ONTARIO SOURCE TESTING CODE

Standards Development Branch
Ontario Ministry of the Environment

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Protecting Our Environment Ontario

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1.0 Preface

The information provided in this document is based on field experience and existing practices and aimed at providing consistency in the emission measurements from stationary sources. This document provides a set of guidelines and required methodologies for the measurement of emissions of air contaminants from stationary sources when such emissions are required for the purpose of determining compliance with the Environmental Protection Act and the Regulations thereunder. Where a Director may exercise discretion relating to the measurement of emissions of air contaminants from stationary sources, this guideline sets out minimum expected standards that the Director will apply in exercising his or her discretion in considering each situation on a case-by-case basis.

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While every effort has been made to ensure the accuracy of the information contained in this Code, it should not be construed as legal advice. In the event of conflict with requirements identified in the Regulation, which is being referenced, then the regulatory requirements shall determine the appropriate approach.

Note: Mention of trade names or commercial products does not constitute endorsement for use by the Ontario Ministry of the Environment.

2.0 Acknowledgements

This document has been prepared by the working group on Source Testing which was composed of representatives of the Standards Development Branch, Ontario Ministry of the Environment. We appreciate the comments provided by environmental consulting organizations in Ontario as well as input from the Operations Division in the Ministry.

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Introduction

The Ontario Source Testing Code (OSTC) specifies methods and procedures for the measurement of emissions of air contaminants (pollutants) from stationary sources when such emission data are required for the purpose of determining compliance with the Environmental Protection Act of the Province of Ontario and the regulations thereunder. Strict adherence to the procedures described and reference methods listed is required to eliminate the possibility of a test being rejected by the Ministry of the Environment due to variations from the procedures described in this Code.

For the purpose of this Code:

(i) **"Ministry"** means the Ontario Ministry of the Environment;

(ii) **"Director"** means any Ministry employee appointed by the Minister pursuant to Section 5 of the Environmental Protection Act, and acting within the designated Region where source testing is being conducted;

(iii) **"Provincial Officer"** means the Provincial Officer as defined by the Environmental Protection Act; and,

(iv) **"Source Assessment Specialist"** means a Ministry specialist in source testing procedures from the Standards Development Branch, Technology Standards Section.

This Code was developed to provide consistency in emission measurements from stacks, ducts and area sources in order to accurately estimate emissions from the source. The Code is intended to provide accuracy, consistency, uniformity and compatibility in stationary source emission measurements among industry users and source testing consultants. This Code applies only to emission measurements from stationary sources that have batch, cyclic or continuous processes.

It will also provide guidance to industry, consultants and Ministry staff when conducting emission testing survey(s) related to the development of emission factor(s) for unique processes and assessing emissions for use in emissions inventories and Emission

Summary and Dispersion Modelling (ESDM) reports completed in support of Ontario Regulation 419/05 (O. Reg. 419/05).

It should be noted that in cases where a Director may exercise discretion with respect to measurements of emissions of air contaminants from stationary sources, to the extent that this document sets out that something is “required” or “shall” be done or sets out a “requirement”, it does so only to identify minimum expected standards the application of which remain subject to the discretion of the Director.

The Code is divided into nine parts and is intended to facilitate the stationary source emission testing for the user.

Part A: Provides an overall guidance and procedures to be followed including quality assurance and quality control (QA/QC) for conducting stationary source emission tests and reporting protocols.

Part B: Specifies procedures and methods for selecting a gas sampling location and determining the number of sampling points required for a stack test (Method ON-1).

Part C: Describes how to calculate stack gas velocity and volumetric flow rate (Method ON-2).

Part D: Specifies methods to be used for calculating the molecular weight of dry stack gas (Method ON-3).

Part E: Describes the methods for the determination of moisture in stack gas (Method ON-4).

Part F: Specifies procedures for determining the particulate concentration of stack gas (Method ON-5).

Part G: Specifies procedures for determining odour emissions from stationary sources (Method ON-6).

Part H: Specifies procedures for determining the particulate matter size distribution of stack gas (Method ON-7).

Attachments: The attachments include a listing of all reference source testing methods and a guidebook to prepare a pre-test plan document.

Part A

Guidance and Procedures for Conducting Stationary Source Emission Measurements

1.0 INTRODUCTION

The guideline portion of the Ontario Source Testing Code (Code) covers comprehensively what needs to be done to generate an accurate, reliable and representative emission measurement from a stationary source.

The methods referred to in this code are the most reliable technical procedures available at the date of issue. However, as new and improved techniques become available, the methods will be revised, replaced or supplemented accordingly and the code will be appropriately amended.

Prior to implementing any of the methods referred to or described in this code, it is recommended that this introductory material be carefully reviewed. Outlined herein are the major requirements concerning the operating conditions of the process, the proper planning and execution of a source sampling test, the desirable qualifications of sampling personnel and the requirements for a satisfactory source testing report.

2.0 PURPOSE and SCOPE

This document standardizes sampling protocols and methods for stationary source emissions testing which may be required under Certificates of Approval, Regulation(s), by Provincial Officer's Orders and Notices or as requested by the Ministry.

The Ministry, through its Standards Development Branch (Technology Standards Section), must be contacted prior to conducting a source test if any deviation from the methods and procedures included in this code is contemplated. Written approval must be obtained from the Ministry if any deviation is made to the methods cited herein.

3.0 STACK SAMPLING TEAM

The recommended qualifications for the stack sampling team are in Attachment 3.

4.0 COMPLIANCE TEST

A compliance test is a source test conducted for the purpose of determining compliance with the Environmental Protection Act of Ontario, any other Ontario Act, regulations, or any other legal instrument promulgated thereunder (such as Certificate of Approval, Provincial Officer's Order, notices, etc.), performed and reported in accordance with the requirements of this code.

The Ministry (Standards Development Branch, the appropriate District Office, and any other Ministry unit listed in the legal instrument requiring the source testing) must be advised, in writing (via email, fax, normal mail or courier) at least fifteen (15) days in advance of any proposed compliance testing (O. Reg. 419/05, Section 11(1)). If a shorter notice is required, contact the source testing specialist for guidance.

The proposed source testing strategy needs to be supported by terms of reference, in the form of a pre-test plan, with relevant process and test information. Following the submission and approval of the pre-test plan (by the Ministry's Standards Development Branch), a minimum of fifteen days notice is required (O. Reg. 419/05, Section 11(1)) prior to the source testing. Also note that the pre-test plan needs to be submitted electronically, to the Ministry's Standards Development Branch (email: source.testing@ontario.ca), and to any other Ministry unit requiring the testing or required to be notified by the legal document imposing the condition to test.

Note that the Ministry's Standards Development Branch (SDB), or any other unit within the Ministry, is not responsible for the distribution of documents required to be submitted to the Ministry. The legal instrument, requiring the source testing, should be consulted to determine the recipients of the documents and the party responsible to distribute them.

The source test must be performed following the conditions stated in the Certificate of Approval, or as stated by any other legal instrument. If required, source testing staff from this Ministry's Standards Development Branch must be allowed to tour the process, inspect the sampling site and witness the sampling tests.

It should be noted that there are instances where there is a need to improve the emissions data quality; such as, under the "emission refinement" concept of O. Reg. 419/05. Under this "emission refinement" concept, testing must be conducted comprehensively across a full range of operating conditions as according to Section 11(1)(2) of O. Reg. 419/05".

The source (for each set of operating conditions, if applicable) must be tested three times, sequentially, under similar process conditions after reaching steady state operation. The average of the three test results should be used to determine compliance and/or to refine the emissions data for that tested source.

A complete final report, prepared as outlined in this code's Part A, Chapter 9, must be submitted to this Ministry's Standards Development Branch and to the appropriate Ministry's District or Area Office, within 90 days after completing the source test or within the time frame required by the Certificate of Approval condition or any other legal instrument.

The final source testing report needs to be submitted electronically and in hardcopy, to both the Ministry's Standards Development Branch (electronically to: source.testing@ontario.ca) and the appropriate Ministry District Office. If a copy of the final report is required to be submitted to the Environmental Assessment and Approvals Branch, the recipient of the final report will be the Certificate of Approval Review Section's applicable Unit (Air & Noise, Waste, or Water & Wastewater).

As the Ministry is limited to 10 MB for routine email, if the electronic copy of the report exceeds 10 MB, access to the Ontario Government's Enterprise Email Services (at https://attachmail.ontario.ca) will be needed. When the source testing report is ready to

be submitted, an email needs to be sent to the Ministry's Standards Development Branch, to provide the required invitation to access the Enterprise Email Service.

4.1 Compliance Test under O. Reg. 419/05

Under O. Reg. 419/05, a facility has options on providing emission rates based on the quality of emission data. Under this data quality approach, two of the conditions that require source testing are highlighted in the following Chapters 4.1.1 and 4.1.2.

4.1.1 Highest Data Quality

Ontario Regulation 419/05 makes specific reference to the use of source testing for the purposes of determining an emission rate for use with an approved dispersion model. Specifically, paragraph 2 of Section 11(1), with respect to source testing must be met in order for the data to be considered of the highest data quality:

1. The testing must be conducted comprehensively across a full range of operating conditions;
2. The testing must be conducted according to a plan approved by the Director as likely to provide an accurate reflection of emissions;
3. The Director must be given written notice at least fifteen (15) days before the testing and representatives of the Ministry must be given an opportunity to witness the testing; and,
4. The Director must approve the results of the testing as an accurate reflection of emissions.

It is important to note that the testing must be conducted across a range of operating conditions, such that the potential variability in emissions with production rate or operating conditions can be determined. Examples of this could include tests at "maximum" and "typical" production rates, tests with and without a supplementary process operating (if this is a plausible scenario) and/or tests with varying products or production materials. It should be noted that consideration of variations in processing rates and operating scenarios could result in a number of permutations and combinations.

The testing must also be conducted according to an approved pre-test plan, the Ministry must be given the opportunity to witness the testing, and the Director must accept/approve the results. Proponents are strongly encouraged to contact the Technology Standards Section Manager, at the Ministry's Standards Development Branch, for guidance in selecting the operating conditions for testing and confirmation/approval that the testing will satisfy Section 11(1) paragraph 2 of O. Reg. 419/05, prior to completion and submission of the pre-test plan.

4.1.2 Above Average Data Quality

The use of source testing to estimate emission rates is, in most cases, consistent with paragraph 1 of Section 11(1) of the O. Reg. 419/05 when:

1. Source tests are validated; and,
2. Source testing at one specific operating condition.

Validated source testing conducted at one specific operating condition is anticipated to provide above-average data quality of emission rate estimate.

Note: The most current version of O. Reg. 419/05 is required to be used when O. Reg. 419/05 is quoted by any Ministry issued legal instrument.

5.0 PRE-TEST REQUIREMENTS

A preliminary survey should be conducted before proceeding to execute a source testing program. The following areas should be covered in the preliminary survey:

1. Source and Process Information;
2. Source Test Area Information; and,
3. Preparation of Pre-test Plan (Attachment 2).

A brief outline of the information needed in each of these three areas is given below.

5.1 Source and Process Information

Prior to source testing, the source testing supervisor or leader should tour the plant in order to familiarize him or herself with the process and to collect and evaluate the pre-test information. From the evaluation of this information, the supervisor will be able to define the process conditions which must be maintained during the test and the modifications required at the sampling site to carry out a proper source test. The supervisor’s conclusions and recommendations regarding these matters must be discussed with the production personnel and the responsible company official for their concurrence.

The Ministry's Standards Development Branch should be notified of any pre-test meeting in order to resolve any potential disagreement and to ensure a mutually satisfactory sampling program. The Ministry representative may participate in the meeting, if necessary.

5.2 Source Test Area Information

The North American Industry Classification System (NAICS) code (or codes) is required to be specified in this portion of the pre-test plan.

In this chapter, provide a brief description of the process under investigation and a flow diagram. The description should cover the type of process (cyclic, batch or continuous), the rate or capacity at which the process is normally run, the design rate of the process equipment and the temperature, pressure, characteristics of the contaminants and gas flow rates at which the contaminants are emitted in the atmosphere, the frequency of start-ups and shutdowns for continuous processes and an action plan for handling upset situations should also be mentioned.

This information is required to properly plan the sampling location, the number of points to be sampled, and to ensure that the location selected is free of flow disturbances and meets Part B requirements of this Code.

To accurately locate the point of emissions of the sources to be tested, provide the geographical coordinates of the sources to be tested. Two approaches can be used: latitude/longitude system, or the Universal Traverse Mercator (UTM) system. The UTM system provides coordinates (in meters) on a world wide flat grid for easy computation; while, the latitude/longitude system provides the location (in angles, minutes or arcs, and seconds of arcs) based on the Prime Meridian (Greenwich) and the Equator, as the reference planes.

The test area information also provides the source testing supervisor with the opportunity to personally verify the physical characteristics of the source (site) in order to evaluate potential test locations, considering such factors as:

(i) Safety related issues at the stack sampling site;

(ii) Shelter for stack team personnel;

(iii) Accessibility to the sampling location;

(iv) Sampling platform space and scaffolding requirements; and,

(v) Availability of necessary power sources.

Note: It is suggested that the source testing supervisor check that the sampling platform and its access are in compliance with the Ontario Ministry of Labour (MOL) requirements and regulations if any.

5.3 Preparation of Pre-Test Plan Document

The pre-test plan document should cover:

1. Relevant process information;
2. Appropriate stack gas sampling details; and,
3. Equipment and Methods to be used in stack gas sampling.

A copy of the "Guidebook to Prepare a Pre-Test Plan Document" along with its set of forms is provided in Attachment 2 for the user. The pre-test plan should be prepared in accordance with this guidebook.

5.3.1 Appropriate Process Information

This chapter of the pre-test plan should indicate the relationship of the source or process under investigation to the overall or other plant process (i.e., other lines or processes that may affect the emissions of the source or process under investigation).

5.3.2 Appropriate Stack Gas Sampling Details

The stack gas sampling portion of the pre-test plan should cover the location of the sampling points (supported with a diagram) and minimum number of sampling points needed for the stack test as per Part B. Also, the stack gas velocity and flowrate have to be determined as per Part C.

5.3.3 Equipment and Methods Used for Gas Sampling

The pre-test plan document should indicate which methods will be used for sampling specific contaminants (e.g., particulate matter, SO_2, NOx, volatile organic compounds (VOCs), etc.). It should be noted that molecular weight of the stack gas (dry basis) and its moisture content must be determined as per Parts D and E respectively.

Specific methods to be used for determining the concentration of particulate, SO_2, NOx, CO, VOCs, O_2, CO_2, among others, are listed in Attachment 1.

6.0 CONDUCTING A SOURCE SAMPLING TEST

A source sampling test is performed in order to measure the emissions of an air contaminant from an industrial operation or a process. The rate and magnitude of these emissions vary with changes in the production rate and the process operating parameters and pollution abatement device. It is therefore crucial for the proper interpretation of the test results that all parameters affecting the emissions be closely monitored during the execution of the source sampling.

Standardized forms provided within individual methods should be used to ensure that all required information is obtained. Models of the formats to be used in the field, laboratory and calculations are included in the various methods. Ink should always be used to

record data. Source testing field data sheets and process data sheets should clearly indicate the date and the "clock" time that the test took place.

7.0 QUALITY ASSURANCE AND QUALITY CONTROL

7.1 Planning the Test Program

A Quality Assurance/Quality Control (QA/QC) program should define the objectives and functional activities designed to achieve accurate and representative data from a sampling program or a source sampling test. Detailed and specific QA/QC activities should be developed for each test program, based on the specific reference method being used.

7.2 Chain-of-Custody Procedure for Source Sampling

As part of the overall quality assurance activities associated with collection and analysis of source samples, particular attention should be directed to the handling of the sample and the analysis report.

Source test results, and the sample itself, are used to prove the compliance status of the facility. The test results should show that they accurately represent the conditions that prevailed at the time the test was conducted. This proof requires the demonstration of the following:

1. The sample being collected properly;
2. The sample being handled properly;
3. The sample being analyzed in accordance with specified test procedures and the calculated results documented; and,
4. The test report being prepared completely and accurately.

Failure to comply with these requirements may be grounds for the Ministry's Director to reject the results.

For typical formats of forms used for laboratory, container labels, and on the chain-of-custody receipts, refer to Parts B to H of this document or to the specific reference sampling method being used.

7.3 Frequently Encountered Errors in Source Sampling

The errors involved in the application of all methods described in this code are, in most cases, random in nature and will vary from source to source and from sampling team to sampling team. The computation procedure for the estimation of these random errors is given in the literature[1].

In addition to these random errors, errors of bias may be associated with methods for specific contaminants due to either poor collection efficiencies or errors associated with the analytical techniques. If such errors exist, they are discussed in the description of the individual methods.

When sampling for particulate matter, metal emissions, organic compounds emissions, or gaseous emissions with moisture saturated streams; it is important to sample the gas stream isokinetically as sub- and super-isokinetic sampling would result in over or under estimation of the contaminant emission respectively.

To obtain a representative sample for calculating the contaminant emission rate, it is of utmost importance to position the sampling ports at a suitable location. Failing to take into account the impact of flow disturbance before and after the sampling location can affect the results.

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[1] Brenchley, D.L., Industrial Source Sampling, Ann Arbor Science Publishers, Inc., Ann Arbour Michigan, 1973.

Also, it is necessary to separate the sample from the parent stream without creating a disturbance and to avoid any physical and chemical changes in the contaminants collected from the gas sample that may alter its characteristics.

8.0 SAMPLING METHODS for MEASURING STACK GAS CONTAMINANTS

This Code is comprised of test Methods ON-1 to ON-7 which describes the apparatus and techniques used to conduct source testing. Limitations on the applicability of the methods are stated within each method.

A list of acceptable reference test methods for the determination of the emission rates and concentrations of other contaminants is given in Attachment 1. Where no reference method is listed, or an alternate method is proposed, the Ministry's Source Assessment Specialists need to be contacted for guidance.

A testing protocol (that includes the reference test method used, deviations and modifications to the reference, and sampling strategies), encompassed in the pre-test plan, needs to be agreed upon between the source operator, source tester and the Ministry's Source Assessment Specialist to ensure that a common understanding is reached on what is the acceptable test protocol for a particular application, under a particular set of operating conditions.

9.0 REPORTING REQUIREMENTS

Data collection is the responsibility of the stack sampler or consultant. The source testing supervisor should ensure that the process and test data is collected and recorded accurately and completely, and included in the final report along with all pertinent process information recorded during testing.

