stable cut-point as long as it is routinely serviced to minimize inlet surface particle accumulation. Poor maintenance of the inlet may result in a shift of the particle size cut-off, or undesired particle re-entrainment. Excessive particulate build up on the inner walls of the sample tubing can affect PM concentration measurements. Scheduled preventive maintenance routines will significantly mitigate the potential for this type of interference.

Flow tolerance

The size selective inlets are designed to operate at an airflow rate of 16.67 $l\ min^{-1}$ and require this flow rate to prevent particulate matter that exceeds the inlet cut size from entering the sample stream. Airflow must be maintained within ± 4% of 16.67 $l\ min^{-1}$ to ensure only the desired particulate (e.g. $PM_{2.5}$) is being measured.

System Leaks

Air leaks in the sampling system can result in reduced PM measurement. The PM analyzer must pass a leak check to produce valid data. Leak check verifications must reference thresholds set by the instrument manufacturer.

For instruments not referenced refer to instrument manuals, and consult the Ministry to confirm required thresholds.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. Thermo Scientific reports the precision of the 5014i instrument to be ± 2.0 µg/m^3 for measurements less than 80 µg/m^3, and 4 µg/m^3 to 5 µg/m^3 for measurements greater than 80 µg/m^3. Met One Instruments report the accuracy and precision of their BAM instruments to be consistent with U.S. EPA requirements for Class III PM$_{2.5}$ and PM$_{10}$ measurement.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. Typical accuracy's are reported by manufacturers in the range of ±5 % to ± 10%.

6. Recommended Equipment and Apparatus

The following instruments are commercially available and used within the Ministry's network:

- Met One BAM-1020 with Smart Heater System
- Thermo Scientific 5014i

This list does not exclude other commercially available PM analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. Indeed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy analyzers not listed above. Regardless of the equipment deployed all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Instruments typically have a measurement range of 0 mg/m³ to 10 mg/m³. Some manufactures report detection limits that are less than less than 4 µg/m³ over a one hour period or less than 1 µg/m³ over a 24 hour period. PM$_{2.5}$ analyzers/monitors deployed within the provincial jurisdiction of B.C. must have the sample range set at 0 – 1000 ug/m^3 to capture extreme particulate events (e.g., wildfire smoke).

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, zone type (residential, commercial, industrial) of the monitoring location and probe siting requirements that are outlined in Section 8.

Refer to Section 2 of Part B1 of the B.C. Field Sampling Manual for further information on site selection method.

9. Installation Requirements

Follow analyzer specific installation requirements discussed in the analyzer manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- A data acquisition system (DAS) should be connected to the analyzer to record or download the measurement data from the analyzer. The DAS must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20°C to 30°C but must ultimately be capable of maintaining a temperature range of 4 °C to 50 °C (5014i Instrument spec); 0 °C to 50 °C (BAM1020). An enclosure's temperature should be as consistent as possible, and typically should not deviate by more than 2 °C over a one hour period.
- At locations where a straight intake from the sample inlet point to the analyzer is not possible, locating the analyzer in an outdoor enclosure should be considered. The outdoor enclosure should be temperature controlled.
- The appropriate size fraction separator should be installed onto the inlet tube for PM_{10} or $PM_{2.5}$.
- A temperature controller and a temperature sensor system must be installed on the inlet.
- Adequate clearance within the shelter must be provided to accommodate a sample heater.
- The portion of the inlet tube within a shelter or building should be adequately insulated to avoid condensation build up within the sampling tube.
- The inlet probe configuration should confirm to the following criteria:

Inlet Probe Requirement	Condition
Inlet height above ground	2 m to 15 m
Distance from support structure	> 2 m
Distance from trees	> 20 m or twice the height of trees above the inlet elevation, whichever is greater
Distance from any air flow obstacles (i.e., buildings)	twice the height of obstacles above the inlet elevation, whichever is greater
Airflow restrictions	Unrestricted in at least 3 of the 4 wind quadrants (N, S, E, W)
Local source influences	Local source influences must be considered in locating the site for ambient PM

10. Operational Requirements

The following activities should be performed by the operator of a PM analyzer:

Action	Time/Frequency	Description	Record Keeping
Analyzer Operational Parameter Set Up	• At installation	• RH set point no higher than 35% (BAM-1020) • RH control set to ON • Sample range set to 0 – 1000 ug/m^3 • Sample offset set to -0.005 mg/m^3 • Flowrate 16.7 l min-1	• Record in logbook
Verify Operational Parameters	• Weekly	Check operation of instrument, record operating parameters	• Record in logbook
Leak Check	▪ Monthly ▪ Before calibration ▪ Before and after nozzle cleaning	• As per manufacturers operation manual. • BAM 1020 = less than 1.5 l min^{-1} • 5041i = less than 0.42 l min^{-1}	• Record in logbook

	▪ After each filter tape change out		
Calibration (ambient temperature, pressure sensors, internal RH and temperature sensors, flow controller)	• Bi-annually	• As per Section 12 of this SOP	• Record in logbook
Sample Filter Change	• Inspect monthly, change as required (typically 60 days)	• As per manufacturers operation manual. • Sites with heavy PM concentrations may need more frequent filter change.	• Record in logbook
Self-test – (BAM 1020)	• After each filter tape change	• As per manufacturers operation manual	• Record in logbook
Logged Concentration	• Weekly	• Compare DAS concentration value with the concentration displayed on the analyzer. The values should be within 1 µg/m³	• Record in logbook
Clean nozzle and nozzle area - (BAM 1020)	• Monthly	• As per manufacturers operation manual	• Record in logbook
Flow Check	• Quarterly	• As per manufacturers operation manual. • Flow should be 16.67 • l min-1 ± 5%.	• Record in logbook
Re-zero Background - (BAM 1020)	• Annually	• As per instrument manual	• Record in logbook
Clean $PM_{2.5}$ inlet cyclone & PM_{10} inlet, Inspect O-Rings	• Bi-annually	• As per manufacturers operation manual. • Sites with heavy PM concentrations may need more frequent cleaning.	• Record in logbook
Clean air inlet system Replace Inlet O-Rings	• Annually	• As per manufacturers operation manual	• Record in logbook
Sample Pump service/overhaul - (BAM 1020)	• Service: as required • Overhaul by pump type: • Medo pump 9 to 12 months • Gast pump 24 months	• As per manufacturers operation manual	• Record in logbook
Replace Muffler - (BAM 1020)	• As required	• As per manufacturers operation manual	• Record in logbook
Sample Path Inspection (Probe to Analyzer)	• Monthly	• Where necessary replace with new lines, tighten loose connections, clean manifold if required	• Record in logbook

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

Verification and calibration should be performed in accordance with the manufacturer’s manual.

PM analyzer verifications generally require:

- Pre-verification leak check (as per manufacturer's instructions)
- Verification of ambient temperature and pressure sensors
- Verification of internal RH and temperature sensors (if required by manufacturer)
- Verification of volumetric flow

Verifications must demonstrate compliance with the following acceptable tolerance levels:

Instrument	Leak Tolerance	Flow Tolerance	Temperature Tolerance	Pressure Tolerance	RH Tolerance
BAM 1020	< 1.5 l in^{-1}	4%	± 2° C	± 10 mmHg	10 %
5014i	<0.42 l in^{-1} (±2.5%)	4%	± 2° C	± 10 mmHg	10 %

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Environmentally Protected Beta Attenuation Monitor (E-BAM).* AENV Air Monitoring and Audit Centre.

AENV 2011. *Standard Operating Procedure for Dilution Calibrations*. AENV Air Monitoring and Audit Centre.

Environment Canada (EC) 2010. *Operating Procedures for BAM Samplers for* $PM_{2.5}$ *Monitoring in the NAPS Network*. EC National Air Pollution Surveillance (NAPS) Operations Unit.

Met One 2016 *BAM 1020 Particulate Monitor Operation Manual, BAM 1020-9800.* Revision Q.

EC 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Thermo Scientific 2009. Model 5014i Beta Instruction Manual Continuous Ambient Particulate Monitor.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Particulate Matter (PM)**	**Standard Operating Procedure for the Continuous Measurement of Ambient PM Using Integrated Nephelometry and Beta Attenuation**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-05b** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides guidelines and instructions for the continuous ambient monitoring of particulate matter within the provincial jurisdiction of British Columbia (B.C.).

These guidelines and instructions have been written specifically for particulate matter that is 10 µm or less in aerodynamic diameter (PM_{10}) and particulate matter that is 2.5 µm or less in aerodynamic diameter ($PM_{2.5}$). This SOP describes particulate matter measurements using nephelometry and beta attenuation measurement techniques. Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs 5a, and 5c through 5e.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a PM analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer’s manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Nephelometry and Beta Attenuation Monitor

The principle detection and quantification method deployed in monitoring ambient mass concentrations of particulate matter involves nephelometry and beta attenuation. Monitors are set to a size fraction of interest, typically PM_{10} or $PM_{2.5}$, by attaching a size-selective inlet which allows ambient air to be drawn through the analyzer at a rate of 16.7 litres per minute ($l\ min^{-1}$). The sample initially passes through an 880 nm light beam within the nephelometer. The nephelometry response is proportional to the concentration of particulate matter present in the sample. The sample then passes through the beta attenuator where particulate matter, if present in the sample air, is deposited onto a glass fibre filter tape. A radioactive source within the analyzer emits beta rays that pass through the glass fibre tape to a scintillation counter. The presence of particulate matter will attenuate the beta rays which are detected and measured by the scintillation counter. The level of attenuation caused by the particulate matter is proportional to the ambient concentration of particulate matter. The beta attenuation chamber measures alpha emissions from the accumulated particles and excludes negative mass artifacts associated with the presence of daughter nuclides from radon gas decay. A more detailed description of the particulate matter measurement principle is typically provided within the manufacturer’s operation manual.

4. Interferences

Particulate matter measurements can be interfered with by dust accumulation on the optical sensor, debris in the BAM sample chamber, moisture buildup, temperature, inlet and sample tube loss, and system leaks.

Dust Accumulation on Optical Sensor

Dust accumulation on the optical sensor may interfere with the measurement of PM. This can occur after heavy dust storm events or incrementally over time. To mitigate potential interference by dust the nephelometric chamber should be cleaned once per year.

Moisture

Conditions in which the relative humidity (RH) is high can result in an accumulation of water vapour on the filter tape. This results in a mismeasurement of PM as the water vapour attenuates beta rays. This interference can be minimized by using a dynamic heating system (DHS) to maintain the relative humidity of the air passing through the filter tape. Typically RH will be controlled to 35% to prevent vapour condensation on the filter tape.

Inlet and Sample Tube Loss

The particle size-selective inlets have a stable cut-point as long as they are routinely serviced to minimize inlet surface particle accumulation. Poor maintenance of the inlet may result in a shift of the particle size cut-off, or undesired particle re-entrainment. Excessive particulate build up on the inner walls of the sample tubing can affect PM concentration measurements. Scheduled preventive maintenance routines will significantly mitigate the potential for this type of interference.

Flow tolerance

Size selective inlets are designed to operate with an airflow rate of 16.67 l min^{-1}. This flow rate is required to prevent particulate matter that exceeds the inlet cut size from entering the sample stream. Airflow must be maintained within ± 4% of 16.67 l min^{-1} to ensure that only the desired particulate fraction (i.e. $PM_{2.5}$) is being measured.

System Leaks

Air leaks in the sampling system can result in reduced PM measurement. The PM analyzer must pass a leak check to produce valid data. The leakage rate must be less than 0.8 l min^{-1}. Consult the manufacturer's operation manual for leak check instructions specific to the analyzer.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy. The precision of a measurement is generally considered to be the 'repeatability of the measurement'.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The SHARP 5030 and 5030i Thermo Scientific manufacturer reports the hourly precision to be ± 2 $\mu g/m^3$ for measurements less than 80 $\mu g/m^3$ and ± 5 $\mu g/m^3$ for measurements greater than 80 $\mu g/m^3$. The reported accuracy of the 5030 model is ± 5% compared to a 24 hour Federal Reference Method. The accuracy of the 5030i model is reported as ± 5% using NIST-traceable mass foil set.

6. Recommended Equipment and Apparatus

The following are commercially available combined Nephelometry and Beta Attenuation analyzers considered to be suitable for use within the provincial jurisdiction of B.C.:

- Thermo Fisher Scientific Model SHARP-5030
- Thermo Fisher Scientific Model 5030i

This list does not necessarily exclude other commercially available PM analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy instruments not listed above. Regardless of the instrumentation deployed, all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Thermo Fisher Scientific report that the SHARP Models 5030 and 5030i can operate at a user selectable range of 0 mg/m³ to 10 mg/m³. The detection limit is less than 0.5 µg/m³ for a one hour time resolution.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of monitoring location.

Refer to Section 2 of Part B1 of the B.C. Field Sampling Manual for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements discussed in the analyzer manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- A data acquisition system (DAS) should be connected to the analyzer to record or download the measurement data from the analyzer. The DAS must also record and monitor any alarm conditions of the analyzer. The monitor should be set to monitor in hybrid mode.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20°C to 30°C but must ultimately be capable of maintaining a temperature range of 4 °C to 50 °C (5030i Instrument spec). The enclosures temperature should not deviate by more than 2 °C over a one hour period.
- At locations where a straight intake from the sample inlet point to the analyzer is not possible, locating the analyzer in an outdoor enclosure should be considered. The outdoor enclosure should be temperature controlled. The appropriate size selective-inlet must be installed onto the inlet tube.
- A temperature controller and temperature sensor system must be installed on the inlet.
- The instrument's front panel should be oriented to the north to avoid direct sunlight.
- The portion of the inlet tube within a shelter or building should be adequately insulated to avoid condensation build up within the sampling tube.
- The inlet probe configuration should conform to the following criteria.

Probe Requirement	Condition
Height above ground	2 m to 15 m
Distance from support structure	> 2 metres
Distance from trees	> 20 m or twice the height of trees above the inlet elevation, whichever is greater
Distance from any air flow obstacles (i.e., buildings)	> twice the height of obstacles above the inlet elevation, whichever is greater
Airflow restrictions	Unrestricted in at least 3 of the 4 wind quadrants

Local source influences	Local source influences must be considered in locating the site for ambient PM

10. Operational Requirements

The following activities should be performed by the operator of a SHARP-5030 and 5030i PM analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Operational Parameter Set Up	At installation	• RH nominal value 35% • Filter change mass = 1500 µg • Filter change hours = 24 • Filter cycle = 8 hours • Temp control system set to ON • Air flow = 1000 l hr^{-1}	• Record in logbook
Calibration • Temperature, RH and barometric sensor calibration • Flow rate • Mass foil calibration • Nephelometer zero	▪ Annually or after repairs	• As per Section 12 of this SOP. Leak check prior to calibration	• Record in logbook
Verify Operational Parameters	▪ Weekly	• Check operation of instrument, record operating parameters	• Record in logbook
Sample Filter Change	▪ Inspect monthly, change as required (typically 6 months)	• As per manufacturers operation manual. Sites with heavy PM concentrations may need more frequent filter change.	• Record in logbook
Self-test	▪ After each filter tape change	• As per manufacturers operation manual	• Record in logbook
Logged Concentration	▪ Weekly	• Compare DAS concentration value with the concentration displayed on the analyzer. The values should be within 1 µg/m³	• Record in logbook
Leak Check	▪ Monthly ▪ Before calibration ▪ Before and after nozzle cleaning ▪ After each filter tape change out	• As per manufacturers operation manual. A display of less than 0.8 l min-1 passes the leak check.	• Record in logbook
Nephelometer Zero	• Monthly	• As per instrument manual	• Record in logbook
Flow Check	• Quarterly	• As per manufacturers operation manual	• Record in logbook
Clean PM$_{2.5}$ inlet cyclone & PM$_{10}$ inlet Inspect O-Rings	• Every 3 months	• As per manufacturers operation manual	• Record in logbook
Clean air inlet system Replace Inlet O-Rings	• Annually	• As per manufacturers operation manual	• Record in logbook
Inspect/change pump vanes	• Annually	• As per manufacturers operation manual	• Record in logbook
Replace Muffler	• As required	• As per manufacturers operation manual	• Record in logbook

Clean the Nephelometer	- Annually	- As per manufacturers operation manual	- Record in logbook
Sample Path Inspection (Probe to Analyzer)	- Monthly	- Where necessary replace with new lines, tighten loose connections, clean manifold if required	- Record in logbook

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

Verification and calibration should be performed in accordance with the manufacturer’s manual.

PM analyzer verification generally require:

- Pre-verification leak check (as per manufacturer’s instructions)
- Verification of ambient temperature and pressure sensors
- Verification of internal RH and temperature sensors (if required by manufacturer)
- Verification of volumetric flow
- Mass foil verification using a series of null and span foils
- Nephelometer zero verification

Verifications must demonstrate compliance with the following acceptable tolerance levels:

Instrument	Leak Tolerance	Flow Tolerance	Temperature Tolerance	Pressure Tolerance	RH Tolerance
5030	<0.42 l in^{-1} (±2.5%)	4%	± 2° C	± 10 mmHg	10 %
5030i	<0.42 l in^{-1} (±2.5%)	4%	± 2° C	± 10 mmHg	10 %

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Environment Canada (EC) 2010. *Operating Procedures for BAM Samplers for PM$_{2.5}$ Monitoring in the NAPS Network*. EC National Air Pollution Surveillance (NAPS) Operations Unit.

Environment Canada (EC) 2014. Thermo SHARP5030 Monitor Operating Instructions, Environment Canada, NAPS Operations.

Thermo Fisher Scientific 2013. *Model 5030 Instruction Manual Synchronized Hybrid Ambient Real-time Particulate Monitor*.

Wood Buffalo Environmental Association (WBEA) 2013. Standard Operating Procedure, Procedures for operating continuous Thermo Scientific SHARP 5030 PM$_{10}$ and PM$_{2.5}$ Analyzers.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Dustfall and Metals**	**Standard Operating Procedure for the Sample Collection of Dustfall (Settleable Particulate Matter) and Metals**
Revision No: Original Revision Date: 05 May, 2020	**Reference No: SOP-05c Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the measurement of dustfall (settleable particulate matter), within the provincial jurisdiction of British Columbia (B.C.).

This SOP describes dustfall sample collection using a dustfall container. Subsequent analysis of the sample by an analytical laboratory is required to complete the measurement of dustfall. The laboratory analysis procedure is not covered in detail within this SOP.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Dustfall sampling within the provincial jurisdiction of B.C. must be carried out with consideration to Part B of the BCFSM, and this document.

Dustfall sampling is considered to be a relatively coarse method of measurement and is used primarily for monitoring nuisance dust. This method provides a measure of airborne substances that settle onto a surface over a period of time, rather than providing the concentration of dustfall in ambient air at a given point in time. Where monitoring objectives include the protection of human heath, monitoring of particulate matter in ambient air (PM_{10} and/or $PM_{2.5}$) would be more appropriate than monitoring dustfall.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Sampling Method

Dustfall Containment

A weather resistant open top container of known dimensions is prepared by a laboratory. The containers are cleaned and sealed by the laboratory with a measured quantity of reagent water, which acts to prevent resuspension of any material that settles into the container. At the sampling location, the container is set up on a stand and opened so that particulate matter can settle into the container. The container is left for a period of 30 days. At the end of the sampling period the container is sealed and returned to the laboratory for analysis. The laboratory analysis determines the total dustfall as the mass of the water soluble and insoluble material collected within the container. Dustfall results are reported in units of mass per area per time. Common units are milligrams per square decimeter per day ($mg/dm^2/day$).

Additional analysis can be undertaken to determine the fixed (non-organic) and volatile (organic/combustible) portions of the dustfall, and metals content.

4. Interferences

Potential interferences include precipitation (rain and snow), freezing temperatures, hot temperatures, algae growth, wildlife, and contamination by material which did not settle into the container, other debris (e.g., leaves, etc.).

Freezing

If the liquid within the container freezes, settled particulates are no longer captured by the liquid collection medium and can potentially be re-suspended, invalidating the dustfall measurement. To mitigate the potential of this type of interference the laboratory should be consulted to add an anti-freeze reagent (typically isopropyl alcohol) to the container during the preparation stage.

Precipitation

Rain and snow can collect in the container during the sampling period. The dustfall sample is invalidated if the precipitation during the sample period causes the container to overflow. To prevent this potential interference the liquid level within the sample container should be routinely checked during periods of high precipitation. If the level of the liquid rises to within 2.5 centimetres (cm) of the top of the container a new container should be deployed. In this circumstance both containers are used to determine the dustfall during the 30 day sampling period. Selecting a larger sized sampling container can also help prevent liquid overflow.

High precipitation levels can also cause dilution of the antifreeze mixture used in the container, which in turn can cause the liquid within the container to freeze and possibly damage the container. To prevent this from occurring, the laboratory can increase the ratio of antifreeze to reagent water during the container preparation.

Hot Temperatures

Consistently hot temperatures and or strong winds occurring over the sampling period may cause partial or full evaporation of the reagent water. Complete evaporation of the liquid (reagent water) renders the dustfall sample invalid. During periods when high temperatures are forecast, the reagent water within the sample container should be checked mid-way through the sampling period. If the level of the liquid falls to within 5 centimetres of the container's bottom, the container should be topped up with deionized water to reduce the risk of desiccation. Alternately, selecting a larger sized sampling container with a larger initial charge of reagent water will help prevent desiccation. It is important to note that deionized water is the only acceptable top-up liquid as other liquids may contain dissolved or suspended solids that would invalidate the sampling.

Algae growth

The dustfall measurement relies on the weight of the container's contents, therefore algae growth within the container can be an interferent. To avoid this, the laboratory can add an algaecide in the reagent water for sample events occurring during periods where temperatures are unlikely to drop below freezing. Copper sulphate may sometimes be used as an anti-algae reagent however due to the copper content in the algaecide; this reagent should not be used if the dustfall sample will undergo metals content analysis.

Wildlife

Wildlife interactions with the sampling equipment can cause interference with the dustfall measurement in a number of ways. Birds flying overhead or landing on the sample container can interfere with the collection of dustfall and inadvertently deposit materials into the sample container. Larger animals can damage the equipment, tilt the stand or knock the stand over.

Contamination

The dustfall measurement relies on the weight of the container's contents; therefore, any material that gets into the container that did not settle into the container can be an interferent. This can include material such as leaves and insects.

5. Precision and Accuracy

The precision of a measurement is generally considered to be the ‘repeatability of the measurement’.

Dustfall measurements are affected by factors during the sample collection period (such as measurement height and meteorological conditions) as well as the laboratory’s analysis method.

American Standard Test Method (ASTM), 2017 report that the use of a wind shield and setting the sample container at a collection height of 2 meters (m) (or higher) provides better precision.

The accuracy of the measurement is generally considered to be a measure of the ‘deviation from true’. Determination of precision and bias should be completed by the analytical laboratory as per their quality assurance/quality control (QA/QC) procedures. In the field duplicate sample containers should be used for every ten sample containers. For programs with less than 10 samples, at least one duplicate sample should be used.

6. Recommended Apparatus

For dustfall sampling, a container and stand are required. The following container sizes are commonly used in B.C.:

	Small Size	**Large Size**
Capacity (litres)	2	4
Height (cm)	24.2	~25
Diameter (cm)	12.0	~15
Opening (cm)	9.0	10

The sample container should be constructed of stainless steel or weatherproof plastic with a tight fitting lid. It is important to use containers that were recently shipped from the laboratory as opposed to containers that have been stored for a few months prior to deployment. This quality control step is important for the following reasons:

- The laboratory keeps a blank sample of the contents of the container,
- The type and composition of reagents in the containers vary seasonally. Reagent compositions are based on weather conditions, and;
- Reagents may change based on monitoring objectives (e.g. metals analysis).

The stand can be fabricated from wood or metal. It should hold the container firm and level at a height of at least 2 metres (to container top) above ground level (ASTM, 2017). Use of a wind shield around the container opening is recommended as a best practice. A cross section and plan view of a wind shield for dustfall sampling are provided within reference ASTM, 2017.

7. Measurement Range and Sensitivity

Analysis range and sensitivity depend on the method employed by the laboratory. The lower range of total dustfall measurement reported by a commercial laboratory is typically 0.1 mg/dm^2/day.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data obtained from the site meets the intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives. As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the location. Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

The dustfall station installation should conform to the following:

- The monitoring location should be an open area, with no structures higher than 1 m within a 20 m radius of the dustfall container.
- The container should be placed 2 m above the ground surface (2 m from ground to container opening).
- Locate the container at a distance ≥ 10 stack heights from an operating stack (unless the monitoring objectives are to specifically monitor stack impacts).
- Higher objects such as trees and buildings should not exceed 30 degrees from the horizontal as viewed from the monitoring location. This is shown in the following figure.

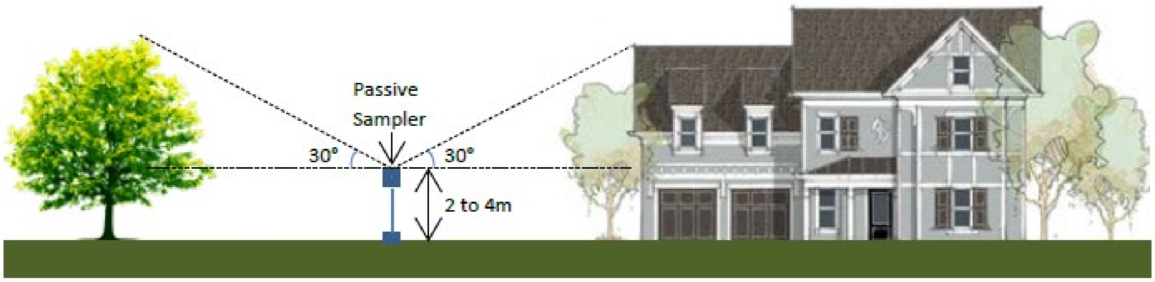

Figure reference: B.R. Irwin, ENV

10. Sampling Requirements

The following activities should be performed by the operator of a dustfall sampling program:

Action	Time/Frequency	Description	Record Keeping
Container Preparation	• Prior to installation	• Use an algaecide addition in warm months. • Use an antifreeze addition when near freezing or freezing conditions are expected during the sampling period.	• Record in logbook
Container Deployment	• At installation	• Record the date, time, location, measurement height, container opening diameter, sample identification and batch number.	• Record in logbook • Complete Chain of Custody (COC) information required by the analytical laboratory.
Maintenance During Sampling Period	• As required during the sampling period	Check liquid levels within container: • To avoid overflows, change container if the liquid level rises to within 2.5 cm of the container's top. Note on the COC if it is suspected that the container may have overflowed. • If the level of the liquid falls to within 5 centimetres of the container's bottom, the container should be topped up with deionized water to reduce the risk of desiccation.	• Record in logbook • Complete COC information required by the analytical laboratory.
Container Retrieval	• At the end of the sampling period (30 days ±2 days after deployment)	• Check for signs of animal interference, and vandalism/tampering. Check the integrity of the sample container. Report any findings.	• Record in logbook • Complete COC information required by the analytical laboratory.