Source testing reports need to be submitted to the Ministry's Standards Development Branch, to the appropriate District or Area Office, and any other Ministry unit listed in the legal instrument requiring the testing, within 90 days after completion of the test (or

within the time frame stated in the Certificate of Approval or any other legal instrument, as it may apply) and should contain the information required in the reference method(s). The final report should also include a list of problems and process upset conditions encountered during testing, deviations from the prescribed method(s), and their potential impacts on the final result.

Source testing report organization is provided in Attachment 2, Chapter 7.

The source testing reports, sent to Ministry, are required to be submitted electronically and in hardcopy. The electronic copy is intended to expedite receiving and processing source testing reports.

Note that in those cases that submission of documents are required by other units within the Ministry, you are directed to follow instructions on submissions from the issuer of the request.

Electronic routine email (external and internal) is limited to 10MB. If the electronic copy of the report exceeds 10 MB, you will need to access our Enterprise Email Services (at https://attachmail.ontario.ca). When the source testing report is ready to be submitted, you will be required to send an email to the Source Assessment Specialist, for him or her to provide you with the necessary invitation to access the Enterprise Email Service.

10.0 LIMITATIONS TO SOURCE TESTING

It is recognized that there will be many processes and situations which may limit the application of the methods described in this code, such as:

(i) Corrosive or highly reactive components;

(ii) High vacuum or pressure;

(iii) High gas temperature;

(iv) High gas moisture content;

(v) High and low gas velocity;

(vi) Very small and very large duct cross-sections;

(vii) Complex flow patterns; and,

(viii) Fluctuations in velocity, particulate loading, and temperatures, due to uncontrollable process variations

The following are guidelines to overcome some of these adverse conditions:

(a) Corrosive or Highly Reactive Components – Use special materials such as glass, quartz or Teflon.

(b) High Vacuum Sources – (found before exhaust fans and high natural draft stacks). Operation of sampling train pump before and after probe insertion to avoid escaping of the impinger solution into the filter holder; gas volume drawn before and after insertion should not be included in sample volume.

(c) High Pressure Sources – Port sealed tightly yet allowance for freedom of movement of the probe; e.g., gas valve and packing gland incorporated in port.

(d) High Temperature Source – Quartz probe liner or water cooled probe with temperature control to avoid cooling below dew point; shielded and aspirated thermocouple.

(e) 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 cooling via evaporation; locate filter between third and fourth impinger (Method ON-5).

(f) High Velocity Source – Sampling site is relocated or duct or stack expanded to reduce velocity; pumps of sufficient capacity to maintain the required sampling rates are used.

(g) Low Velocity Source – In the range of 1.5 to 3.0 m/s (5 to 10 ft/s) an inclined manometer with a scale of 0 to 0.6 kPa (0 to 2.4 in.H_2O) is used; below 1.5 m/s (5 ft/s), the sampling site is relocated or the duct constricted to increase the velocity.

11.0 REFERENCES

1. Alberta Environment, Alberta Stack Sampling Code, Publication # Ref.: 89, ISBN: 0-7732-1406-2, 1995.

2. Alberta Environment, Methods Manual for Chemical Analysis of Atmospheric Pollutants, Second Edition, 1981.

3. Environment Canada, Pollution Measurement Division, Health and Safety Guidelines for Source Testing, November 1994.

4. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December 1993.

5. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

6. Ministry of Environment, Lands and Parks, Province of British Columbia, Stationary Emission Testing Code, Version 1, September 1994.

7. State of Oregon, Department of Environmental Quality, Source Sampling Manual, Volumes I and II, January 1992.

8. United States Environmental Protection Agency, Code of Federal Regulations, Title 40 Part 60, Appendix A, Method 1, July 1. 1994.

9. United States Environmental Protection Agency, Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods, EPA-600/4-77-027

Part B

Method ON-1: Location of Sampling Site and Sampling Points

1.0 PURPOSE

To determine sampling site and number of sampling points and their location based on stack or duct configuration.

2.0 LIMITATIONS

The basic method is not applicable in the following cases:

(i) cyclonic or swirling flow;

(ii) reverse flow;

(iii) stack or duct diameter less than 0.30 m or 0.071 m^2 cross-section area;

(iv) non-circular and non-rectangular stack or duct cross-section; and

(v) sampling site less than two (2) stack or duct diameters downstream from flow disturbance, or less than 0.5 stack diameter upstream from a disturbance.

3.0 EQUIVALENT DIAMETER FOR RECTANGULAR CROSS-SECTIONS

Equivalent diameter, $$D_e = \frac{2LW}{L+W}$$

Eq. 1-1

where:

L = length

W = width

Reference herein to "diameter" includes both diameter of a circular cross-section and equivalent diameter of a rectangular cross-section.

4.0 LOCATION OF SAMPLING SITES

The preferred location of the site is found in a straight, vertical length of stack or duct, close to the point of emission into the atmosphere, at least eight (8) diameters downstream and at least two (2) diameters upstream from any flow disturbance. Deviation from the preferred location is acceptable within the limitations and compensations stated in this method.

4.1 Circular Stacks and Ducts

For a stack or duct of circular cross-section, at least two sampling ports on the same cross-sectional plane separated by 90° (degrees) are required. Where applicable, the diameter passing through one port should be parallel to the centre line of an upstream flow disturbance and the other diameter should be perpendicular to this centre line.

4.2 Rectangular Stacks and Ducts

For a rectangular cross-section, determine the equivalent diameter and locate the ports on the most convenient face of the stack or duct. The number of ports corresponds to the number of traverses required to sample at the requisite number of points, as calculated below. The sampling ports should be located on the same cross-sectional plane.

5.0 TOTAL NUMBER OF SAMPLING POINTS

5.1 Particulate Matter Traverses

For sampling sites which are located at least eight (8) diameters downstream and two (2) diameters upstream from a flow disturbance, the required minimum number of sampling points for a circular or rectangular cross-section is determined according to Tables 1-1 and 1-2.

5.1.1 Circular Cross-Sections

For sites with circular cross-sections, the total number of sampling points is divided evenly between two (2) traverses, the traverses being performed in directions perpendicular to each other.

5.1.2 Rectangular Cross-Sections

For sites with rectangular cross-sections, the equivalent diameter, D_e, is used as the diameter for the purposes of determining the minimum total number of sampling points.

When the number is determined from Table 1-1, it is compared to the values given for the total number of sampling points in Table 1-2 and, where necessary, the number is increased to the next greater value in Table 1-2. In the column titled "Number of Sampling Points per Traverse and Number of Traverses", it is a matter of convenience as to which number represents traverses and which represents sampling points.

If the ratio of length to width of the cross-section is greater than 1.5, the layouts of Table 1-2 are not applicable. In that case the number of traverses and number of sampling points should be chosen such that their ratio most closely approximates the stack or duct dimensional ratio and provides at least the required minimum number of points.

In situations where the sampling sites are not located at least eight (8) diameters downstream and two (2) diameters upstream from a flow disturbance, the required minimum total number of sampling points is determined from Figure1-1.

1. Determine the distances from the selected sampling site to the nearest upstream and downstream flow disturbances and divide each distance by the stack or equivalent diameter to determine the distance in terms of duct diameters.
2. Determine the minimum total number of sampling points from Figure 1-1 for:
   (a) the number of duct diameters upstream; and,
   (b) the number of duct diameters downstream.
3. Select the higher of the minimum numbers of traverse points from (a) and (b), or a greater value, so that for circular stacks or ducts the number is a multiple of four (4), and for rectangular stacks or ducts, the required number of sampling points corresponds to Table 1-2.

5.2 Velocity Traverses (Non-Particulate Matter)

When only velocity or volumetric flow rate is required to be determined, follow the procedures specified in Chapter 5.1 for particulate traverses, except that Figure 1-2 may be used instead of Figure 1-1. **For determination of particulate matter emission rates and concentrations Figure 1-1 must be used.**

6.0 LOCATION OF SAMPLING POINTS

Sampling points are located at the centroid of equal areas of the cross-section of the stack or duct.

6.1 Circular Stacks

For a circular cross-section, half of the total number of sampling points is located on each traverse, the spacing being determined by reference to Table 1-3 or the following equations in this subchapter.

An example of a grid of sampling points is shown in Figure 1-3. The values in Table 1-3 have been calculated from the following equations. These equations may be used to extrapolate the table.

For points from the port to centre:

$$R = 100 \times \left(0.5 - \sqrt{\frac{(2n-1)}{4N}} \right)$$

Eq.1-2

$$n = \frac{N}{2} + (1-h)$$

Eq.1-3

For points from the centre to the far wall:

$$R = 100 \times \left(0.5 + \sqrt{\frac{(2n-1)}{4N}} \right)$$

Eq.1-4

$$n = h - \frac{N}{2}$$

Eq.1-5

where:

R = percentage of stack or duct diameter from port

h = sampling point number (from port)

N = number of sampling points per traverse

6.2 Rectangular Stacks

For rectangular cross-sections, the area is divided into as many equal rectangular sections as there are sampling points. These rectangular sections are laid out according to the numbers in the right-hand column of Table 1-2 or as described in Chapter 5.1.2. Sampling points are located at the centroid of these areas.

For circular stacks with diameter *greater* than 0.61 m (2.0 ft), if a sampling point is located within 2.5 cm (1.0 in.) of a wall, it must be relocated a distance of 2.5 cm (1.0 in.) away from the wall. For stacks with diameter *less* than 0.6 m (2 ft), if a sampling point is located within 1.3 cm (0.5 in.) of a wall it must be relocated to a distance of 1.3 cm (0.5 in.) away from a stack wall or a distance equal to the inside diameter of the nozzle, whichever is greater. If a relocated point coincides with another sampling point then the sampling time is doubled at that point. It is assumed that this problem will not occur with rectangular cross-sections.

7.0 CYCLONIC FLOW CONFIRMATION

The absence of cyclonic flow confirmation check is mandatory and must be performed for all sampling sites. The cyclonic flow confirmation check is conducted using the S-type Pitot tube and manometer described in Part C (Method ON-2) and employing the following procedure:

1. Level and zero a manometer. Connect an S-type Pitot tube to the manometer;
2. Position the S-type Pitot tube at a sampling point so that the planes of the face openings are parallel to the cross-sectional axis of the stack or duct;
3. Rotate the Pitot tube (up to ±90°) about its longitudinal axis until the manometer reading (ΔP) is zero. Record the absolute value of the rotational angle to the nearest degree. If the Pitot tube does not have to be rotated to produce zero ΔP then a rotational angle of 0° is measured. Repeat this procedure for all sampling points in each traverse; and
4. Calculate the arithmetic average of the recorded angles for each traverse; if the average is less than 15°, sampling may proceed as normal; if it is greater than 15°, then cyclonic flow is confirmed. If cyclonic flow is confirmed, refer to Appendix 1C for alternate procedure to follow.

8.0 REVERSE FLOW CONFIRMATION

Reverse flow confirmation check is mandatory and must be performed for all sampling sites. Reverse flow is confirmed if, at any sampling site, there are one or more sampling

points at which a negative velocity pressure head (ΔP) is found. If reverse flow is confirmed, refer to Appendix 1C for an alternate procedure to follow.

9.0 DISCUSSION OF METHOD ON-1

9.1 Purpose

This method is used to ensure collection of representative samples of particulate matter and to measure stack gas velocities by the use of other methods described later. More particularly, procedures are described for determination of a preferred sampling site on the duct or stack and for determination of the total number of sampling points required at that site.

The procedures outlined here account for flow disturbances and various duct or stack configurations. Procedures are also provided to increase the number of sampling points where a non-ideal sampling site must be used. This method applies (within the stated limitations) to all stacks and ducts, vertical and horizontal, with circular or rectangular cross-sections.

9.2 Limitations

9.2.1 Cyclonic Flow

Cyclonic flow must be suspected in cases such as: after inline turbine fans, cyclones, inertial demisters following Venturi scrubbers, in stacks or ducts having tangential inlets or configurations which tend to induce swirling, among others.

The procedure in Chapter 7 on cyclonic flow configuration is followed to verify the absence of such flow. If cyclonic flow is found, the overall flow is indeterminate and Method ON-1 should not be applied.

9.2.2 Reverse Flow

Reverse flow must be suspected in cases where there is an obstruction in the stack or duct (e.g., baffle plates) upstream of the sampling site. If a negative velocity pressure head is detected, reverse flow is confirmed and Method ON-1 should not be applied.

9.2.3 Flow Disturbances

Flow disturbances in a stack or duct include: bends, constrictions, expansions, fans, turning vanes, air cleaning equipment, visible flames, hoppers, exits, etc. Beyond the stated limitations of this method, flow conditions may be indeterminate and collected data unreliable.

9.3 Location of Sampling Sites

In order to obtain a representative measurement of a flow parameter, the overall sampling conditions must be stable. This criterion can best be met when there is a steady and relatively uniform velocity profile. In order to achieve this profile, the effect of disturbances must be minimized.

The preferred site location is eight (8) or more diameters downstream from a disturbance and two (2) or more diameters upstream from a disturbance. It is assumed that the effects of the disturbances will be minimal at these distances. If a less than preferable location must be used, increasing the number of sampling points should result in collection of more accurate data.

Note: Sampling ports located at less than four (4) diameters downstream from a disturbance and/or less than one (1) diameter upstream from a disturbance are considered non-representative sampling locations. In the case that the minimum requirement cannot be met, stack extensions may be required. Alternatively, preliminary flow data may be submitted with the pre-test plan with the consultant's rationale explaining how the stack gas characteristics (at this location) support the argument that it will allow for the collection of a representative sample.

A vertical stack is preferred, especially with respect to particulate matter sampling, since gravity could cause stratification of the particles at non-vertical sites. Traverses must be

conducted in two (2) perpendicular directions of the same cross-sectional plane when testing at stacks or ducts with circular cross-sections.

Furthermore, one traverse should be parallel and the other perpendicular to the centerline of an upstream flow disturbance. These procedures are employed for two reasons:

(i) to determine the uniformity of the flow across the entire cross-sectional plane; and,

(ii) to provide a more accurate measurement of the flow parameters.

10.0 APPENDICES TO METHOD ON-1

10.1 APPENDIX 1A: Stack or Duct Diameter Less than 0.3 metres or Greater than 5.0 metres

Use of the standard sampling equipment in small diameter stacks or ducts presents obvious spatial difficulties. Altering the stack or duct by expanding its cross-sectional area may not be an adequate solution since the resulting flow velocity may be too low to be measured accurately.

10.1.1 Stack diameter less than 0.3 metres

In all cases where the stack or duct diameter between 0.1 m and 0.3 m (0.0078 m^2 and 0.071 m^2 in cross-sectional area, respectively), use Method 1A listed in the US EPA Title 40 of the Code of Federal Regulations, Part 60, Appendix A. For stacks or ducts with an internal diameter of less than 0.10 m, the Ministry's Source Assessment Specialist should be contacted to discuss the matter.

10.1.2 Stack Diameter Greater than 5.0 metres

In the case of diameters larger than 5.0 m, the Ministry's Source Assessment Specialist should be contacted in order to determine an acceptable number of sampling points.

Extrapolation, based on Table 1-3, might indicate an unnecessarily large number of sampling points in some cases.

Some stacks or ducts may be so large that it is impossible to traverse the entire diameter with a commercially available probe. It may be necessary then to use four ports, equally spaced about the stack or duct, in the plane of the cross-sectional area of the sampling site. It may also be necessary to construct a probe which would be long enough to perform a whole or half traverse. In such cases, the Ministry's Source Assessment Specialist should be contacted before any sampling procedure is finalized.

10.2 APPENDIX 1B: Sampling in Non-Circular, Non-Rectangular Stack or Duct Cross-Sections

In the case of a stack or duct with an elliptical cross-section the following procedure is used to determine the sampling site and sampling points:

1. Determine the location of the sampling site and the number of sampling points per traverse according to the method, using the major axis as the diameter; an equal number of sampling points are used for the major and minor axes.
2. For location of sampling points on the major axis, the following equation is used:

$$Y = \frac{A(2n-1)}{N}$$

Eq. 1-6

where:

Y = distance from centre of elliptical cross-section to sampling point n

n = the number of a sampling point (the points being numbered from the centre outwards)

N = total number of sampling points per traverse

A = half the length of the major axis

3. For location of sampling points on the minor axis, the following equation is used:

$$X = \frac{B(2n-1)}{N}$$

Eq. 1-7

where:

X = distance from centre of elliptical cross-section to sampling point n

n = the number of a sampling point, the points being numbered from the centre outwards

N = total number of sampling points per traverse

B = half the length of the minor axis

Note: Equations 1-6 and 1-7 are used to calculate the location of pairs of sampling points equidistant from the centre.

Equivalent diameters of non-circular, non-rectangular and non-elliptical cross-section are obtained by calculating the ratio 4A/P, where A stands for area and P for perimeter.

10.3 APPENDIX 1C: Elimination of Cyclonic or Reverse Flow

In some cases it may be practical to eliminate cyclonic or reverse flow in the stack or duct. This may be accomplished by altering the stack or duct by removal of internal obstructions, relocation of the sampling site, installing stack extension, addition of straightening vanes, alteration of inlet configuration, etc.

The US EPA 40 CFR 60 Method 5D (Figure 5D-1) provides an example of flow straightening vanes. Note that any flow disturbance correction alternative must be coordinated with the plant engineer, as it might negatively affect the process.

If relocating the sampling site or flow disturbance correction alternatives are not practical to correct cyclonic flows, use the US EPA 40 CFR 60 Method 2F, which determines stack gas velocity and volumetric flow rate with three dimensional probes.

If stack or duct gas flow problems cannot be overcome, contact the Ministry's Source Assessment Specialist to discuss possible solutions.

11.0 REFERENCES

1. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December, 1993.

2. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

3. United States Environmental Protection Agency, Code of Federal Regulations, Title 40, Part 60, Appendix A.

TABLE 1-1: MINIMUM NUMBER OF SAMPLING POINTS AT A SITE

Minimum Number of Sampling Points at a Site (8 Diameters Downstream and 2 Diameters Upstream of a Flow Disturbance)		
Inside Diameter of Circular Stack or Duct or Equivalent Diameter	**Minimum Number of Sampling Points per Test**	
Meters	Circular Duct	Rectangular Duct
0.3 to 0.61	8	9
> 0.61	12	12

TABLE 1-2: CROSS-SECTIONAL LAYOUT FOR RECTANGULAR STACKS OR DUCTS

Cross-Sectional Layout for Rectangular Stack or Duct	
Number of Sampling Points	**Number of Sampling Points per Traverse and Number of Traverses**
9	3 x 3
12	3 x 4
16	4 x 4
20	4 x 5
25	5 x 5
30	5 x 6
36	6 x 6
42	6 x 7
49	7 x 7

TABLE 1-3: LOCATION OF TRAVERSE POINTS ON DIAMETERS OF CROSS-SECTIONS OF CIRCULAR STACKS

TRAVERSE POINT NUMBER ON A DIAMETER	PERCENT OF STACK DIAMETER FROM INSIDE WALL TO TRAVERSE POINT											
	Number of Traverse Points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10					97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.9	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9

19	96.1	91.3	86.8
20	98.7	94.0	89.5
21		96.5	92.1
22		98.9	94.5
23			96.8
24			98.9

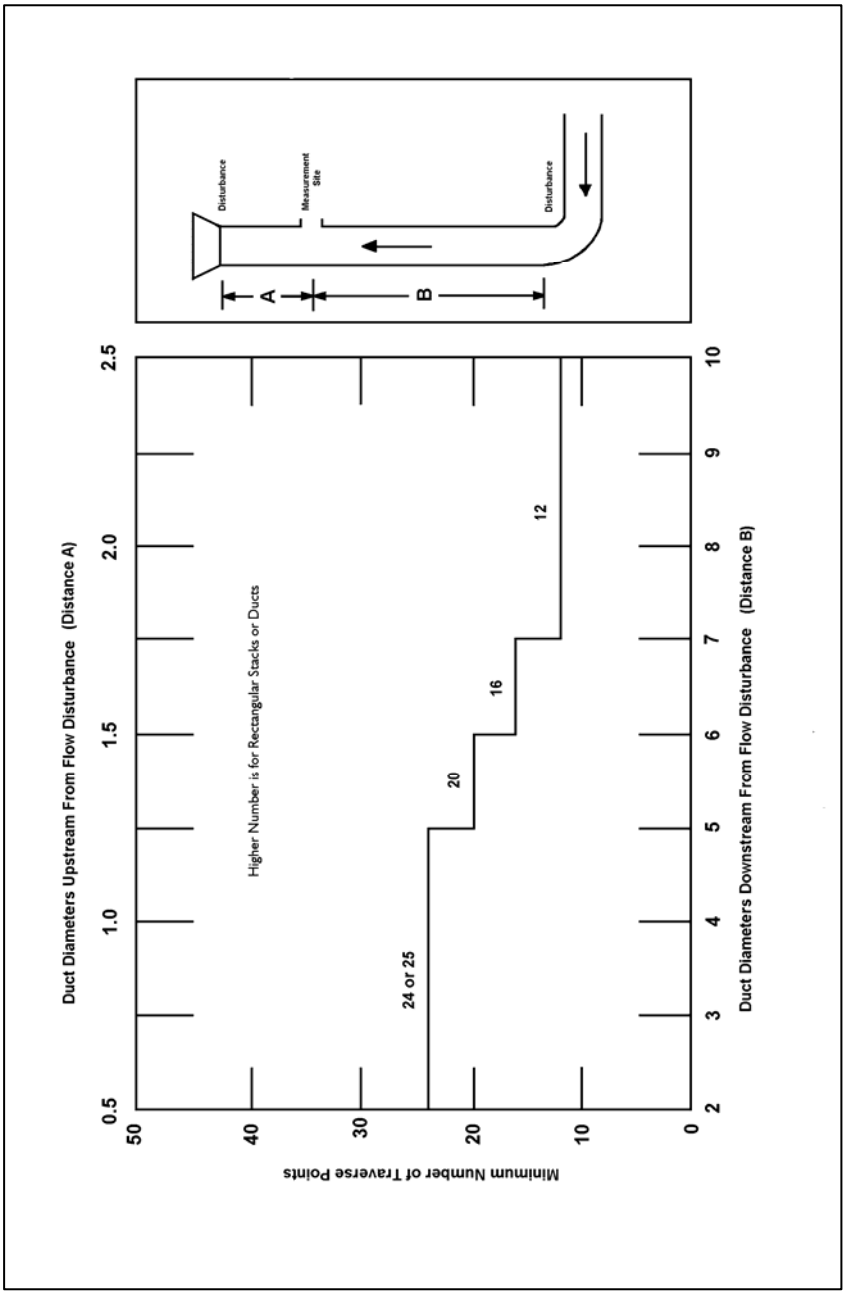


FIGURE 1-1: MINIMUM NUMBER OF TRAVERSE POINTS FOR PARTICULATE

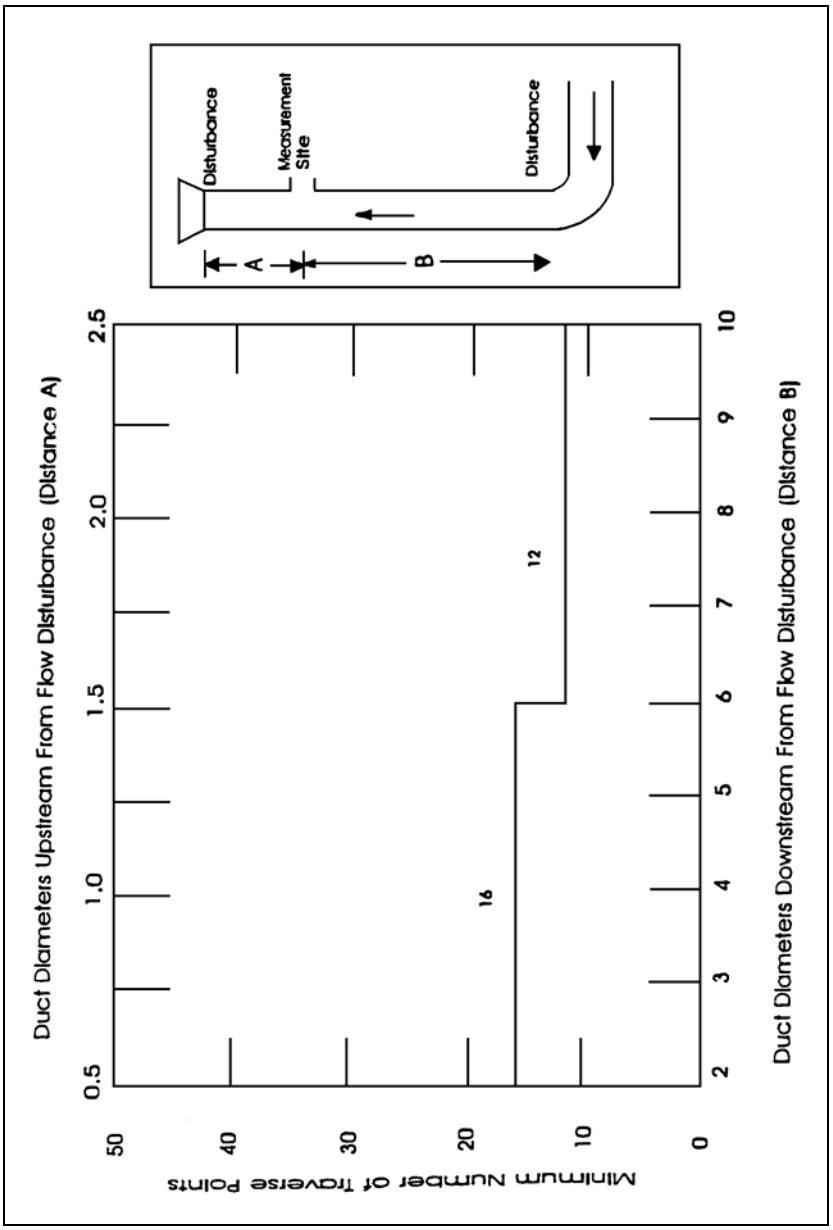


FIGURE 1-2: MINIMUM NUMBER OF TRAVERSE POINTS FOR VELOCITY

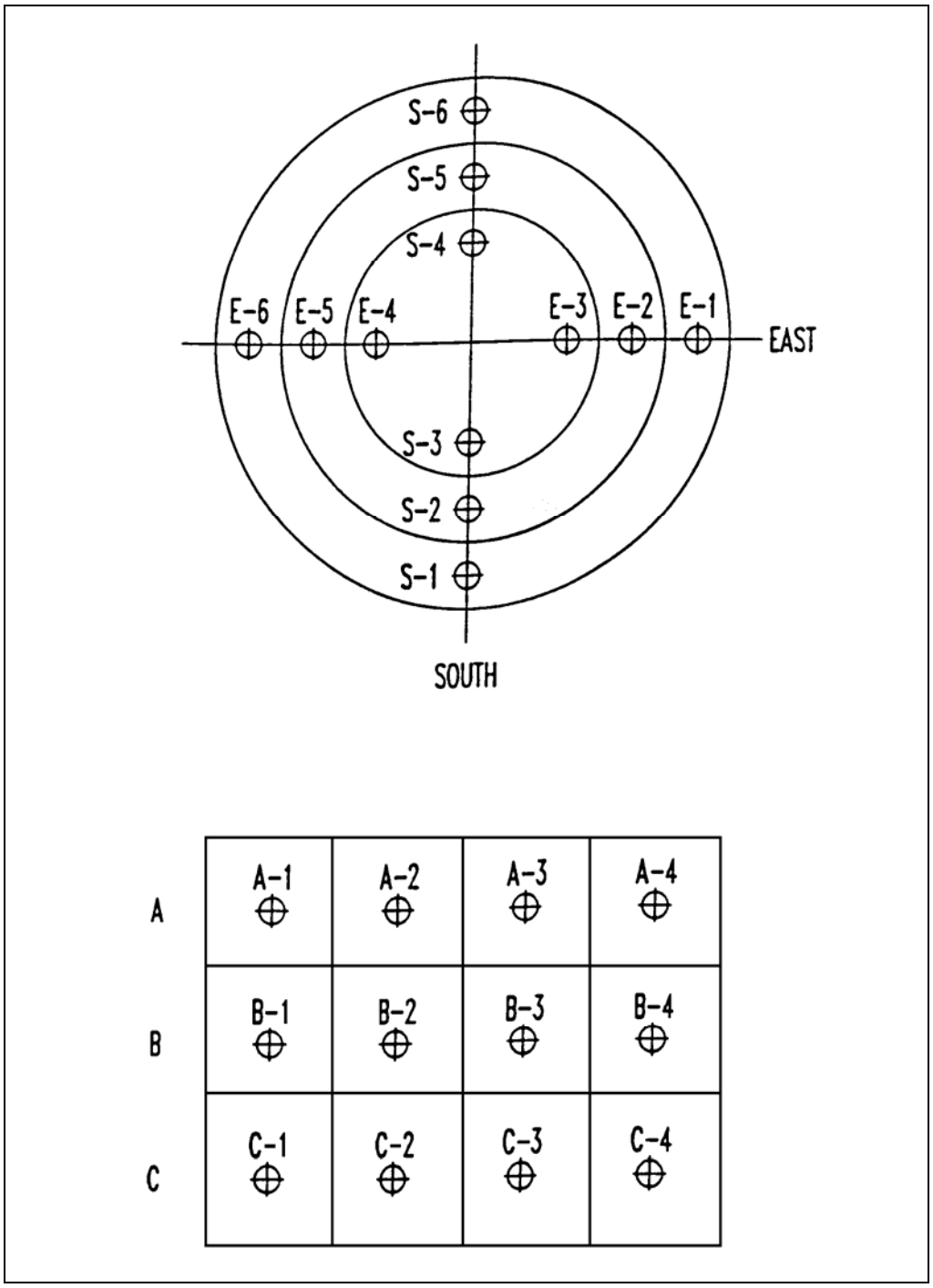


FIGURE 1-3: LOCATION OF TRAVERSE POINTS ON CIRCULAR AND RECTANGULAR CROSS-SECTIONS DIVIDED INTO 12 EQUAL AREAS

Part C

Method ON-2: Determination of Stack Gas Velocity and Volumetric Flow Rate

1.0 PURPOSE

To determine the velocity profile, the average gas velocity and volumetric flow rate in a stack or duct. The method is based on the measurement of the velocity pressure heads and stack gas temperatures. It takes into consideration the stack gas molecular weight, pressure and the configuration of the stack or duct.

2.0 LIMITATIONS

The basic method is not applicable in the following cases:

(i) cyclonic or reverse flow (see Part B: Method ON-1);

(ii) gas velocity pressure too low to be accurately measured with an inclined manometer or device of equivalent sensitivity; and,

(iii) fluctuating velocity pressure readings.

Where any of the above situations occur, reference should be made to the appendices.

3.0 APPARATUS

(a) Pitot tube **–** S-type (Stausscheibe or reverse type) Pitot tube. Alternatively, a standard Pitot tube may be used where particulate matter or condensate plugging of the static and impact pressure holes will not occur. Figures 2-1 and 2-2 show a typical configuration of Standard and S-Type Pitot tubes respectively.

(b) Differential pressure gauge – Inclined manometer or device of equivalent sensitivity, readable to the nearest 0.10 mm H_2O for velocity pressure (ΔP) values between 0.10 mm and 25 mm H_2O and readable to the nearest 1.0 mm H_2O for ΔP values greater than 25 mm H_2O. A more sensitive gauge is

required if a ΔP reading covers less than five (5) smallest scale divisions. See Chapter 7.3, Appendix 2C regarding more sensitive gauges.

(c) Temperature sensor – Thermocouple or other calibrated device capable of measuring stack gas temperature to within 1.5% of the minimum gas temperature. Temperature sensor must be checked according to the procedure outlined in Chapter 7.5, Appendix 2E.

(d) Probe – The combination of a calibrated Pitot tube and temperature sensor rigidly fixed to a sampling probe, facilitating simultaneous measurement of temperature and velocity pressure head at each point during sampling. The configuration of this combination is shown in Figure 2-3.

Note: The sampling probe can be omitted when the stack gas velocities only are measured; however, this combination of temperature sensor fixed to the Pitot tube must be calibrated separately.

(e) Stack Gas Pressure Sensor – The static tap of a standard Pitot tube or one leg of an S-type Pitot tube, with the face opening planes positioned parallel to the gas flow, connected to a manometer capable of measuring stack pressure to within 2.5 mm Hg or equivalent devices.

(f) Barometer – Barometer capable of measuring atmospheric pressure to within 2.5 mm Hg. Alternatively, the daily atmospheric pressure as provided by Environment Canada may be used with an altitude adjustment being made for the elevation of the sampling site at a rate of 2.5 mm Hg per 30 meters of elevation increase or vice versa for elevation decrease.

4.0 PROCEDURE

1. Use a Pitot tube calibrated exactly as it will be used (alone or as part of a probe assembly: thermocouple, sheathing and nozzles that will be used in sampling). The Pitot tube must be calibrated in accordance with the American Society for Testing and Materials (ASTM) Standard Practice D3796-09 “Practice for Calibration of Type S Pitot tubes”, or its most recent version. Additional information is also found in Chapter 7.1, Appendix 2A.

   Before each test, the Pitot tube must be examined to determine if it has incurred any damage, especially to its leading edge. If damaged, or if there is noticeable but non-removable particulate build-up, it must either be repaired or replaced, and in either case, recalibrated.

   Also, if the Pitot tube has shifted in position relative to the other components of the probe assembly since the last calibration, the Pitot must be recalibrated before use or repositioned exactly.

2. Conduct a leak-check of the Pitot tube and Pitot lines by pressurizing one of the Pitot tube openings until a minimum pressure head of 75 mm H_2O is registered on the differential pressure gauge. Seal off the selected Pitot tube opening and verify that the pressure remains constant. Similarly, leak-check the other Pitot tube openings.

3. Level and zero the manometer. Since the manometer level and zero may drift due to vibration and temperature changes, periodic checks of the manometer level and zero must be made during the measurement. All data are to be recorded according to the format shown in Table 2-1. If a differential pressure gauge other than a manometer is used, it must be calibrated every 6 months, in accordance with Chapter 7.2, Appendix 2B.

4. Determine the stack gas static pressure by connecting one leg of the manometer to the static tap of a standard Pitot tube or to one leg of an S-type Pitot tube with the face opening planes positioned parallel to the gas flow. This reading may be positive or negative depending on the conditions in the stack or duct. Determine the atmospheric pressure using the barometer. The static pressure reading, if necessary, is converted to the units of the atmospheric pressure reading and added to that pressure to give the absolute stack gas pressure, in accordance with Equation 2-1.

5. The velocity pressure (ΔP) and temperature are measured at each sampling point. Ensure the face opening planes of the S-type Pitot tube are maintained perpendicular to the cross-sectional plane of the stack or duct. The velocity pressure tap of the standard Pitot tube or the face opening planes of the S-type Pitot are maintained perpendicular to the longitudinal axis of the stack or duct. If a ΔP reading is less than 5 smallest scale divisions, a more sensitive gauge must be used at that point (See Chapter 7.3, Appendix 2C).

6. If a ΔP reading fluctuates more than ±20% of the average value at a point, during the preliminary survey, the stack gas flow needs to be stabilized before proceeding with the testing. If these reading fluctuations start during sampling, the test should be stopped until the source of the fluctuations are determined. If the stack gas flow can be stabilized, the test may proceed; otherwise, the test should be abandoned.

Note: If ΔP reading fluctuates more than ±20% of the average value at a point, the data gathered is unacceptable.

If the high velocity reading fluctuations persist, contact the Ministry's Source Assessment Specialist to discuss possible solutions. See Chapter 7.4, Appendix 2D for additional comments on velocity reading fluctuations.

7. Calculate the stack gas velocity at each sampling point according to Equation 2-2. Calculate the stack gas volumetric flow rate using Equation 2-3.

5.0 EQUATIONS FOR METHOD ON-2

$$P_s = P_{bar} + 0.098 P_{static}$$

Eq. 2-1

where:

P_s = absolute stack gas pressure, kPa

P_{bar} = atmospheric pressure, kPa

P_{static} = stack gas static pressure, cm H_2O

0.098 = factor to convert cm H_2O to kPa

$$U_s = 128.6 C_p \sqrt{\frac{(\Delta P T_s)}{M_s P_s}}$$

Eq. 2-2

where:

U_s = stack gas velocity (at a point), m/s

C_p = Pitot tube coefficient

T_s = absolute stack gas temperature, K

ΔP = stack gas velocity pressure head, kPa

M_s = stack gas molecular weight - wet basis, kg/kmol

P_s = absolute stack gas pressure, kPa

$$Q_S = 3600 U_{s(avg)} A_s (1 - B_{wo}) \frac{T_{ref} P_s}{(T_{s(avg)} P_{ref})}$$

Eq. 2-3

where:

Q_s = stack gas volumetric flow rate (dry basis at reference conditions), m^3/h

$U_{s(avg)}$ = average stack gas velocity, m/s (average of U_s's determined at each point)

A_s = cross-sectional area of stack or duct, m^2

B_{wo} = proportion of water in stack gas

T_{ref} = 298K

$T_{s(avg)}$ = average stack gas temperature, K (average of T_s's determined at each point)

P_s = absolute stack gas pressure, kPa

P_{ref} = 101.3 kPa

6.0 DISCUSSION OF METHOD ON-2

6.1 Purpose

This method is applied in all cases of representative measurement of enclosed gas flows. Given the gas composition as determined in Parts D and E (Methods ON-3 and ON- 4), with this method the gas velocity is determined at each point of a cross-sectional area as defined in Part B (Method ON-1). The average velocity of the stack gas and an overall stack gas volumetric flow rate are then calculated.