		• Seal the sample: record the date, time, sample identification and batch number. • Send the sealed sample container to the laboratory for analysis. Minimize the storage period and refrigerate the sample container if submission to the laboratory is delayed.	

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

This section is not applicable to this measurement method.

13. References

Alberta Government. 2016. *Air Monitoring Directive Chapter 4: Monitoring Requirements and Equipment Technical Specifications* Version Dec 16, 2016.

American Standard Test Method (ASTM) 2017. *Standard Test method for Collection and measurement of Dustfall (Settleable Particulate Matter).* Designation: D1739 – 98 (Reapproved 2017).

Leung, T.B., Manna, B.B. 1984. *Site Selection Guidelines and Criteria for Ambient Air Monitors*. Air Quality Engineering Unit, Waste Management Branch.

Ontario Ministry of Environment. Last Accessed June 2017. *Operations Manual for Air Quality Monitoring in Ontario*. Available at https://www.ontario.ca/document/operations-manual-air-quality-monitoring-ontario-0#section-2.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Particulate Matter (PM)**	**Standard Operating Procedure for the Non-Continuous Measurement of Particulate Matter in Ambient Air – by High Volume Sampler**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-05d** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the discrete non-continuous ambient monitoring of total suspended particulates (TSP) and particulate matter of 10 µm or less in aerodynamic diameter (PM_{10}), within the provincial jurisdiction of British Columbia (B.C.).

This SOP describes particulate matter measurements using a high-volume sampler. Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs-5a through 5c and SOP-5e. Subsequent analysis of the sample filter by an analytical laboratory is required to complete the measurement of PM using this method. The laboratory analysis procedure is not covered in detail within this SOP.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a high volume sampler within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the BCFSM, the manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Sampling Method

High Volume Filter Collection and Gravimetric Mass Determination

The high-volumer sampler can be fitted with a TSP or PM_{10} inlet head to provide selective sampling of the particulate size fraction of interest. The sampler draws ambient air through the inlet head and filter which traps any particulate matter that may be present in the air stream. The sample filter is pre-conditioned, inspected and pre-weighed before sampling. The sampler draws air through the filter at a controlled flow rate of between 1.13 m^3/min^{-1} and 1.70 m^3/min^{-1}. After sampling the filter is re-conditioned and re-weighed. The difference in filter weight before and after sampling provides the mass of the particulate matter in the sampled air.

During the sampling period the elapsed sampling time is recorded. The flow rate and elapsed time are used to calculate the total sample volume in cubic meters (m^3). The mass of particulate matter and the sample volume are used to calculate the average particulate concentration in micrograms per cubic meter ($\mu g/m^3$) over the sampling period.

A high volume sampler employs one of the following types of flow control systems:

- Mass flow control system
- Volumetric flow control system
- Electronic flow controller

Mass flow controlled samplers use a hot wire anemometer probe to monitor the volumetric flow rate within the sample collection chamber and the sampler adjusts the motor speed to maintain the desired volumetric flow rate.

A volumetric flow control system uses a choke-flow orifice of a specific size that is calibrated to maintain a predetermined volumetric flow rate. The orifice is calibrated to draw constant volume under a given average temperature and pressure.

An electronic flow controller uses internal temperature and pressure sensors and a microprocessor to electronically control the motor to adjust the volumetric flow rate.

4. Interferences

Potential interferences with this sampling method include filter contamination and damage, particulate accumulation on the size selective inlet, extraneous objects, liquid aerosols, reactant residue, filter selection, motor dust, sample particulate size range, accumulated snow, flow rate variation over the sampling period and air leakage.

Filter contamination and damage

Filter contamination can interfere with measurement results. The filter should be secured and kept clean prior to filter installation. After the sampling event the filter should be removed as soon as practical. To minimize contamination it is recommended that powderless nitrile gloves be worn when handling filters. Any damage to the filter during handling will invalidate the measurement. Filter damage is commonly associated with filter media sticking to the faceplate gasket.

Particulate accumulation on the size selective inlet

Particle size selective inlets provide a stable cut-point as long as they are routinely serviced to minimize particulate accumulation on the inlet surface. Inadequate maintenance of the size selective inlet may result in a shift of the particle size cut-off, or undesired particle re-entrainment.

Extraneous objects

Objects such as insects may get drawn into the sampler and be weighed as PM.

Liquid aerosols

Liquid droplets such as fog can be drawn into the sampler and be retained by the filter. If the amount of liquid droplets is significant, the filter becomes wet and will not function as designed.

Reactant residue

A gas constituent within the sampled air may react with the filter medium, or sorb onto the filter. This action may cause a residue to be retained and weighed as PM.

Filter selection

High concentrations of ambient SO_2 and NO_2 can interfere with glass fibre filters.

Motor dust

ASTM, 2009 report that dust containing metals from sampler motors, particularly copper, can significantly contaminate samples.

Particle size range

The high volume sampling method allows particulates of up to 100 µm in diameter to be collected. Collection efficiency decreases for particles greater than 20 µm in diameter and consequently particulate sample collection can be biased to the smaller particulate sizes.

Accumulated snow

Snow can accumulate on the filter during winter conditions and special care is required for filter handling in this circumstance to ensure that particulates captured on the filter are not removed.

Flow rate variation

This interference is specific to a sample collection approach that uses an average flow rate calculated from a discrete flow rate measurement recorded at the start and end of a sampling period. Throughout the sampling period as the PM accumulates on the filter, the flow rate through the filter is gradually reduced. If at some point in the sampling period a significant drop in flow rate occurs, then the average of the flow rate at the start and end of the sampling period will not accurately represent the total sample volume. This is not a potential interference for samplers that continuously monitor and record flow rate throughout the sampling period or samplers that sense a decrease in air flow as the particulate builds up on the filter and makes adjustments to maintain the flow rate (such as a mass or electronic flow controller). Inadequate flow can also result from voltage loss in extension cords. When using extension cords for sampler power, 12 gauge wire is recommended and extra care is required when using extension cords beyond 15 metres.

Air Leakage

If the faceplate gasket is improperly sealed (e.g. due to deterioration, dirt or improper installation) the measurement will be invalidated.

5. Precision and Accuracy

The precision of an analysis is generally considered to be the 'repeatability of the measurement'.
ASTM, 2009 report that the relative standard deviation (coefficient of variation) for multi-laboratory variation is 3.7%.

The accuracy of an analysis is generally considered to be a measure of the 'deviation from true'. The accuracy of this method is unknown.

6. Recommended Equipment and Apparatus

The following instruments are commercially available and suitable for use within the provincial jurisdiction of B.C.:

- Ecotech HiVol 3000 High Volume Air Sampler
- Tisch Environmental High Volume Air Sampler (Various models including mass flow controlled, volumetric flow controlled and electronic based controller)

Note that different makes/models allow for different data collection and recording over the sampling period. Some samplers allow for documentation of flow rate at the start and end of the sampling period, whereas other samplers provide a continuous record of operating parameters throughout the sampling period using either a chart recorder or electronic datalogger. A sampler's data collection and recording capabilities should be considered during equipment selection to ensure monitoring objectives are met. Samplers that provide a continuous record of operating parameters during sample collection are preferred over samplers that only allow for documentation of flow rate at the start and end of sampling.

A calibrator kit is required to calibrate the sampler.

Filters should generally:

- collect more than 99% of TSP that passes through,

- be strong enough to minimize leaks,
- not react with the air or particulate passing through it,
- be thermostable (i.e. not have differing efficiencies based on temp fluctuation), and;
- not contain high levels of the targeted compound to be monitored.

There are a variety of filter types with differing effectiveness relative to these criteria. In selecting the appropriate filter it is important to take into account the monitoring environment, monitoring objectives and required filter analysis. Generally a glass-fibre filter is used, however, silica fiber filters, cellulose paper and polyvinyl chloride (PVC) filters can be used depending on the analysis required. If further metals analysis on the sample filter is required, a TX40 (Teflon coated glass fibre filter) is recommended. A glass fibre filter is not recommended if analysis to determine silica content is required. Some sampler types (such as the Ecotech) use a filter cassette to hold the filter in place.

This list does not necessarily exclude other commercially available high volume air samplers. It is highly recommended however that you consult with B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy a non-continuous PM sampler that is not listed above. Regardless of the instrument deployed, all samplers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

By using different sample inlets, high volume samplers can be used to collect TSP and PM_{10} samples.

ASTM, 2009 report that the minimum amount of particulate detectable is 3 milligrams (mg). For a sampler operated at an average flow rate of 1.70 m^3/min, this results in a lower concentration limit of 1 to 2 µg/m^3. B.C. ENV, 2013 report that an estimated upper concentration is at least 780 µg/m^3 and 420 µg/m^3 for TSP and PM_{10} respectively.

8. Site Requirements

Sampling site specifications should be developed to ensure that the data obtained from the site meets the intended or established sampling objectives. It is recommended that sampling site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with sampling objectives. As a preliminary guideline site selection should consider and address: sampling objectives, representativeness of the region, interference from the surrounding area, zone type (residential, commercial, industrial) of the location. Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

Follow sampler specific installation requirements discussed in the manufacturer's manual. The installation should also conform to the following:

- The sampler inlet should be located at a height of 2 m to 7 m above ground level.
- If the sampler is located on a roof or other structure the inlet should be at least 2 m from walls or parapets and not near any building vents or flues.
- The sampler should be located away from structures such as trees and buildings. The distance between any obstacle and the sampler should be at least twice the height of the obstruction.
- There should be unrestricted flow in 3 of the 4 wind quadrants.
- The appropriate size fraction separator should be installed onto the instrument for PM_{10} monitoring.
- The sampler should be located away from localized sources of particulate that could influence monitoring results such as unpaved roads and temporary generators unless identified as a source of interest when establishing the site's monitoring objectives.
- If the sampler has a motor and a metals analysis of the sample is required, consideration should be given to venting the exhaust motor away from the sample inlet.
- High volume samplers draw a considerable amount of electricity and care to select an appropriate extension cord is required. Extension cords should not exceed 15 metres and be constructed with 12 gauge conductors (wire). Ensure power is supplied in a manner consistent with all applicable electrical codes. Consider installing dedicated power for extended sampling programs (e.g., outlet with cover at sampler).

10. Operational Requirements

Follow instrument specific operational requirements discussed in the manufacturer's manual. Exact requirements will vary by sampler, however in general the following activities should be performed by the operator of a high volume sampler:

Action	Time/Frequency	Description	Record Keeping
Sampling Frequency	▪ At installation	• Sampler to operate every 6th day on the North American standard, unless an alternative schedule has been agreed with the B.C.	• Record in logbook
Sampling Period	▪ At installation	• Samples should be collected over a 24 hour period (midnight to midnight).	• Record in logbook
Sampling Start	▪ At the start of each sample period	• Perform flow verification to verify the flow rate is within 1.13 to 1.70 m^3/min. If the flow rate is outside this range a calibration should be performed. • Use filter within 30 days of conditioning by the laboratory. • Record sampler ID, filter ID's and date. • Record start time, flow rate, ambient temperature and ambient pressure	• Record in logbook • Complete Chain of Custody (COC) information required by the analytical laboratory
	▪ After each use	• Clean as per manufacturers operation manual • Inspect inlets and clean if required. • Inspect the filter screen and remove any foreign deposits. • Inspect the faceplate gasket and ensure it is clean and in good condition to allow a correct seal. Do not overtighten the faceplate gasket as filter damage may occur.	• Record in logbook
Data Retrieval	▪ At filter retrieval	• Visually check for any leaks, damage or other possible interferences during the sampling period (e.g. vegetation clearing occurred).	• Record in logbook

		• Retrieve filter within 5 days of the sampling event. • Record end and elapsed time, flow rate, sample volume, ambient temperature and ambient pressure.	• Complete COC information required by the analytical laboratory
Routine checks and Maintenance	▪ Every 400 to 500 running hours	• Check motor brushes and change if required (for samplers that have motor brushes)	• Record in logbook
	▪ Every 1500 running hours or after replacing motor brushed two times	• Replace motor	
	▪ Every 800 running hours	• Inspect top and bottom motor gaskets and replace if necessary. • Inspect flow meter tubing and replace if necessary. • Check Rotameter and clean if required (for samplers that have rotameters)	
Calibration	▪ At installation ▪ After the sampler fails for any reason ▪ After maintenance or change of motor or motor brushes ▪ After a flow verification indicated that the flow is outside of the acceptable range. ▪ After the manufacturer's specified number of sampling hours. ▪ At least quarterly	▪ As per Section 12 of this SOP	• Record in logbook

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

Calibration should be performed following the manufacturer's manual and in accordance with Section 6 of Part B1 of the BCFSM. Certain aspects specific to the high volume sampler's calibration are included in this section. Exact calibration procedures will vary by sampler make/model and type, for example calibration procedures vary between mass flow controlled and volumetric flow controlled samplers.

Several parameters require calibration including flow, ambient temperature, ambient pressure, clock and date. The calibration procedure comprises the following sequential steps:

- Step 1 – Leak check As-found verification of flow, temperature and pressure
- Step 2 – As-found verification of flow, temperature and pressure
- Step 3 – Multi-point verification; calibrate if necessary.
- Step 4 – As-left verification

Step 1, leak checks (internal and external) are undertaken to ensure there are no leaks in the sample train before undertaking a calibration. In Step 2 verification is used to confirm that samples obtained prior to this check were collected under valid conditions. The verification comprises a check against a known standard. The flow verification should be performed using a flow meter which is calibrated or certified annually against a NIST traceable standard. Similarly, temperature and pressure verification should be performed using a temperature and pressure standard which is calibrated or certified annually against a NIST traceable standard.

The pass criteria for all parameters for Steps 1 and 2 are provided in the following table.

Parameter	Pass Criteria
Flow	Between 1.13 m^3/min to 1.70 m^3/min with a correlation coefficient of 0.990 or better.
Temperature	As stated within the manufacturers manual for a specific sampler.
Ambient pressure	As stated within the manufacturers manual for a specific sampler.
Clock and date verification check	Clock should be within ±2 minutes of standard time, and the date should be correct.
Leak check	No air leakage detected by operator

Parameters that do not meet the pass criteria in the table above should be adjusted in Step 3. After adjustment a final verification (Step 4) is undertaken to confirm parameters are within the required criteria.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alaska Department of Environmental Conservation 2011. *Standard Operating Procedures for Lead monitoring Using a TSP High-Volume Sampler*. Division of Air Quality Air Monitoring and Quality Assurance Section.

American Standard Test Method (ASTM) 2009. *Standard Test Method for Determination of Total Suspended Particulate Matter in the Atmosphere (High-Volume Sampler Method)*. Designation D4096-91 (Reapproved 2009).

Ministry of Water, Land and Air Protection 2013. *British Columbia Field Sampling Manual Part B Air and Air Emissions Testing.* Water, Air and Climate Change Branch.

EcoTech 2013. *HiVol 3000 High Volume Air Sampler User Manual*. Version 1.8.

Environment Canada 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

State of California Air Resources Board 2008. *Air Monitoring Quality Assurance Volume V Audit Procedures for Air Quality Monitoring Appendix D Performance Audit Procedures for High Volume Samplers*. Monitoring and Laboratory Division.

State of California Air Resources Board 1992. *Standard Operating Procedures for Air Quality Monitoring Appendix E High Volume Sampler*. Monitoring and Laboratory Division.

Tisch Environmental not dated. *Operations Manual TE-5170 Total Suspended Particulate Mass Flow Controlled High Volume Air Sampler.*

United States Environmental Protection Agency (US EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

US EPA 1999. *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.

United States Code of Federal Regulations 2013. *Title 40 Part 58 Appendix E, Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring.* Prepared by the US Government Publishing Office.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Particulate Matter (PM)**	**Standard Operating Procedure for the Non-Continuous Measurement of Particulate Matter in Ambient Air Using a Low Flow Rate Sampler**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-05e** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for discrete non-continuous ambient monitoring of total suspended particulate (TSP), particulate matter of 10 microns (µm) or less in aerodynamic diameter (PM_{10}), and particulate matter of 2.5 µm or less in aerodynamic diameter ($PM_{2.5}$), within the provincial jurisdiction of British Columbia (B.C.).

This SOP describes particulate matter (PM) measurements using a low flow rate sampler, (e.g., Partisol™). Subsequent analysis of the sample filter by an analytical laboratory is required to complete the measurement of PM. The laboratory analysis procedure is not covered in detail within this SOP.

Operating guidelines and instructions for particulate matter measurements using other analytical methods are provided in SOPs 5a through 5d.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a low flow rate sampler within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the BCFSM, the equipment manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca

3. Principle of the Measurement Method

Low Flow Rate Filter Collection and Gravimetric Mass Determination

The Sampler can be fitted with a TSP, PM_{10} or $PM_{2.5}$ inlet head to provide selective sampling of the particulate size fraction of interest. The Sampler draws ambient air through the inlet head and a 47 millimeter (mm) diameter sample filter, which traps the particulate. The sample filter is pre-conditioned, inspected and pre-weighed before sampling. After sampling the filter is reconditioned and reweighed. The difference in filter weights provides the mass of the target size particulate that accumulated on the filter during the sampling period. The Sampler draws air through the filter at a controlled flow rate of 16.67 liters per minute ($l\ min^{-1}$). During the sampling period the elapsed sampling time is recorded. The flow rate and elapsed time are used to calculate the total sample volume in cubic meters (m^3). The mass of the accumulated particulate and sample volume are used to calculate the average particulate concentration in micrograms per cubic meter ($\mu g/m^3$) over the sampling period.

The Partisol™ model 2025i is equipped to exchange sample filters automatically at a pre-set time interval, and a capacity of 16 filter cassettes. A dichotomous version of this Sampler provides dual sample trains that sample both PM_{10} and $PM_{2.5}$ simultaneously in the same unit.

4. Interferences

Filter contamination can interfere with measurement results. The filter should be secured and kept clean prior to installation. After the sampling event the filter should be removed as soon as practical. To minimize contamination it is recommended that powderless nitrile gloves are worn when handling filter cassettes.

Any damage to the filter during handling will invalidate the measurement.

5. Precision and Accuracy

Since particulate measurement relies on pre-sampling and post-sampling filter weights any contamination of the filter can lead to invalid results.

One blank filter should be submitted to the laboratory with each shipment of sampled filters. The blank filter is a 'trip blank' and as such should remain in the holder/petri dish and be returned to the laboratory with the same batch of filters it was received with. It is recommended that you consult with your laboratory to determine if your particular monitoring objectives should also include a field blank.

6. Recommended Equipment and Apparatus

The following instruments are commercially available and suitable for use within the B.C. ENV's jurisdiction:

- Thermo Scientific Partisol™ Model 2025i and 2025i-D
- Thermo Scientific Partisol™ Model 2000i and 2000i-D
- Thermo Scientific Partisol™ Model Plus 2025 and 2025D
- Thermo Scientific Partisol™ Model 2000-D
- Thermo Scientific Partisol™ Model 2000-FRM
- Rupprecht & Patashnick Partisol™ Model 2000

Generally, a 47 mm Teflon filter is used for $PM_{2.5}$ sampling and a TX40 (Teflon coated glass fibre), quartz fibre or Teflon materials are used for PM_{10} and TSP sampling. However; if further analysis (e.g. metals analysis) on the sample filter is required, a different filter type may be recommended by the analytical laboratory.

This list does not necessarily exclude other commercially available non-continuous PM filter Samplers, and Samplers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. It is recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy a non-continuous PM Sampler that is not listed above. Regardless of the instrument deployed, all Samplers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

By using different sample inlets, low flow rate samplers can be used to collect TSP, PM_{10} and $PM_{2.5}$ samples.

The lower range of particulate concentration resulting from this method of sampling is typically around 2 $\mu g/m^3$. Environment Canada reported in 2008 that the upper concentration limit is at least 200 $\mu g/m^3$ for $PM_{2.5}$ sampling at a flow rate of 16.7 $l\ min^{-1}$ over a sampling period of 24 hours.

8. Site Requirements

Sampling site specifications should be developed to ensure that the data obtained from the site satisfies the requirements of intended or established sampling objectives. It is recommended that sampling site requirements be established in consultation with ENV to ensure that siting requirements are commensurate with sampling objectives.

As a preliminary guideline, site selection should consider and address: sampling objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the location.

Refer to Section 2 of Part B1 of the B.C. Field Sampling Manual for further information on site selection.

9. Installation Requirements

Follow the installation requirements provided in the manufacturer's manual. The installation should also conform to the following:

- The Sampler inlet should be located at a height of 2 m to 7 m above ground level.
- If the Sampler is located on a roof or other structure the inlet should be at least 1 meter from walls or parapets and positioned away from building vents or flues.
- The Sampler should be located away from structures such as trees and buildings. The distance between any obstacle and the Sampler's inlet should be at least twice the height of the obstruction.
- The Sampler should be located in a position that accommodates an unrestricted air flow in 3 of the 4 wind quadrants.
- The appropriate size fraction separator must be installed onto the instrument for the particulate size fraction of interest.
- The tube connecting the size selective inlet to the filter compartment should be vertical with no bends.
- The Sampler should be located away from localized sources of particulate such as unpaved roads that could influence monitoring results unless identified as a source of interest when establishing monitoring objectives.

10. Operational Requirements

Follow instrument specific operational requirements discussed in the manufacturer's manual. Exact requirements will vary by Sampler, however in general the following activities should be performed by the operator of a low flow rate Sampler:

Action	Time/Frequency	Description	Record Keeping
Sampling Frequency	▪ At installation	• Sampler to operate every 6th day on the North American standard, unless an alternative schedule has been agreed with by the B.C. ENV.	• Record in logbook
Sampling Period	▪ At installation	• Samples should be collected over a 24 hour period (midnight to midnight).	• Record in logbook
Filter Cassettes	▪ At installation	• Use filters within 30 days of conditioning by the laboratory. • Record Sampler ID, filter and cassette ID's and date.	• Record in logbook • Complete Chain of Custody (COC) information required by the analytical laboratory
	▪ After each use	• Clean cassette as per manufacturer's operation manual. • Inspect the rubber seals and replace if necessary.	• Record in logbook
Data retrieval	▪ At filter retrieval	• Retrieve filter within 5 days of the sampling event. • Record end and elapsed time, sample volume, filter temperature, ambient temperature (minimum, maximum and average), and ambient pressure.	• Record in logbook • Complete COC information required by the analytical laboratory

Routine checks	- Weekly	- Check water trap on PM_{10} inlet and empty if required.	- Record in logbook
	- Quarterly - Prior to calibration	- Verification (as-is check) as per manufacturer's operation manual for flow, pressure, temperature, date and clock. - If any of the parameters are outside of the pass criteria listed in the table provided in Section 12 of this SOP, a calibration should be performed. - Perform leak check. - Inspect inlets and impactor; clean if required. - Lubricate O-rings. Inspect and replace if required. - Lubricate V seals on the $PM_{2.5}$ inlet. Inspect and replace if required.	
	- Bi-annual	- Inspect Sampler interior, inlet and impactor and clean if required. - Check the in-line filter and replace if required. - Perform calibration (temperature, pressure, flow and clock).	
	- Annual	- Replace the in-line filter. - Rebuild the pump. - Check the clock battery and replace if required. - Temperature, pressure and flow rate verification check standards should be calibrated against a National Institute of Standards and Technology (NIST) traceable standard.	
Internal/External Leak check	- Monthly - Prior to bi-annual inspection (of Sampler interior, inlet and impactor) - Prior to calibration	- Perform Internal and external leak check as per the manufacturer's operation manual.	- Record in logbook
Calibration (temperature, pressure, flow, clock)	- At installation - Bi-annually	- As per Section 12 of this SOP - If the temperature or pressure sensor requires calibration (adjustment) then the flow must be verified and recalibrated.	- Record in logbook

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the BCFSM and the manufacturer's manual. The following instructions and information are specific to low flow rate Sampler calibration.

Several parameters require calibration including flow, temperature, ambient pressure, clock and date. The calibration procedure comprises the following sequential steps:

- Step 1 – Leak check
- Step 2 – As-found verification of flow, temperature and pressure
- Step 3 – Multi-point verification; calibrate if necessary
- Step 4 – As-left verification

Step 1, leak checks (internal and external) are undertaken to ensure there are no leaks in the sample train before undertaking a calibration. In Step 2 verification is used to confirm that samples obtained prior to this check were collected under valid conditions. The verification comprises a check against a known standard. The flow verification should be performed using a flow meter which is calibrated or certified annually against a NIST traceable standard. Similarly, temperature and pressure verification should be performed using a temperature and pressure standard which is calibrated or certified annually against a NIST traceable standard. The pass criteria for all parameters for Steps 1 and 2 are provided in the following table.

Parameter	Pass Criteria
Flow	±4% of 16.7 l min^{-1} (between 16.00 l min^{-1} and 17.34 l min^{-1})
Temperature	±2 °C from true
Ambient pressure	±10 mmHg from true
Relative Humidity	±10%
Clock and date verification check	Clock should be within ±2 minutes of standard time, and the date should be correct.
Leak check	As per instrument manual

Parameters that do not meet the pass criteria in the table above should be adjusted in Step 3. After adjustment a final verification (Step 4) is undertaken to confirm parameters are within the required criteria.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control.

Environment Canada 2008. *Method for the measurement of PM10 Concentration in Ambient Air Using Filter Collection*. Environment Canada Environmental Science and Technology Centre.

Environment Canada 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

Environment Canada 2012. *National Air Pollution Surveillance (NAPS) Network Reference Method for the Measurement of PM2.5 Concentration in Ambient Air Using Filter Collection and Gravimetric Mass Determination*. Air Quality Research Division.

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Measurement of Particulate Matter in Ambient Air Using the Partisol 2000H.* AENV Air Monitoring and Audit Centre.

California Environmental Protection Agency Air Resources Board (CARB) 2016. *Standard Operating Procedures for Thermo Scientific Partisol Model 2025i Sequential Air Sampler*. AQSB SOP 404, Second Edition.

Thermo Scientific 2015. *Partisol 2025i Sequential Air Sampler/Partisol 2025i-D Dichotomous Sequential Air Sampler Instruction Manual.*

United States Code of Federal Regulations 2013. *Title 40 Part 58 Appendix E, Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring.* Prepared by the US Government Publishing Office.

United States Environmental Protection Agency (US EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Sulphur Dioxide (SO_2)**	**Standard Operating Procedure for the Continuous Measurement of Ambient SO_2**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-06** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instruction for the continuous ambient monitoring of Sulphur Dioxide (SO_2) within the provincial jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of an SO_2 analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer’s manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Ultraviolet fluorescence

The principle detection and quantification method deployed for the measurement of ambient concentrations of SO_2 involves ultraviolet (UV) fluorescence and a photomultiplier tube.

$$SO_2 + hv_1 \rightarrow \text{excited state } SO_2 \rightarrow SO_2 + hv_2$$

The concentration of SO_2 in a sample of ambient air is quantified as a measure of ultraviolet (UV) fluorescence absorbed by the SO_2 molecules in the sample. A bulb within the analyzer emits the UV rays which are absorbed by the SO_2 molecules at a wavelength of 214 nm. The absorption of UV rays causes the SO_2 molecules to transition to an excited state. As the excited state SO_2 molecules return to their normal state they release energy by emitting UV light at a wavelength of 330 nm. The SO_2 analyzer measures the amount of UV light present at a wavelength of 330 nm using a photo multiplier tube. The measurement of 330 nm UV rays is then used to quantify the concentration of SO_2.