6.2 Limitations

6.2.1 Cyclonic or Reverse Flow

Method ON-2 is not applicable if cyclonic or reverse flow is present at the sampling location. The method requires that the flow at the sampling point be reasonably parallel to the longitudinal axis of the stack or duct and in the general direction of the gas stream. If cyclonic flow is suspected, its presence is confirmed by the procedure outlined in Part B (Method ON-1).

6.2.2 Low Gas Velocity

This method is also not applicable in situations where the gas velocity is so low that the differential pressure gauge is unable to accurately measure the velocity pressure head; the limit is five (5) smallest scale divisions. For most manometers on stack sampling units, this limit is 1.0 mm H_2O, which corresponds to about 3.0 m/s for an ambient air stream at ambient temperature. Reference should be made to Chapter 7.3, Appendix 2C, concerning more sensitive pressure gauges.

6.2.3 Fluctuating Gas Velocity

A further limitation to the applicability of Method ON-2 occurs in cases where the stack gas velocity fluctuates significantly, i.e., ΔP readings at a point vary more than ±20% of the estimated average ΔP reading. A 20% error with respect to ΔP represents approximately a 10% error in the velocity calculation. At lower velocities, the inaccuracy of a fluctuating reading is compounded by the greater relative error associated with reading the pressure gauge at the low end of the scale. If severe fluctuations are encountered, reference should be made to Chapter 7.4, Appendix 2D.

It is noted that this method is not limited with respect to sampling site selection criteria in relation to upstream and downstream flow disturbances outlined in Part B (Method ON-1); i.e., this method may be used at any point in a flowing gas stream to determine the velocity at that point. However, at points closer to a disturbance, there is a greater likelihood of fluctuating velocities and thus more inaccuracy in the ΔP readings. Thus

the same geometrical limitations outlined in Part B (Method ON-1) may be applicable when determining whether or not a given sampling site is satisfactory for representative flow measurements.

7.0 APPENDICES TO METHOD ON-2

7.1 APPENDIX 2A: Configuration of Pitot Tubes

7.1.1 Pitot Tube Calibration

For the purposes of Method ON-2 and any other method where a Pitot tube is required, the Pitot tube must be properly calibrated. That is, the Pitot tube must be calibrated exactly as it will be used, i.e., if used as part of a probe assembly (nozzle, temperature sensor and sheathing), the Pitot tube must be similarly fixed in relation to the other components of the assembly for both calibration and usage.

Furthermore, if there is any noticeable, but very minor damage to the Pitot tube openings or if there is noticeable but non-removable particulate build-up, either of which has occurred since the last calibration, the Pitot tube must be recalibrated before use.

The Pitot tube must be calibrated in accordance with the ASTM Standard Practice D3796-09 “Practice for Calibration of Type S Pitot tubes”, or its most recent version.

7.1.2 Compliance Test

In the case of a compliance test, it is mandatory that the most recent Pitot tube calibration data (done within six months) and results be included in any report submitted to the Ministry. These data should be dated and signed by the person(s) performing the calibration.

7.1.3 Pitot Tube Inspection

Prior to use, an inspection should be performed to confirm that the Pitot tube has not been damaged in any manner. If damaged, the Pitot tube must be repaired and recalibrated. If repair is not practical, the Pitot tube shall be discarded.

7.1.4 Probe Assembly

Generally, the probe assembly, including the Pitot tube, will have a similar configuration as shown in Figures 2-3 and 2-4. Both goose-neck (buttonhook) type and 90° bend nozzles may be used except in stacks or ducts with heavy dust loading where only goose-neck nozzles may have to be used. Figures 2-3 and 2-4 indicate recommended spatial requirements so that aerodynamic interference among components of the assembly is minimized. However, these distances may only be slightly exceeded since the function of the probe assembly is to measure stack parameters as close as possible to the point where the sample is drawn into the probe. Figure 2-5 provides graphical details and equation for estimating the probe sheath blockage area.

The temperature sensor is attached so that the sensor tip does not touch any metal. The tip of the nozzle must extend at least two (2) nozzle diameters below the tip of the upstream leg of the S-type Pitot tube. The S-type Pitot tube on a probe assembly can be calibrated with a nozzle of similar shape to the one selected for the testing. Should a nozzle outside of the typical size range be used (i.e. >13mm), pitot tube calibrations need to be completed with a nozzle of similar diameter (within 2mm).

7.2 APPENDIX 2B: Calibration of Differential Pressure Gauges other than Manometers

The calibration is done by comparing ΔP readings obtained with the gauge and an inclined manometer at a minimum of three (3) different flow velocities which approximate the ΔP's found in the stack or duct. The readings must agree to within 5% at each point for the gauge to be acceptable (see Equation 2-4). Calibration results are reported as shown in Table 2-2

$$\text{Percent Difference} = \left(\frac{\Delta P_{gauge} - \Delta P_{manometer}}{\Delta P_{manometer}} \right) \times (100\%)$$

Eq. 2-4

7.3 APPENDIX 2C: Substitutes for Inclined Manometers in the Case of Low Stack Gas Velocities

As stated in Chapter 3(b), if a ΔP reading is found to be less than five (5) smallest scale divisions on the gauge being used, a more sensitive device must be employed. Such devices include hot wire anemometers, rotating and swinging vane anemometers, and variable area flow meters.

7.4 APPENDIX 2D: Fluctuating Velocity Pressure Readings

If a ΔP reading fluctuates more than ±20% of the average value at a point, the data gathered at the point are unacceptable. Fluctuation of gas velocity generally does not arise due to stack or duct configuration but rather variations in the process or upstream machinery. If the operation of the process or machinery cannot be stabilized, it may be possible to dampen the fluctuations in velocity by temporarily extending the stack or duct or providing a stack gas expansion chamber before the differential pressure gauge.

7.5 APPENDIX 2E: Calibration and Check of Temperature Sensors

The temperature sensor must be calibrated according to accepted routine procedures and the calibration values checked every six (6) months. This is done by comparing sensor readings to several known temperatures covering the range expected in the field. The apparatus used for this purpose are an ice bath, boiling water and a heated oil bath with a liquid-filled thermometer. If the sensor readings do not compare within 1.5% of the known absolute temperatures, the sensor must be replaced.

Alternatively, an electronic temperature calibrator may be used for internal calibration of thermocouples. In these cases the electronic temperature calibrator must have a valid calibration certificate, tied to a primary standard. Both calibration records need to be

provided upon request by the Ministry, and included in an appendix of each source test report.

8.0 REFERENCES

1. American Society of Testing and Materials, Standard D3796-90(2004), Standard Practice for Calibration of Type S Pitot Tubes, 2004.

2. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December, 1993.

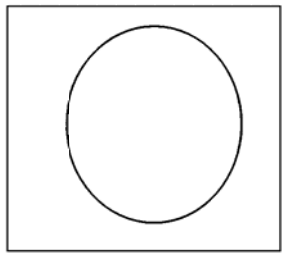
3. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

4. United States Environmental Protection Agency, Code of Federal Regulations, Title 40 Part 60, Appendix A, July 1. 1994.

TABLE 2-1: FIELD SAMPLING REPORT TEMPLATE

Plant: _____ *
Location: _____ *
Date: _____ *
Operators: _____ *
Run No.: _____ *
Pitot Coefficient: _____ *
Dry Gas Meter Correction Factor: _____
Stack Gas Molecular Weight (kg/kmol): ___
Traverse Number and Direction: _____

Ambient Temperature (°C): _____ *
Atmospheric Pressure, P bar (mm Hg): _____ *
Assumed Moisture (%): _____ *
Static Pressure, P static (mm H_2O): _____ *
Stack Diameter (m): _____ *
Nozzle Diameter (mm): _____
Probe Length (m): _____
Probe Liner: _____



Sampling Point Number	Sampling Time (Min.)	Stack Temp. T_s (°C)	Velocity Head ΔP, (mm H2O)	Orifice Pressure Drop ΔH (mm H_2O)	Gas Sample Volume, Vm. (m^3)	Dry Gas Meter Temp.		Sample Box Temp. (°C)	Impinger Outlet Temp. (°C)	Probe Temp. (°C)	Vacuum (mm Hg.)
						Inlet $T_{m(in)}$ (°C)	Outlet $T_{m(out)}$ (°C)				
1											
2											
3											
4											
5											
6											
7											
8											

* Information required for Method 5

1.1.1 TABLE 2-2: DIFFERENTIAL PRESSURE GAUGE CALIBRATION DATA TEMPLATE

Test Number	$\Delta P_{manometer}$ (mm H2O)	ΔP_{gauge} (mm H2O)	Percent Difference
1 2 3 . . .			

FIGURE 2-1: TYPICAL STANDARD PITOT TUBE CONFIGURATION

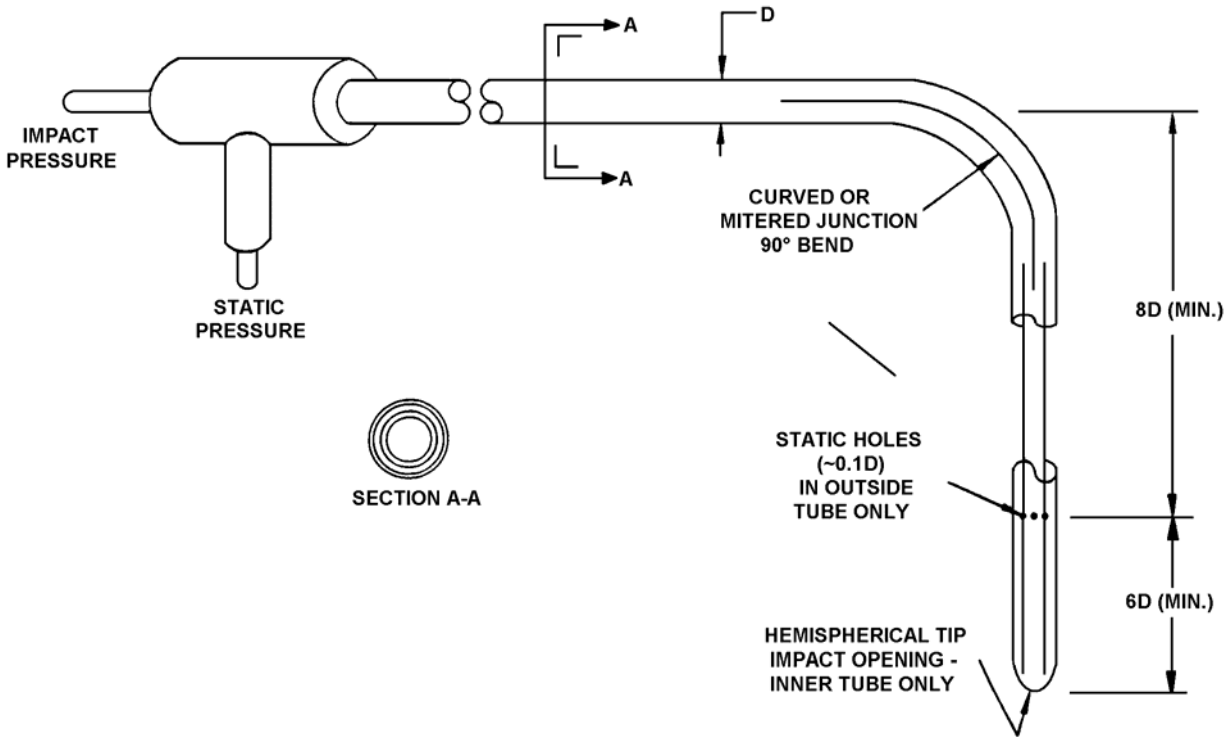
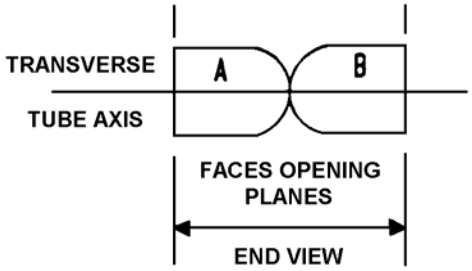
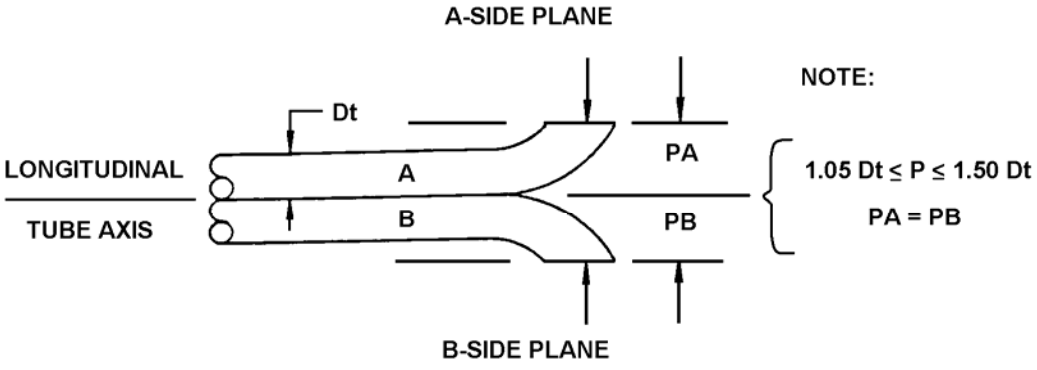
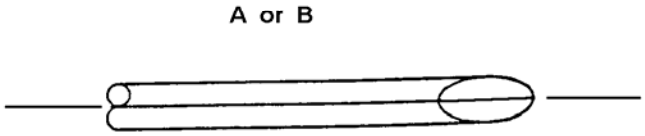


FIGURE 2-2: TYPICAL S-TYPE PITOT TUBE CONFIGURATION



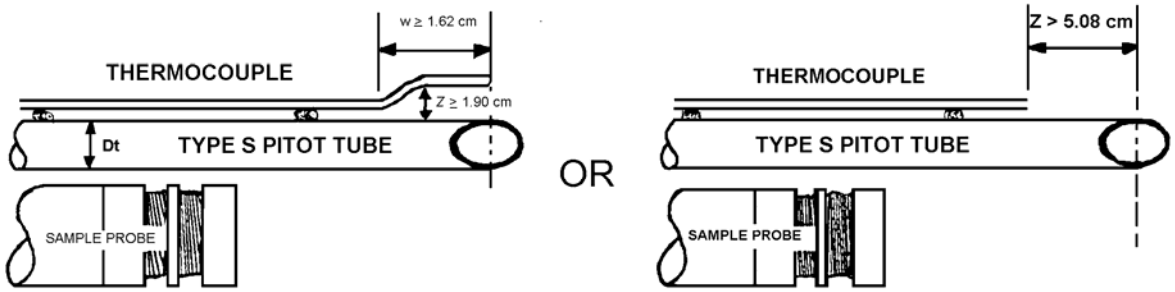


TOP VIEW

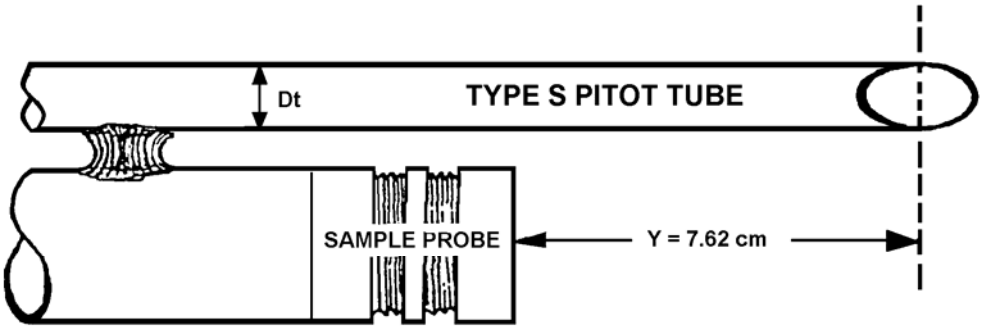


SIDE VIEW

FIGURE 2-3: CONFIGURATION OF PITOT TUBE, SAMPLING PROBE, AND THERMOCOUPLE



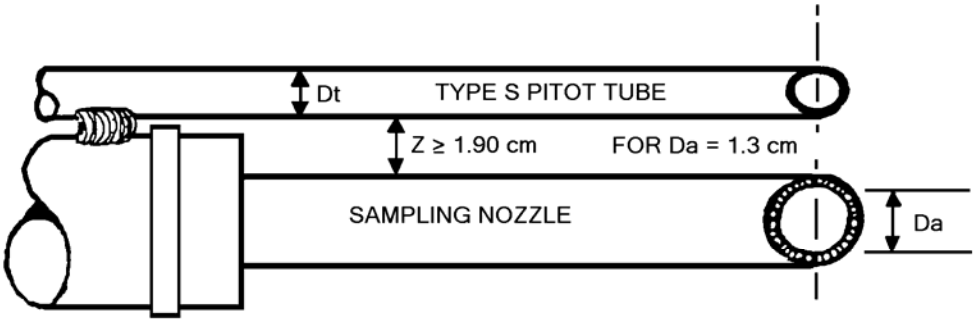
Proper thermocouple placement to prevent interference:
Dt between 0.48 and 0.95 cm



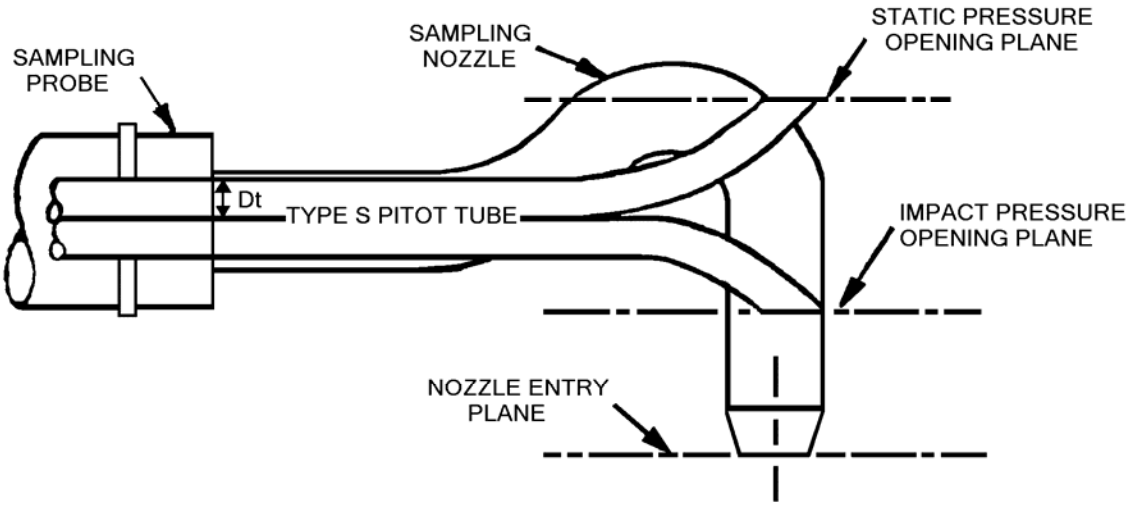
MINIMUM PITOT - SAMPLE PROBE SEPARATION
NEEDED TO PREVENT INTERFERENCE:
Dt BETWEEN 0.48 cm AND 0.95 cm

FIGURE 2-4: PITOT TUBE AND SAMPLING NOZZLE CONFIGURATION

(Botton-Hook type nozzle. Centre of nozzle and Pitot tube opening aligned. Dt is between 4.8 mm and 9.5 mm)



A. BOTTOM VIEW: SHOWING MINIMUM PITOT TUBE NOZZLE SEPARATION



B. SIDE VIEW: TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE. THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

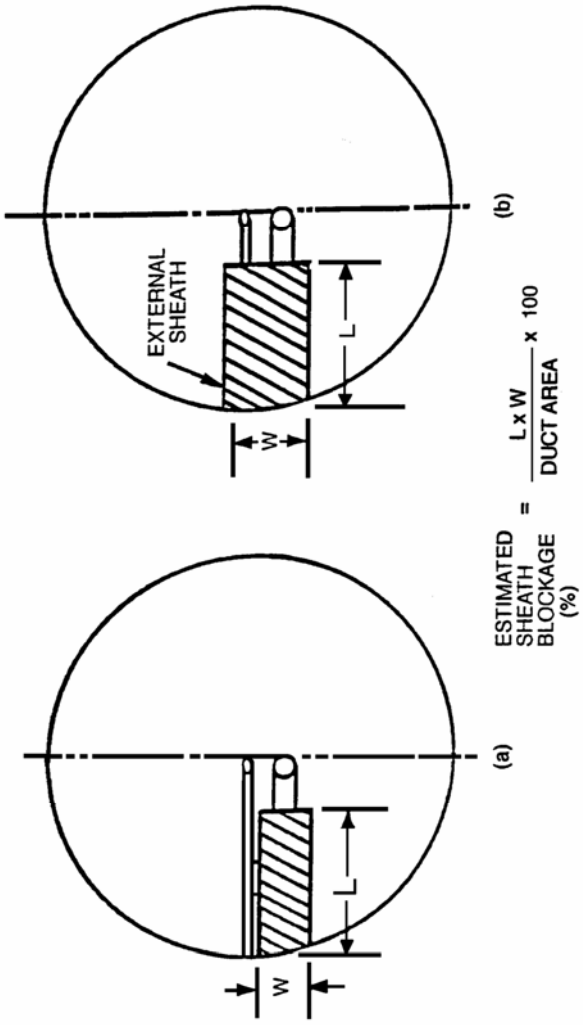


FIGURE 2-5: TYPICAL PROBE SHEATH BLOCKAGE AREA

Part D

Method ON-3: Determination of Molecular Weight of Dry Stack Gas

1.0 PURPOSE

To determine the concentrations of oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen (N_2) and the dry stack gas molecular weight from a gas stream.

2.0 LIMITATIONS

This method is not applicable in the following case:

(i) gas streams with significant concentrations of gases other than O_2, CO_2, CO, N_2, argon (Ar) and water (H_2O) – for example, sulfur dioxide (SO_2).

Where this situation occurs, molecular weight calculation of all other gases with significant concentrations should be included.

3.0 APPARATUS

Two modes of sampling collection are listed in this method are grab samples and integrated samples.

A grab sample contains a representative portion of a gas stream at a given point in time, with the representativeness depending on low variability of the characteristics of the gas stream being sampled.

An integrated sample is composed of a mixture of grab samples collected at different times, and it gives average contaminant concentration values.

Note: The continuous determination instrumental analyzer is the Ministry's recommended approach; and it will be requested exclusively, when a more detailed environmental fingerprint of CO_2, O_2, and CO needs to be established.

3.1 Grab Sampling

The basic components of a grab sampling train (see Figure 3-1):

(a) Probe – stainless steel or borosilicate glass with in-stack (e.g., glass wool plug) or out-stack particulate matter filter; other materials inert to the sampling gases are acceptable.

(b) Pump – one-way squeeze bulb or equivalent device.

(c) Moisture Removing Device – (optional, if moisture content of stack gas is not greater than that of ambient air) - a device to remove water from gas stream without removing the gaseous components.

(d) Gas Analyzer – calibrated analyzer based on electrochemical principle, calibrated continuous gas analyzer, gas chromatograph, Fyrite, or other device(s) provided that gas component percentage is measurable to at least 0.2% and is determined on a dry basis.

3.2 Integrated Sampling

Basic components of an integrated sampling train (see Figure 3-2):

(a) Probe – same as 3.1(a).

(b) Condenser – same as 3.1(c).

(c) Pump – leak free, diaphragm pump or equivalent; surge tank between pump and rotameter to dampen diaphragm pulsation effect.

(d) Valve – needle valve to adjust sample gas flow rate.

(e) Flow Rate Meter – rotameter or equivalent device capable of measuring flow to within ±2% of the selected flow rate.

(f) Flexible Bag – leak free, inert, plastic (e.g., Tedlar®, Mylar, Teflon) or plastic coated aluminum (e.g., aluminized Mylar) or equivalent; capacity consistent with flow rate and sampling time (recommend at least 30 litres).

Note: A flexible bag is not needed when the sample is continuously extracted using an instrumental procedure. In this case, a portion of the gas stream is conveyed to an instrumental analyzer(s) for continuous determination of O_2, CO_2 and CO concentration(s). In this case, refer to the US EPA 40CFR60 Method 3A (for O_2 and CO_2 determination) and Method 10 (CO determination) for sampling train configuration, performance specifications and test procedures.

(g) Gas Analyzer – same as 3.1(d).

4.0 PROCEDURE

4.1 Grab Sampling

If the stack gas flow is non-stratified and its composition remains uniform, the following procedure is used to determine the dry molecular weight:

1. Assemble the grab sampling train as shown in Figure 3-1; a pump may be necessary if the source is under a vacuum. Ensure that all connections ahead of the analyzer are secure and leak-free.

2. Assemble the analyzer, calibrate, and leak-check it according to the manufacturer's instructions or accepted standard procedure.

3. Position the probe at the centre of the stack or duct when the diameter is smaller than 2.0 m or at a point no closer than 1.0 m to the walls of larger stacks or ducts. Purge the sampling system and then draw a sample into the analyzer and immediately analyze for the percentages of CO_2, CO, O_2 and N_2.

4. Calculate the dry molecular weight according to Equations 3-1 to 3-3 (found in Chapter 5). Repeat the sampling and analysis two more times. Individual values should not deviate from their mean by more than 0.3 kg/kmol. If they do, repeat the procedure three more times and select three determinations which satisfy the above criterion of deviation. Report the mean value to the nearest 0.1 kg/kmol.

Note: The concentrations of the individual components are used only to determine the molecular weight. They are not necessarily representative of the true values as a stricter criterion of precision should be used for individual component analysis.

5. Results for stack gas composition determination are recorded on a data gathering form similar to Table 3-1.

4.2 Integrated Sampling

If the stack gas flow is non-stratified but its composition varies with time or if the precision criterion for grab sampling cannot be met, the following procedure is used to determine the dry molecular weight:

1. Leak-check the sample bag prior to use, according to the following procedure: connect the bag to a manometer and pressurize it to 5 to 10 cm H_2O; allow to stand for 10 minutes; any displacement of the manometer indicates a leak. Alternatively, allow the pressurized bag to stand overnight; a deflated bag indicates a leak.

2. Assemble the integrated sampling train as shown in Figure 3-2. The configuration of the train is optional provided that a dry sample can be drawn into a non-reactive sample bag at a constant rate. Ensure that all connections are secure and leak-free.

3. Assemble the analyzer, calibrate and leak-check it according to the manufacturer's instructions or accepted standard procedure.

4. Position the probe at the centre of the stack or duct when diameter is smaller than 2.0 m or at a point no closer than 1.0 m to the walls of larger stacks or ducts. Continuously draw a sample into the bag, at a constant rate, throughout the stack gas velocity traverse or the particulate matter test. The sampling rate is fixed to provide a full sample bag at the completion of the test. The recommended sample volume is no less than 30 litres.

5. Analyze the integrated sample within 8 hours of collection and calculate the dry molecular weight according to Equations 3-1 to 3-3 (found in Chapter 5). Repeat the analysis until the molecular weights of any three determinations differ from their mean by no more than 0.3 kg/kmol and report the mean value to the nearest 0.1 kg/kmol.

4.3 Stratified Gas Flow

Stratification of gases does occur where the gas mixture has a significant difference in density from the surrounding air.

Gas stratification in the stack or duct may be present where there is an ambient air intake close to the sampling site, mixing of exhausts from different processes, or possibly in horizontal ducts carrying a mixture of gases, one or more of which is

relatively heavier than the others, etc. Where stratification is known or suspected to exist, the following procedure is used to determine the dry molecular weight:

1. Choose a traverse such that a gas concentration profile across it would reveal any stratification. For example, the traverse should be parallel to the centre line down through the normal at the point of entry of the inlet gases into the duct or stack. In the case of horizontal inlet bends into the duct or stack, the traverse is usually horizontal, while in the case of vertical inlet bends, the traverse is usually vertical.

2. In the case of stacks or ducts with diameters less than 1.0 m, select 4 equally spaced points along the traverse; in the case of stacks or ducts having larger diameters, select 6 equally spaced points along the traverse.

3. Perform at least 3 molecular weight determinations according to the grab sampling techniques at each point. Average the results at each point and determine the value to the nearest 0.1 kg/kmol. Then average these values to determine the overall mean value. If the average values at each of the points are within ±5% of the overall mean value, then the molecular weight may be determined by the integrated sampling technique. If one or more of the point values is not within ±5% of the overall mean value, significant stratification is indicated and a specified technique will be required for molecular weight determination.

Note: Significant gas stratification in a stack or duct presents difficulties with regards to accurate source sampling, since the velocity determination depends on the molecular weight and the fixing of an isokinetic sampling rate depends on the calculated velocity. It may be necessary to determine the molecular weight at each individual sampling point. It may also be possible to use a multi-nozzle probe to obtain an integrated sample.

5.0 EQUATIONS FOR METHOD ON-3

$$\%(N_2 + Ar) = 100 - (\%CO_2 + \%O_2 + \%CO)$$

Eq. 3-1

$$\%Ar = 0.0119(\%N_2)$$

Eq. 3-2

where:

% = percent by volume

Ar = argon (molecular weight, M.W. = 40)

N_2 = nitrogen (M.W. = 28)

CO_2= carbon dioxide (M.W. = 44)

CO= carbon monoxide (M.W. = 28)

O_2 = oxygen (M.W. = 32)

Note: Argon is included in the calculations only if the main source of nitrogen is air.

$$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.40(\%Ar) + 0.28(\%N_2 + \%CO)$$

Eq. 3-3

where:

M_d = molecular weight (dry basis), kg/kmol

6.0 DISCUSSION of METHOD ON-3

6.1 Purpose

This method is applied in all cases where it is necessary to determine the stack gas composition with respect to O_2, CO_2, CO and N_2. Stack gas composition data are used to calculate the stack gas molecular weight and this value is ultimately used to calculate the stack gas flow rate.

6.2 Limitations

6.2.1 Presence of Other Gases

The presence of significant concentrations of gases other than O_2, CO_2, CO, NO_2 and Ar (ambient concentration) may interfere with the accurate operation of the equipment outlined in this method. These gases may interfere with the action of the analyzer or they may cause a dilution of the sample which is unaccounted for.

6.2.2 Effects of Gas Components on Analyzers

Other types of analyzers are also susceptible to interference. This may include co-absorption in spectral absorption devices, quenching effects, etc. The specific analyzer must be examined with respect to the effects of the various stack gas components on its operation.

6.3 Apparatus

The configurations of the grab sampling and integrated sampling apparatus should resemble Figures 3-1 and 3-2. However, the use of other devices is permitted, provided the overall function of the apparatus is maintained; i.e., a representative sample of clean stack gas is transferred, without chemical change, from the source to the analyzer.

7.0 REFERENCES

1. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December, 1993.

2. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

3. United States Environmental Protection Agency, Code of Federal Regulations, Title 40 Part 60, Appendix A, July 1. 1994.

TABLE 3-1: GAS COMPOSITION DATA TEMPLATE

Date:
Operators:
Location:
Method of Sampling (grab or integrated):
Type of Analyzer:

Replicate Analysis Number	$\%CO_2$	$\%O_2$	%CO	$\%N_2$	%Ar	Molecular Wt. (kg/kmol)	Difference From Mean Molecular Wt.
1							
2							
3							
4							
5							
.							
.							
.							

Average Mean Molecular Weight: _____

FIGURE 3-1: GRAB-SAMPLING TRAIN

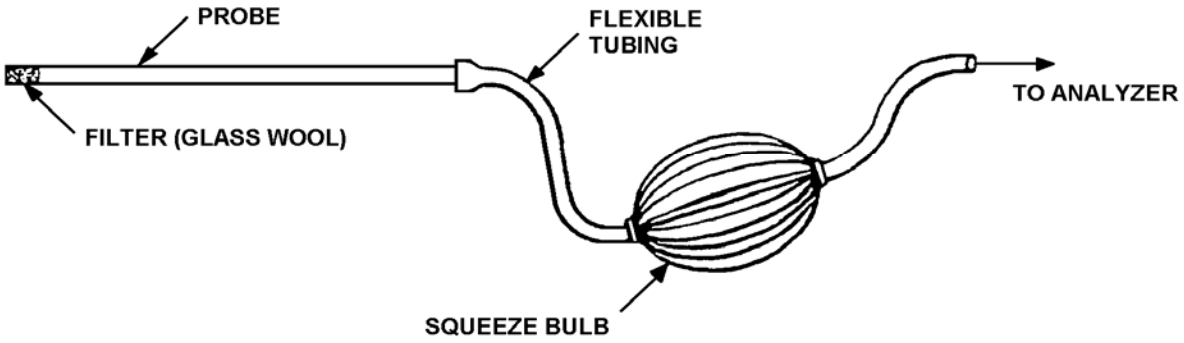
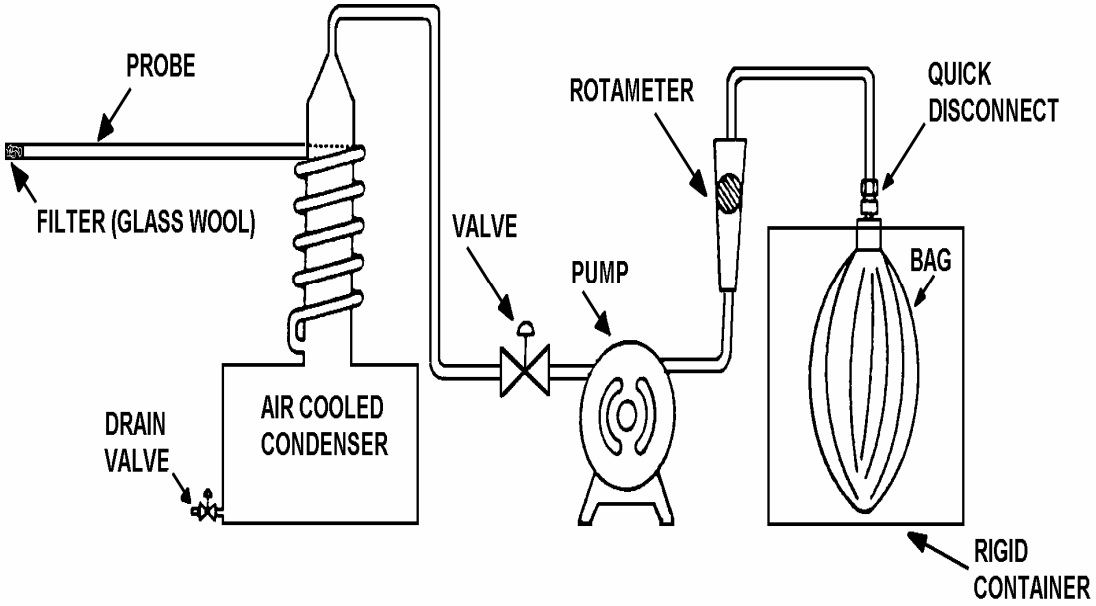


FIGURE 3-2: INTEGRATED GAS SAMPLING TRAIN



Part E

Method ON-4: Determination of Moisture Content of Stack Gas

1.0 PURPOSE

To determine the moisture content of stack gas.

2.0 APPARATUS

(a) Probe – Probe made of stainless steel, glass tubing or other material (stack conditions permitting) capable of being maintained at a minimum temperature of about 120°C and equipped with a heated filter bypass.

(b) Condenser – Condenser comprising of four impingers connected in series with leak-free fittings (e.g., ground glass). The first, third and fourth impingers are of the Greenburg-Smith design modified by replacing the tip with a glass tube about 1.3 cm I.D. extending to about 1.3 cm from the bottom of the flask. The second impinger is of the standard Greenburg-Smith design. A sensor capable of measuring temperature to within 1°C is placed at the outlet of the fourth impinger. Known volumes of water are placed in the first and second impingers and a known weight of desiccant is placed in the fourth impinger. The impingers are maintained in an ice bath. Alternatively, functionally equivalent systems are acceptable.