A more detailed discussion on the SO_2 measurement principle is typically provided within the manufacturer’s operation manual.

4. Interferences

As the principle method of measuring the concentration of SO_2 relies on the measurement of ultraviolet (UV) fluorescence, compounds that emit UV rays at similar wavelengths may, if present, interfere with the measurement of SO_2. Compounds such as Nitric Oxide (NO), hydrocarbons, Ozone (O_3), Carbon Dioxide (CO_2) and water (H_2O) emit UV rays at similar wavelengths and as such have the potential to interfere with SO_2 measurements.

Hydrocarbons

To minimize interference from hydrocarbons, SO_2 analyzers can be equipped with a hydrocarbon scrubber.

NO

The presence of NO compounds at sufficiently high concentrations can result in a detectable interference in SO_2 measurement. The use of optical filters can greatly reduce this interference by limiting the wavelength emitted by the UV bulb and the wavelength of the photomultiplier tube (PMT) to those specific to SO_2 absorption and emission. Greater interference can be observed when measuring trace levels of SO_2 when sufficiently high concentrations of NO are present in ambient air. If typical ambient levels of NO are known to be high relative to SO_2, particularly for trace level analyzers, it is recommended that the analyzer be tested for its degree of sensitivity to NO using span gas at concentrations of 600 ppb to 800 ppb NO.

O_3

Although current analyzers are equipped to reduce interference caused by O_3 it's important to recognize this potential interference. O_3 interferes with the measurement of SO_2, due to its absorption of a broad wavelength range of UV light. To counteract this interference the wavelength of the PMT is kept to a short light path.

Particulate Matter

The presence of particulate matter in an air sample may to interfere with SO_2 measurement. This can be minimized by using a particle filter of 5 µm pore size (for analyzers that do not have an internal filter). The filter must be made of an inert material such as Teflon and should be installed at the sample inlet.

Chemical Reactions

Chemical reactions between SO_2 and NO, CO_2, and H_2O are reported to have negligible interference.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of a sensor can be evaluated and adjusted by performing a calibration against a certified sulphur dioxide calibration standard mixture (See sections 11 and 12 below). Accuracy can also be evaluated through span checks and calibrations.

6. Recommended Equipment and Apparatus

The following instruments are commercially available SO_2 analyzers deemed to be suitable for use within the provincial jurisdiction of B.C.:

- Thermo Environmental Instruments (TEI) Models 43i SO_2 Analyzers.
- Teledyne API T200
- Ecotech EC9850T

This list does not necessarily exclude other commercially available SO_2 analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy SO_2 analyzers not listed above. Regardless of the equipment deployed all analyzers must meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available SO_2 analyzers can operate at a user selectable range of 0 ppb to 1000 ppb. For B.C. ENV monitoring purposes the range should be set at 0 ppb to 200 ppb or 0 ppb to 500 ppb. In areas where high SO_2 concentrations are likely to exist consult with B.C. ENV to establish an appropriate range to capture peak ambient concentrations.

Detection limits are determined by instrument type but are generally around 0.3 ppb.

8. Site Requirements

Monitoring site requirements should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with the monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type of the monitoring location (residential, commercial, industrial).

Refer to Section 2 of Part B1 of the B.C. Field Sampling Manual for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements provided in the analyzer manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- All connection tubing, connectors and fittings from the manifold to the analyzer inlet must be made of Teflon or a material of equivalent chemical inertness.
- A Teflon particulate filter capable of removing at least 99% of 1 micron and larger particles must be placed in the sampling line upstream of the analyzer, unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel).
- A data acquisition system (data logger) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a temperature controlled, temperature stable enclosure. The enclosure's temperature must be maintained between 20 °C to 30 °C.
- Remove any sources of solvents and volatile hydrocarbons from the vicinity of the station.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated SO_2 analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. Monitoring range should be 0 ppb to 500 ppb	▪ Record in logbook

Multipoint Verification	▪ After installation (or relocation) following a 24 hour warm up period; ▪ For new analyzers, after the first 3 months of operation; ▪ After analyzer repairs/maintenance that may have affected the performance of the instrument; ▪ When the span check is less than or is equal to ± 10 % of reference value; ▪ When the zero check exceeds ± 1.0 ppb; ▪ Quarterly required if using weekly zero/span checks. A maximum 6 month interval is permissible if using daily zero/span checks.	▪ As per Section 6 of Part B1 of the BCFSM	▪ Record in logbook
Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual	▪ Record in logbook
Verify Operational Parameters	▪ Each station visit	▪ As per manufacturers operation manual	
Inlet Filter Change	▪ Inspect monthly, change as required	▪ As per manufacturers operation manual	
Analyzer Maintenance	▪ As recommended by manufacturer or as required	▪ As per manufacturers operation manual	▪ Record in logbook
Sample Path Inspection (Probe to Analyzer)	▪ Monthly	▪ Where necessary replace with new lines, tighten loose connections, clean manifold as required	▪ Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify the analyzers performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer’s manual.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer’s manual.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Measurement of* SO_2 *by* SO_2 *Fluorescence*. AENV Air Monitoring and Audit Centre.

AENV 2011. *Standard Operating Procedure for Dilution Calibrations*. AENV Air Monitoring and Audit Centre.

Environment Canada (EC) 2010. *Continuous Measurement of Sulphur Dioxide* (SO_2) *in Ambient Air by UV Fluorescence*. EC National Air Pollution Surveillance (NAPS) Operations Unit.

Thermo Fisher Scientific 2015. *Model 43i Instruction Manual Pulsed Fluorescence SO_2 Analyzer*.

EC 2004. *NAPS Network Quality Assurance and Quality Control Guidelines*. EC Environmental Protection Service Environmental Technology Advancement Directorate Analysis and Air Quality Division. Report No. AAQD 2004-1.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Various Compounds**	**Standard Operating Procedure for the Passive/Diffusive Method of Air Sample Collection**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-07** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the passive (diffusive) measurement of air compounds within the provincial jurisdiction of British Columbia (B.C.).

This SOP describes passive sample collection. Subsequent analysis of the sample by an analytical laboratory is required to complete the measurement of the target air compound. The laboratory analysis procedure is not covered in detail within this SOP.

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Passive sampling within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the BCFSM, and this document.

Passive monitoring is a diffusive sampling method that is generally used to determine low level concentrations of air compounds over a sampling period that ranges between 24 hours to 30 days. This sampling method is suitable for remote locations as the method itself does not require electricity. A thirty day sampling period is recommended as a nominal passive sampling period. For monitoring objectives designed to consider concentrations measured at shorter time scales, or those designed to measure concentrations that are expected to exceed the high or low thresholds of the passive samplers, active monitoring of ambient air concentrations would provide a more appropriate sampling method.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.
This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Sampling Method

Passive Samplers

A passive sampler is a simple device capable of sampling gaseous compounds in ambient air via diffusion or permeation. Passive sampling does not require active movement of air through the sampler. Gaseous compounds, if present in the ambient air, diffuse through a static air layer or permeate a membrane. Samplers are generally specific to one target compound.

Samplers for the following compounds are commercially available:

- speciated volatile organic compounds (VOCs) including benzene,
- aldehydes, ketones, and phenolics,
- chlorinated compounds,
- alcohols,

- sulphur dioxide (SO_2),
- hydrogen sulphide (H_2S),
- nitrogen dioxide/oxides of nitrogen (NO_2/NO_X),
- ozone (O_3),
- ammonia (NH_3), and;
- nitric acid (HNO_3).

Regardless of the target compound this method deploys a sampler body or sampling tube of known dimensions that is prepared by a laboratory. Sampler bodies and sampling tubes contain a diffusion barrier and a chemical-specific sampling media. At the sampling location, the sampler housing is set up on a stand and the sampler bodies or tubes are taken out of their protective containers and installed in the housing. The passive samplers are normally exposed for a period of 30 days although this may vary depending on the requirements of the sampling program. Sample trip blanks (unopened samplers) and duplicate samples are deployed and returned to the laboratory as part of the same batch. A duplicate sample should be deployed for every 10 samples. Where possible one passive station in a network should be co-located with a reference method or equivalent.

At the end of the sampling period, the sampler bodies or tubes are placed within their protective containers and sealed plastic bags and returned to the laboratory for analysis. The laboratory analysis determines the average concentration of the compound over the sampling period. Average regional or local meteorological conditions (temperature, relative humidity, and wind speed) for the sampling period are generally required for accurate analysis of the passive concentrations. Common measurement units are parts per billion (ppb).

4. Interferences

Potential interferences include precipitation, particulate matter contamination, physical damage to the sampler body or membrane, siting exposure that differs from the meteorological data representing station conditions, and contamination by incidental exposure to the target compound that was not part of the ambient environment.

Precipitation

Wetting can damage the passive sampler media, or may introduce dissolved gases to the sampler media resulting in inaccurate measurements. To prevent precipitation interference passive samplers should be installed facing downwards and within a housing equipped with a rain shelter; or deployed in a similar manner which will prevent wetting of the media.

Particulate Matter

Air compounds may be absorbed by particulate matter, resulting in inaccurate measurements if particulate matter is allowed to settle on the sampler media. To prevent this, passive samplers should be installed facing downwards in a housing or deployed in a similar manner which will prevent the settling of suspended particulate matter on the media.

Physical Damage

The diffusion barrier on passive samplers is delicate and can be easily damaged if handled improperly. Proper care must be taken to avoid touching the diffusion barrier during deployment or retrieval of the samplers. Samplers should be positioned in a location where they are unlikely to be damaged by wildlife.

Siting Exposure

Passive samplers must be deployed in a setting which has similar meteorological characteristics to the meteorological station data used to determine the concentrations of target compounds. A white housing will generally be appropriate to minimize the effects of solar radiant heating. Excessive winds can interfere with sampling. This can be minimized by using a sample housing.

Contamination

Passive samplers must be left in their protective containers and stored according to laboratory specifications to prevent the uptake of compounds when not deployed, e.g., in transit. Contact with the diffusion barrier when handling must be prevented to avoid contamination of the samplers. Sample blanks must not be opened, and should remain in their protective containers throughout the sampling period. Sample blanks must be treated similarly to the deployed samplers throughout the sampling program, and placed in a similar temperature environment as the deployed samplers during the sampling period.

5. Precision and Accuracy

Passive sampling measurements are affected by factors such as measurement height and meteorological conditions during the sample collection period as well as the laboratory's analytical method.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. The accuracy of the measurement is generally considered to be a measure of the 'deviation from true'. Determination of precision and bias should be completed by the analytical laboratory as per their quality assurance/quality control (QA/QC) procedures. In the field, one duplicate passive sample and one method blank should be deployed for every batch of 1 to 10 passive samplers, and all samplers should be deployed as per Section 9 'Installation Requirements'.

6. Recommended Apparatus

For passive sampling, a sampler body with a diffusion barrier and stand are required. A sampler housing and rain shield are recommended unless the sampler body can be mounted in a configuration that effectively mitigates or eliminates the potential for interference. Passive sampler housings provided by laboratories often double as a rain shield.

To prevent contamination, the samplers should be stored and transported in protective cases which are themselves kept within a sealable plastic bag. It is important to use samplers when shipped from the laboratory and then return them to the laboratory soon after retrieval for the following reasons:

- The samplers have a pre-exposure storage life ranging from a few weeks to a few months
- The samplers have a post-exposure storage life ranging from a few weeks to a few months

For a given network and monitoring period, it is important to use samplers, including blanks and duplicates, from the same laboratory batch to eliminate variability from sampler manufacture.

The stand can be fabricated from wood or metal, or could be an existing structure that does not prevent the proper sampling of air compounds (i.e. an existing fence post).

7. Measurement Range and Sensitivity

Analysis range and sensitivity depend on the method employed by the laboratory and by the compound being monitored. The lower range of passive detection limits reported by a commercial laboratory is typically on the order of 1 ppb to 10 ppb for a 24-hour exposure, to 0.01 ppb to 0.1 ppb for a 30-day exposure. Maximum sample concentrations are in the order of 20 ppb to 100 ppb. The sampling rate is moderately sensitive to meteorological conditions, and these must be taken into account.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data obtained from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. Ministry of Environment and Climate Change Strategy (ENV) to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline, site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the location.

Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

The passive sampling station installation should conform to the following:

- The sampler housing shall be mounted to a supporting structure in accordance with the manufacturer's specifications and in a configuration that ensures that there is no restriction to airflow.
- The sampler must be deployed in a manner that prevents the diffusion barrier from becoming wet, protects the diffusion barrier from the precipitation of suspended particulates, and protects the diffusion barrier from high wind speeds (i.e. use a housing/rain shield).
- The sampler housing shall be placed so that the diffusion barrier of the sampler body is at a height of 2 m to 4 m above ground surface.
- Co-located samplers should be within a 4 m horizontal distance of each other.
- Passive samplers within a monitoring network should be positioned at the same sampling height.
- Higher objects such as trees and buildings should not exceed 30 degrees from the horizontal plane of the sampler body as illustrated in the following figure.

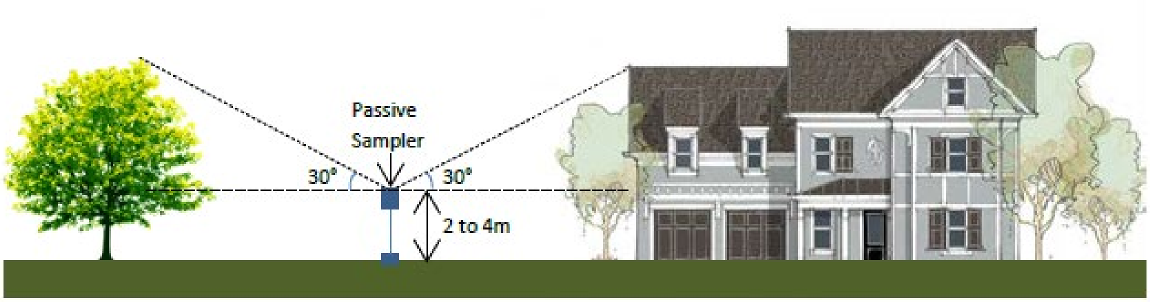

Figure reference: Blair R. Irwin, ENV 2018

10. Sampling Requirements

The following activities should be performed by the operator of a passive sampling program:

Action	Time/Frequency	Description	Record Keeping
Sampler Storage	• Prior to or after installation	• Store in a cool location out of direct light. Store samplers and method blanks together. Do not open storage containers outside of the deployment period.	n/a
Sampler Deployment	• At installation	• Record the date, time, location, measurement height, and sample identification and batch number; record sample identification on the sampler body.	• Record in logbook; record sample ID on sampler body. • Complete Chain of Custody (COC) information required by the analytical laboratory.
Sampler Retrieval	• At the end of the sampling period (30 days ±4 days after deployment, unless otherwise determined)	• Check for signs of damage/tampering. Check integrity of samplers. • • Place the protective cap on the sampler, return the sampler to its protective	• Record in logbook. • Complete COC information required by the analytical laboratory.

		container, place in a sealable bag, and record the date, time, and sample identification number at the time of sample collection. - Send to laboratory for analysis. Minimize storage period.	

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

This section is not applicable to this measurement method.

13. References

Alberta Government. 2016. *Air Monitoring Directive, Chapter 3: Ambient Monitoring Site Selection, Siting Criteria and Sampling System Requirements.* Version Dec 16, 2016.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Ammonia (NH_3)**	**Standard Operating Procedure for the Continuous Measurement of Ambient NH_3**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-08** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Ammonia (NH_3) within the jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of NH_3 analyzers within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been reviewed by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Chemiluminescence

The principle detection and quantification method deployed for ambient concentrations of NH_3 is chemiluminescence. NH_3 measurement is based on the same principle deployed for nitrogen dioxide (NO_2) measurement. A photomultiplier tube is used to measure the light (hv) emitted by the chemical reaction of nitric oxide (NO) and ozone (O_3).

$$NO + O_3 \rightarrow NO_2 + O_2 + hv$$

This method involves two measurement processes. The first process measures the total amount of nitrogen in the ambient air sample, which includes the nitrogen within NH_3, NO_2, and NO. The second process measures the amount of NO and NO_2 (collectively referred to as NO_X). The concentration of NH_3 is then calculated as the difference between the two measurements.

First Process – Total Nitrogen Measurement

In the first process, the total nitrogen concentration is determined by passing an ambient air sample through a high temperature (approximately 750 °C) chamber which converts both NH_3 and NO_2 to NO. In a subsequent reaction chamber the converted NO molecules and original NO molecules present in the air sample react with O_3. When exposed to O_3, the converted NO molecules and original NO molecules are readily oxidized to NO_2 in a 1:1 relationship. As excited NO_2 decays to a lower energy state it releases infrared light with an intensity that is linearly proportional to the amount of NO. The infrared light emitted during this chemical reaction is measured using a photomultiplier tube. The infrared light measurement is used to determine the concentration of total nitrogen.

Second Process – NO_X Measurement

In the second process, the concentration of NO_X (which includes NO and NO_2) is determined by passing the ambient air sample through a molybdenum catalysis oven that is heated to approximately 325 °C, which converts NO_2 to NO. The lower converter temperature prevents the catalytic conversion of NH_3 to NO conducted in the first process. In a subsequent reaction chamber the converted NO molecules and original NO molecules present in the air sample react with O_3. The light emitted during this chemical reaction is measured using a photomultiplier tube. The infrared light measurement is used to determine the concentration of NO_X.

Use of Outputs from Processes 1 and 2 to Calculate NH_3

The concentration of NH_3 is determined by the difference of total Nitrogen and NO_X as follows:

$$NH_3 \ = total\ Nitrogen \ \ (catalyst\ converted\ NH_3, and\ NO_X) \ - \ NO_X$$

A more detailed discussion of the NH_3 measurement principle is typically provided within the manufacturer's operation manual.

4. Interferences

Nitrogen based compounds

The presence of nitrogen based compounds in ambient air may interfere with NH_3 measurement using this method. These compounds are known to erroneously increase analyzer response as they can undergo chemical reactions within the catalysis oven or reaction chamber resulting in an inaccurate analyzer response. Some of the nitrogen based compounds known to interfere with NH_3 measurement include nitrites and nitrates.

H_2O

Water and high levels of carbon dioxide (>0.5 %) have the potential to interfere with measurements. Analyzers situated in areas of high humidity should use a gas dryer to reduce moisture in the sample. The gas dryer should be positioned in the sample line upstream of the analyzer.

Particulate Matter

Particulate matter in ambient air is known to reduce analyzer response by absorbing and scattering light. Interference by particulate matter can be minimized by placing a particle filter at the sample inlet (for analyzers that do not have an internal filter). The particle filter must have a 5 micron pore size and be made of an inert material such as Teflon.

5. Precision and Accuracy

Air contaminant concentration measurements are affected by an instrument's precision and accuracy.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of the sensor can be checked by performing analyzer calibrations against a certified standard gas mixture (see Sections 11 and 12). Accuracy can also be evaluated through periodic span checks.

6. Recommended Equipment and Apparatus

The following are common commercially available NH_3 analyzers suitable for use within the provincial jurisdiction of B.C.:

- Thermo Environmental Instruments (TEI) Model 17i Ammonia Analyzer
- Thermo Scientific Model 17i Ammonia Analyzer
- Teledyne API Model T201 Ammonia Analyzer

This equipment list does not necessarily exclude the use of other commercially available NH_3 analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Environmental Federal Reference and Equivalent Methods. It is recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy an NH_3 analyzer not listed above. Regardless of the equipment deployed, all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available NH_3 analyzers can operate at user selectable ranges between 0 and 20000 parts per billion (ppb); for B.C. ENV monitoring purposes analyzers should be set to a range of 0 ppb to 5000 ppb.

Detection limits are determined by instrument type, but are generally around 1 ppb.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data generated from the site satisfies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the monitoring location.

Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements provided in the analyzer manufacturer's manual. Installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- The ¼ inch diameter connection tubing from the manifold to the analyzer inlet must be made of Teflon or equivalent material for chemical inertness.
- A Teflon particulate filter meeting the manufacturer's pore size specifications must be placed in the sampling line upstream of the analyzer, unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel).
- To reduce the risk of moisture entering the analyzer it is recommended that horizontally mounted manifolds be oriented with the ports facing upwards (with the exception of manifolds such as the "ARB style" which must be mounted vertically); ensure any water traps are oriented vertically.
- A data acquisition system ('DAS' of 'data logger') should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1V or 10V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20 °C and 30 °C but must ultimately be capable of maintaining the operating range specified by the manufacturer. Enclosure temperatures should not deviate by more than 2 °C over a one hour period.
- Remove any sources of solvents and volatile hydrocarbons from the vicinity of the station.
- A permeation dryer should be placed in the sampling line upstream of the analyzer.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated NH_3 analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation.	▪ As per manufacturers operation manual. Monitoring range should be 0 ppb to 5000 ppb.	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) following a 24 h to 72 h warm up period; ▪ After analyzer repairs/maintenance that may affect performance of the instrument; ▪ When zero check exceeds ±0.1 ppm; ▪ When span drift is ≥ ±10% of reference value; ▪ For new analyzers, after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold above is reached (whichever happens first).	▪ As per Section 12 of this SOP.	▪ Record in logbook
Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual.	▪ Record in logbook
Verify Operational Parameters	▪ Each monitor station visit	▪ As per manufacturers operation manual	
Inlet Filter Change	▪ Inspect monthly, change as required	▪ As per manufacturers operation manual. A filter change can affect flow and pressure so a verification or full calibration is required.	
Analyzer Maintenance	▪ As recommended by manufacturer or as required	▪ As per manufacturers operation manual.	▪ Record in logbook
Sample Path Inspection (Probe to Analyzer)	▪ Each monitor station visit	▪ Where necessary replace with new lines, tighten loose connections, clean manifold if required. ▪ Any alteration to the sample pathway should be accompanied by verification or full calibration.	▪ Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify analyzer performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the BCFSM.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the BCFSM and the manufacturer's manual. Certain specifics of the NH_3 analyzer calibration are as follows:

A 3-stage calibration is required, which is unique to NH_3 analyzers. The first stage is typical of other continuous gas analyzer types and involves serial dilution of a NO standard to verify analyzer NO and NO_X response.

In the second stage the NO_2 response is verified by gas phase titration. Two levels of ozone are generated and calibrated in the gas phase titration to verify the linearity of the analyzer. This involves titrating the NO standard used in the first stage with a known concentration of ozone. The introduced ozone converts the equivalent amount of NO into NO_2, which is converted back into NO by the analyzer's converter oven and read as NO_x. As the NO and NO_X channels were calibrated and verified in the first stage, the analyzer's response to the remaining NO, not converted by ozone, can be accepted as accurate. Comparison of the introduced ozone concentration with the analyzer's NOx and NO response therefore allows for a determination of converter efficiency, and verification of the NO_2 channel.

In the third stage, a known concentration of NH_3 is used to verify the catalytic conversion process of the analyzer. Similar to the second stage of calibration, four different levels of NH_3 are generated to verify the linearity of the analyzer.

13. References

Alberta Environment (AENV) 2011. *Standard Operating Procedure for NH_3 Analyzers.* AENV Air Monitoring and Audit Centre.

Greater Vancouver Regional District (GVRD) 2006. *Measurement of Ammonia (NH_3) using Chemiluminescence Ambient Air Monitoring Program Methods*. Air Quality Policy and Management Division.

Thermo Fisher Scientific 2014. *Model 17i Instruction Manual Chemiluminescence NH_3 Analyzer*.

United States (US) Environmental Protection Agency (EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Wood Buffalo Environment Association 2013. *Procedures for Operating Continuous Ammonia (NH_3) Analyzers*.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Formaldehyde**	**Standard Operating Procedure for the Non-Continuous Measurement of Ambient Formaldehyde**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-09** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the non-continuous active sampling of ambient formaldehyde using cartridge samplers, within the provincial jurisdiction of British Columbia (B.C.).

Subsequent analysis of the sample by an analytical laboratory is required to complete the measurement of ambient formaldehyde. The laboratory analysis procedure is not covered in detail within this SOP. For further information regarding the laboratory analysis of formaldehyde see section 8 of the B.C. Environmental Laboratory Manual (B.C. ENV, 2015).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a cartridge formaldehyde sampler within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the sampler manufacturer's manual/instructions, and this document.

The sampling method described in this SOP can be used to measure ambient concentrations of formaldehyde over long durations. This method is suitable for durations of 1 to 24 hours when formaldehyde concentrations are low (~1 ppb to 20 ppb), or short durations of 5 to 60 minutes, when concentrations are in the parts per million (ppm) range. For longer monitoring durations (up to 7 days), passive monitoring or continuous methods should be considered. This method is not compatible with personal sampling pumps due to the high pressure drop across the cartridge.

2. Document Control

This Standard Operating procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Sampling Method

Cartridge Sampler

Air is drawn through a sampling cartridge containing silica gel that is coated with 2,4-Dinitrophenylhydrazine (DNPH) reagent. The sampler system draws air through the cartridge at a controlled flow rate that is generally between 0.5 $l\ min^{-1}$ and 2 $l\ min^{-1}$. Aldehydes and ketones, if present in the sample stream readily form stable derivatives which are captured within the cartridge. During the sampling period the elapsed sampling time is recorded. When sampling is complete the cartridge is sent for laboratory analysis by high performance liquid chromatography (HPLC) to determine the formaldehyde content. The flow rate and elapsed time are used to calculate the total sample volume in cubic meters (m^3). The mass of formaldehyde and the sample volume are used to calculate the average formaldehyde concentration in micrograms per cubic meter ($\mu g/m^3$) over the sampling period.

4. Interferences

Potential common interferences include the presence of ozone in the sample, reagent contamination, sunlight, ambient temperature, relative humidity and system leaks.

Ozone

The presence of ambient ozone in concentrations of 50 ppb and greater is known to interfere with the cartridge sampling method. Ozone reacts with both the DNPH coating and the derivatives captured on the cartridge. To minimize this interference an ozone denuder or scrubber (typically a copper tube coated with potassium iodide) can be placed upstream of the sampling cartridge.

Reagent contamination

The DNPH reagent may be contaminated with formaldehyde. This potential interference can be minimized by instructing the laboratory to determine impurity levels prior to use, and confirming that they are less than the certification blank levels of 0.15 µg/cartridge.

Sunlight

Exposure of the cartridges to sunlight may cause artifacts. Sunlight exposure should be avoided during storage, and during sampling by using a sampler shield.

Ambient temperature

High temperatures can cause loss of formaldehyde-DNPH derivatives. Cartridges should be stored and transported at temperatures less than 4 degrees Celsius (°C) prior to, and following sampling. Ambient air temperatures during sampling may also affect sample collection efficiency and a heated inlet probe is recommended for ambient temperatures less than 15 °C.

Relative humidity

Very low (<10%) or high (>90%) humidity is reported to impact collection efficiency. Very low or high relative humidity conditions also affect the performance of ozone denuders or scrubbers used in the sampling system. In high humidity environments the scrubbers can become saturated. To avoid this potential interference a heated inlet probe can be used.

System Leaks

Air leaks in the sampling system can result in reduced formaldehyde measurement. The formaldehyde sampler must pass a leak check to produce valid results. Consult the manufacturer's operation manual for leak check instructions specific to the sampler.

5. Precision and Accuracy

Cartridge sampling measurements are affected by factors such as measurement height, meteorological conditions and the laboratory's analysis method.

The precision of a measurement is generally considered to be the 'repeatability of the measurement'. The accuracy of the measurement is generally considered to be a measure of the 'deviation from true'. Determination of precision and bias should be completed by the analytical laboratory as per their quality assurance/quality control (QA/QC) procedures. During sampling at least one field blank should be used, or the number of blanks should be 10% of field samples whichever is greater. The use of trip blanks and laboratory blanks is also recommended.

6. Recommended Equipment and Apparatus

The following instruments are commercially available and suitable for use within the provincial jurisdiction of B.C.:

- Xonteck Model 924 Toxic Air Sampler
- ATEC Model 2200 Toxic Air Sampler

Depending on ambient sampling conditions, a heated inlet probe or dryer may be required. An ozone denuder or scrubber should be used.

This list does not necessarily exclude other commercially available formaldehyde sampler systems recognized by the United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy a sample system that is not listed above. Regardless of the instrument deployed all samplers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Analysis range and sensitivity depend on the method employed by the laboratory and the volume of sample. The typical measurement range for formaldehyde using this method is 10 ppb to 1 ppm.

8. Site Requirements

Sampling site specifications should be developed to ensure that the data obtained from the site satisfies the requirements of intended or established sampling objectives. It is recommended that sampling site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with sampling objectives.

As a preliminary guideline site selection should consider and address: sampling objectives, representativeness of the region, interference from the surrounding area, zone type (residential, commercial, industrial) of sampling location.

Refer to Section 2 of Part B1 of the BCFSM for further information on site selection method.

9. Installation Requirements

Follow sampler specific installation requirements discussed in the manufacturer's manual.
The installation should also conform to the following:

- The sampler inlet should be located at a height of 2 m to 7 m above ground level.
- If the sampler is located on a roof or other structure the inlet should be at least 1 m from walls or parapets and positioned away from building vents or flues.
- The sampler should be located away from structures such as trees and buildings. The distance between any obstacle and the sampler should be at minimum, twice the height of the obstruction above the inlet.
- Air-flow should be unrestricted in 3 of the 4 wind quadrants.

10. Operational Requirements

Follow instrument specific operational requirements discussed in the manufacturer's manual. In general the following activities should be performed by the operator of a sampler:

Action	Time/Frequency	Description	Record Keeping
Sample Start	• At the start of each sampling period	• Record start time, flow rate, sample volume, ambient temperature, ambient pressure and relative humidity. • Record the date, time, location, measurement height, and cartridge identification and batch number. • Cartridges should be used within 30 days of preparation by the laboratory.	• Record in logbook • Record available information on the Chain of Custody (COC) form provided by the analytical laboratory.

Sample Retrieval	• At end of sampling period	• Record end and elapsed time, flow rate, sample volume, ambient temperature, ambient pressure and relative humidity. • Record the date, time, location, measurement height, and cartridge identification and batch number. • Note any instrument errors. • Remove cartridge using polyethylene gloves, seal at ends using Teflon tape and follow the packing requirements of the cartridge supplier. Packing requirements could include the use of DNPH soaked filter paper within the packaging. • Ship in a box not a cooler (since the cooler could contain formaldehyde). • Refrigerate at 4 °C until analysis. • Refrigeration period prior to analysis should not exceed 2 weeks.	• Record in logbook • Complete the COC as required by the analytical laboratory.
Leak Check	• Each sampling event (or at frequency stated by manufacturer)	• As per manufacturers operation manual. • Leak rate should be within the tolerances stated by the manufacturer (e.g. less than 2% of full scale).	• Record in logbook
Calibration	• Quarterly or at replacement frequency stated in manufacturer's manual	• As per Section 12 of this SOP.	• Record in logbook
• Check that time is within ± 5 min from true • Check pressure on vacuum manifold • Inspect sample inlet, tubing and power cord, replace if required	• Monthly	• As per manufacturers operation manual	• Record in logbook
Clean control box filter	• Quarterly	• As per manufacturers operation manual	• Record in logbook
Clean inside and outside of control and pump boxes	• Quarterly	• As per manufacturers operation manual	• Record in logbook
Check and replace ozone scrubber	• Bi-annually or at the replacement frequency stated in manufacturer's manual	• As per manufacturers operation manual	• Record in logbook
Replace pump vanes	• Annual	• As per manufacturers operation manual	• Record in logbook

11. Zero and Span Checks

This section is not applicable to this measurement method.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the BCFSM and following the manufacturer's manual. Certain specifics to a formaldehyde sampling system are as follows:

- Several parameters require calibration including flow, ambient temperature and ambient pressure.
- Calibration of the sampling system flow controller should be undertaken using a flow meter which is calibrated or certified annually against a National Institute of Standards and Technology (NIST) traceable standard.
- Similarly, temperature and pressure verification should be performed using a temperature and pressure standard which is calibrated or certified annually against a NIST traceable standard.

13. References

B.C. ENV 2016. *British Columbia Environmental Laboratory Manual 2015 Edition*. Section 8. Environmental Monitoring, Reporting & Economics Knowledge Management Branch.

Environment Canada 2013. *Determination of Carbonyl Compounds in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC)*. Method No. 1.01/2.8/M.

American Standard Test Method (ASTM) 2016. *Standard Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology).* Designation D5197-16.

ATEC 2014. *Model 2200 Toxic Air Sampler Operations and Maintenance Manual*. Version 2.00.

Bay Area Air Quality Management District (BAAQMD) 2012. *Standard Operating Procedure Data Mgt SOP 607 Toxics 924*. Revision 607.2.00.

California Environmental Protection Agency Air Resources Board 2004. *Standard Operating Procedures for Xontech 924 Toxics Air Sampler*. AQSB SOP 801. First Edition.

US EPA 1999. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. Compendium Method TO-11A. Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC) [Active Sampling methodology]*. Center for Environmental Research Information Office of Research and Development.

Revision History: 0.0 (New document)

Approval

Monitoring Parameter: **Methane and Non-Methane Hydrocarbons**	**Standard Operating Procedure for the Non-Continuous Measurement of Ambient Methane and Non-Methane Hydrocarbons Using Gas Chromatography**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-10** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the continuous ambient monitoring of Methane and Non-Methane Hydrocarbons (NMHC), within the provincial jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a Methane/NMHC analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the BCFSM, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Gas Chromatography (GC)

The principle detection and quantification method deployed for monitoring Methane and Non-Methane Hydrocarbons (NMHC) in ambient air is gas chromatography (GC). Methane/NMHC analyzers use a semi-continuous collection and analysis sequence that draws air samples into a separation column where it is pushed by an inert carrier gas into a flame ionization detector (FID). Due to the differences in molecular weight and volatility the sample's various gas components are separated based on retention time.

Retention time is described as the time it takes for a component to travel though and emerge from the column. Methane has a lower molecular weight and higher volatility than other hydrocarbons which results in a lower retention time. For this reason methane is the first compound to emerge from the separation column. The Methane is then directed to a flame ionization detector (FID). The signal produced by the FID is converted to a methane concentration by comparing the response to a known concentration of a methane standard. Non-methane hydrocarbons emerging later from the separation column produce an FID signal which is converted to an NMHC concentration using comparisons with a known concentration of a propane standard. After the NMHC measurement is complete, the analyzer initiates the next sample analysis.

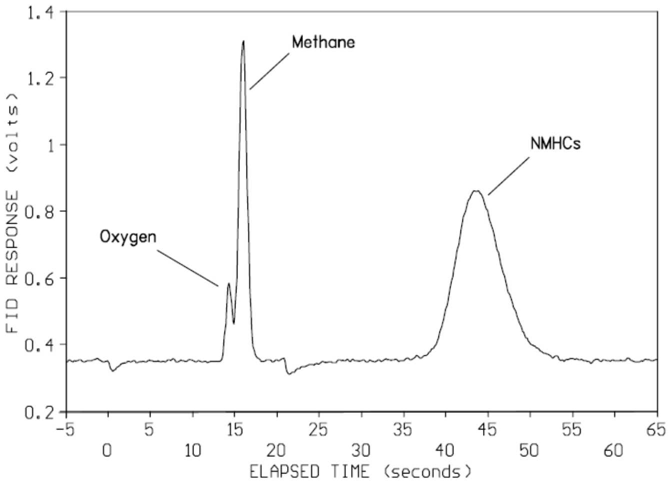

Figure reference: Thermo Scientific, 2012

A typical gas chromatogram from a Thermo Scientific Model 55i Analyzer using 2 ppm each of methane and propane (a NMHC) is shown in the figure above.

4. Interferences

Particulate Matter

The presence of particulate matter in air samples may interfere with Methane/NMHC analyzer response. Interference by particulate matter can be minimized by using a particle filter at the sample inlet. The filter must have a 2 µm diameter pore size and be made of an inert material such as Teflon.

5. Precision and Accuracy

The precision of an analysis is generally considered to be the ‘repeatability of the measurement’. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the ‘deviation from true’. The accuracy of a sensor can be checked by performing calibrations against a certified calibration standard mixture (See Sections 11 and 12). Accuracy can also be confirmed through periodic span checks and multipoint checks/calibrations.

6. Recommended Equipment and Apparatus

The following are common commercially available methane/NMHC analyzers suitable for use within the provincial jurisdiction of B.C.:

- Thermo Scientific Direct Methane, Non-Methane Hydrocarbon Analyzer, Model 55i
- Synspec GC’s Alpha 115

This list does not necessarily exclude other commercially available Methane/NMHC analyzers, and analyzers recognized by the United States (US) Environmental Protection Agency (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. Ministry of Environment and Climate Change Strategy (ENV) if you intend to deploy Methane/NMHC analyzers that are not listed above. Regardless of the instrument deployed, all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available Methane/NMHC analyzers operate at user selectable ranges between 0 ppm and 5000 ppm; for B.C. ENV monitoring purposes analyzers should be set to a range of 0 ppm to 20 ppm for Methane/NMHC.

The detection limit is determined by instrument type but is generally around 0.05 ppm.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data obtained from the site satisfies the requirements of intended or established monitoring objectives. It is highly recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the monitoring location.

Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements discussed in the analyzer manufacturer's manual. The installation should also conform to the following:

- The monitoring station's sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program's *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- The ¼ inch diameter connection tubing from the manifold to the analyzer inlet must be made of Teflon or equivalent material for chemical inertness.
- A Teflon particulate filter capable of removing at least 99% of 1 µm diameter and larger particles must be placed in the sampling line upstream of the analyzer, unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel).
- A data acquisition system ('DAS' or 'data logger') should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The data logger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20 °C and 30 °C but must be capable of maintaining the operating temperature range specified by the manufacturer. Enclosure temperatures should not deviate by more than 2 °C over a one hour period.

10. Operational Requirements

The following activities should be performed by the operator of a continuous automated Methane/NMHC analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. Monitoring range should be 0 ppm to 20 ppm.	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) following a 24 h to 72 h warm up period; ▪ After analyzer repairs/maintenance that may affect performance of the instrument; ▪ When zero check exceeds ± 0.1ppm;	▪ As per Section 12 of this SOP.	▪ Record in logbook

	▪ When span drift is ≥ ± 10% of reference value; ▪ For new analyzers, after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any threshold above is reached (whichever happens first).		
Zero and Span Verification	Daily preferred, weekly minimum	▪ As per manufacturers operation manual.	▪ Record in logbook
Verify Operational Parameters	Each monitor station visit	▪ As per manufacturers operation manual.	
Check Support Gas Pressures	Each monitor station visit	▪ Check gas cylinder pressures and replace if they drop below 500 psi.	
Inlet Filter Change	Inspect monthly, change as required	▪ As per manufacturers operation manual. A filter change can affect flow and pressure so a verification or full calibration is required.	
Analyzer Maintenance	As recommended by manufacturer or as required	▪ As per manufacturers operation manual.	▪ Record in logbook
Sample Path Inspection (Probe to Analyzer)	▪ Each monitor station visit	▪ Where necessary replace with new lines, tighten loose connections, clean manifold if required. ▪ Any alteration to the sample pathway should be accompanied by verification or full calibration.	▪ Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify analyzer performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the BCFSM.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the BCFSM and following the manufacturer's manual. Methane/NMHC analyzers are typically calibrated using the dilution method.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Alberta Environment (AENV) 2011. *Standard Operating Procedure for Measurement of Methane/Non-Methane Hydrocarbons Using FID Detection.* AENV Air Monitoring and Audit Centre.

CARB 2002. *Standard Operating Procedure for the Determination of non-Methane Organic Compounds in Ambient Air by Gas Chromatography Using Dual Capillary Columns and Flame Ionization Detection*. Northern Laboratory Branch Monitoring and Laboratory Division.

Synspec 2010. *Synspec GC's Alpha 115 and Alpha 116 Methane/Total Non Methane HydroCarbons Operator manual*.
Thermo Scientific 2012. Model 55i *Instruction Manual Direct Methane, Non-Methane Hydrocarbon Analyzer*.

United States Environmental Protection Agency (US EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

Wood Buffalo Environmental Association (WBEA) 2013. Procedures for Operating Continuous Methane/Non-Methane Hydrocarbon Analyzers.

Revision History: 0.0 (New document)

Approval

Monitoring Parameters: **Benzene, Toluene, Ethylbenzene & Xylene (BTEX)**	**Standard Operating Procedure for the Semi-Continuous Measurement of Ambient BTEX**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-11** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides operating guidelines and instructions for the semi-continuous ambient monitoring of hydrocarbons including Benzene, Toluene, Ethylbenzene and Xylene (BTEX) within the provincial jurisdiction of British Columbia (B.C.).

This SOP forms part of the B.C. Field Sampling Manual (BCFSM). Part B - Air and Air Emissions Testing, of the BCFSM provides additional information on Air Quality Monitoring that must be used in conjunction with the information provided in this SOP. Installation and maintenance of a BTEX analyzer within the provincial jurisdiction of B.C. should be carried out with consideration to Part B of the B.C. Field Sampling Manual, the analyzer manufacturer's manual, and this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance it provides are based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Principle of the Measurement Method

Gas Chromatography (GC) with a Photoionization Detector (PID) or Flame Ionization (FID) Detector

The principle detection and quantification method deployed for ambient concentrations of BTEX is gas chromatography (GC).

The analyzers used in the semi-continuous measurement of BTEX repeatedly collect and analyze small volumes of ambient air (the 'sample') that are drawn into the analyzer using a vacuum pump. Each sample enters a separation column which consists of two sequential columns; a stripper column and an analysis column. The two columns are identical but have different lengths. In these columns the gas components (compounds) of a sample differentiate based on their specific physical properties (e.g. molecular mass) and chemical properties (e.g. volatility). The specific properties of a gas compound determine the speed at which they travel through the columns. For example, compounds with the lowest molecular weight and highest volatility travel the fastest through the separation column. These compounds have the lowest column retention times and as such, are the first to emerge from the separation column. Based on these principles, compounds are identified using retention times.

The concentration of compounds emerging from the column are quantified by a detector; commonly a photoionization detector (PID). Photoionization detectors use ultraviolet radiation to ionize gas components. The resulting ions produce an electrical current that elicits a response commensurate with the concentration of the ionized gas. Photoionization detectors are capable of achieving a high resolution at low concentration ranges; typically in the parts per trillion (ppt) to parts per million (ppm) range.

Following each sample cycle, the sample path is flushed with clean air in preparation for the next sample.

4. Interferences

Particulate Matter

The presence of particulate matter in an air sample may interfere with a BTEX analyzer's response. Interference by particulate matter can be minimized using a particle filter at the sample inlet. The particle filter must have a 2 µm diameter pore size and be made of an inert material such as Teflon.

Water Vapour

The presence of water vapour may result in an inconsistent detector response. This potential interference can be mitigated by using a dryer and ultra-pure carrier gas. The sample cycle should be sufficient to clear all compounds from the column before proceeding to the next sample cycle.

5. Precision and Accuracy

The precision of an analysis is generally considered to be the 'repeatability of the measurement'. This can be confirmed through zero and span checks, and calibrations.

The accuracy of the sensor is generally considered to be a measure of the 'deviation from true'. The accuracy of a sensor can be checked by performing calibrations against a certified calibration standard mixture (See Sections 11 and 12 of this SOP). Accuracy can also be confirmed through periodic span checks and multipoint checks/calibrations.

6. Recommended Equipment and Apparatus

The following is a commercially available BTEX analyzer suitable for use within the provincial jurisdiction of B.C.:

- Syntech Spectras Analyser GC 955

This list does not necessarily exclude other commercially available BTEX analyzers, and analyzers recognized by United States (US) Environmental Protection Agency's (EPA) Federal Reference and Equivalent Methods. In deed as technology advances, new analyzers will enter the market which may be suitable for use within the provincial jurisdiction of B.C. It is highly recommended however that you consult with the B.C. ENV if you intend to deploy BTEX analyzers that are not listed above. Regardless of the instrument deployed, all analyzers should meet the specifications described within this document.

7. Measurement Range and Sensitivity

Typical commercially available BTEX analyzers operate at a user selectable range of ppt to % range, depending on customizable detection options. For B.C. ENV monitoring purposes analyzers should be set to the ppt to ppm range.

8. Site Requirements

Monitoring site specifications should be developed to ensure that the data obtained from the site satisifies the requirements of intended or established monitoring objectives. It is recommended that monitoring site requirements be established in consultation with the B.C. ENV to ensure that siting requirements are commensurate with monitoring objectives.

As a preliminary guideline site selection should consider and address: monitoring objectives, representativeness of the region, interference from the surrounding area, and zone type (residential, commercial, industrial) of the monitoring location.

Refer to Section 2 of Part B1 of the BCFSM for further information on site selection.

9. Installation Requirements

Follow analyzer specific installation requirements discussed in the analyzer manufacturer’s manual.

The installation should also conform to the following:

- The monitoring station’s sampling inlet and manifold shall meet the requirements of the most recent version of the National Air Pollution Surveillance (NAPS) Program’s *Monitoring and Quality Assurance/Quality Control Guidelines* Section 8.2 and Section 8.3.
- The ¼ inch diameter connection tubing from the manifold to the analyzer inlet must be made of Teflon or an equivalent material for chemical inertness.
- A Teflon particulate filter capable of removing at least 99% of 1 µm diameter and larger particles must be placed in the sampling line upstream of the analyzer, unless the analyzer is equipped with a similar internal filter. The filter holder should be constructed of an inert material (e.g. Teflon, stainless steel, aluminum).
- A data acquisition system (‘DAS’ or ‘data logger’) should be connected to the analyzer to record or download the measurement data from the analyzer. If an analog data logger is used, it must be set to match the voltage range of the analyzer, typically at 1 V or 10 V full scale. It must be ensured that the analog output matches the digital output displayed on the analyzer. The datalogger must also record and monitor any alarm conditions of the analyzer.
- The analyzer must be placed in a weather resistant enclosure that is vented, heated and cooled to maintain a stable temperature preferably in the range of 20°C to 30°C but must be capable of maintaining the operating temperature range specified by the manufacturer. Enclosure temperatures should not deviate by more than 2°C over a one hour period.
- A permeation dryer should be placed in the sampling line upstream of the analyzer.

10. Operational Requirements

The following activities should be performed by the operator of a semi-continuous automated BTEX analyzer.

Action	Time/Frequency	Description	Record Keeping
Analyzer Range Set Up	▪ After installation	▪ As per manufacturers operation manual. Monitoring range should be 0 ppb to 1000 ppb.	▪ Record in logbook
Multipoint Verification	▪ After installation (or relocation) following a 24 h to 72 h warm up period; ▪ After analyzer repairs/maintenance that may affect performance of the instrument; ▪ When zero check exceeds ± 0.1 ppm; ▪ When span drift is ≥ ± 10% of reference value; ▪ For new analyzers after the first 3 months of operation; ▪ Bi-annually if span checks are conducted daily – or when any threshold above is reached (whichever happens first); ▪ Quarterly if span checks are conducted less than daily – or when any of the thresholds above is reached (whichever happens first).	▪ As per Section 11 of this SOP	▪ Record in logbook
Zero and Span Verification	▪ Daily preferred, weekly minimum	▪ As per manufacturers operation manual	▪ Record in logbook
Verify Operational Parameters	▪ Each monitoring station visit	▪ As per manufacturers operation manual	
Check Support Gas Pressures	▪ Each monitoringing station visit	▪ Check gas cylinder pressures and replace if they drop below 500 psi	

Inlet Filter Change	- Inspect monthly, change as required	- As per manufacturers operation manual. - A filter change can affect flow and pressure so a verification or full calibration is required.	
Analyzer Maintenance	- As recommended by manufacturer or as required	- As per manufacturers operation manual	- Record in logbook
Sample Path Inspection (Probe to Analyzer)	- Each monitoringd station visit	- Where necessary replace with new lines, tighten loose connections, clean manifold if required. - Any alteration to the sample pathway should be accompanied by verification or full calibration.	- Record in logbook

11. Zero and Span Checks

Zero and span checks are required to verify the analyzers performance between calibrations. These checks should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual.

12. Calibration

Calibration should be performed in accordance with Section 6 of Part B1 of the B.C. Field Sampling Manual and the manufacturer’s manual.

13. References

National Air Pollution Surveillance (NAPS) Program. Monitoring and Quality Assurance/Quality Control Guidelines.

Government of Alberta 2015. *Ambient Air Monitoring Performance Specification Standards – Continuous Analyzers VOCs (BTEX and Styrene).*

Syntech 2011. *Syntech Spectras Analyser GC 955 – Manual for the Syntech Spectras GC955-series.*

United States Environmental Protection Agency (US EPA) 2013. *QA handbook for Air Pollution Measurement Systems Volume II Ambient Air Quality Monitoring Program*. US EPA Office of Air Quality Planning and Standards Air Quality Assessment Division.

US EPA 2013. *Method 18 – Measurement of Gaseous Organic Compound Emissions by Gas Chromatography*.

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Approval

Monitoring Parameters: **Ambient Air Quality & Meteorological Data**	**Standard Operating Procedure for Ambient Air Quality and Meteorological Data Validation**
Revision No: Original **Revision Date: 05 May, 2020**	**Reference No: SOP-12** **Parent Document: Part B1 – B.C. Field Sampling Manual**

1. Introduction and Scope

This Standard Operating Procedure (SOP) provides instruction for the data validation of air quality monitoring and meteorological data within the provincial jurisdiction of British Columbia (BC).

Guidelines produced by the National Air Pollution Surveillance (NAPS) program set a national standard for data validation which are incorporated in this document.

2. Document Control

This Standard Operating Procedure is a controlled document. Document control provides a measure of assurance that the specifications and guidance provided by it is based on current information that has been scrutinized by a qualified reviewer/s. Controlled documents are reviewed within a five year life cycle. Please ensure that the revision date listed in the header of this document does not exceed five years.

This SOP and the B.C. Field Sampling Manual are available at: www2.gov.bc.ca.

3. Overview

Many factors related to instruments and data acquisition systems may affect data validity, and it is difficult to identify or adjust the anomalous data through a single step. As such, data validation is completed in four steps that subject the data to increasingly detailed levels of scrutiny and analysis. The first level of data validation, Level 0, provides a review of data completeness and validity as it relates to station operations. Level 1 provides assurance of data rationality and consistency specific to station operation and parameter. Level 2 verifies data validity in a broader scope such as pollutant relationship and buddy site comparison, and Level 3 assesses the data using advanced techniques such as modelling and statistical tests.

Figure 1 illustrates ENV's data validation process. Table 1 summarizes data validation activities, frequency, and responsibilities.

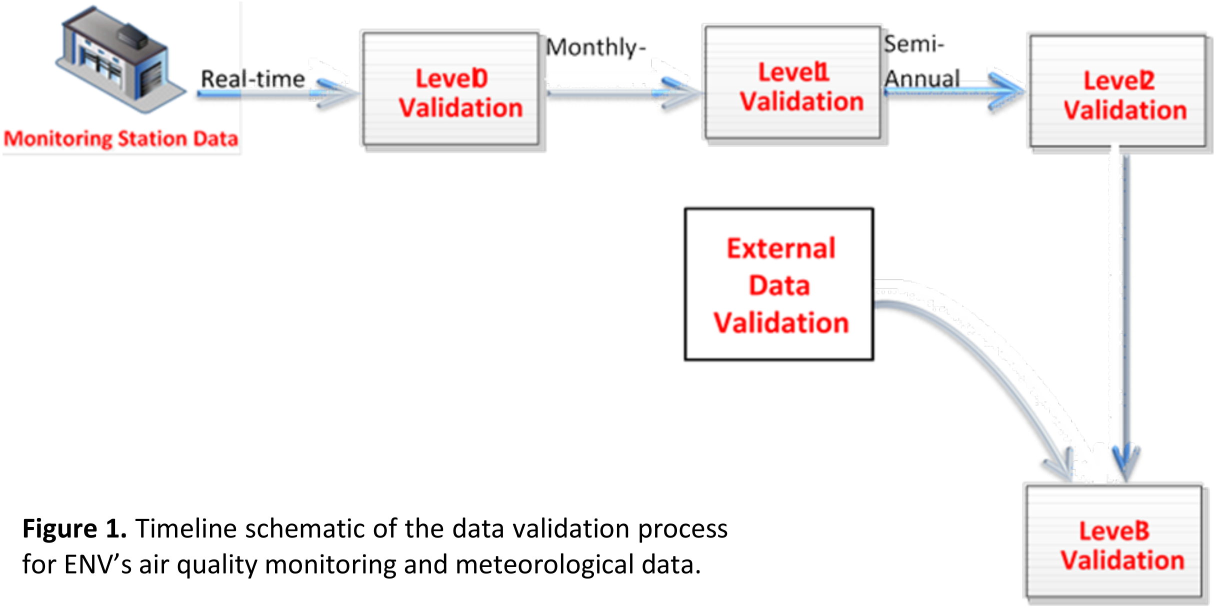


Figure 1. Timeline schematic of the data validation process for ENV's air quality monitoring and meteorological data.

Level 0 - a combination of automated data invalidation actions which occur in the data logger, analyzer, central polling system, and manual data verification actions taken by site operators and data validation specialists. Level 0 data validation activities are conducted at the highest frequency of near-real time to weekly.

Level 1 - a collaborative and continuous effort between the data validation specialist and site operator. Level 1 validation involves a review of calibration results, logbook entries and an assessment of data anomalies. These activities which occur on a monthly to quarterly basis focus on a detailed identification of data issues based on parameter and instrument-specific behaviour, and a correlation of data with station activities. This function requires a technical understanding of instrumentation and factors affecting instrument performance and data quality. The Level 1 data validation process provides the most detailed attention to individual parameters. Detailed electronic logbook entries provided by site operators is a critical component of this process.