(c) Metering System – Metering system comprising of a vacuum gauge, leak-free pump, calibrated dry gas meter capable of measuring volume to within 2% and including an inlet and an outlet temperature sensor capable of measuring temperature to within 1°C or temperature compensation, an orifice meter for checking the instantaneous sampling rates and the dry gas meter calibration factor in the field, and additional equipment as shown in Figure 4-1.

(d) Barometer – Barometer capable of measuring atmospheric pressure to within 2.5 mm Hg. Alternatively the daily atmospheric pressure as provided by Environment Canada may be used, with an altitude adjustment for the sampling site at the rate of minus 2.5 mm Hg per 30 meters of elevation increase or vice versa for elevation decrease.

(e) Graduated Cylinder – Graduated cylinder with subdivisions no greater than 2 ml.

(f) Balance – Balance capable of weighing to the nearest 0.5 g.

Note: The sampling train configuration is similar to that in Part F (Method ON-5), but without the filter.

3.0 PROCEDURE

A moisture determination performed according to the following procedure is required for any compliance test. In Chapter 6.1, Appendix 4A, several methods for determining an approximate moisture content which may be used for setting isokinetic sampling are discussed.

1. In general, a multi-point traverse is required for the purposes of this method. Sampling site location, number of sampling points and their location are determined according to Part B (Method ON-1). However, methods for determination of specific pollutants may allow for moisture determination at a single sampling point.

2. Place 100 ml of water in each of the first two impingers and transfer 200 to 300 g of pre-weighed desiccant into the fourth impinger. A tared weighing procedure for desiccant plus impinger may be used. Volume is recorded to the nearest ml and weight to the nearest 0.5 g.

3. Assemble the moisture sampling train as shown in Figure 4-1. The orifice meter may be used to maintain a constant sampling rate. The dry gas meter must be calibrated according to the procedure specified in Chapter 6.2, Appendix 4B and the calibration checked before each test series according to the procedure outlined in Chapter 6.3, Appendix 4C.

4. A total sampling time is selected such that a minimum total gas volume of 0.60 STD m^3 will be collected at a rate approximating the normal pollutant sampling rate. If performed simultaneously with a pollutant emission test using the same train, the moisture determination shall be continuous and for the same length of time as the emission test. If this method is being performed simultaneously with a particulate matter test using the same train, the sampling rate is isokinetic.

5. Pre-heat the probe and out-stack filter heating system, if applicable, to a temperature of at least 120°C to prevent water condensation ahead of the condenser. Allow time for the temperature to stabilize. Fill the ice bath just prior to sampling.

6. A pre-test leak-check is mandatory and is performed according to the following procedure:

   Pre-Test Leak Check

   a) Plug the nozzle or inlet to the probe.

   b) Draw a vacuum of 380 mm Hg, or the highest vacuum anticipated during the test. The recommended procedure for drawing a vacuum is to start the pump with the bypass valve fully open and the coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of the bypass valve, as this may cause water to flow into the filter holder.

   c) Maintain the vacuum for at least 1 minute. A leakage rate of 0.00057 m^3/min or greater is unacceptable and, if so found, the sampling train must be dismantled and reassembled until the leak is adequately reduced or eliminated.

   d) When the leak-check is completed, first slowly remove the plug from the nozzle or inlet to the probe and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced into the filter holder or probe and silica gel from being entrained into the third impinger.

7. To begin sampling, position the probe inlet at the first, or sole, sampling point. Immediately start the pump and adjust the flow to the desired rate as determined in Chapter 3, Step 4. Traverse the cross-section, if required, and sample at each point for an equal length of time. The sampling rate is maintained within 10% of a constant rate, or 10% of isokinetic rate when this method is being performed in conjunction with a pollutant test that requires isokinetic sampling.

8. Ensure that the temperature of the gas leaving the last impinger is less than 20°C. More ice and perhaps some salt may have to be added during the test to maintain a low gas temperature. Data are recorded according to the format shown in Table 4-1. The dry gas meter volume readings are recorded at the beginning and the end of each sampling increment. Other required readings are taken at least once during each sampling increment.

9. After sampling for the required length of time, a post-test leak-check must be performed according to the procedure described in Chapter 3, Step 6 and modified in that the test vacuum is equal to or greater than the highest vacuum drawn during the test. If the leak-check is unacceptable, the test results must be discarded and the test repeated.

10. Measure and record the volume of the condensed moisture to the nearest ml or grams and the increase in weight of the desiccant to the nearest 0.5 g. Data are recorded according to the format shown in Table 4-1.

4.0 EQUATIONS FOR METHOD ON-4

The following equations are used to calculate the moisture content and stack gas molecular weight. If there are water droplets in the gas stream, it is assumed that the gas is saturated. In such a case the moisture content is determined from psychrometric tables and compared with the value determined by this method. The lower of the two values is the one used as the moisture content.

$$W_w = W_c + W_d$$

Eq. 4-1

where:

W_w = weight of moisture collected by the condenser, g or ml

W_c = weight of moisture condensed in the impingers, g or ml

W_d = weight of moisture captured by the desiccant, g or ml

$$V_{w(ref)} = \left(1.36 \times 10^{-3}\right) W_w$$

Eq. 4-2

where:

$V_{w\,(ref)}$ = volume of H_2O, as gas, at 101.3 kPa and 298K, m^3

$$V_{m(ref)} = \frac{2.94 \gamma P_m V_m}{T_{m(avg)}}$$

Eq. 4-3

where:

$V_{m(ref)}$ = volume of gas sample at 298K and 101.3 kPa, m^3

γ = dry gas meter correction factor (see Equation 4-6 in Chapter 6.2, Appendix 4B)

V_m = volume of gas sample recorded on dry gas meter, m^3

P_m = absolute pressure at dry gas meter, kPa (for this method use barometric pressure)

$T_{m(avg)}$ = absolute temperature at dry gas meter, K. (The average of inlet and outlet temperatures recorded during each sampling increment or, if applicable, the meter compensation temperature.)

$$B_{wo} = \frac{V_{w(ref)}}{V_{m(ref)} + V_{w(ref)}}$$

Eq. 4-4

where:

B_{wo} = volume fraction of H_2O in stack gas

$$M_s = M_d(1 - B_{wo}) + 18B_{wo}$$

Eq. 4-5

where:

M_s = molecular weight of stack gas, kg/kmol

M_d = molecular weight of dry stack gas, kg/kmol

5.0 SAMPLE CALCULATIONS

The sample data for one traverse are recorded in Table 4-1. Normally a second traverse is done and calculations are based on total sample volume and moisture collected on both traverses. Moisture data are recorded in Table 4-2.

$$V_m = 57.5630 - 56.5800$$

$$= 0.983\,\mathrm{m}^3$$

$$P_m = P_{bar}$$

$$= 100.5\,\mathrm{kPa}$$

$$V_{m(ref)} = \frac{2.94\gamma V_m P_m}{T_{m(avg)}}$$

$$= \frac{2.94 \times 0.991 \times 0.983 \times 100.5}{297}$$

$$= 0.969\,\mathrm{m}^3$$

$$V_{w(ref)} = 0.00136 W_w$$

$$= 0.00136 \times 146.6\mathrm{g}$$

$$= 0.199\,\mathrm{m}^3$$

$$B_{wo} = \frac{V_{w(ref)}}{V_{m(ref)} + V_{w(ref)}}$$

$$= \frac{0.199}{0.969 + 0.199}$$

$$= 0.170$$

If the molecular weight of the dry stack gas is determined to be 29.66 kg/kmole then:

$$M_s = M_d(1 - B_{wo}) + 18B_{wo}$$

$$= (29.66 \times 0.830) + (18 \times 0.170)$$

$$= 27.68\,\text{kg/kmol}$$

Therefore the molecular weight of the stack gas is 27.7 kg/kmol.

6.0 APPENDICES TO METHOD ON-4

6.1 APPENDIX 4A: Approximation Methods for the Determination of Moisture Content

The following procedures may be used to determine the moisture content of stack gas for the purposes of setting isokinetic sampling rates.

(i) Previous tests conducted on the source under scrutiny;

(ii) Mass balance calculations;

(iii) Drying tubes;

(iv) Wet and dry bulb thermometer technique – can be used if stack gas temperature is less than 100°C, the gas stream velocity is greater than 5 m/s and the gas stream does not contain water droplets or acid mist; and,

(v) Condensation techniques – for example, two (2) midget impingers in an ice bath, as shown in Figure 4-2. Note that if the silica gel tube moisture content is not determined, the calculated value for B_{wo} must be increased by the moisture content of saturated gas at the temperature of the gas leaving the second impinger. Twenty-one degrees Celsius (21°C) may be used as an estimate or a temperature sensor can be placed at the outlet of the second impinger. At 21°C, the moisture content of saturated gas is 0.025.

6.2 APPENDIX 4B: Calibration of Dry Gas Meter and Determination of Orifice Coefficient

The dry gas meter is calibrated at least once every six (6) months against a standard capable of measuring volume within ±1% accuracy, at a rate approximating that of the dry gas meter. The standard is either a primary standard or a device calibrated against a primary standard. For example, a calibrated wet test meter may be used, as illustrated in the following procedure:

1. Assemble the components as shown in Figure 4-3. The components within the broken lines are usually integrated in the control unit of a standard particulate matter sampling train.

2. Operate the equipment with the orifice manometer set at 10 mm H_2O (0.5 in. H_2O) for at least 15 minutes to ensure that the pump is at operating temperature and all interior surfaces of the wet test meter are wetted.

3. Perform tests and record data according to the requirements of Table 4-3, i.e. draw the required volume of air at the stated orifice manometer setting and record the volume through the gas meter, the time required to draw the required volume and the other parameters.

4. Moisture content of the air may be determined by any practical means, e.g., the wet and dry bulb technique sufficiently accurate for ambient air.

5. Calculate γ for each test volume by using Equation 4-6:

$$\gamma = \frac{V_w \left(P_{bar} + 0.098\,\Delta M\right)\left(t_d + 273\right)\left(1 - B_{wo}\right)}{V_d \left(P_{bar} + 0.098\,\Delta H\right)\left(t_w + 273\right)}$$

Eq. 4-6

where:

γ = dry gas meter correction factor

V_w = volume recorded by standard, m^3

V_d = volume recorded by dry gas meter, m^3

P_{bar} = barometric pressure, kPa

ΔM = standard wet test meter manometer reading, cm H_2O

ΔH = dry gas meter orifice manometer reading, cm H_2O

t_d = average of inlet and outlet temperature at dry gas meter, °C

t_w = temperature at primary or secondary standard, °C

B_{wo} = moisture fraction of air

6. Calculate the average γ by graphing Q(standard) versus Q(dry), where Q(standard) equals the numerator of Equation 4-6 divided by the time (θ, defined below) and Q(dry) equals the denominator of the respective equation divided by time (θ). The slope of the best fitting line is the average γ. A more accurate means of determining the average γ is to determine the best fitting line by first order linear regression. If all individual values of γ are within ±2% of the average, then the calibration is acceptable. If this criterion cannot be met, it may be necessary to have the dry gas meter internally adjusted and recalibrated.

7. Calculate K_o for each test volume by using Equation 4-7 (below) from data used to calculate an acceptable γ.

$$K_o = \frac{\left(\frac{\gamma_{(avg)} V_d \left(t_{do} + 273\right)}{\theta\left(t_d + 273\right)}\right)}{\sqrt{\frac{\Delta H\left(t_{do} + 273\right)}{M\left(P_{bar} + 0.098\,\Delta H\right)}}}$$

Eq. 4-7

where:

K_o = orifice coefficient

$\gamma_{(avg)}$ = average dry gas meter correction factor

M = molecular weight of air

θ = time, minutes

8. Calculate the average K_o arithmetically.

6.3 APPENDIX 4C: Dry Gas Meter Calibration Check

Before each test series, the dry gas meter correction factor must be checked on the sampling site according to the following procedure:

1. At no less than three different orifice manometer settings approximately covering the range of values expected in the test series, draw ambient air sample volumes, each for a duration of at least three minutes. Record the dry gas meter volume, the time period, the ΔH, the orifice temperature (equal to temperature leaving the dry gas meter) and the dry gas meter temperature.

2. Determine the ratio, R, of the dry gas meter volumetric flow rate versus the orifice flow rate using the values for $\gamma_{(avg)}$ and K_o as determined in Chapter 6.2, Appendix 4B. Use Equation 4-8 below.

$$R = \frac{\left(\frac{\gamma_{(avg)} V_d \left(t_{do} + 273\right)}{\theta\left(t_d + 273\right)}\right)}{\left(K_o \sqrt{\frac{\Delta H\left(t_{do} + 273\right)}{M\left(P_{bar} + \Delta H\right)}}\right)}$$

Eq. 4-8

If the value of R is 1.0 ±0.05, the meter correction factor is acceptable for use in the following test series. Otherwise, the meter must be recalibrated before use.

7.0 REFERENCES

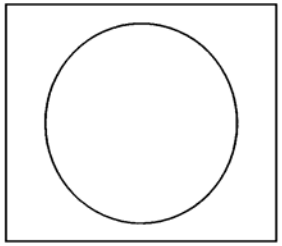
1. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December, 1993.

2. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

3. United States Environmental Protection Agency, Code of Federal Regulations, Title 40 Part 60, Appendix A, July 1. 1994.

TABLE 4-1: FIELD SAMPLING REPORT (EXAMPLE)

Schematic of Stack Cross-section



Plant*:
Location*:
Date*:
Operators
Run No.*:
Pitot Coefficient*: 0.850
Dry Gas Meter (γ) Factor*: 0.991
Initial Leak Check (m^3/min):
Final Leak Check (m^3/min):

Ambient Temperature (°C): 23
Barometric Pressure (kPa)*: 100.5
Assumed Moisture Content (%):
Static Pressure (mmH_2O)*: 10.9
Stack Diameter (m)*: 2.30
Nozzle Diameter (mm): 7.75
Probe Length (m):
Probe Liner:
Gas Stack Molecular Weight (kg/kgmol): 29.66

Traverse Number and Direction – 1, N-S

Sampling Point Number*	Sampling Time* (Min.)	Stack Temp. T_s (°C)	Velocity Head ΔP ($mm\ H_2O$)	Orifice Pressure 'Drop ΔH' ($cm\ H_2O$)	Dry Gas Meter Reading (Litres)	Dry Gas Meter Temp.		Sample Box Temp. (°C)	Impinger Outlet Temp. (°C)	Probe Temp. (°C)	Vacuum (mm Hg.)
						Inlet T_m in (°C)	Outlet T_m out (°C)				
1	0	234	1.09	3.56	000.00	19	19	120	18	118	76
	3	236	1.09	3.56	062.90	22	19	120	18	120	76
2	6	236	1.09	3.56	124.90	21	21	120	19	120	76
	9	237	1.07	3.56	186.60	21	21	120	19	117	76
3	12	237	1.17	3.81	247.80	23	22	120	20	125	76
	15	237	1.14	3.81	312.70	24	22	120	19	120	76
4	18	237	1.14	3.81	377.30	24	22	120	19	120	76
	21	237	1.19	3.81	441.90	25	23	120	18	119	76
5	24	237	1.02	3.05	506.50	27	23	120	19	120	76
	27	238	1.02	3.30	564.60	27	24	120	20	118	76
6	30	238	1.02	3.56	623.80	28	24	120	19	119	89
	33	238	1.02	3.56	685.00	28	25	120	19	117	89
7	36	238	1.02	3.56	745.90	28	26	120	20	120	89
	39	238	0.99	3.43	806.80	29	27	120	19	121	89
8	42	238	0.94	3.30	867.10	29	28	120	18	120	89
	45	237	0.97	3.30	925.20	29	28	120	18	122	89
	48				983.50						
		avg. 237	avg. 1.06	avg. 3.53		avg. 26	avg. 23				

* Information required for Method 5

TABLE 4-2: MOISTURE DATA (EXAMPLE)

	Final Weight (g)	**Tare Weight (g)**	**Weight of Moisture (g)**
Impinger #1:	828.1	696.6	131.5
Impinger #2:	447.0	436.2	10.8
Impinger #3:	417.7	417.5	0.2
Impinger #4:	685.7	681.6	4.1

TABLE 4-3: DRY GAS METER CALIBRATION AND ORIFICE COEFFICIENT DATA TEMPLATE

Date:
Barometric Pressure in. kPa:
Dry Gas Meter Number:

Orifice Manometer Setting, ΔH cm H_2O	Gas Volume Standard V_w, m^3	Gas Volume Dry Gas V_d, m^3	Temperature °C				Time Θ Minutes	Standard (Wet) Manometer Reading Δm cm H_2O	Meter Correction Factor γ	Orifice Coefficient K_o
			Standard (Wet) t_w	Dry Gas Meter						
				Inlet t_{di}	Outlet t_{do}	Ave. t_d				
1.3	0.15									
2.5	0.15									
5.0	0.30									
10.0	0.30									
15.0	0.30									
20.0	0.30									