Level 2 – occurs on a semi-annual or annual frequency. The Level 2 validation process includes the generation and distribution of statistical summaries to site operators and primary data users including ENVs Air Quality (AQ) Meteorologists and the Clean Air Group. Level 2 data validation activities are also performed by external agencies who transmit their data annually (overwriting all autopolled data for their sites). Level 2 validation is a pre-requisite for verified data applicable for Canadian Ambient Air Quality Standards (CAAQS) reporting and decision making.

Upon completion of Level 2 validation, both imported and validated data are certified with a Final Edit attribute which locks the data from editing. Data validation specialists have administrative rights to unlock this data.

Level 3 – provides an annual independent evaluation of validated data prior to publication. Level 3 validation is performed by ENV prior to publishing the B.C. Lung report, and the importation of data from B.C. by Environment and Climate Canada which generally occurs in June of the following year.

Table 1. Verification and Validation activities and frequency of execution.

Level 0 Verification			
Validation Activities	**Responsibility**	**Frequency**	**Description**
Digital monitor status validation	Local station logger	Near Real-time	Configured at the local station logger and includes automated flags based on instrument status.
Automated range check	Central polling system	Hourly	Includes automated flagging and data correction for out-of-range values
Overall system and communications check	ENV	Hourly	Includes use of website, DrDashboard and "Last Received" status to determine status of communications, instruments, and the entire system
Review of diagnostics data and investigation of suspicious hourly data	Site operator	Daily - weekly	Includes reviewing instrument diagnostics to verify proper operation, and review sub-hourly data (ENV sites)
Review of alarms and alerts (automated email, AQHI+)	Site operator	Daily - weekly	Includes automated email alerts sent by the Central Polling system to warn of instrument issues
Review of verification/calibration results	Site operator	Daily - weekly	Check daily zero and span values
Station/instrument status check	Site operator	During remote checks and station visits	Includes remotely checking the status of the instrument and the corresponding data, and visiting the station and inspecting the site and instruments.
Level 1 Validation			
Validation Activities	**Responsibility**	**Frequency**	**Description**
Review of Level 0 Verification	ENV/ Site operator	Monthly-Quarterly	Review automated invalidation
Review of logbook entries	ENV	Monthly-Quarterly	Manual review of logbook entries and adding/removing data flags
Review of operational and instrument parameters	ENV/ Site operator	Monthly-Quarterly	Review any instrument-specific operational limitations
Adjustment of data and adding comments	ENV	Monthly-Quarterly	Includes baseline adjustments, below zero adjustments,and derived parameter relationship check, and consolidation of logbook entries into data edit
Review of calibration/audit results	ENV	Quarterly/Semi-annual	Verify previous data based on calibration/audit results
Level 2 Validation			
Validation Activities	**Responsibility**	**Frequency**	**Description**
Review of Level 1 Validation	ENV	Semi-annual	Review of Level 1 Validation
Review of data summary/statistics/compare historical data	ENV/site operators/AQ meteorologists	Semi-annual/annual	Creation of statistical summaries. Requires input from stakeholders, site operators for data outliers and data-affecting events
Examination of meteorological data	AQ meteorologist	Annual	

Examination of relationships between pollutants	AQ meteorologist	Annual	
Comparison of buddy sites	AQ meteorologist	Annual	
Rejection of outlier data	EMRE/AQ meteorologist	Annual	
Level 3 Validation			
Validation Activities	**Responsibility**	**Frequency**	**Description**
Independent third-party review	Third party/science specialists	Annual	Includes the State of the Air Report created annually by the ENV Clean Air group. This report involves detailed statistical analysis on the historical context, and in the context related to public health (ENV sites)
Dataset comparison	Third party/science specialists	As needed	
Analysis using models and statistical tests	Third party/science specialists	As needed	
Examination of meteorological data	Third party/science specialists	As needed	
Communication of potential issues with primary validators	All stakeholders	As needed	

4. Data Validation Tools and Resources

The tools and resources available for data validation are listed in Table 2. These include web-based applications and data that are accessible to the general public, and specialized software that are available inside the ENV network. Other applications can be deployed on-site with physical access to the station's datalogger, or remotely via remote terminal connections.

Personnel performing data validation are not limited to the resources listed in Table 2. Open source resources such as R Programming Language, specialized software packages (e.g., SAS, SPSS), and standard spreadsheet applications are available and capable of facilitating these tasks.

Table 2. Tools and Resources ENV Staff Used for Data Validation

Resource	Description	User/Access	Validation Level
Envidas Ultimate Viewer	Displays current data from within the station's logger	Site operator	Level 0
Envidas Ultimate Reporter	Displays data archived in the station's logger	Site operator	Level 0
Minute Data Feed[1]	Contains most recent 2 weeks of sub-hourly data	ENV Staff	Level 0
Minute Data Summary[2]	HTML summary of sub-hourly data, daily zero/span checks	AQ Tech	Level 0
Envista ARM	Tool for data retrieval and basic to advanced analysis	ENV Staff	Levels 0,1,2,3
Envistaweb[3]	Public version of Envista ARM	Public	Levels 0,1,2,3
Open Data Portal (unverified data)[4]	.csv data of unverified hourly data (year-to-date)	Public	Level 0,1,2
Open Data Portal (verified data)[5]	.csv data of validated hourly data (after Level 2)	Public	Level 2, 3

DrDashboard[6]	Snapshot of current system status	ENV System Group	Level 0
SAS Summaries[7]	Statistical summary of annual data	ENV Staff	Level 2,3

1 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/MinuteData/

2 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/MinuteDataValidation/

3 https://envistaweb.env.gov.bc.ca/

4 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/Hourly_Raw_Air_Data/

5 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/AnnualSummary/

6 file share \\sfp.idir.bcgov\s140\S40036\Air\Operations ORCS\Data\DR DashBoard

7 ftp://ftp.env.gov.bc.ca/pub/outgoing/AIR/SAS_SUMMARIES/

5. Level 0 Verification

Section 3 of this SOP provides an overview of the Level 0 verification process which includes all of the activities listed in Table 1. This section provides additional information about the automated verification activities performed during the Level 0 verification process including procedures for manually flagging data.

Automated validation processes are configured within a stations data logger. These processes utilize a ‘digital monitor status’ that is triggered by the self-diagnostics features found in gas and particle analyzers (Table 3). Automated validation processes ensure that measurements are performed under acceptable operating conditions. Whenever instruments operate outside of acceptable conditions, a status flag is generated. All of ENV’s core stations are equipped with Envidas Ultimate dataloggers which are capable of capturing and applying these flags. Other loggers, such as the ESC-8816, 8832 and Campbell Scientific, do not have this capability but can be configured to report high or low range values for readings that are invalid. The ENV’s data collection system is not able to collect zero, span or logbook entries from all logger makes and models and as such consultation with ENV is strongly recommended prior to acquiring a data logging system.

Digital monitor status items are specific to an analyzer’s make and model, and are only enabled for those parameters that may indicate invalid data. Table 3 lists activated flags by instrument type. The activated flags are specific to sample flow and pressure, detector temperature, and detector conditions.

Table 3. Standard Digital Monitor Status Validation in Envidas Ultimate for BC ENV stations.

PARTICULATE

- **SHARP 5030**
  - Pump Switched off
  - Sum Status of data and program memory A
  - Sum status of sampling and measuring system B
  - Sum status of air flow regulation D
  - Sum status of the sample heater E
- **SHARP 5030i**
  - pump
  - service
- **TEOM 1400**
  - MasTrand
  - Temp
  - Flow
  - Filter

O3

- **APIT400/APIT400U**
  - PHOTOREF
  - O3GENREF
  - O3GENDRIVE
  - PHOTOSPRESS
  - PHOTOSFLOW
  - PHOTOSTEMP
  - ALTEMP
  - PHOTOLTEMP
  - BOXTEMP
- **TEI49**
  - flowa
  - flowb
  - bench temp
  - lamp temp
  - press

SO2/TRS

- **API100A**
  - SAMPPRESS
  - SAMPFLOW
  - RCELLTEMP
  - BOXTEMP
  - PMTTEMP
- **APIT100**
  - SAMPPRESS
  - SAMPFLOW
  - RCELLTEMP
  - BOXTEMP
  - PMTTEMP
- **TEI43**
  - Internal temp
  - react temp
  - pres
  - flow

CO

- **APIT300U**
  - SAMPPRESS
  - SAMPFLOW
  - BENCH TEMP
  - WHEELTEMP
  - BOXTEMP
- **TEI 48**
  - internal temp
  - chamber temp
  - flow
  - press

The Central Polling system also performs automated invalidation based on range checks and forced zero that are applied to the database as a phase of each hourly polling cycle. Automated validation criteria are standardized based on instruments and parameters. For particulate matter (PM), PM$_{2.5}$ and PM$_{10}$ are automatically invalid when values are below -3.49 µg/m^3 and -9.98 µg/m^3 respectively and above 985 µg/m^3. Forced zeroing of PM is configured to remove the negative values from 0 to -3.49 µg/m^3 for PM$_{2.5}$ and 0 to -9.98 µg/m^3 for PM$_{10}$. Gas analyzers are not configured for auto-invalidation but have an above/below alert system triggered by hourly averages below -5 ppb and values above the 99th percentile for a particular station. When activated, the site's operator receives an email notification of the unusual high or low value.

Level 0 verification includes station and instrument checks. Whenever data-impacting issues are detected, site operators should mark down the instrument channels to prevent reporting erroneous data to the general public. In addition a centrally generated alert system is configured to notify site operators of unusually high or low values. The ENV Data Group also regularly checks station and instrument status, and will communicate suspected issues.
In order to avoid publishing erroneous data, site operators are required to regularly check stations, alerts, and ENV Data group emails.

- **Envidas Ultimate loggers**: Use Envidas Viewer to mark down the channel at the station; if required, access the terminal remotely.
- **ESC loggers**: Data can be marked down from the configuration settings of the logger panel.

- **Loggers without data flagging capability:** contact the ENV Data Group to request channels be marked down centrally. Once analyzer function is restored, contact the ENV Data Group to remove the flag.

6. Level 1 Validation Overview

The original theoretical foundation of the Level 1 validation process performed by ENV was based on the "Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone" (CCME, 2011) and included operational and instrument specifications considerations.

Level 1 data validation is performed by the Air Data Quality Assurance Specialist (ADQAS) who works closely with operators to help ensure that their instruments are working properly, and that data are annotated and, when necessary, adjusted appropriately. Validation logs are maintained in an Excel spreadsheet that lists all stations and their active analyzers.

6.1 Level 1 General Validation Procedure

The following Level 1 validation activities are performed by the Air Data Quality Assurance Specialist (ADQAS):

1. **Review field records** - online logbook within Envista ARM for all ENV stations and a few permittee sites and electronic operator reports sent by email by most of the permittee sites. Contact operators to obtain reports that have been delayed for over three months.

   NOTES: Envista ARM logs are of a uniform format whereas reports sent by email are customized by the site operators and as such are stylistically inconsistent. When Level 1 validation is complete all electronic permittee reports are saved in an archive file share listed chronologically by station.

2. **Review AQSLog** - determine which analyzers are active for the station under review. Open the corresponding edit table in Envista ARM. Separate data streams by parameter and parameter type (e.g., gas). Each type of data is handled in a separate edit table, as the three types of parameters follow different validation and adjustment protocols.

3. **Review screening flags** - assigned during Level 0 verification. Reconcile flags with field records. Contact air technicians/operators if issues are found. Review operational acceptance limits for each parameter/analyzer, and determine if any data should be invalidated due to instrument-specific operational limitations.

4. **Review all gaseous parameters** - daily zero/span and multi-point calibration reports provided by site operators, and audit reports provided by the ENV Air Audit Team (where applicable). Review all information sources to ensure measurement uncertainty remained within the acceptance criteria prescribed in the NAPS guidelines.

5. **Ensure data** - are annotated appropriately if special actions were taken according to field reports, e.g. monthly calibration, regular maintenance, ENV audit, etc. Outliers or extreme values are investigated as follows:

   a) check 1-minute data to verify if the pattern is consistent;

   b) consult with regional technician/AQ meteorologist to check if an exceptional event occurred;

   c) if uncertain, keep values valid and flag for review under Level 2 validation.

6. **Adjust data** - apply appropriate methods to adjust data if necessary. Adjustments can include outlier disqualification, baseline adjustments, below zero adjustments, and parameter relationship preservation. Baseline/drift adjustments are usually performed for an entire month or from calibration to calibration depending on presence/absence of zero drift. Baseline adjustments are performed prior to adjustments of negative values to zero.

The general procedure for baseline adjustments of gas analyzer data is as follows:

a) Plot a timeseries of hourly data for the pollutant and time period (typically one month) under review. Adjust the range of the y-axis to -1 to 10 ppb (-1 to 2 ppb for CO). Review the timeseries for zero drift (i.e. a trend in daily minimum concentration over days/weeks).

b) Plot the daily zero/span checks for the time period under review to confirm if zero drift has occurred.

c) Review zero values measured during multi-point verifications (conducted by the site operator) to verify if zero drift is caused by malfunction of the instrument or depletion of scrubber used for zero checks.

d) For cases where baseline drift has occurred, a constant offset is applied over the affected period (i.e. stepwise adjustment). The magnitude of the offset is typically the average daily minimum concentration (for the parameter and period of interest). However, the minimum daily zero check value and the zero value from the most recent multi-point verification (conducted by the site operator) must be reviewed for verification.

e) All negative values remaining after the baseline adjustment should be adjusted to zero.

These procedures are applied only when instrument issues are absent. If there is no indication of instrument issue in the logbook and zero checks are drifting or noisy, confirm with the site operator that the instrument was working properly. If no operational issues are reported, professional judgement needs to be applied to determine if the noise/drift is excessive. If so, data may be invalidated. In these cases, the site operators should be informed so that the issue can be investigated and repaired.

Refer to section 5.2 for additional pollutant-specific information to be used in conjunction with this procedure. PM validation procedures differ from gasous analyzers and are covered in section 5.2.

7. **Run a monthly matrix report** - detailing each hour's reading against the day of the month (hour for the columns and date for the rows in a month, the descriptive statistics on daily basis or on monthly basis for the same hour are summarized in the report):

a) check the lowest values for the month for those ambient analyzers that should not exhibit negative values; and

b) confirm consistency of diurnal patterns within the month.

8. **Mark data** - with Final Validation Edits in Envista ARM validation settings.

6.2 Level 1 Validation Procedure for Criteria Ambient Air Pollutants

$NO/NO_2/NO_x$

1. If NO/NOx zero checks are ≤ ±0.3 ppb, no adjustments are required with the exception of when negative hourly values (NO/NO_2/NOx) are observed;

2. If NO and/or NOx zero checks are > ±0.3 ppb, apply zero baseline adjustments for the affected channel(s) as described in Step 6 of Section 5.1. NO and NOx are adjusted first. NO_2 is adjusted if necessary, to maintain the relationship between parameters (NO_2 = NOx – NO). If a zero baseline adjustment is performed to one channel, then the adjustment must be performed on one or both of the other channels to ensure the relationship is preserved;

   Note: The NOx validation process was implemented in 2017. Baseline adjustments prior to implementation were only performed for NO and NO_2 with a neglection of the relationship preservance.

3. If a few small negative values (e.g. -0.1 ppb) are found, adjust them to 0 using a filter function. If negative values are many and relatively large, baseline adjustments would be performed on affected channels based on an evaluation of zero checks and the most recent multi-point calibration results.

Ozone

Evaluate the diurnal pattern to ensure that the highest concentrations occur between mid-afternoon and early evening, and the lowest concentrations occur in the early morning. Perform the baseline adjustment procedure as described in Step 6 of Section 5.1.

1. If daily zero performance checks are ≤ ±0.5 ppb, no adjustments are necessary unless negative hourly values are present (note: negative O_3 raw data readings are rare);

2. If daily zero performance checks are > ±0.5 ppb, zero adjustments are applied according to Step 6 of Section 5.1.

SO_2/TRS

SO_2/TRS concentrations are expected to be close to 0 ppb most of the time.

1. If daily zero performance check values are ≤ ±0.3 ppb, baseline adjustments are not required. Adjust negative values to 0;

2. If daily zero performance check values are > ±0.3 ppb, baseline adjustments are required. Follow the procedure outlined in Step 6 of Section 5.1.

CO

CO analyzers deployed in ENV stations perform an auto zero correction every 12 hours. The automated adjustments are reviewed to ensure the reliability of zero data collected during daily performance checks. Follow the baseline adjustment procedure outlined in Step 6 of Section 5.1.

Note: CO values below 0.1 ppm are unusual; accordingly CO baseline adjustments are based on 0.1 ppm instead of 0.

1. If zero-check values are ≤ ±0.1 ppm adjustments are not required;

2. If zero-check values are > ±0.1 ppm adjust the baseline. The minimum monthly value minus 0.1 ppm is usually applied as the baseline offset.

3. Negative values are invalidated; readings exceeding 2 ppm are suspect and should be scrutinized closely. For example check station temperature for potential correlations with readings exceeding 2 ppm to confirm or refute potential impacts of enclosure/equipment temperatures.

PM_{10} and $PM_{2.5}$

If PM_{10} and $PM_{2.5}$ are measured at the same site, evaluate them collectively. The magnitude of PM_{10} concentrations should be greater than $PM_{2.5}$ while both pollutants should follow similar trends over time. It is important to note that cases can occur where $PM_{2.5} > PM_{10}$. This can occur in cases where a TEOM (older technology) is used to measure PM_{10} and newer FEM analyzers (e.g. BAM, SHARP) are used to measure $PM_{2.5}$. The anomaly occurs because newer FEM technologies are able to better capture the semi-volatile component of the PM whereas the TEOM heats the sample causing the semi-volatile component to be driven off and not measured.

Small negative values ranging between -9.98 $\mu g/m^3$ and 0 $\mu g/m^3$ for PM_{10}, and -3.49 $\mu g/m^3$ and 0 $\mu g/m^3$ for $PM_{2.5}$ are automatically corrected to 0; negative values equal to or exceeding -9.98 $\mu g/m^3$ for PM_{10}, or -3.49 $\mu g/m^3$ for $PM_{2.5}$ are invalidated automatically when ingested into the database.

PM data does not require a baseline check like gas analyzers. The verification process for PM generally follows five rules:

1. Review automated corrections carefully for correctness. Correction criteria/alerts should be checked/corrected in Envista Setup if issues are found in the automated corrections.

2. Investigate outliers/spikes. Review 1-minute values and/or consult with the site operator to check if anomalies were caused by a special event such as grass mowing or a wildfire. Add an explicit note to any extreme values that are determined to be valid.

3. Where power failure/tape changes/filter changes occur, review data with added attention to investigate their validity. Events related to sample tape with a BAM or SHARP instrument or extended filter usage with a TEOM instrument may cause invalid readings. Identify the filter usage by filter pressure which is usually maintained under 70% for a TEOM. Invalidate the PM data where the filter pressure exceeds 90%.

4. Look for flat lines or noisy traces in the data. For all cases identified, review field reports and/or consult the site operator. These types of signatures in the data can sometimes indicate equipment failure or other issues (i.e. invalid data).

5. Typical parameter groupings to review for PM validation are:
   a) PM_TEOM and filter pressure;
   b) PM_BAM and BAM volume;
   c) PM_SHARP, OPTIC_SHARP and BETA_SHARP where the OPTIC and BETA are used as diagnostics;

   Note: OPTIC was validated prior to September, 2017. It has subsequently only been used for diagnostics.

6.3 Level 1 Validation for Meteorological Data

Temperature/Relative Humidity

1) Hourly temperature and relative humidity are reviewed collectively since the two parameters have a strong (negative) correlation. Review all auto corrections made to the data. Check the range of data and time of day when maximum and minimum temperature values occur, a reversed pattern should be evident for relative humidity.

2) Closely scrutinize data when temperatures are less than -35 °C or greater than 40 °C. Temperatures outside this range are uncommon in British Columbia and may indicate invalid data. Relative humidity between 100 and 105% are corrected to 100%, those over 105% are invalidated.

3) Closely inspect data that flanks periods when a power failure occurred or periods with extended flat lines. These types of data signatures may indicate operational issues with the sensors (i.e. invalid data).

Wind Speed/Wind Direction

1) Hourly wind speed, wind direction (scaler and vector values), and sigma values of wind direction (SigmaALL) are reviewed simultaneously in a month. Check the maximum and minimum value to confirm wind speed/wind direction are in a reasonable range.

2) Review the data for flat lines (constant value over a few hours). Contact the site operator to check if maintenance of sensors or bearings is needed.

3) SigmaALL is the standard deviation of 1-minute wind vector within an hour. If SigmaALL equals 0, invalidate all wind data including wind speed and wind direction.

Precipitation

OTT Pluvio

Check the Pluvio status flag. If not zero, invalidate the data. A flag other than zero indicates the gauge was under maintenance or a fault was detected on measurement. Check for spiking and compare the precipitation with the total volume of the rain gauge. Peak precipitation usually results in an increase of water volume in the gauge and an increase of relative humidity.

Snow Depth

Campbell Scientific SR-50A

Snow Signal Quality (SSQ) is used as an diagnostic parameter to identify the validity of snow depth data. If SSQ equals zero, the corresponding snow depth readings should be invalidated. Snow Depth sensors should be marked down in the non-snow season.

7. Level 2 Validation

Level 2 validation is initiated with the generation and distribution of annual statistical summaries following the completion of Level 1 validation of the previous year’s data. This typically occurs late in the first quarter following the data validation year. ENV uses summaries generated by executing R Statistics scripts and produces the following reports:

- Flatline reports → a summary of data flatlines from valid data entries
- Negative reports → negative values within validated data entries
- Annual Summary → historical data and present year data summaries

Table 4. Level 2 validation activities and frequency of execution

Validation Activities	Responsibility	Frequency
Review of Level 1 Validation	ENV	Semi-Annual
Generation and distribution of SAS summaries	ENV	Annual
Review of data summary/statistics/compare historical data	ENV/site operators/ AQ meteorologists	Quarterly/Semi-Annual/Annual
Examination of meteorological data	AQ meteorologist	Annual
Examination of relationships between pollutants	AQ meteorologist	Annual
Comparison of buddy sites	AQ meteorologist	Annual
Rejection of outlier data	ENV/AQ meteorologist	Annual
Examine audit results	ENV	Quarterly/Semi-annual

Annual summaries contain historic and current year annual means, percentiles, CAAQS exceedance counts (hours, days), and data captures. Summaries are distributed to all ENV groups involved with ambient air data monitoring and validation outlined in Section 2 of this document.

The annual summaries serve as a tool for closer data examination by advanced data users. Suggested actions once summaries are received include:

- Review of data trends (e.g., check increasing or decreasing annual trends, etc.)
- Examination of mean, and percentiles for outliers and other anomalies
- Comparison with neighbouring sites
- Comparison with related parameters (e.g., ozone and NO/NO_2 relations)
- Examination of diurnal and seasonal patterns

Open communications between operational monitoring and reporting groups occur during Level 2 data validation period. This facilitates sharing of software tools, expertise, and details regarding the history and patterns of each station.

Issues with any of the reported data are examined, assessed and flagged, unflagged or adjusted as necessary by the ADQS if necessary. Clean Air also receives the SAS Summaries which they use to conduct an independent evaluation of data.

When all of the concerns regarding data validity have been addressed and data validated by MetroVancouver is incorporated, the following activities take place:

- ENV Air and the Climate Networks Unit informs clients and stakeholders about completion of the data validation process.
- ENV's implementation of the Envistaweb "Welcome" page is updated to denote the latest valid data.
- The annual data csv generator is executed to post verified hourly data in ENV's FTP feed. This makes the data available through the BC government's open data portals.
- Annual data reporting to the ECCC NAPS data group is coordinated starting with an email notice of the completion of level 2 data validation, and configuring the FTP NAPS export feed.

8. Level 3 Validation

Level 3 validations is an independent process. For ENV, this occurs on an annual basis prior to the publication of the BC Lung Association's State of the Air Report, CAAQS reporting, and data sharing with ECCC. This process typically occurs mid-year with the publication of the results from the previous year.

Data validated through Level 2 are exported to ECCC for annual NAPS reporting. Stations and parameters that are included in the Memorandum of Understanding (MOU) between ENV and ECCC are configured in the FTP export listing. Any change in the listing from the previous year are reported to ECCC to configure into their system. An FTP export is then initiated and ENV receives a verification notice once the export is successfully completed. The ECCC's data group closely reviews the data. Anomalies are reported back to ENV for closer examination.

9. References

Canadian Council of Ministers of the Environment (CCME) 2011. *Ambient Air Monitoring Protocol For PM$_{2.5}$ and Ozone: Canada-wide Standards for Particulate Matter and Ozone*. www.ccme.ca. December 2017.

Revision History: 0.0

Approval

Part B2

Stationary Air Emissions Testing

Part B2 Table of Contents

1 Introduction

The requirements contained in this document are intended to supplement and update various stack sampling reference methods, and will clarify specific points as well as stating any requirements which may be unique to the Ministry of Environment, Lands and Parks (MELP).

1.1 Acknowledgements

The staff of the Greater Vancouver Regional District (GVRD) prepared the original version of this document which has subsequently been adopted and modified by the Ministry of Environment, Lands and Parks. Publication of the GVRD material is with the permission of the GVRD.

1.2 Purpose and Scope

This document standardizes sampling protocols and methods which may be required by permit, approval, regulation, or bylaw. It also serves as a guideline for stationary emission testing survey reporting for regulatory staff, permittees, and consultants.

Reference to the "Regulatory Body or Agency" means the governing body, Ministry of Environment, Lands and Parks and/or the delegated Greater Vancouver Regional District which regulates the discharge of contaminants into the air, as stated in the Waste Management Act (WMA). "Regulatory Administrator" has the same meaning as Director, District Director and manager, as defined in the WMA and Air Quality Director under Greater Vancouver Regional District Bylaw 725. "Regulatory Officers" has the same meaning as an officer defined in the WMA.

The Regulatory Administrator must be contacted if any deviations from the methods or equipment included in this code are contemplated (Appendix 7.1). Request for testing deviations require prior written approval by the Regulatory Administrator. Any questions with respect to details contained in this document should be directed to the attention of:

Director, Air Resources Branch
Environment and Resource Management Department
Ministry of Environment, Lands and Parks
Location: 3-2975 Jutland Rd
Victoria, B.C. V8T 5J9
Mail: P.O. Box 9341 Stn Prov Govt
Victoria, B.C. V8W 9M1
Phone: (250) 387-9933 or 387-9932
Fax: (250) 356-7197

Director, Air Quality Department
Greater Vancouver Regional District
4330 Kingsway
Burnaby, B.C. V5H 4G8
Phone: (604) 436-6700
Fax: (604) 436-6707

1.3 Continuous Emission Monitoring

For in-stack continuous emission monitors (CEMs), the Regulatory Agency requires the use of Environment Canada or United States Environmental Protection Agency (U.S. EPA) protocols and performance specifications (as listed in Appendix 7.1), unless otherwise superseded by other Provincial or GVRD requirements.

1.4 Validation of New Methods

The Regulatory Agency may adopt new stationary source test methods that are not used in other jurisdictions provided the requirements of U.S. EPA Method 301 have been met (see Appendix 7.1 listing). The onus is on the source owner or operator proposing the new method to ensure that all the requirements of Method 301 have been met. Before a new method can be accepted, the Regulatory Administrator may require substantial documentation to indicate all the information required under Method 301 is supplied as appropriate.

1.5 Trade Names or Commercial Products

Mention of trade names or commercial products does not constitute endorsement by the Ministry of Environment, Lands and Parks or the Greater Vancouver Regional District.

2 2. Pre-Test Conditions

The following conditions must be met prior to sampling:

- All manual source testing results submitted to the Regulatory Agency must have been conducted or continuously supervised on-site by at least one individual who has passed relevant stack sampling courses as required by the Regulatory Administrator. Relevant courses include the following:
    - British Columbia Institute of Technology (BCIT), Stack Testing and Sampling;
    - Mount Royal College (Calgary), Stack Sampling Course;
    - University of Windsor, The Windsor Stack Sampling Course;
    - Fanshawe College (London, Ontario), Air Sampling and Evaluation LabII; and
    - United States Environmental Protection Agency (U.S. EPA), Source Sampling for Pollutants.

  Note: It may be possible to challenge the above courses. Further information may be obtained by contacting the educational institution.

- It is the responsibility of the owner/operator of a facility to provide safe access to the chosen sampling location and a firm platform for obtaining samples shall be provided following Appendix 1 of this chapter and pertinent Workers' Compensation Board Regulations.

- The chosen sampling site must meet the minimum requirement of two stack diameters downstream and a half a diameter upstream from the last flow disturbance. Note that this requires more sampling points compared to a sampling site that is located eight stack diameters downstream and two diameters upstream from the last flow disturbance.

- The cross-sectional sampling point layout within a rectangular duct must be chosen such that the ratio of the length to the width is between 1.0 and 2.0.

- For particulate sampling, the mean rotational angle for all sampling points must not exceed +/-20o from the 0o reference position (calculated as outlined in Appendix 2 of this chapter).

- For sources that operate under Provincial permit, approval, regulation or bylaw, the proponent is to provide the Regulatory Administrator with a minimum of five working days advance notice before emission compliance testing is carried out. Alternately, the proponent can provide the Regulatory Administrator with another mutually acceptable minimum advance notice duration, in writing, before emission testing is carried out.

- For sources that operate under GVRD permit, approval or bylaw, the proponent shall provide the Regulatory Administrator with a minimum of three working days advance notice before any emission compliance testing is carried out.

- The results of all air emission testing performed for regulatory compliance requirements under permit, approval, regulation or bylaw shall be retained by the facility, for a period of five years, and be made available to the Regulatory Administrator upon request.

- A detailed test plan must be submitted in writing for approval for any non-routine (e.g., Destruction Removal Efficiency or Special Waste Facility) testing programs 30 days prior to the scheduled sampling.

3 3. Additional Sampling Requirements

In addition to the requirements of the Reference Method for Source Testing: Measurement of Releases of Particulate from Stationary Sources (EPS 1/RM/8), or U.S. EPA Methods 1 to 5, the following requirements must be fulfilled for all compliance testing:

- A minimum of three test runs constitute a valid stack survey, unless the method being used specifically states otherwise. Where less than three runs are being used, the Stack Emission Survey Report must quote the language and section of the method that allows exception from the three test run requirement.

- For a valid stack survey, the individual test runs should be taken on the same day. The duration, over which the three test runs are extracted, for a valid stack survey, should not exceed two days. Any individual run shall be taken on one given day. Alternately, the proponent can provide the Regulatory Administrator with another mutually acceptable duration for stack sampling, in writing before emission testing is carried out.

- The results of individual test runs and the average of all test runs constituting a valid stack survey shall be reported. The arithmetic average of all test runs taken during a valid stack survey shall be used to assess compliance with the limits stated in permits, approvals, regulations or bylaws.

- The minimum duration of one complete test run must be 60 minutes, except testing for dioxins, furans, PCBs and PAHs which shall be a minimum of 240 minutes per individual test run, unless the method being used states otherwise. Where exception is being made, the language and section of the method that allows for this must be quoted in the Stack Emission Survey Report (see Appendix 9.1).

- The sampling nozzle shall be sized to obtain a sample volume of 1 m3 (as sampled) or greater for particulate testing.

- Sample points shall be calculated using the applicable tables found in EPS 1/RM/8 or the US EPA CFR 40 Part 60. The general guidelines are:

    - stacks with diameters greater than 61 cm - 12 point minimum, 24 point maximum (25 for rectangular stacks)
    - stacks with diameters between 30 and 61 cm - 8 point minimum, 24 point maximum (25 for rectangular stacks)

  - Consult the applicable tables for calculating points at locations requiring more than the minimum number of points and less than the maximum.

  - In the recovery procedure for a standard particulate test, acetone and deionised water must be used for washing the interior surfaces of the nozzle, probe, cyclone (if used), and filter holder (the front half of the sampling train). Make blank determinations on the acetone and water and subtract the weight from the washing particulate catch. The blank volumes approximate the average amount of water and acetone used for each front half wash.

  - In performing grab sampling (e.g., bag, bomb, or container for independent analysis), unless the method being used states otherwise:

    - two grab samples withdrawn one after the other constitute a single test run,
    - a minimum of three test runs are required for each valid stack survey, and

  - an interval of at least one hour is required between the individual test runs.

- For cases where deviations from the above three conditions are applied, the Stack Emission Survey Report must quote the language and section of the method that allows the exception(s).

- High volume particulate sampling is considered to be non-standard and requires prior written approval from the Regulatory Administrator. If sampling by these methods has been approved, the method outlined in Appendix 3 of this chapter must be followed.

- Leak checks are mandatory and should be carried out as outlined in Appendix 4 of this chapter.

- Sampling under adverse conditions may require specialized equipment or procedures. Some of these are listed in Appendix 5 of this chapter.

4 4. Calibration Requirements

The following table outlines the general requirements for the calibration of source testing equipment:

Equipment	Interval	Recommended Procedure
Dry Gas Meter	Annually when equipment remains at a permitted facility. Every 6 months when equipment is used at various facilities.	Against a: • spirometer, • wet test meter, • calibration checked dry gas meter, and/or • critical orifice as indicated in U.S. EPA Method 5.
Magnehelic Gauges	Annually when equipment remains at a permitted facility. Every 6 months when equipment is used at various facilities.	Against an inclined manometer, as indicated in U.S. EPA Method 2.
Nozzles	Calibrate before initial field use. When nozzles become nicked, dented or corroded they are to be reshaped and calibrated prior to use.	Calibrate by measuring with a micrometer. Examine thoroughly prior to each field use. See U.S. EPA Method 5.
Pitot Tubes	After each field use re-examine. For a new pitot tube or in the event of any damage such that the pitot tube does not meet specification, repair and calibration is required.	Calibrate in a wind tunnel using the procedures outlined in U.S. EPA Method 2.
Thermocouples	Every 6 months.	Against a National Institute of Standards & Technology (N.I.S.T) thermometer, with ice, water, and hot oil as indicated in U.S. EPA Method 2.
Rotameters		Need not be calibrated, but should be cleaned and maintained according to the manufacturer's instruction, as indicated in U.S. EPA Method 3.

In addition to the requirements above, if critical orifices are used as a means of checking calibration, they are to be checked once every two years against a spirometer, wet test meter, or calibrated dry gas meter. The calibration certificate must include all pertinent data, the date of calibration, and the name of the technician who performed the calibrations. Valid calibration certificates for all pertinent equipment used in the emission survey must be included in the report. The calibration sheets to be used are those referenced in Appendix 6 of this chapter, or those which include all the pertinent data outlined in these reference calibration sheets.

All calibrated instruments shall be permanently and uniquely identified for easy reference.

A copy of the most current calibrations shall be carried with the source testing team on all field tests and must be provided to Regulatory Agency audit staff or officer upon request.

Note that the stated interval of either six months or annually should be considered a maximum time frame, as calibrations must be conducted as required.

5 5. General Reporting Requirements

The stack emission survey reports must be tabulated, summarized, and forwarded to the Regulatory Administrator in the appropriate Region or District either as an attachment to the Permittees’ quarterly reports or as a separate report.

All stack emission survey reports shall be clearly legible and contain the necessary detail as specified in the report requirements in Appendix 9 of this chapter. All reports shall include, but not be limited to, the information listed in Appendix 9, unless prior written authorization has been obtained from the Regulatory Administrator.

The electronic reporting of data may be required in the future.

6 Method Specific Reporting Requirements

In addition to the requirements specified in EPS 1/RM/8, or U.S. EPA Methods 1 to 5, the following outlines the minimum reporting requirements for Methods 1 through 5, high volume particulate sampling, and gaseous constant rate sampling.

6.1 Method 1 - Determination of Sampling Site and Traverse Points

(a) Report all stack dimensions. A diagram of the sampling site must include the following:

- Measured distance and number of duct diameters upstream and downstream from the last flow disturbance
- Stack shape and cross sectional distances
- Stack cross sectional area
- Number of sample ports
- Nipple length and diameter

(b) Include the measured location of all traverse points, along with a notation of any points which have been combined during the testing period [i.e., multiple points within 1.3 to 2.5 cm (0.5 to 1 inch) of the stack wall].

6.2 Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate

(a) A cyclonic flow check is required at each measurement location. In the report, include the rotational angle for each individual point as well as the calculated mean rotational angle for all sampling points. The cyclonic flow check need not be repeated for each survey provided a previous cyclonic flow check has been performed and no modifications affecting the flow patterns have taken place since that time.

(b) Report the devices used for velocity measurement along with the range of the instrument used to measure the differential pressure. Calibration data is required for the S-type pitot tubes, standard pitot tubes, and/or magnehelic gauges used during the measurement period.

6.3 Method 3 - Determination of Gas Composition and Molecular Weight

6.3.1 Grab Sampling (Orsat or “Fyrite”)

Take a minimum of three individual samples during each test run - one at the start, midpoint, and conclusion of each test. Report the time the individual tests were carried out and the results of these measurements.

6.3.2 Integrated Sampling

Note the type of collection bag (Tedlar, Mylar, Aluminized Mylar) as well as the sampling time and rate. Report the time lapse between collection and analysis along with results of the leak check procedure performed on the system.

6.3.3 Continuous Sampling (Non-Permanent In-Stack)

(a) Report the type of analyzer, method of detection, calibration procedure with results, and leak check results.

(b) Report sample times and any interruptions or problems with the measurement system.

6.4 Method 4 - Determination of Moisture Content of Stack Gas

(a) The moisture calculations for saturated conditions shall include two values:

1. a moisture value from the condenser method
2. a moisture value from a psychometric chart and/or saturation vapour pressure tables, as found in Appendix 10 of this chapter.

(b) The lower of the two reported values is to be considered the correct moisture value and is to be used in all subsequent calculations.

(c) Record the temperature of the last impinger for each sampling interval on the field sheet.

(d) Record reported weights or volumes of impingers individually including the weight difference of the silica gel.

6.5 Method 5 - Determination of Particulate Emissions

(a) Calibration sheets are required for the following equipment:

1. Dry Gas Meters
2. Pitot Tubes
3. Magnehelic Gauges
4. Orifice Meters
5. Thermocouples
6. Nozzles

(b) A flow chart or schematic of the collection system components is required. This schematic shall indicate but not be limited to: the type of sampling probe liner, type and number of impingers, and contents and volume of impingers.

(c) Leak tests are to be conducted as outlined in Appendix 4 of this chapter. The field sheets must document the time, vacuum reading, and the leakage rate.

(d) The sampling field sheet must be complete and legible. Readings are taken and recorded for each sampling interval which must be a minimum of 2.5 minutes and a maximum of 5 minutes. This is to include:

1. Stack temperature
2. Velocity pressure (Δ P)
3. Orifice pressure (Δ H)
4. Dry gas meter, probe, hot box, and last impinger temperature
5. Pump vacuum (millimeters of Hg)
6. Dry gas meter volume

(e) In addition, document all pre-test estimates of moisture, stack temperature, maximum velocity pressure and the nozzle estimate on field sheets.

(f) Document the sample recovery procedure, including all clean up procedures for the sampling probe, cyclone, filter holder and impingers.

6.6 Continuous Emission Monitoring Survey (Non-Permanent In-Stack)

With the exception of sources covered under the MELP Asphalt Plant Regulation, three one-hour tests with calibrations run between each test are required for a valid continuous emission monitoring survey. Emission calculations for tests of one hour will be based on readings at one minute intervals (a minimum of 60 measurements).

For sources covered under the MELP Asphalt Plant Regulation, a single one hour test is required for a valid emission monitoring survey for organics and carbon monoxide. Calibration runs are to be performed both before and after the test. Emission calculations will be based on readings at one minute intervals (a minimum of 60 measurements).

Reports for continuous emission monitoring surveys shall include:

(a) A detailed sampling system description and schematic diagram

(b) Copies of digital or chart recorder printouts labeled with individual test start and finish times, chart speed, pre-and post calibrations, span, drift determination, parameters sampled, number of sample points, and NOx converter efficiency.

(c) Tables for:
  1. Analysis of calibration gases
  2. Analyzer calibration data
  3. System calibration bias and drift test
  4. Sample tables are found in Appendix 8 of this chapter.

6.7 High Volume Particulate Sampling Methods

Please note that Method 5 is mandatory and only for unusual circumstances will the use of the high volume procedure for compliance testing be considered. Prior written approval from the Regulatory Administrator is required, as it is a non-standard testing method. Information submitted to the Regulatory Agency shall include but not be limited to:

(a) A detailed diagram of the sampling site including the duct locations where sampling was conducted.
(b) A detailed schematic of the sampling apparatus.
(c) Calibration sheets for the following equipment:

1. Pitot tubes
2. Magnehelic Gauges

   3. Thermometers
   4. Calibration curve for the flow orifice.

(d) The size of the nozzle used.

(e) The sampling field sheets and all information necessary to conduct the calculations. A sample calculation shall be conducted for one run. The percent isokinetics for each sampling point must be submitted.

(f) Documentation of the sample recovery procedure which was used.

6.8 Determination of Gaseous Emissions from Stationary Sources

(a) Sampling and analytical procedures must follow approved methods and be documented. Gas sampling trains shall be operated within the recommended maximum flow rates outlined in the method. Any deviation from recognized procedures will require prior written approval from the Regulatory Administrator.

(b) A flow chart or schematic of the collection system components is required. This diagram must include the impinger contents and volumes as well as the type of impinger and sequence. Document the type of impinger connections.

(c) Calibration sheets are required for:
   1. Dry Gas Meters
   2. Pitot tubes
   3. Magnehelics
   4. Thermometers
   5. Orifice meter

(d) On the gas sampling field sheet, detail sampling conditions as described in Appendix 9 of this Chapter at an interval not greater than 10 minutes between readings.

(e) In addition, Determination of Nitrogen Oxides (Flask Method) requires:

   1. The volume of the collection flask - flask valve combination must be measured prior to sampling. Record the measured volume on the flask.

   2. On the field sheet, include the flask volume and initial and final flask pressure and temperature. An initial and final barometric pressure are also to be included.

   3. Enclose the sampling field sheet and all information necessary to conduct the calculations. Include an example calculation for one run.

(f) The sample recovery procedure must be documented.

7 7. Sources of Further Information

Alberta Stack Sampling Code. Publication Number: REF. 89 ISBN 0-7732-1406-2, 1995 version effective January 1, 1996.

Air Resources Branch; Source Testing Code (Version #2). Nov. 1980. Province of Ontario, Ministry of Environment, Report # ARB-TDA-66-80.

Asphalt Plant Regulation. BC Regulation 217/97, Deposited June 27, 1997, Province of British Columbia, Ministry of Environment, Lands and Parks.*

Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III. 1988. United States Environmental Protection Agency, Environmental Monitoring Laboratory; Stationary Sources Specific Methods.

Standards of Performance for New Stationary Sources, Vol. 40. United States Environmental Protection Agency, Office of the Federal Register; Parts 53-60.

Source Sampling Manual Volume I. August 1981. State of Oregon, Department of Environmental Quality, Air Quality Control Division.

Occupational Health & Safety Regulation, BC Regulation 296/97, effective April 15, 1998, Workers Compensation Board of British Columbia.

Reference Method for Source Testing: Measurement of Releases of Particulate from Stationary Sources. December 1993. Environment Canada, EPS 1/RM/8.

Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation. September 1993. Environment Canada, EPS 1/PG/7.

* Available at http://www.qp.gov.bc.ca/stat_reg/regs/elp/R217_97.htm

8 8. Revision History

May 05, 2020	Formatting of this ‘Part’ Part B2 was completed for consistency. Technical information, schematics and otherwise all content were not changed.
October 10, 2013:	This section republished without change. Appendix 10.3 - Sample Container, Preservation, and Hold Times for Air (Vapours) included.
February 28, 2001:	The Stationary Air Emissions Testing Section was revised in detail, with the revised draft reviewed by private sector representatives.
November 1999:	Initial publication.

Appendix 1 Platform, Access and Safety Requirements

Appendix 1.1 Additional Platform, Access and Safety Requirements for Monitoring Stack Emissions

The Workers' Compensation Board (WCB) of British Columbia helps create a working environment that protects the health, safety and well being of workers. To achieve this, the WCB administers the Occupational Health and Safety Regulation adopted under the authority of the Workers Compensation Act and the Workplace Act.

For platform access and safety requirements related to the monitoring of stack emissions, all applicable WCB requirements should be adhered to. The following section is intended only to serve as guidance for setting up stack sampling platforms, access ladders and other associated works. The latest WCB requirements are to be used in all cases where the following guidelines are in conflict.

(a) Safe access to the sampling locations and a firm platform for obtaining stack samples shall be provided.

- Access ladders shall be constructed in accordance with the latest Workers' Compensation Board (W.C.B.) requirements. In addition, it is recommended that a "safety climb" with two sets of harnesses be provided.
    - The basic platform shall be 1.07 metres (3.5 feet) wide with a 1.07 metre (3.5 foot) high railing. If 2 ports are required at 90°, the stack platform shall serve the quarter of the stack circumference between the ports and shall extend at least 0.91 metres (3 feet) beyond each port. The 1.22 metre (4 foot) section of the top railing in front of the ports (Fig. 1.1 and 2) shall be hinged in such a manner that the top rail can swing upward and over 180 degrees. This facilitates the movement of the sampling box and probe perpendicular to the stack during a traverse without interference from the top railing of the platform.
    - The sampling port shall consist of a standard 10 cm (4 inch) male-threaded pipe nipple welded to the stack at the sampling location with a screw cap to cover the opening. The ports shall be installed flush with the interior stack wall and shall extend outward from the exterior stack wall at least 7.6 centimetres (3 inches). Properly grounded electric outlets of 110/120 volts (15-20 amps), near each sampling port, or, spaced in such a manner as to be accessible for sampling at all ports, shall be installed to provide power for the sampling train components and accessories. The sampling port shall be approximately 1.52 metres (5 feet) above the base of the platform. An eyebolt shall be installed 0.91 metres (3 feet) directly above each port. The eyebolt should be hooked with a 3.2 millimetre (1/8 inch) steel cable of the length indicated in Fig. 3. This cable should be supplied by the platform owner and should remain on the stack for future testing.
- Circular stacks with an inside diameter greater than 1.22 metres (4 feet) or rectangular stacks (Fig. 2) with the largest dimension greater than 1.22 metres (4 feet), shall be equipped with platform extensions as indicated in Fig. 3. The required extensions are in addition to the basic platform width of 1.07 metres (3.5 feet) and must be firmly secured. The 1.22 metre (4 foot) width of the extension shall be centered around the traverse axis. Schematic diagrams showing facilities for circular and rectangular stacks are shown in Figs. 1, 1.1 & 2 respectively.
    - Constant rate or gaseous sampling does not require the installation of multiple ports and eyebolts.

(b) Access to working platform (W.C.B. regulation 30.14 and American National Standards Institute (A.N.S.I.) A143-3 1974);

- Adequacy of the working platform (A.N.S.I. A14-3 1974);
- Guardrail system around working platform (W.C.B. regulation 8.70 and 8.78);
- Transfer of equipment up to the working platform (W.C.B. regulation 30.16).

(c) The W.C.B. permits the Regulatory Agency to specify platform widths greater than 76 cm (30 inches), if desirable or necessary;

- The stairs, ladder and platform must be certified by a Professional Engineer;
- It is the responsibility of the stack owner to comply with Industrial Health and Safety requirements concerning the access to the stack and the platform.

Appendix 1.2a Sampling Facilities on Circular Stacks

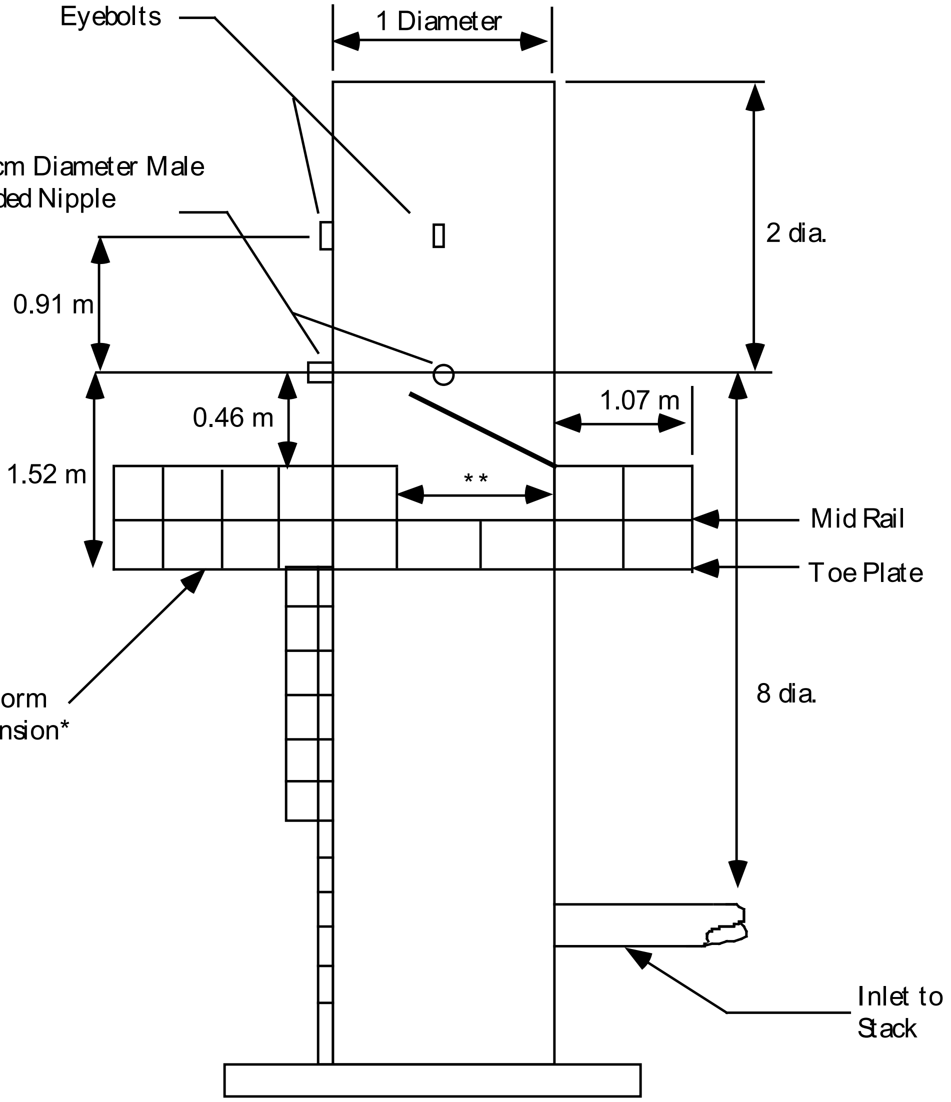


Figure 1

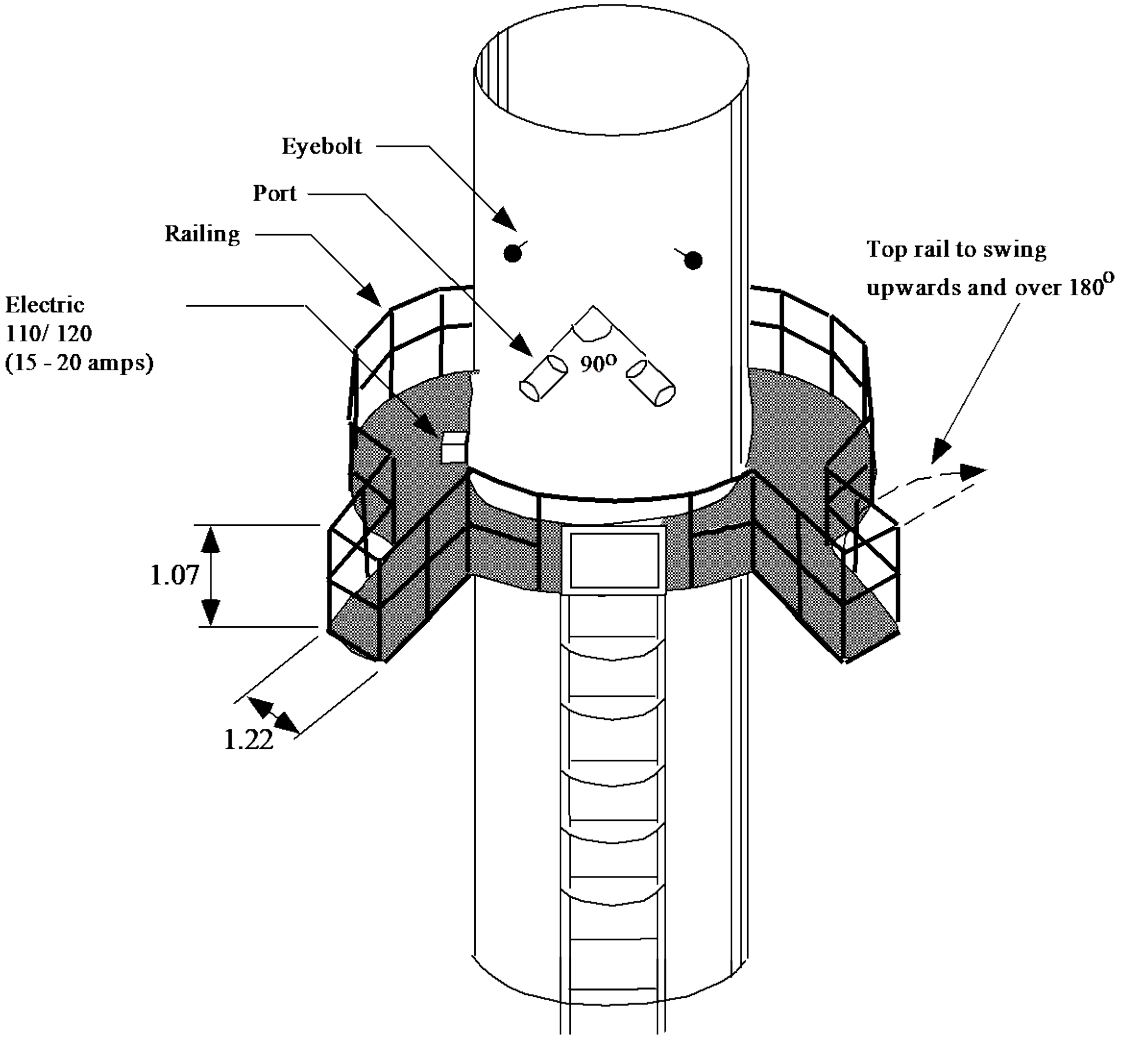
Note:

* Stacks with Inside Diameter (I.D.) less than 1.22 m do not require platform extension. See figure 1.1 for length of platform extension when I.D. is greater than 1.22 m.