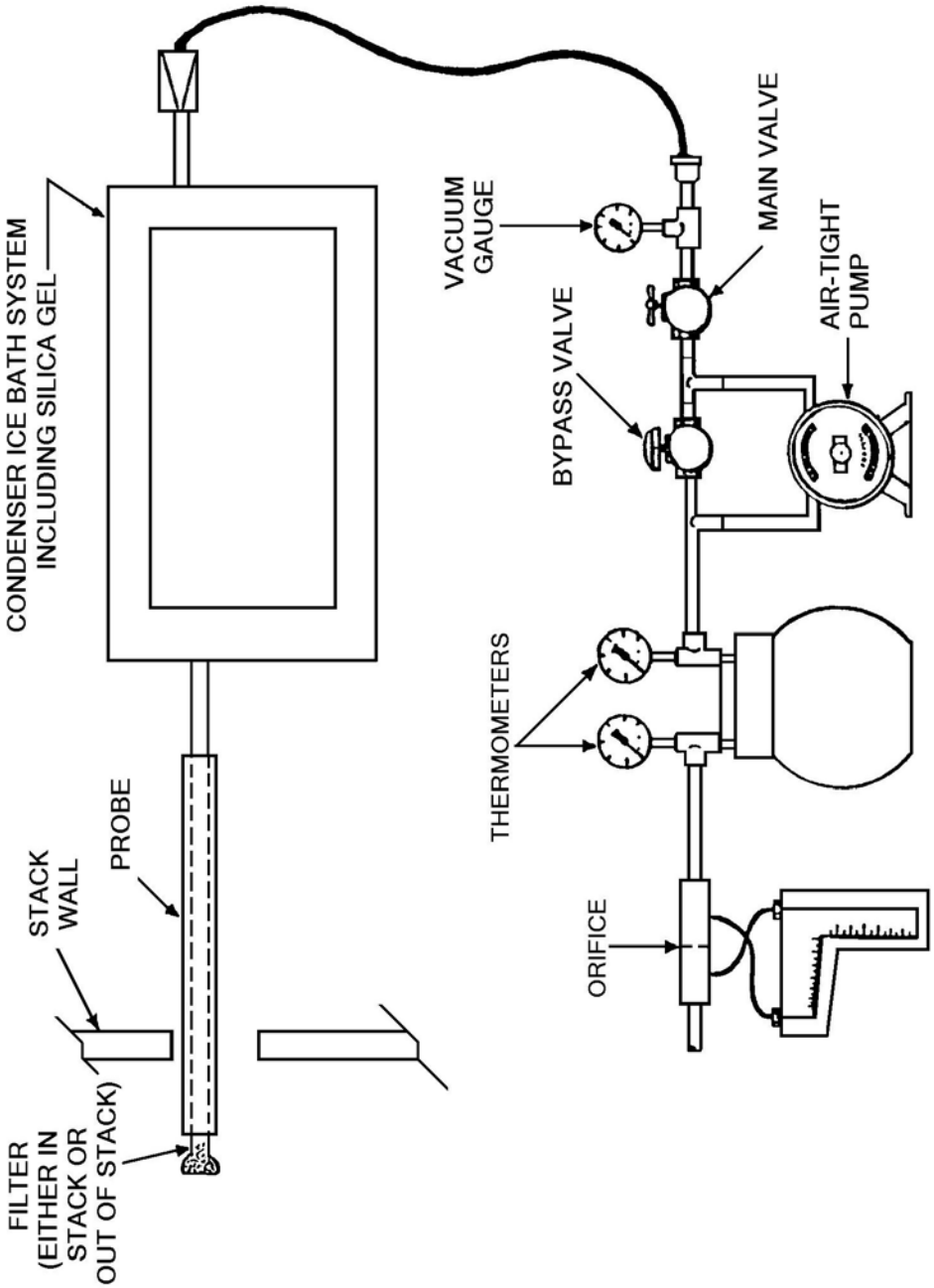


FIGURE 4-1: MOISTURE SAMPLING TRAIN

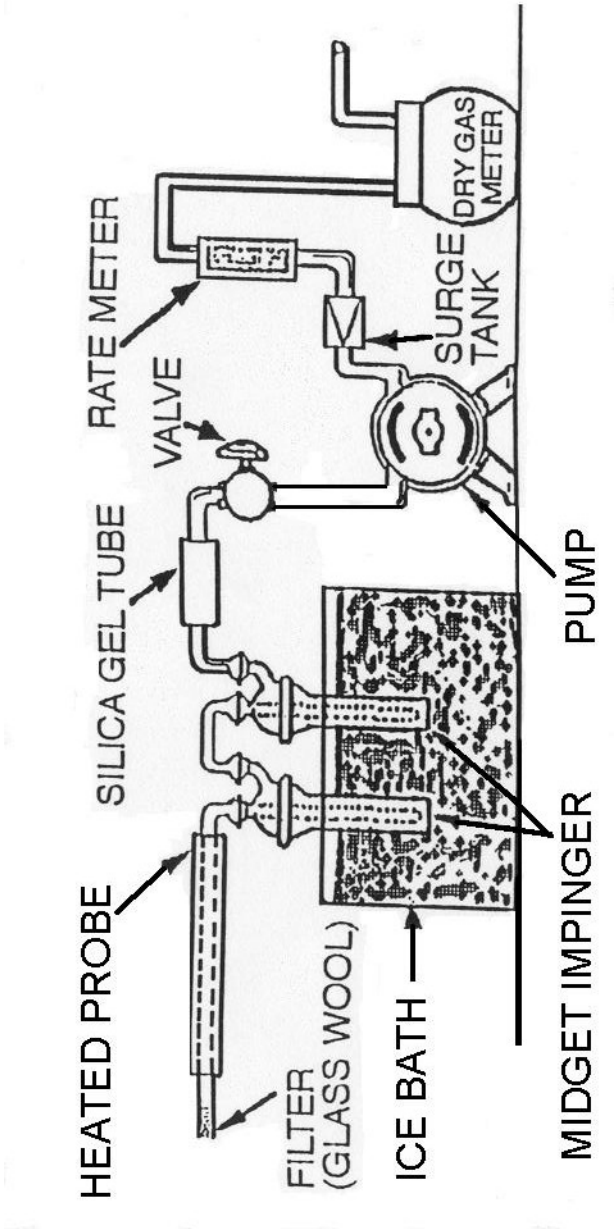


FIGURE 4-2: MIDGET IMPINGERS MOISTURE SAMPLING TRAIN

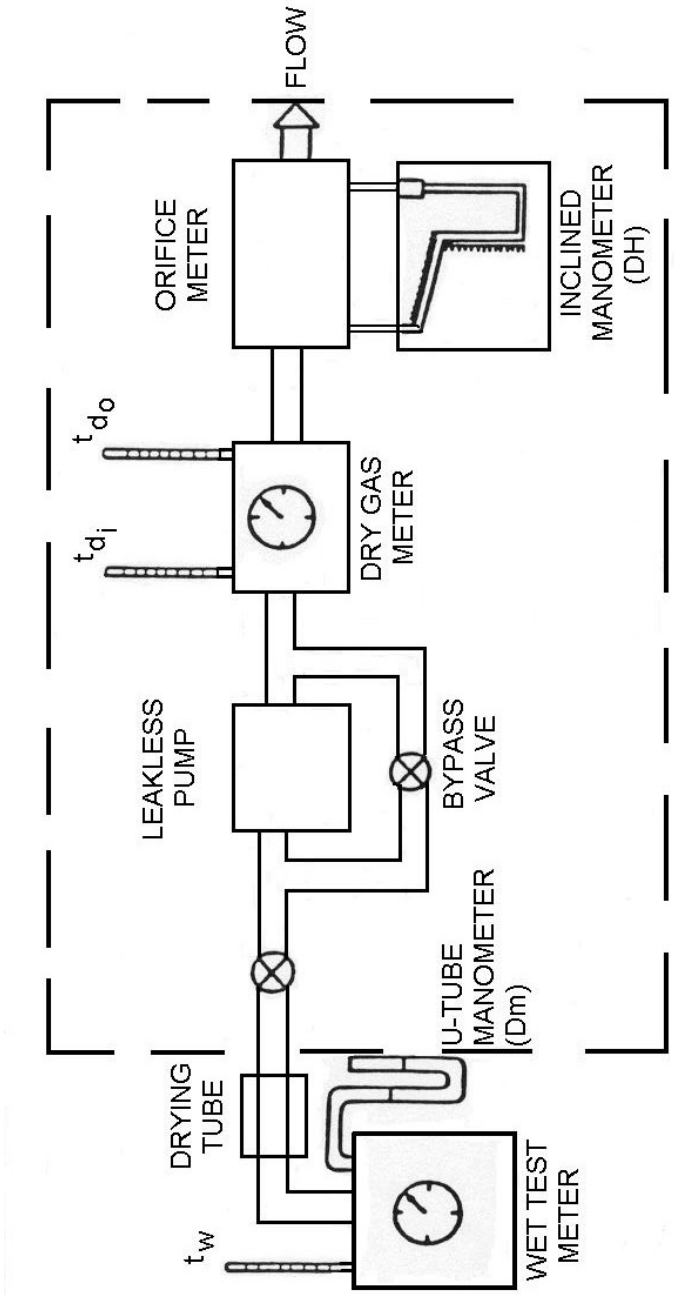


FIGURE 4-3: ASSEMBLY FOR CALIBRATION OF DRY GAS METER

Part F

Method ON-5: Determination of Particulate Emissions from Stationary Sources

1.0 PURPOSE

To determine the particulate matter concentration of a gas stream in a stack or duct and the particulate emission rate, using an isokinetic sampling technique and an out-stack glass fibre filter which is maintained at a temperature of 120°C.

Particulate matter refers to any filterable material, with an aerodynamic diameter between 44 um and 0.3 um, that maintains its solid state properties at 120^{o}C, under ambient atmospheric pressure.

Note: The Ministry may require condensable particulate matter to be included in the determination of particulate matter emissions. If condensable particulate matter is required to be tested, it will be clearly indicated by the Ministry in the Certificate of Approval or any other legal document being used by the Ministry.

The Source Assessment Specialist needs to be contacted for guidance, if condensable particulate matter is required to be included in the calculation of particulate matter emissions.

2.0 LIMITATIONS

This method is not applicable in the following cases:

(i) Gas streams containing significant concentrations of one or more substances with a dew point greater than 120°C;

(ii) For condensable matter determination;

(iii) Non-continuous processes;

(iv) Positive pressure baghouses;

(v) Low particulate matter concentrations (less than 5 mg catch); or

(vi) Cyclonic flow.

Where any of the above situations occur, reference is to be made to Chapter 9 Appendices.

3.0 APPARATUS

3.1 Sampling Train

Commercially available sampling trains generally are comprised of the individual components shown in Figure 5-1. Such trains are acceptable for use with this method. Specifically, the required components for this method are:

(a) Probe Nozzle – Stainless steel (316, seamless), glass or quartz, with a sharp, tapered leading edge; button-hook or elbow design. A range of nozzles should be available to allow for isokinetic sampling at sources with different gas velocities, e.g., 0.3175 cm to 1.270 cm.

(b) Probe – Structurally stable, long enough to traverse at least half of the stack diameter, capable of maintaining a gas temperature of 120°C at the exit end during sampling and including a probe temperature sensor. The probe is lined with borosilicate or quartz glass, if the stack temperature is less than 480°C. However, the probe is lined with quartz glass, if the stack temperature is more than 480°C and less than 900°C. For stack gas temperatures lower than 250°C, a Teflon liner may be used where length and strength limitations prevent the use of glass or quartz, or corrosion resistant metal liners for higher temperatures (Probe is usually sheathed for protection and insulation and water cooled, if required).

(c) Pitot tube – S-type (Stausscheibe or reverse type) or standard type. Reference should be made to Part C (Method ON-2) concerning Pitot tube and probe assembly (Pitot tube, temperature sensor and nozzle) configuration and calibration.

(d) Temperature Sensor – Thermocouple or other calibrated device capable of measuring stack gas temperature to within 1.5% of the minimum temperature. Temperature sensor is fixed to the probe assembly so that the tip of the sensor extends beyond the probe sheath and does not touch any metal. The

temperature sensor must be checked according to the procedure outlined in Part C (Method ON-2, Chapter 7.5, Appendix 2E).

(e) Differential Pressure Gauges – Two inclined manometers or devices of equivalent sensitivity, readable to the nearest 0.10 mm H_2O for ΔP values between 0.10 and 25 mm H_2O and readable to the nearest 1.0 mm H_2O for ΔP values greater than 25 mm H_2O. A more sensitive gauge is required if a ΔP reading is found to be less than five (5) smallest scale divisions. See Part C (Method ON-2, Chapter 7.2, Appendix 2B) regarding calibration of differential pressure gauges other than manometers and Part C (Method ON-2, Chapter 7.3, Appendix 2C) regarding more sensitive gauges.

(f) Filter Holder – Borosilicate glass with a glass or sintered stainless steel frit filter support and silicone rubber gasket (other inert materials may be used); designed to avoid leakage around the filter.

(g) Miniature Cyclone – Optional, although it should be used when the particulate catch is expected to exceed 100 mg.

(h) Filter and Cyclone Heating System – Capable of maintaining a temperature of 120°C around the filter holder and cyclone (if used) during sampling and including a temperature gauge capable of measuring to within 1°C to enable monitoring and regulation of the temperature.

(i) Condenser – Comprising of four impingers connected in series with leak-free fittings (e.g., ground glass). The first, third and fourth impingers are of the Greenburg-Smith design modified by replacing the tip with 1.3 cm I.D. glass tubing extending to about 1.3 cm from the bottom of the flask. The second impinger is of the standard Greenburg-Smith design. A temperature sensor capable of measuring temperature to within 1°C is placed at the outlet of the fourth impinger. Known volumes of water are placed in the first and second impingers and a known weight of desiccant is placed in the fourth impinger. The impingers are maintained in an ice bath. Alternatively, functionally equivalent systems are acceptable.

(j) Metering System – Comprising of a vacuum gauge, leak-free pump with coarse and fine control valves, calibrated dry gas meter capable of measuring volume to within 2% and including an inlet and an outlet temperature sensor capable of measuring temperature to within 1°C or temperature compensation and a calibrated orifice meter.

(k) Barometer – Mercury aneroid or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg. Alternatively, the daily atmospheric pressure as provided by Environment Canada may be used with an altitude adjustment for the sampling site at the rate of minus 2.5 mm Hg per 30 meters of elevation increase or vice versa for elevation decrease.

(l) Gas Composition Determination Equipment – See Parts D and E (Methods ON-3 and ON-4).

3.2 Sample Recovery and Analysis Equipment

(a) Brushes – Sized and shaped to clean out probe and nozzle; nylon bristles with stainless steel wire handle and extensions of stainless steel, Nylon, Teflon, or other inert material.

(b) Wash Bottles – Glass or polyethylene; acetone should not be stored in polyethylene bottles for longer than one month.

(c) Liquid Sample Storage Containers – Glass or polyethylene (500 or 1000 ml) with leak-free acetone resistant caps. Acetone samples should not be stored in polyethylene longer than one month.

(d) Petri Dishes – Glass or polyethylene, large enough to hold an unfolded filter.

(e) Graduated Cylinder – With subdivisions no greater than 2 ml.

(f) Balance – Capable of weighing to the nearest 0.5 g.

(g) Desiccant Containers – Air tight.

(h) Funnel and Rubber Policeman.

(i) Dessicator.

(j) Analytical Balance – Capable of weighing to the nearest 0.1 mg.

4.0 REAGENTS AND MATERIALS

4.1 Sample Collection

The following items are required for sample collection:

(a) Filters – glass fibre without organic binder, exhibiting at least 99.95% efficiency (<0.05% penetration) on 0.3 micron dioctyl phthalate smoke particles (manufacturer's test data are sufficient).

(b) Water – distilled or de-ionized. Run blank prior to field use to eliminate a high background on test samples.

(c) Silica Gel – new or fully regenerated, 6 to 16 mesh indicating type. To regenerate silica gel, dry at 175°C for 2 hours.

(d) Stopcock Grease – heat-stable silicone grease insoluble in acetone.

(e) Crushed Ice.

4.2 Sample Recovery

The following items are required for sample recovery:

(a) Acetone – reagent grade, 0.001% residue, in glass bottles.

(b) Water – distilled or de-ionized. Run blank prior to field use to eliminate a high background on test samples.

4.3 Sample Analysis

The following items are required for sample analyses:

(a) Acetone – reagent grade, 0.001% residue, in glass bottles.

(b) Desiccant – new or fully regenerated, self-indicating, e.g., 6 to 16 mesh indicating type silica gel, anhydrous calcium sulphate.

5.0 PROCEDURE

5.1 Sampling Equipment Preparation

1. The Pitot tube (probe assembly), dry gas meter and orifice meter must be maintained in accordance with standard accepted procedures and calibrated prior to testing, in accordance with the procedures specified in Part C (Method ON-2, Chapter 7.1, Appendix 2A) and Part E (Method ON-4, Chapter 6.2, Appendix 4B). Such calibration data must be available on request, prior to or during the actual testing and also must be submitted with the final report.

2. Filters are checked visually against a light for irregularities and flaws or pinhole leaks. They are identified by appropriate labelling of their shipping containers (Petri dishes).

3. Filters are desiccated at 20°C ±6°C and ambient pressure for at least 24 hours and then weighed at intervals of at least 6 hours to a constant weight, i.e., 0.5 mg change from the previous reading. Weight of filters is recorded to the nearest 0.1 mg. Record the filter weighing room relative humidity which must not exceed 50% during weighing. The filter should not be exposed to the ambient atmosphere for longer than 2 minutes.

4. Weigh the cyclone collection flask, if used, and record the weight to the nearest 0.1 mg.

5. Select the sampling site location and number of sampling points in accordance with Part B (Method ON-1).

5.2 Preliminary Survey

A preliminary survey must be performed to determine gas flow parameters in order to prepare for actual sampling at isokinetic rates. Gas temperature, molecular weight, static pressure and the velocity profile (including cyclonic and reverse flow checks) are required parameters for this purpose. It is also important to know the range of particulate matter loading so that a sampling period can be established.

The parameters noted above can be determined by completing Parts C to F (Methods ON-2 to ON-5). For this purpose, Method ON-5 may be modified. For example, total sampling time may be reduced by decreasing the number of sampling points or the sampling time per point. The information learned from such a test would include the gas temperature, velocity profile, moisture content and particulate matter loading. From this information, assuming the parameters of the source remain constant, isokinetic sampling rates can be calculated and the proper nozzle size determined. Also, the sampling period can be determined so as to meet the minimum criteria for particulate matter catch or total gas volume sampled.

5.2.1 Preliminary Survey Omissions

Portions of the preliminary survey do not have to be performed, if it can be shown that the respective parameters are known to a satisfactory degree of accuracy. Written documentation should be provided.

5.2.2 Nozzle Size

The nozzle size must be selected so that it is not necessary to change the nozzle during the sampling test in order to achieve isokinetic sampling. As well, the probe liner and probe length should be suitable for the conditions of the gas stream and the size of the stack or duct. With very large cross-sections it may be necessary to perform four half-diameter traverses.

5.2.3 Testing Period Criteria

The minimum criteria for the actual testing period are:

1. Sampling for five (5) minutes per traverse point, and a minimum of two (2) readings per point; and

2. 25 mg of particulate catch with at least 1.7 dry standard m^3 of stack gas, or 3.4 dry STD m^3 of stack gas with less than 25 mg particulate catch.

Notes: (1) more than 5 minutes per point may be necessary to achieve criterion, and

(2) The Ministry's Source Assessment Specialist is required to be contacted for approval of any deviations from the requirement to sample for five (5) minutes and a minimum of two (2) readings per point;

5.3 Preparation of Sampling Train

1. Place about 100 ml of distilled or de-ionized water in each of the first two impingers and weigh each of the first three impingers and record to the nearest 0.5 g or measure the volume of water in each impinger to the nearest 1 ml.

2. Place 200 to 300 g of desiccant in the fourth impinger, the weight being taken either directly or as the tared weight of desiccant and impinger and recorded to the nearest 0.5 g.