* * The 1.22 m top rail-guard in front of ports (with or without platform extension) shall be hinged to swing upwards and over 180 degrees when necessary.

All dimensions are in metres unless otherwise noted.

Appendix 1.2b Sampling Facilities on Circular Stacks



Schematic Diagram

Figure 1.1

All dimensions are in metres.

Appendix 1.3 Sampling Facilities on Rectangular Stacks

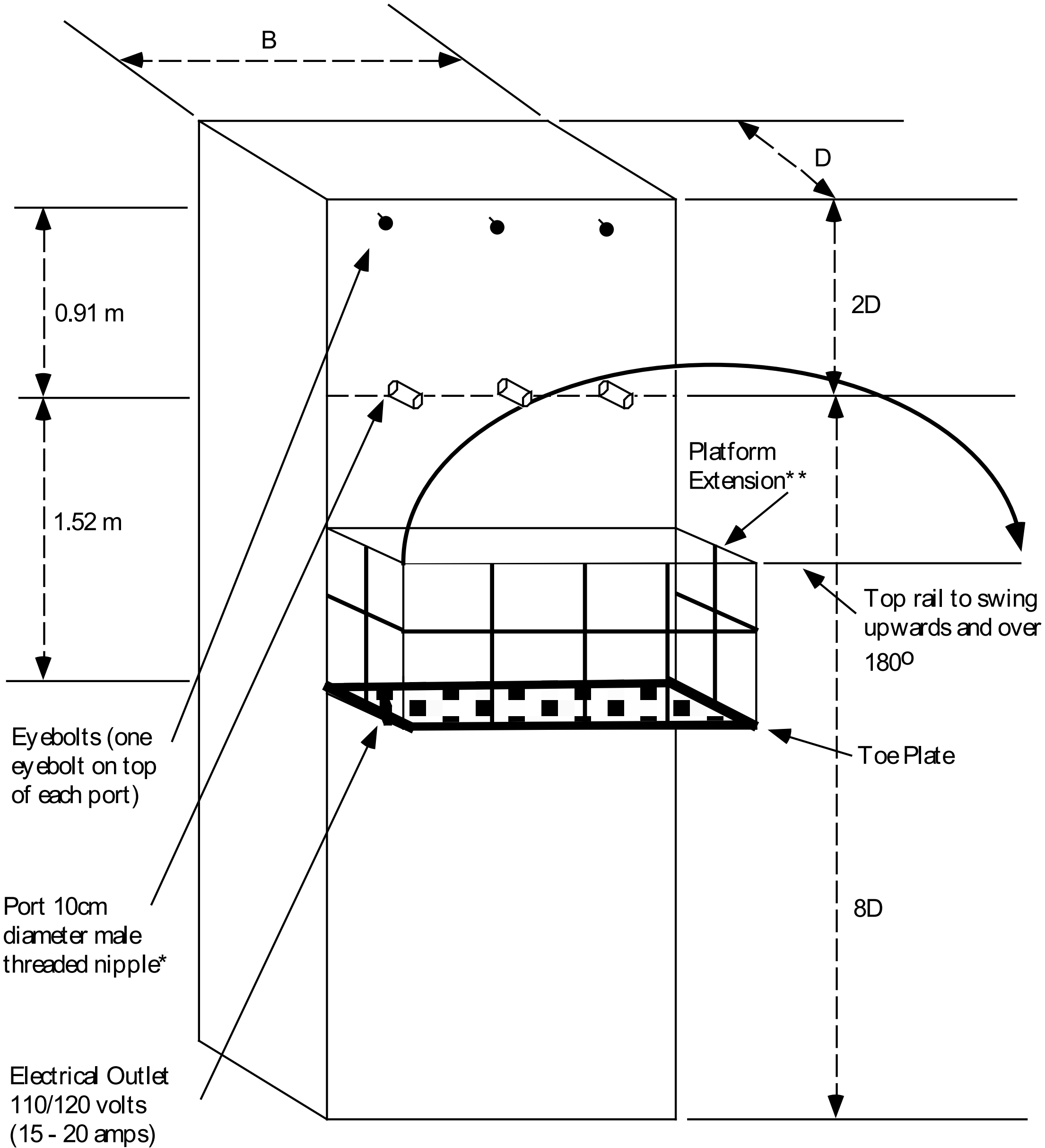


Figure 2

Note:

* The number of ports required is described in the text.

** Stacks with I.D. less than 1.22 metres do not require platform extension. However, top rail in front of the ports, shall be hinged to swing upwards and over when necessary.

All dimensions are in metres, unless otherwise noted.

Appendix 1.4 Dimensions of a Stack Sampling Platform

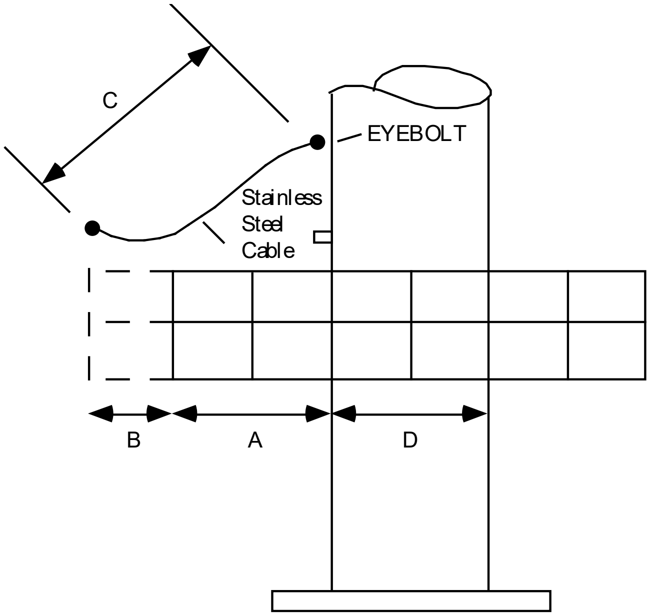


Figure 3

D DIAMETER OR LARGEST DIMENSION OF A STACK (m)	A BASE PLATFORM WIDTH (m)	B PLATFORM EXTENSION (m)	C LENGTH OF STEEL CABLE (m)
≤ 1.22	1.07	0	2.44
1.22 < D ≤ 1.83	1.07	0.46	3.96
1.83 < D ≤ 2.44	1.07	0.76	3.96
> 2.44	1.07	1.07	3.96

Appendix 2 Cyclonic Flow Check & Pitot Leak Check Procedure

Cyclonic Flow

Location of a suitable sampling site for velocity measurement or for particulate and mist determinations requires that the gas flow be essentially parallel to the stack walls.

If there is a possibility of cyclonic flow [as determined in Section 6.2 (a)], checks with a pitot tube and draft gauge should be made as follows:

Pitot Leak-Check

(a) Connect calibrated S-type pitot tube to a manometer.

(b) Leak check the system by drawing a vacuum of two to four inches of water on the manometer. The manometer reading should not change over a 15 second period.

(c) Repeat this procedure applying a positive pressure to the system.

(d) If the system leaks, correct the problem and repeat the leak check procedure.

Cyclonic Flow Check

(a) Carefully zero the manometer and insert the pitot tube so that the planes of the face openings are perpendicular to the stack area cross sectional plane - that is, parallel to the expected gas flow. The pitot tube is thus rotated 90° from its usual position.

(b) Traverse the stack area by measuring the velocity head at each sampling point with the pitot tube in this position. Keep the sampling port opening sealed while traversing. Temperature need not be measured at this time.

(c) When the gas flow is exactly parallel to the stack walls and, therefore, parallel to the pitot tube face openings, no reading will be obtained on the manometer. If a reading is obtained, rotate the pitot tube around its longitudinal axis until a zero reading is indicated on the manometer.

(d) Record the angle of rotation for each point (starting with 0° in the pitot tubes initial position) required to obtain a zero manometer reading.

(e) Obtain an arithmetic average of the angles of rotation at each traverse point, including angles of 0°. If the average angle of rotation is < 20°, the gas flow conditions are acceptable. If the average angle is > 20°, the conditions are not acceptable; testing must be halted and the Regulatory Administrator is to be consulted.

To facilitate measurement of pitot tube rotation, a number of devices can be made, depending on the user. Fabrication of a protractor that will fit over the sampling port along with a movable indicating arm clamped to the pitot tube will provide a measurement of the angle of rotation. A level indicator (available at most hardware stores) calibrated in 5° increments can also be mounted on the pitot tube and used to measure rotation.

The preferred device is a degree level (available at most hardware stores) with 1° increments which can be mounted on the end of a pitot tube. Its alignment with the head of the pitot tube can be checked by one of two methods:

1. the use of two indicating levels, one at the front and one at the end or,

2. by placing the pitot on a stable surface then place the indicating level at the front and then at the end and compare readings. The readings do not have to be the same. The differential, using the front as the reference, or true value can be subtracted or added to the corresponding angular determinations of stack flow.

Appendix 3 High Volume Particulate Sampling

Appendix 3.1	**Sample Collection Procedures**
Appendix 3.2	**Sample Recovery**
Appendix 3.3	**Analytical Procedure**

Appendix 3.1 Sample Collection Procedure

(a) Use a pitot tube to map the velocity distribution across the face of the exhaust. Areas of zero or negative flow should also be included if present. At each point at which the velocity is measured, measure the flow in the direction giving maximum deflection of the pitot pressure gauge.

(b) Select six or more points of outgoing (positive) flow from the points measured above to sample. The points shall be representative of the flow pattern and should include the point of maximum velocity. If six points of positive flow cannot be obtained, use the maximum number possible. Do not choose any points closer than 5 cm (2 inches) from the wall.

(c) Measure the average exhaust temperature.

(d) Determine the nozzle size required for isokinetic sampling. An estimate of the orifice temperature is required. For low temperature exhausts the orifice temperature is usually very close to the exhaust temperature. For higher temperature exhausts, a trial run may be necessary to determine the expected orifice temperature.

(e) Calculate the required orifice pressure drop for each chosen sampling point to obtain an isokinetic sample. Mount the nozzle so that the nozzle opening is parallel to the cyclone or stack exhaust. This will keep the differential pressure gauge properly positioned to read as it was designed to. With the probe out of the stream, turn on the blower and adjust the flow rate to that calculated for the first sampling point. Locate the probe nozzle at the first sampling point and immediately start the timer. Move the probe around until the velocity pressure matches that calculated for the flow rate which was pre-set. The sample rate may need to be adjusted after entering the gas stream. The probe nozzle must be pointing directly into the flow.

(f) Continually monitor the velocity during the sampling period (with the pitot tube mounted to the probe) and move the probe around as required to keep it in an area where the velocity matches the original velocity used to calculate the pre-set sampling rate. Record the sampling time, the orifice temperature and pressure drop on the data sheet.

(g) A survey shall consist of three tests. The minimum sample time per test shall be 15 minutes with a minimum sampling time per point of 3 minutes.

(h) Repeat the above steps for each sampling point. The blower need not be turned off between points if readjustment to the new sampling rate can be made rapidly.

(i) Care should be taken so that the nozzle does not touch the walls of the exhaust stack as deposited particulate may be dislodged and enter the train. If there is reason to believe this happened, discontinue the sample, clean the train and restart the test.

(j) If excessive loading of the filter should occur or the pressure drop should increase such that isokinetic conditions cannot be maintained, replace the filter and continue the test.

(k) At the conclusion of the sampling period, remove the probe from the exhaust and turn off the blower (do not reverse this order as the filter may be broken and the sample lost). Plug the nozzle to prevent sample loss and transport the sample to the recovery area.

(l) Measure the moisture content of the stack gas and the barometric pressure (absolute). The moisture may usually be measured by the wet-dry bulb technique.

Appendix 3.2 Sample Recovery

(a) The probe and nozzle should be brushed with the blower turned on to suck the particulate onto the filter.

(b) After filter removal and storage, the nozzle, probe and front half of the filter holder must be rinsed with acetone or methanol and brushed until all visible particulate is removed.

Appendix 3.3 Analytical Procedure

The filter must be weighed immediately upon removal from the dessicator because of the relatively large filter and the possibility of a hygroscopic filter catch.

9 Appendix 4 Sample Train Leak Check Procedures

Leak checks are necessary to assure that the sample has not been biased (low) by dilution air. The method specifies that leak checks be performed at certain intervals as discussed below:

Pre-test - A pre-test leak check should be conducted by plugging the nozzle inlet and pulling a vacuum at 380 mm Hg (15 inches Hg) for at least one minute. The leakage rate must be less than 0.57 L/min. (0.02 ft^3/min.) or 4% of the estimate average sampling rate, whichever is less. Sampling cannot proceed until the leakage rate is acceptable.

During Sampling - If a component (e.g., filter assembly or impinger) change is made (including problems due to breakages or cracks) during the sample run, a leak check shall be conducted before the component change. The leak check shall be performed at a vacuum equal to the maximum vacuum reached up until that point in the test. If this test has a leakage rate above the accepted maximum of 0.57 L/min. (0.02 ft^3/min.) the sampling shall be considered invalid, and redone. After the component change the pre-test shall be repeated.

Post-test - A leak check is mandatory at the conclusion of each sample run. The leak check should be conducted at 380 mm (15 in.) Hg. If the leak check fails at 380 mm (15 in.), then the test may be repeated at the maximum vacuum reached during any point in the test run. The maximum allowable leakage rate is 0.57 L/min. (0.02 ft^3/min.) or 4% of the average sample rate, whichever is less. A correction factor may be applied if the leakage is in excess of the acceptable limits. However, approval for acceptance must be granted by the Regulatory Administrator and each case will be assessed individually.

Appendix 5 Sampling under Adverse Conditions

It is essential that a sample be representative of the source from which it was taken. Various conditions may affect this criterion. The following are some ways which these adverse conditions may be overcome:

Corrosive or highly reactive components - The use of special materials such as Inconel, glass, quartz or Teflon.

High vacuum sources - (found before exhaust fans and high natural draft stacks) - Operation of the sampling train pump before and after probe insertion to avoid the escape of impinger solution into the filter holder; gas drawn before and after should not be included in the sample volume.

High pressure sources - Port sealed tightly yet allow for freedom of movement of the probe; for example, a gas valve and packing gland could be incorporated in the port.

High temperature source (> 600°C or 1100°F) - Quartz or Inconel probe liner or water cooled probe with temperature control to avoid cooling below dew point; shielded thermocouple.

High moisture content source - Probe temperature maintained above the dew point; probe sheathed with insulation layer within an outer layer to prevent droplets from impinging on the actual probe, creating a cooling effect via evaporation; for Method 5 locate a filter between the third and fourth impinger (as specified in the method).

High velocity source - Relocate sampling site or expand duct or stack to reduce the velocity; pumps of sufficient capacity to maintain the required sampling rates can be used.

Low velocity source - Sources with a velocity in the range of 1.5-3.0 m/s (5-10 ft/s) should be measured using an inclined manometer with a scale of 0 to 0.6 kPa (0-2.4 in. H_2O). Sources with velocities below 1.5 m/s (5 ft/s) should have the sampling site relocated or the duct constricted to increase the velocity.

Appendix 6 Calibration Forms

Appendix 6.1 General Calibration Form

Equipment	Date Of Calibration	Place Of Calibration	Method
S - Type Pitot			
Orifice Meter			
Temperature Device			
Rotameter			
Nozzle Diameter			
Dry Gas Meter			
Magnehelic Gauge			

Appendix 6.2 Orifice Meter Calibration Form

Technician : ______________________

Date : ______________________

Signature : ______________________

Console I.D. : ______________________

Parameter Summary	**Run No. 1**	**Run No. 2**	**Run No. 3**	**Run No. 4**	**Run No. 5**
Md = mol. wet dry air					
Pb = atmospheric press.					
Y = dry gas meter calibration					
ΔH = press. diff.@ orifice					
Ri = initial dry gas vol.					
Rf = final dry gas vol.					
Δ t = measured interval (min.)					
Qm = Y (Rf - Ri)/ Δt					
To = dry gas outlet temp.					
Tm = To + 273 or 460					
Pm = Pb + ΔH/13.6					
Ko = Qm/(Tm/Pm• ΔH/Md)1/2					
				Average Ko	

Appendix 6.3 Nozzle Diameter Calibration Form

Technician : ____________________
Date : ____________________
Signature: ____________________

Nozzle I.D.	Nozzle Diameter (a)			∆Diameter (b)	Average Diameter (c)
	D1	D2	D3		

Where:

(a) D1, D2, D3 = three different nozzle diameters; each diameter must be measured with a micrometer to within 0.25 mm (0.001 in.)

(b) ∆Diameter = maximum difference between any two diameters, must be less than or equal to 1.0 mm (0.004 in.)

(c) Average Diameter = average of D1, D2 and D3

Appendix 6.4 Temperature Calibration Form

Technician : ____________________
Date : ____________________
Signature : ____________________
Barometric Pressure : ____________________
Land Elevation: ____________________

Type of Device and I.D.: ____________________

Calibration Medium	Mercury In Glass Thermometer Temp.		Temperature Device Reading
	Actual Reading	Corrected	
ICE BATH			
BOILING WATER			
HOT OIL			

Note: Temperature Device must read within 1.5% of certified mercury in glass thermometer to be acceptable.

Appendix 6.5 S-Type Pitot Calibration Form

Technician: ______________________

Date : ______________________

Signature : ______________________

Pitot I.D. : ______________________

Nozzle I.D.: ______________________

Approx. Wind Vel.	Ref. Pitot Vel. Press		S-Type Pitot Vel. Press		Pitot Coefficient
Ft/sec.	ΔPref.	Cref.(ΔPref.) $^{1/2}$	ΔPs	(ΔPs)$^{1/2}$	Cp

Calibration Equation : Cp = Cref.(ΔPref./ΔPs)$^{1/2}$

Cref. = ______________________

Where:

ΔPref. = velocity pressure measured by reference pitot

Cref. = coefficient of reference pitot

ΔPs = velocity pressure measured by S-type pitot

Cp = coefficient of S-type pitot

Appendix 6.6 Magnehelic Calibration Form

Technician : ________________

Date : ________________

Signature : ________________

Gauge I.D. : ________________

Scale : ________________

Manometer ΔP1	**Magnehelic ΔP2**	**% Pressure Difference**

Average Percent Pressure Difference =(ΔP1 -ΔP2)/ ΔP1 •100

The magnehelic gauge must read within 5% of the gauge oil manometer (over its usable range) or the calibration and/or magnehelic gauge is not acceptable.

Appendix 6.7 Dry Gas Meter Calibration Form

Technician : ______________________

Date : ______________________

Signature : ______________________

Console I.D.: ______________________

Parameter Summary	Run No. 1	Run No. 2	Run No. 3
Ta = ambient (wet test meter) temp.			
ΔP = press. diff. @ wet test meter			
Pb = atmospheric pressure			
Pv = vapour pressure			
ΔH = press. diff.@ orifice			
Ti = dry test inlet temp.			
To = dry test outlet temp.			
Ri = initial dry test vol.			
Rf = final dry test vol.			
Vi = initial wet test vol.			
Vf = final wet test vol.			
$Pw = Pb + \Delta P$			
$Pd = Pb + \Delta H$			
Tw = Ta + 273 or 460			
Td = [(Ti + To)/2] + 273 or 460			
Bw = Pv/Pb			
Calibration Equation Result (Y)			
	Average (Y)		

Calibration Equation : $Y = [(Vf - Vi)/(Rf - Ri)] [(Pw/Pd)(Td/Tw)](1 - Bw)$

The calibration factor must be within 2% (0.98-1.02) of the wet test meter or spirometer reading for the meter to be acceptable.

Appendix 7 Regulatory Agency Approved Test Methods

Appendix 7.1 Parameters and Approved Methods

Parameter	Method	Notes
Ammonia	EPA CTM 27	
Arsenic	EPA 108	
Benzene, Toluene, Ethyl benzene, Xylenes (BTEX)	EPA 18	
Beryllium	EPA 104	
Carbon Dioxide (CO_2)	see Gas composition and molecular weight listing	
Carbon Monoxide (CO)	EC c, EPA 10, EPA 10a, EPA 10b	
Chloride (Total)	EPA 26	
Chlorine and Chlorine Dioxide (Cl/ClO_2)	EPA 40CFR63.457	
Combined Trains (Multi-metals including mercury)	EPA 29	
Combined Trains (particulate/metals/gaseous hydrogen chloride (HCL)	EC f	
Continuous Emission Monitoring (certification/QA/QC)	EC d, EPA PS-1 to PS-7	
Fluoride	Alcan 3010, EPA 13a, EPA 13b	Alcan 3010 only applies to aluminium production facilities
Formaldehyde (HCOH)	NCASI a, SW 0011	NCASI only applies to wood products facilities, use SW 0011 for all other facilities
Gas composition and molecular weight (Orsat or fyrite)	EPA 3	
Gas composition and molecular weight (CO_2, O_2 instrumental)	EPA 3a	
Gas composition and molecular weight (CO2, O2 Orsat)	EPA 3b	
Hexavalent Chromium	EPA ALT 014, IC 306	
Hydrogen Chloride (HCl) Halides and Halogens	EPA 26, EPA 26a	EPA 26a is to be used when acid particulate matter is present in the emission
Hydrogen Sulphide (H2S)	EPA 11, EPA 15	EPA 15 also includes Carbonyl Sulphide (COS) and Carbon Disulphide (CS2)
Lead (Pb)	EPA 12	

Parameter	Method	Notes
Mercury	EPA 101a	
Metals (Ag, As, Cd, Cu, Mn, Ni, Pb, Sn, Tl, Zn)	EPA 29	
Moisture Content	EPA 4	
Nitrogen Oxides (NOx)	EPA 7, EPA 7a, EPA 7c, EPA 7d, EPA 7e, EPA 20	
Opacity	EPA 9, EPA 9 alternative 1, MELP a, EPA 203	EPA 9 is the observation method; EPA 9 alternative 1 is the lidar method. EPA 203 is a proposed continuous method.
Organics (Total gaseous non-methane as carbon, grab)	EPA 25	
Organics (Total gaseous hydrocarbons as methane, continuous)	EPA 25a	To be used for testing asphalt plants
Organics (Speciation of hydrocarbons, grab)	EPA 18	
Organics (polychlorinated biphenyls (PCBs) and other semi volatile organic compounds)	EC a	
Organics (boiling point ≥ 100oC, semi-volatile organics (Semi-Vost), polychlorinated dibenzo-para-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs))	EC a, EPA 23	
Organics (boiling point ≤ 100oC, volatile organics (VOST))	SW 0030	
Oxidants (ozone)	IC 411	With adjustments to impinger volumes*
Oxygen (O2)	See Gas composition and molecular weight listing	
Particulates	EC e, EPA 5, EPA 5d, EPA 5f	
Particulates (Cyclonic flow)	Appendix 12	Appendix 12 is contained within this chapter of the B.C. Field Sampling Manual
Particulates (High volume)	EPA CTM 003, Oregon 8	**
Particulates (In-stack)	EPA 17	
Particulates (Sizing)	EPA 201a	
Particulates (PM10)	EPA 201, EPA 201a	
Particulates (and condensable organics)	EPA 202, Oregon 7	
Sampling site and traverse points	EC e, EPA 1	
Sampling site and traverse points	EPA 1a	

Parameter	Method	Notes
(Stacks/ducts 4-12” diameter)		
Sulphur	EPA 16	
Sulphuric acid mist and sulphur dioxide (SO2)	EPA 8	
Sulphur dioxide (SO2)	EPA 6, EPA 6a, EPA 6c	

Parameter	Method	Notes
Total Reduced Sulphur (TRS) compounds	Appendix 11, EPA 15a, EPA16, EPA 16a, EPA 16b	Appendix 11 is under review, a revised method is anticipated for the next revision of this manual. .
Validation Protocol	EPA 301	For new methods or the expansion of applicability for existing methods **
Velocity and volumetric flow rate (Stacks/ducts > 12” diameter)	EC e, EPA 2	
Velocity and volumetric flow rate (Direct measurement)	EPA 2a, EPA 2d	
Velocity and volumetric flow rate (3-D probe)	EPA CTM 019	
Vinyl chloride	EPA 106	
Volatile organic compounds (VOCs)	see Organics listing	
For the test methods followed by an asterisk (*) impingers must be analyzed and reported individually to prove that sample breakthrough has not occurred. Test methods followed by a double asterisk (**) require prior written approval.		

Testing of any parameters not listed or the altering of any methods listed above requires the approval of the Regulatory Administrator. A minimum of 30 days advance notice by a written request along with the supporting documentation for the Regulatory Administrator’s evaluation is required to determine the acceptability or rejection of such proposals. The Regulatory Administrator’s written approval is required before non-listed or altered method testing is to proceed.

Appendix 7.2 Method Sources

Alcan **ALCAN METHODS**

a. Method 3010-98 Sampling of the Cell Room Roof Vents at the A.S. & C. Aluminum Smelters in Quebec. Measurement of Total Particulates and Total Fluorides (Particulates and Gaseous) Revision: June 1998.

Listed in Appendix 7.1 as “Alcan” followed by the letter “a”.
Alcan test methods can be obtained from Alcan International Limitée, Centre de recherche et de développement, Arvida - Madame Pâquerette Leclerc, 1955, boul. Mellon, C.P. 1250, Janquière Québec, G7S 4K8.

EC **ENVIRONMENT CANADA-ENVIRONMENTAL PROTECTION SERVICE TEST METHODS**

a. Reference Method for Source Testing: "Measurement of Releases of Selected Semi-Volatile Organic Compounds from Stationary Sources" EPS 1/RM/2, June 1989.

b. Reference Method for Source Testing: "Measurement of Releases of Gaseous Hydrogen Chloride from Stationary Sources" EPS 1/RM/1, June 1989.

c. Reference Method for Source Testing: "Measurement of Releases of Carbon Monoxide from Stationary Sources" EPS 1/RM/4, July 1990.

d. Report: "Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation" EPS 1/PG/7, September 1993.

e. Reference Method for Source Testing: **"**Measurement of Releases of Particulate from Stationary Sources" EPS 1/RM/8, December 1993.

f. Report: "The National Incinerator Testing and Evaluation Program: Air Pollution Control Technology" EPS 3/UP/2, September 1986.

Listed in Appendix 7.1 as “EC” followed by a letter from a to f to match the above listing.

EC test methods can be ordered through Environment Canada at: Environmental Protection Publications, Technology Development Branch, Conservation and Protection, Environment Canada, Ottawa, Ontario, K1A 0H3.

EPA **UNITED STATES ENVIRONMENTAL PROTECTION AGENCY - CODE OF FEDERAL REGULATIONS 40 Parts 60 and 61 -TEST METHODS**
Listed in Appendix 7.1 as "EPA" followed by the appropriate method number, or for conditional test methods "EPA CTM" followed by the method number.
Most EPA test methods can be found at the United States Environmental Protection Agency Technology Transfer Network (TTN) Website at http://www.epa.gov/ttn/emc/
Methods listed as "EPA 40CFR" are contained in the United States National Archives and Records Administration, Code of Federal Regulations. For downloading see http://www.access.gpo.gov/nara/about-cfr.html#page1

IC **INTERSOCIETY COMMITTEE - APCA, ACS, AICHE, APWA, ASCE, ASME, AOAC, HPS, IPA - TEST METHODS**
Listed in Appendix 7.1 as "IC" followed by the appropriate method number IC test methods are listed in a publication entitled "Methods of Air Sampling and Analysis," Third Edition, James P. Lodge, Jr., Editor, Intersociety Committee APCA, ACS, AIChE, APWA, ASME, AOAC, HPS, ISA, Lewis Publishers, Inc, 1989.

MELP **BRITISH COLUMBIA MINISTRY OF ENVIRONMENT LANDS AND PARKS**
Source Testing Code For the Visual Measurement of The Opacity of Emissions From Stationary Sources.
Listed in Appendix 7.1 as "MELP" followed by the letter "a"
Can be found at http://www.env.gov.bc.ca/epd/cpr/codes/stcvmoe.html

NCASI **National Council for Air and Stream Improvement**
Chilled Impinger Method for use at Wood Products Mills to Measure Formaldehyde Methanol, and Phenol.
Listed in Appendix 7.1 as "IC" followed by the letter "a".
NCASI test methods can be obtained from the National Council of the Paper Industry for Air and Stream Improvement (NCASI), Inc., P.O. Box 13318, Research Triangle Park, NC 27709-3318, (919) 558-1999. For general NCASI information see http://www.ncasi.org/

Oregon **STATE OF OREGON - DEPARTMENT OF ENVIRONMENTAL QUALITY AIR QUALITY DIVISION – SOURCE SAMPLING MANUAL VOLUME 1**
Listed in Appendix 7.1 as "Oregon" followed by the appropriate method number.
Oregon test methods can be obtained from the Source Testing Co-ordinator, Department of Environmental Quality, 2020 Southwest 4th Ave, Suite 400, Portland, OR 97201, Tel: (503) 229-5554, Fax (503) 229-5265. Further information is available on the web at: http://www.deq.state.or.us/

SW U.S. EPA TEST METHODS FOR EVALUATING SOLID WASTE
Volume IC: Laboratory Manual Physical/Chemical Methods, Publication SW-846.
Listed in Appendix 7.1 as "SW" followed by the appropriate method number.
SW test methods can be obtained from the National Technical Information Service (NTIS), Technology Administration, U.S. Department of Commerce, Springfield, VA 22161, Tel: (703) 605-6000 or 1-800-553-6847, Fax: (703) 605-6900. Further information is available at http://www.ntis.gov/

Appendix 8 CEM (Non-Permanent In-Stack) Reporting Forms

Appendix 8.1	**Analysis of Calibration Gases**
Appendix 8.2	**Analyzer Calibration Data**

Appendix 8.1 Analysis of Calibration Gases

Analytical method used:_________________________

Date:_______________________

	Gas Concentration (indicate units)		
Sample Run	Zero*	Mid-range**	High-range***
1			
2			
3			
Average			
Maximum Percent Deviation			

* Average must be less than 0.25 % of span

** Average must be 50 to 60 % of span

*** Average must be 80 to 90 % of span

Appendix 8.2 Analyzer Calibration Data

Source Identification:____________________

Test Personnel:_________________________

Date:_____________________________

Analyzer Calibration Data for Sampling:________________________

Runs:____

Span:____

	Cylinder Value	**Analyzer Calibration**	**Absolute Difference**	**Difference**
	(Indicate Units)	Response (Indicate Units)	(Indicate Units)	(Percent of Span)
Zero gas				
Mid-range				
High-range				

Appendix 9 Compliance Testing Report Requirements

Appendix 9.1	**Source Emission Survey Report Format**
Appendix 9.2	**Compliance Testing Report Summary Table**
Appendix 9.3	**System Calibration Bias and Drift Check**

Appendix 9.1 Source Emission Survey Report Format

Stack emission survey reports should contain the information listed below unless mutually acceptable arrangements regarding the report content have been made between the facility and the Regulatory Administrator.

1. Title Page

The title page shall contain:

(a) plant name,

(b) plant location,

(c) permit, approval or registration number,

(d) date of survey,

(e) name of the sampling firm, and

(f) report author(s).

2. Summary

The summary of the source emission survey shall include but not be limited to:

A compliance testing report summary, which lists the parameters, described in Appendix 9.2.

An indication of how the source emission survey compares with applicable emission limits and previous emission testing shall be provided.

3. Table of Contents

A table of contents listing the report sections and the appendices shall be provided.

4. Introduction

The introduction shall include, but not be limited to, information on:

the reason for the survey,

the name(s) and contact telephone number(s) of the team member(s) which have taken relevant stack sampling courses,

a list of stack sampling, and plant personnel present during testing with contact telephone numbers,

the name of the company which prepared the analytical results, and

a list of analytical personnel and contact telephone numbers.

General comments on:

how the plant was operating,

process data (relevant to the operation of the source of emissions and to the performance of pollution abatement equipment), and

presence of dust/fly ash on and around the plant, or other pertinent observations (such as opacity).

5. Test Methods

This section shall contain:

a brief outline of the methods and equipment used to collect and analyze the samples.

a detailed explanation of any deviation from the approved stack sampling methods or from any other accepted sampling methods (prior written approval required).

6. Results

The section shall contain but not be limited to tables which contain the following:

emission source description with permit appendix number or other identifying information,

name of pollutant(s),

pollutant concentration for each run and the average for the survey (mg/m3), corrected to reference conditions as stated in the permit, approval, regulation or bylaw (i.e. specific %O2 or %CO2),

stack emission flow rate (m3/min.) at standard reference conditions of 20oC, 101.325 kPa, dry gas,

pollutant mass emission rate(s) (kg/hr.),

process production rate at the time of the survey (tonnes of product/hr. or other units as appropriate),

average or normal process production rate (same units as (f)) and

maximum process production rate (same units as (f)).

7. Discussion

A discussion of the survey shall include but not be limited to explanations for any deviations from normal due to problems associated with:

plant operation,

pollution control equipment operation,

inadequate sampling facilities,

sampling equipment, and

sample analysis.

For cases where there is a large variation (greater than 20%) between the emission survey conducted and previous surveys, an explanation of probable causes is also required.

8. Data Sheets

Stack sampling field sheets, or digital or chart recorder outputs. Originals or legible photocopies for each sample run performed as part of the survey are required. Information on the sheets shall include but not be limited to:

plant name, location, emission source description, date of survey, and run number (an individual sheet is required for each run),

(ii) relevant constant parameters for equipment as noted in the sampling method being performed and as stated in this code,

(iii) tabulated results that pertain to individual traverse points, grab samples or the specific survey which was performed, or digital or chart recorder outputs (with appropriate labeling),

(iv) sample recovery procedures used, if applicable,

(v) example calculations as appropriate.

Laboratory certificates of analysis, if applicable.

System calibration bias and drift check, described in Appendix 9.3 if applicable.

9. Appendices

Stack sampling site diagram (with stack dimensions and measured locations of traverse points).

Cyclonic flow check.

Completed instrument calibration forms for equipment used during the survey.

Detailed sampling system description and schematic diagram.

Certificate of completion for relevant stack sampling course.

Appendix 9.2 Compliance Testing Report Summary Table

Permit #(if applicable) ____________________
Facility Name: ____________________
Location (Legal Address) ____________________
Reason for test: ____________________
Test methods used: ____________________
Process operation: ____________________
Production rate during test: ____________________
Fuel consumption rate: ____________________

Compliance: Yes ___ No ___ (attach explanations)
Report Complete: Yes ___ No ___ (attach explanations)
Test Date: __________19____ to __________19____
Parameters measured: Part ___ CO ___ SO_2 ____ NO_X ___ NO_2 ___
Other: _____ _____ _____ _____ _____
Normal Production rate: ____________________
Type of fuel: ____________________

Pollution control equipment operating conditions: ____________________
Test Results:

Emission Source and #	Parameter	Run #1	Run #2	Run #3	Average	Permit Limit

For Regulatory office use only - Reviewed By : - Date :	I hereby state that the test results are accurate and the test(s) were conducted in accordance with the procedures stated in the methods used. ____________________ signature ____________ date

Appendix 9.3 System Calibration Bias and Drift Check

Source Identification:_________________________________
Test Personnel:_________________________________
Date:_________________________________

Run Number:____________________
Span:_______________________

		Initial Values		Final Values		
	Analyzer Calibration Response	System Calibration Response	System Cal. Bias (% of Span)	System Calibration Response	System Cal. Bias (% of Span)	Drift (% of Span)
Zero gas						
Upscale gas (a)						

(a) As stated in the method being followed.

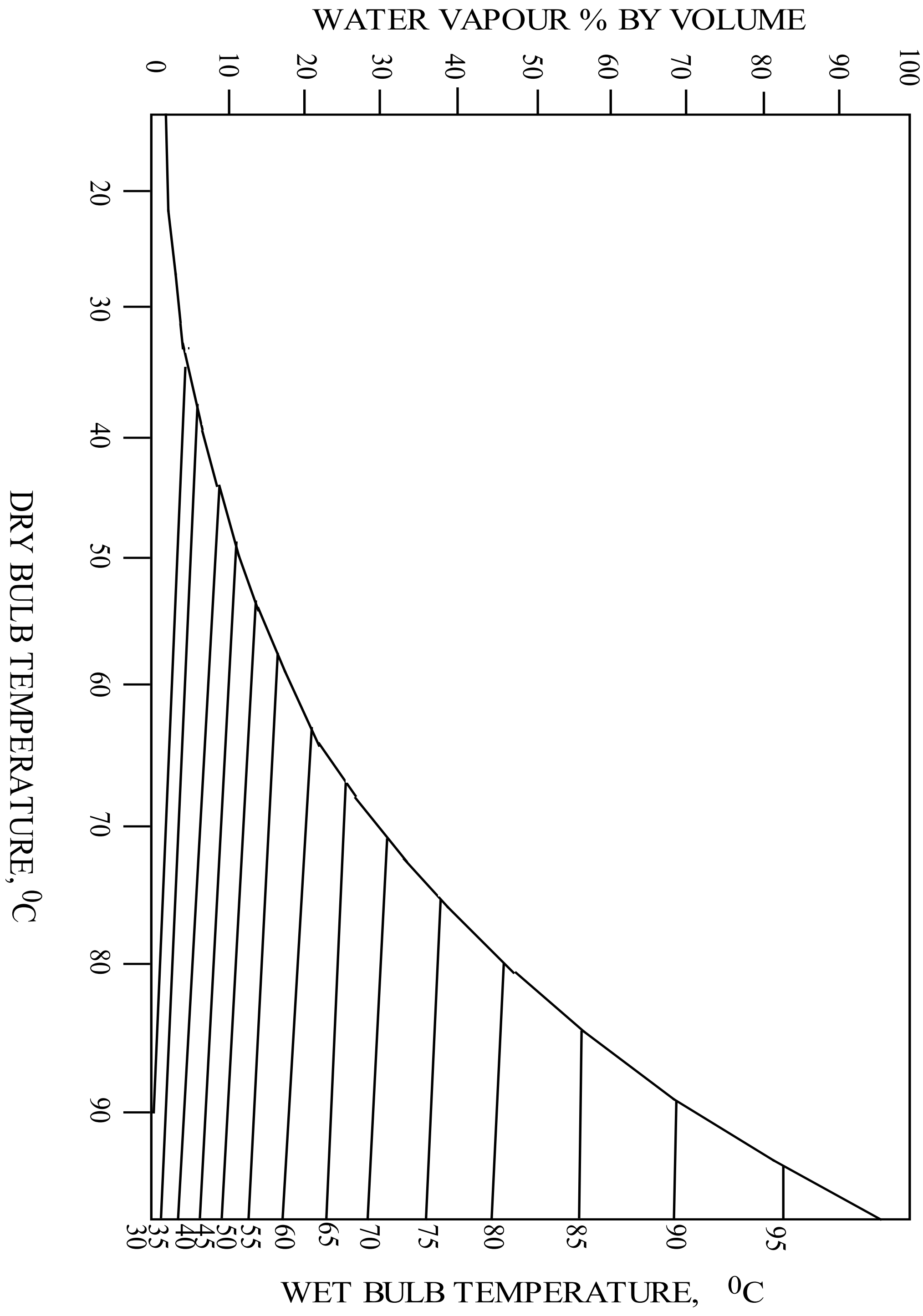
Appendix 10 Psychrometric Charts and Vapour Pressure Tables

Appendix 10.1 Vapour Pressures of Water in Millimeters of Mercury
Appendix 10.2 High Temperature Psychrometric Chart for Air-Water Vapour Mixtures at 101.3 kPa

Appendix 10.1 Vapour Pressures of Water in Millimeters of Mercury

Temp. (°C)	0	1	2	3	4	5	6	7	8	9
0	4.58	4.93	5.29	5.69	6.10	6.54	7.01	7.51	8.05	8.61
10	9.21	9.84	10.52	11.23	11.99	12.79	13.63	14.53	15.48	16.48
20	17.54	18.65	19.83	21.07	22.38	23.76	25.21	26.74	28.35	30.04
30	31.82	33.70	35.66	37.73	39.90	42.18	44.56	47.07	49.69	52.44
40	55.32	58.34	61.50	64.80	68.26	71.88	75.65	79.60	83.71	88.02
50	92.51	97.20	102.09	107.20	112.51	118.04	123.80	129.82	136.08	142.60
60	149.50	156.43	163.77	171.38	179.31	187.54	196.09	204.96	214.17	223.73
70	233.70	243.90	254.60	265.70	277.20	289.10	301.40	314.10	327.30	341.00
80	355.10	369.70	384.90	400.60	416.80	433.60	450.90	468.70	487.70	506.10
90	525.76	546.05	566.99	588.60	610.90	633.90	657.62	682.07	707.27	733.24
100	760.00	787.57	815.86	845.12	875.06	906.07	937.92	970.60	1004.42	1038.92
110	1074.56	1111.20	1148.74	1187.42	1227.25	1267.98	1309.94	1352.95	1397.18	1442.63
120	1489.14	1536.80	1586.04	1636.36	1687.81	1740.93	1795.12	1850.83	1907.83	1966.35
130	2026.16	2087.42	2150.42	2214.64	2280.76	2347.26	2416.34	2488.16	2560.67	2634.84
140	2710.92	2788.44	2867.48	2948.80	3031.64	3116.76	3203.40	3292.32	3382.76	3476.24
150	3570.48	3667.00	3766.56	3866.88	3970.24	4073.88	4183.80	4293.24	4404.96	4519.72
160	4636.00	4755.32	4876.92	5000.04	5126.96	5256.16	5388.88	5521.40	5658.20	5798.04
170	5940.92	6085.32	6233.52	6383.24	6538.28	6694.08	6852.92	7015.56	7180.48	7349.20
180	7520.20	7694.24	7872.08	8052.96	8236.88	8423.84	8616.12	8809.92	9007.52	9208.16
190	9413.36	9620.08	9831.36	10047.20	10265.32	10488.76	10715.24	10944.76	11179.60	11417.48
200	11659.16									

Appendix 10.2 High Temperature Psychrometric Chart for Air-Water Vapour Mixtures at 101.3 kPa



Appendix 10.3 Sample Container, Preservation, and Hold Times for Air (Vapours)

Type of Analysis	Storage Temp[1]	Container Type	Preservation	Maximum Hold Time[2]
Air – Vapours – Organic				
VOCs by Canister Sampling	ambient	SS canister	none	30 days
VOCs by Thermal Desorption	≤6ºC	Thermal desorption tube	none	30 days
VOCs and other Volatile Substances by Charcoal and Miscellaneous Collection Media	≤6ºC (or as applicable reference method)	see BC Lab Manual Method	none	30 days

[1] Storage temperature applies to storage at the laboratory. For all tests where refrigeration at ≤6°C is required at the laboratory, samples should be packed with ice or cold packs to maintain a temperature of ≤10°C during transport to the laboratory. The storage of ≤8°C for microbiological samples applies during storage at the laboratory and during transport to the laboratory. To prevent breakage, water samples stored in glass should not be frozen. Except where indicated by "do not freeze", test results need not be qualified for frozen samples.

[2] Hold Times: Single values refer to hold time from sampling to analysis. Where 2 values are given, the first is hold time from sampling to extraction, and the second is hold time from extraction to analysis.

Appendix 11 Determination of TRS Compounds Using Grab Sampling

The Ministry test method for total reduced sulphur (TRS) is under review. A revised method is anticipated for the next revision of the B.C. Field Sampling Manual.

For the latest status on the review, contact either:

- Director of the Air Resources Branch, Ministry of Environment, Lands and Parks, or
- Director, Air Quality Department, Greater Vancouver Regional District.

Appendix 12 Method for Measuring Particulate Emissions from Stationary Sources with Cyclonic Flow Pattern

Alignment Method

The Technical Committee on Cyclonic Flow Sampling (Ministry of Environment, British Columbia, November 31, 1990) originally compiled this method. For the text which follows minor modifications have been made to ensure that this method is consistent with current Ministry stack sampling procedures. Instead of referring to outdated Ministry methods reference is made to adopted U.S. EPA methods as appropriate. The technical content of the method itself has not been altered.

Forward

The method described in this Appendix is used to measure the releases of particulate matter from stationary sources with cyclonic flow pattern. This method is to be used in conjunction with U.S. EPA Methods 1 to 5. The complexity of the sampling and analytical procedures warrants that personnel performing them be trained and experienced.

Application of this method for compliance testing requires strict adherence to the method in all aspects. Deviations from the method may invalidate the test results. Any changes in equipment, reagents, materials, procedures, or calculations from those specified in the method must be approved by the Regulatory Administrator prior to testing.

This method is subject to amendment from time to time. Users should contact the Ministry for the most up-to-date version that is applicable to the source to be tested.

This method was recommended by the Technical Committee on Cyclonic Flow Sampling. The members of this committee were as follows:

Mr. B.B. Manna, P.Eng., Chair, Ministry of Environment (MoE), British Columbia

Mr. T.B. Leung, P.Eng., MoE, British Columbia

Mr. P.K. Leung, P.Eng., Environment Canada

Mr. L. Begoray, P.Eng., Alberta Environment

Mr. P. Tam, P.Eng., B.H. Levelton & Associates

Appendix 12.1 Principle

Particulate matter is withdrawn isokinetically from a number of sampling or traverse points in an enclosed gas stream. At each traverse point, the nozzle is canted directly into the flow at the pre-determined rotational angle where the maximum gas velocity occurs. The isokinetic sampling rate is based on the actual stack gas velocity. The particulate sample is collected in the nozzle, probe, cyclone (if used) and filter, all maintained within a temperature range required by U.S. EPA Method 5. The particulate weight is determined gravimetrically after removal of uncombined water. Simultaneous determinations of the gas stream moisture content, velocity, temperature, and molecular weight allow calculations of the particulate concentration and the particulate mass emission rate to be made.

Appendix 12.2 Applicability

This method is used to determine the concentration of particulates in enclosed gas streams of stationary sources with cyclonic flow pattern. Gas flow inside a stack or flue is considered cyclonic if the average absolute value of the rotational angles, as determined by Section 4.1 of this method, is greater than 10 degrees.

Prior to considering using this method, the tester must evaluate, to the satisfaction of the Regulatory Administrator, the feasibility of eliminating cyclonic flow patters at the sampling location by one or a combination of the following options:

Option One: Relocation of the sampling ports

Option Two: Installation of flow straighteners to minimize the cyclonic flow pattern

Option Three: Stack extension to minimize cyclonic effects

If none of the above options are feasible, the Regulatory Administrator may determine the applicability of the method for a specific source, taking into consideration pre-test information (to be submitted by the proponent) such as:

(i) Particulate and stack/flue characteristics (e.g. particle size and particulate concentration profile across stack or flue).

(ii) Sampling ports location.

(iii) Rotational (or yaw) and tilt (or pitch) angles.

(iv) Supersaturation state of the gas stream.

(v) Stability of the cyclonic flow pattern with respect to time and space.

Proponents must also consult with the Regulatory Administrator prior to using this method to perform a survey.

Appendix 12.3 Apparatus and Reagents

Same as for U.S. EPA Method 5 - 2 and 3.

Appendix 12.4 Procedures

Pre-sampling Preparations

In addition to following the procedures specified in U.S. EPA Method 5 - 4, a preliminary traverse shall be conducted to determine the velocity and rotational angle at each traverse point.

Insert into the stack an S-type pitot tube that is connected to a differential pressure gauge. Position the pitot tube at the first traverse point. Rotate the pitot tube clockwise or anti-clockwise about its longitudinal axis until the pressure taps are equal (i.e. Δp equals zero or null). Determine and record the rotational angle, α, to the nearest degree by rotating the pitot tube ninety degrees about its longitudinal axis and in the opposite direction. Note that the value of α can be zero, positive or negative depending on the direction of the gas velocity in relation to the stack or flue axis (Figure A1). Record the velocity pressure reading, Δp, for this traverse point. Repeat the procedure for all the traverse points. Conduct a second series for measurements by repeating the procedure for the traverse points. The second test should be conducted under the same process conditions as the first test and the two tests should be conducted at least 60 minutes apart. After the rotational angle of each traverse point inside the stack/flue has been determined, recorded and verified, calculate the average of the absolute value of α. If the average α for each series of measurement is less than or equal to 10 degrees, the source is not considered to have a cyclonic flow pattern. Otherwise, submit the pre-sampling test results to the Regulatory Administrator and obtain prior approval to use this method for measuring particulate emissions under cyclonic flow conditions.

Preparation of Collection Train

Follow the procedures described in U.S. EPA Method 5 - 4.1.3.

Sampling Train Operation

If either or both the rotational angles and velocities measured for the same traverse point during the two discrete test runs as described, under Section 4.1, differ by five degrees and five percent or less respectively, the cyclonic flow pattern is deem to be stable; thus sampling procedures as outlined in Section 4.3.1 should be followed. However, if either or both the rotational angles and velocities differ by more than five degrees or five percent respectively, the cyclonic flow pattern is deemed to be unstable.

Therefore steps must be taken to minimize the time elapsed between the determination of the rotational angle and particulate sampling; sampling procedures are outlined in Section 4.3.2 should be followed.

The basic difference in the sampling procedures for stable and unstable cyclonic flow patterns is that for stable cyclonic flows, isokinetic sampling can be carried out at the pre-determined rotational angle of each traverse point whereas for unstable cyclonic flows, the rotational angle for each traverse point is determined and is used immediately for isokinetic sampling.

Sampling Procedures for Stable Cyclonic Flow Patterns

Prior to sampling, determine the rotational angle of each traverse point by following the procedures described in Section 4.1. Insert the sampling probe into the stack/flue with the nozzle canted directly into the flow at the pre-determined rotational angle of the first traverse point. Immediately start the vacuum pump and adjust the sampling rate to isokinetic conditions. Repeat this procedure for all the other traverse points. The isokinetic sampling rate is based on the actual stack gas velocity. Conduct isokinetic sampling for all the traverse points by following the procedures contained in U.S. EPA Method 5.

Sampling Procedures for Unstable Cyclonic Flow Patterns

Determine the rotational angle of the first traverse point. Adjust the sampling probe with the nozzle canted into the flow at this rotational angle. Immediately start the vacuum pump and adjust the sampling rate to isokinetic conditions. Turn the vacuum pump off at the conclusion of the sampling at the first traverse point. Repeat these procedures for all other traverse points. The isokinetic sampling rate is based on the actual stack gas velocity. Isokinetic sampling for all the traverse points must be conducted by following the procedures described in U.S. EPA Method 5.

Sample Recovery and Sample Analysis

Follow the procedures in U.S. EPA Method 5 - 4.2 and 4.3.

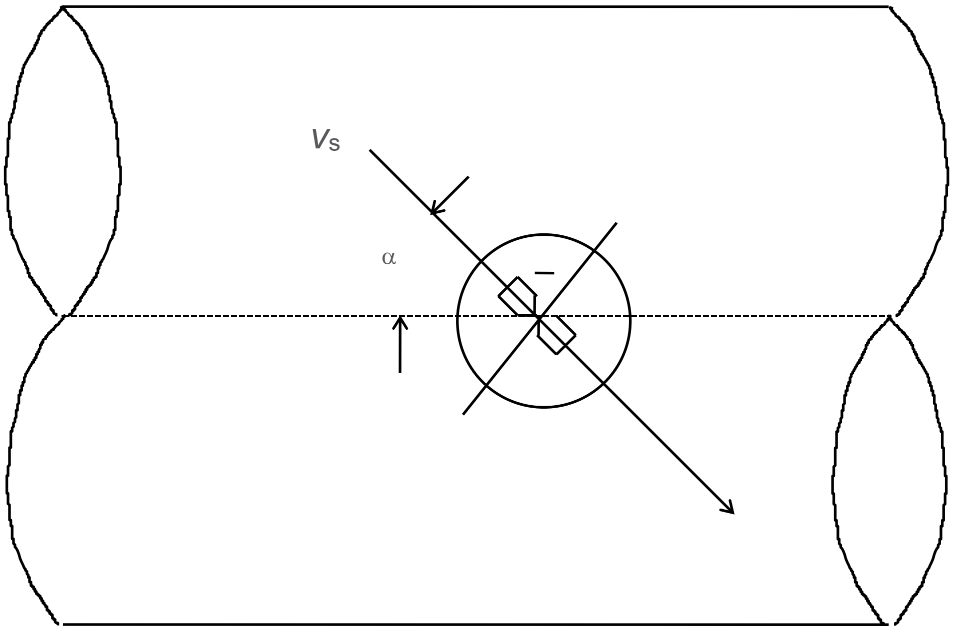
Appendix 12.5 Calculations and Reporting

The following modifications to U.S. EPA Method 5 are required:

To determine the stack/flue gas flow rate, Q_{sp}, use the average of the vertical components of the stack/flue gas velocity, v_s cosine α, at each traverse point. Where possible, the calculated Q_{sp} should be verified independently by other means, such as taking flow measurement at another location.

The particulate emission rate, is the production of the concentration, c_s, and the stack/flue gas flow rate, Q_{sp}, from Section 5.1.

To compensate for the potential bias associated with cyclonic sampling, correction factors may be used in calculating and reporting the final particulate emission rate, c_s, and Q_{sp}. Consult with the Regulatory Administrator regarding the values of the correction factors for a specific stationary emission source.



STACK / FLUE

α = Rotational Angle

V_S = Stack Gas Velocity