3. Place a weighed and identified filter in the filter holder using a pair of tweezers or clean disposable surgical gloves; the filter must be centered and the gasket properly placed so as to prevent the sample gas stream from circumventing the filter.

4. Assemble the sampling train, keeping all openings where contamination could occur covered until just prior to assembly or until sampling is about to begin. A very light coating of silicone grease should be applied to all ground glass joints,

greasing only the outer portion to avoid the possibility of contamination by the silicone grease.

5. A pre-test leak-check is required and it is performed according to the following procedure:

   Pre-Test Leak-Check

   a) Plug the nozzle or inlet to the probe.

   b) Draw a vacuum of 380 mm Hg or the highest vacuum anticipated to occur during the test. The recommended procedure for drawing a vacuum is to start the pump with the bypass valve fully open and the coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of the bypass valve; this will cause water to back up into the filter holder.

   c) Maintain the vacuum for at least 1 minute. A leakage rate of greater than 0.00057 m^3/min or 4% of the estimated average sampling rate, whichever is less, is unacceptable and, if so found, the sampling train must be dismantled and reassembled until the leak is adequately reduced or eliminated.

   d) When the leak-check is completed, slowly remove the plug from the nozzle or inlet to the probe and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced into the filter holder and silica gel from being entrained into the third impinger.

6. Mark the probe with heat-resistant tape or other suitable means to enable the exact positioning of the probe at the sampling points, as determined in Chapter 5.1, Step 5.

7. Clean the portholes prior to the test run to minimize the chance of sampling deposited material.

5.4 Sampling Train Operation

1. Start the probe and filter heating systems. Before commencing the test, verify that both units are maintained at a temperature of 120°C. Place crushed ice around the impingers (if this type of condensing apparatus is used).

2. Remove any protective covering from the nozzle and position the nozzle at the first sampling point, ensuring that all components of the probe assembly are properly oriented with respect to the gas stream, i.e., nozzle and Pitot tube face opening planes are perpendicular to the direction of flow. Block off openings around the probe and porthole to prevent dilution of the gas stream.

3. Immediately start the pump and adjust the flow rate to isokinetic conditions. The various methods for calculating isokinetic rates are discussed in Chapter 9.1, Appendix 5A. If the stack is under significant negative pressure (several centimetres of H_2O) take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

4. Traverse the stack cross-section as required by Part B (Method ON-1). It is recommended to start at the furthest point from the port. Ensure that the probe nozzle does not make contact with the stack wall or ports, thus minimizing the chance of extracting deposited material. Sample at each sampling point for 5 minutes or longer if necessary. As soon as the probe has been moved to the next point adjust the flow rate to isokinetic conditions.

5. For each traverse, data are recorded according to the format shown in Table 5-1. These data shall be recorded at least twice for each sampling point and the length of the time period between recordings shall be between 2.0 and 3.0 minutes (When the point velocities and temperatures are not fluctuating the time period can be increased, pending the permission by the Source Assessment Specialist.) The dry gas meter volume is recorded at the start of the test and at the end of each of these time periods. The other information in the various columns is recorded at some time during each of the periods. During each of these periods, the sampling rate through the train must be 100% ±10% of the isokinetic sampling rate. Each time the probe is moved to a different point with another velocity pressure reading; the sampling rate must be adjusted. Similarly, the sampling rates must be adjusted, and a record of such adjustment made, whenever significant step changes in point velocities or temperatures are noted. Deviations from the ideal isokinetic sampling rate may be determined using Equation 5-5 (found in Chapter 6).

6. During the test run, ensure that the probe and filter housing are maintained at 120°C ±10% and that the temperature at the outlet of the impingers is less than 20°C. It may be necessary to add more ice and possibly salt to attain the required temperature. Periodically check the level and the zero of the manometer.

7. If the pressure drop across the filter becomes too high, making isokinetic sampling difficult to maintain, the filter may be replaced in the midst of a sampling run; similarly, a full cyclone flask or spent silica gel must be replaced. Another complete filter assembly should be used rather than attempting to change the filter itself. Leak-checks must be conducted both before a new component is installed and also before sampling is resumed. The original and substituted components are added together to determine the total moisture content and/or particulate matter catch weight.

8. At the end of the traverse, turn off the course adjust valve, record the final dry gas meter reading, remove the probe and nozzle from the stack, turn off the pump, and conduct a post-traverse leak-check.

9. Repeat Steps 4 to 9 for the second (or more) traverses except that a pre-traverse leak-check is not mandatory. However, it is recommended that pre-traverse leak-checks be performed, since the movement of the sampling train from one port to another may cause leaks.

10. A post-test leak-check is mandatory and is performed according to the following procedure:

    Post-Test Leak-Check

    a) Allow the probe to cool until safe to handle. Plug the nozzle or inlet to the probe.

    b) Draw a vacuum equal to or greater than the maximum vacuum observed during the test. The recommended procedure for drawing a vacuum is to start the pump with the bypass valve fully open and the coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of the bypass valve; this will cause water to back up into the filter holder.

    c) Maintain the vacuum for at least 1 minute. Record the actual leakage rate. A leakage rate of greater than 0.00057 m^3/min or 4% of the sampling flow rate, whichever is less, is not acceptable and, if so found, void the sampling run.

    d) If the leakage rate is acceptable, slowly remove the plug from the nozzle or inlet to the probe and immediately turn off the vacuum pump and proceed with recovering the sample.

5.5 Sample Recovery

1. Upon removing the probe from the port, and having conducted the mandatory post-test leak-check, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent the loss or contamination of the sample. The probe tip should not be tightly capped while the sampling train is cooling as this would create a vacuum in the filter holder, thus drawing water from the impingers into the filter holder.

2. Remove the probe from the sampling train and cover the exposed end, being careful not to lose any sample in the probe. Remove the umbilical cord. Wipe any silicone grease from the filter or cyclone inlet and last impinger outlet and

cover these openings. If a flexible line is used between the first impinger or condenser and the filter holder, disconnect the line at the filter holder and let any condensed water or liquid drain into the impingers/condenser.

3. The probe and filter-impinger assembly should be removed to a clean and sheltered area; inspect the components. Note and report any damage or abnormalities.

4. The filter is carefully removed from the fitter holder, using a pair of tweezers and clean disposable surgical gloves, and placed in a Petri dish (for the purposes of this procedure, hereinafter referred to as Container No. 1). Any particulate or filter matter adhering to the filter holder gasket must also be removed with a brush and a sharp edge and placed with the filter. Label and seal the sample container.

5. If a cyclone was used, remove the cyclone collection flask and seal and label it.

6. Completely recover particulate matter and any condensate from the front end (i.e., the probe nozzle, fittings, probe liner, cyclone (if used) and front half of the filter holder) by washing these components with acetone and placing the wash in a container designated as Container No. 2. Specifically: carefully remove the nozzle and fittings and clean the inside surfaces by rinsing with acetone from a wash bottle and then brush. The procedure is continued until the washings show no visible particles.

7. The probe liner is cleaned by first tilting and rotating the probe while squirting acetone into the upper end as the probe brush is being pushed with a twisting action through the probe. The acetone washing is collected in Container No. 2. This brushing action is repeated until the washing shows no visible particles.

8. After ensuring that all the silicone grease has been removed, clean the front half of the filter holder by rubbing the surfaces with a brush and rinsing with acetone repeatedly until the washing shows no particles. The cyclone is similarly washed and rinsed. These washing are also collected in Container No. 2. After completing the recovery of the front half of the train, seal and label Container No. 2 and mark the liquid level.

9. Disassemble the impinger train and remove any silicone grease from the joints. If a tared weighing procedure is initially used, immediately weigh the impingers and their content or seal the impingers for later weighing. Note and report the condition of the silica gel (i.e., the extent of saturation), transfer the silica gel to Container No. 3, and label and seal Container No. 3. Rubber policeman may be used to aid in the complete transfer of material from the sampling train to the container.

10. Measure and record the amount of liquid caught in the first three impingers to the nearest 0.5 g or 1.0 ml.

5.6 Laboratory Analysis

1. Transfer the filter and any loose particulate matter and filter material from Container No. 1 to a tared weighing dish. Desiccate the sample and the cyclone collection flask, if used, for 24 hours at 20°C ± 6°C and ambient pressure. Then weigh them at intervals of at least 6 hours to a constant weight (i.e. <0.5 mg change from the previous reading, and report the weights to the nearest 0.1 mg.) Record the weighing room relative humidity, which must not exceed 50%. Samples should not be exposed to the ambient atmosphere for longer than 2 minutes.

   If the sampled particulate matter is hygroscopic, a constant weight may be impossible to achieve. If this situation is encountered, the dry weight may be determined by weighing the sample at specific time intervals after removal from the dessicator (e.g., every 30 seconds), plotting the weight versus the time from removal and then extrapolating the graph to time zero to determine the desiccated weight.

2. Transfer the contents of Container No. 2 to a tared beaker and evaporate to dryness under ambient temperature and pressure. Desiccate and weigh the beaker to a constant weight in accordance with the weighing procedure outlined in Step 1 of this chapter and record the weights to the nearest 0.1 mg.

3. Weigh the silica gel from Container No. 3 or the impinger containing the silica gel (if it was not done on site) and report the weight to the nearest 0.5 g.

4. Retain all samples for at least 6 months after the test series. They are to be made available upon request by the Ministry. Analysis data are recorded as shown in Table 5-2. Note that the content of the impingers need not to be analyzed for particulate matter.

5. Determine and report the particulate concentration and particulate emission rate using equations in Chapter 6.

6.0 EQUATIONS FOR METHOD ON-5

$$P_{m(avg)} = P_{bar} + 0.098\,\Delta H_{(avg)}$$

Eq. 5-1

where:

$P_{m\,(avg)}$ = average absolute pressure at the dry gas meter throughout the test, kPa

P_{bar} = barometric pressure, kPa

$\Delta H_{(avg)}$ = average of recorded orifice pressure differentials, cm H_2O

$$V_{m(ref)} = \frac{2.94 \gamma P_{m(avg)} V_m}{T_{m(avg)}}$$

Eq. 5-2

where:

$V_{m(ref)}$ = volume of gas sample at 298K and 101.3 kPa, m^3

γ = dry gas meter correction factor

V_m = volume of gas sample recorded on dry gas meter, m^3

$T_{m(avg)}$ = absolute temperature at dry gas meter, K (the average of inlet and outlet temperatures recorded during each sampling increment or if temperature compensation, that temperature)

$$C_s = \frac{10^{-6} M_p}{V_{m(ref)}}$$

Eq. 5-3

where:

C_s = concentration of particulate matter in stack gas on a dry gas basis at 298K and 101.3 kPa, in kg/m;

M_p = weight of particulate matter from nozzle, probe liner, cyclone, front half of filter holder and filter (may include back half and impingers if requested by the Source Assessment Specialist, mg

$$ER_p = C_s Q_s$$

Eq. 5-4

where:

C_s = concentration of particulate matter in stack gas on a dry gas basis at 298K and 101.3 kPa in kg/m^3

Q_s = volumetric flow rate of dry stack gas at 298K and 101.3 kPa; m^3/h (see Part C, Method ON-2, Eq. 2-3)

ER_p = emission rate of particulate matter, kg/h

$$\%I = \left(\frac{T_s \left(\frac{DGMV}{t} \right) \gamma \left(\frac{1}{1 - B_{wo}} \right) \left(P_{bar} + 0.098 \Delta H \right)}{\left(4.71 \times 10^{-3} \right) T_m P_s U_s D_n^2} \right) \times 100$$

Eq. 5-5

where:

%I = percentage of isokinetic sampling rate

DGMV= incremental volume increase on dry gas meter during period t, m^3

t = incremental sampling period, minutes

B_{wo} = volume proportion of water in stack gas

ΔH = orifice pressure differential during period t, cm H_2O

T_s = absolute stack gas temperature during period t, K

D_n = diameter of nozzle opening, cm

T_m = absolute temperature at dry gas meter (average of temperatures at inlet and outlet) during period t, K

P_s = absolute stack gas pressure, kPa

U_s = stack gas velocity, m/s (See Part C, Method ON-2, Eq. 2-2)

Note: %I is calculated for each set of readings and used to obtain the average %I for the test.

7.0 DISCUSSION OF METHOD ON-5

7.1 Purpose

This method is applied to determine the particulate matter concentration in an enclosed gas stream. A representative sample of stack gas and particulate matter is withdrawn isokinetically from the source using a heated probe, filter, condenser and metering devices.

The particulate matter is collected on an out-of-stack filter (quartz or glass fibre) and in the front half of the sampling apparatus. This method is designed to collect particulates which are greater in size than 0.3 µm at a temperature of 120°C, under ambient atmospheric pressure.

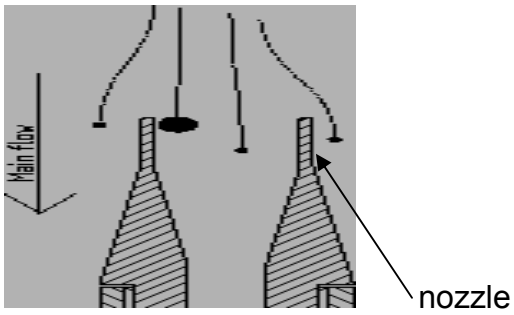
The Source Assessment Specialist needs to be contacted for guidance, if condensable particulate matter is required to be included in the calculation of particulate matter emissions.

7.2 Isokinetic Sampling

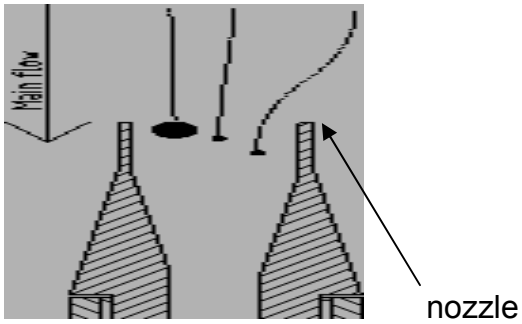
An issue, when taking fractions from a gas stream for particle sampling, is to obtain isokinetic sampling. When the velocity through the sample nozzle is equal to the velocity of the surrounding fluid, the sample is said to be taken isokinetically.

The importance of isokinetic sampling depends on the size of the particles, and their density.

If the sample velocity is too slow, sampling is said to be under-isokinetic (see illustration below). The small particles follow the fluid streamlines, which are bent away from the nozzle. The larger particles tend to follow straight lines due to their inertia. This makes them overrepresented in the sample, and the total particle load per gas volume will be higher, than that of the main gas stream.



If the sample velocity is too high, sampling is over-isokinetic (see illustration below). The streamlines bend into the nozzle, with the big particles following straight lines due to their inertia. This makes the larger particles underrepresented in the sample, and the particle load per gas volume will be lower than that of the main gas stream.



7.3 Limitations

As noted above, the standard temperature at which particulate is collected by this out-stack method is 120°C. It is assumed that normally particulate matter does not volatilize below that temperature. This temperature is selected so as to be above the boiling point of water yet not so high as to volatilize particulate matter.

It is important to ensure that water does not condense on the filter and cause an excessively high pressure drop. However, there are sources which contain substances which can condense at temperatures above the standard (e.g., acid mist), and thus load the filter. For this reason and others, sources containing significant amounts of such substances may not be able to be sampled using the apparatus and procedure

described in this method. Chapter 9.2, Appendix 5B outlines some alternate approaches for use at sources where such conditions exist.

7.3.1 Non-Continuous Sources

Sources which are not in continuous operation, e.g., batch operations, plant shutdowns of short duration, etc., can be sampled with some modifications to the procedure of this method. This is discussed in Chapter 9.3, Appendix 5C.

7.3.2 High Volume Sampling

Positive pressure baghouses and other sources that have low concentrations of particulate matter (less than 5 mg expected catch), low humidity, and non-corrosive gases can be sampled using the High Volume sampling procedure, as outlined in the American Society for Testing and Materials (ASTM) Method D6331-98(2005): Standard Test Method for Determination of Mass Concentration of Particulate Matter from Stationary Sources at Low Concentrations (Manual Gravimetric Method).

7.4 Procedure

The steps of this procedure are separated into several chapters, each chapter of activities being distinct by virtue of its position in the sequence of events and the physical location of the activity. Thus, the preparation procedures are performed in a laboratory. The preliminary survey is usually performed on site a day before the actual testing. The sampling apparatus preparation and sample recovery are done usually in both the laboratory and on site, whereas the analytical procedures are performed in a laboratory at some time after the actual testing.

The procedure is designed so that a representative sample will be obtained from the stack gas; therefore, care must always be taken to ensure that all the components are properly cleaned and that no extraneous matter is picked up in the nozzle or on the filter. Also, the cleanup procedure must be done scrupulously and leak-checks must always be performed to ensure that only stack gas is being sampled.

To ensure that the sample is representative, it must be drawn at an isokinetic rate. This requirement is necessary, because aerodynamic and inertial effects will cause an overestimation of the particulate matter concentration, if sampling sub-isokinetically, or an underestimation for super-isokinetic sampling.

Method ON-5 incorporates the apparatus and procedures of Part E (Method ON-4) and reference should be made to that Part for equations and calculations to determine the moisture content. For each Method ON-5 test run a moisture content analysis and molecular weight analysis (Method ON-3) must be performed.

8.0 SAMPLE CALCULATIONS

Sample data for one traverse are recorded in Table 5-1. Normally, a second traverse is done and calculations are based on total sample volume and moisture for both traverses. Respective portions of these data have been used in the sample calculations in Parts C and E (Methods ON-2 and ON-4). Moisture and particulate collection data are recorded in Table 5-2.

From the sample calculations in Parts C and E (Method ON-2 and 4), the following parameters were determined:

$U_{s(avg)}$ = 15.1 m/s

Q_s = 30.2 Std m^3/s

B_{wo} = 0.1708

Assuming that a molecular weight of dry stack gas, M_d = 29.66 kg/kg-mole

M_s = 27.67 kg/kg-mole

From Table 5-1 the following data is obtained:

$\Delta H_{(avg)}$= 3.53 cm H_2O

$T_{s(avg)}$ = 510 K

$T_{m(avg)}$ = 297 K

P_{bar}= 100.5 kPa

V_m = 0.983 m^3

γ = 0.991

$$P_{m(avg)} = P_{bar} + 0.098\,\Delta H_{(avg)}$$

$$= 100.5 + (0.098 \times 3.53)$$

$$= 100.8 \text{ kPa}$$

$$V_{m(ref)} = \frac{2.94 \gamma P_{m(avg)} V_m}{T_{m(avg)}}$$

$$= \frac{2.94 \times 0.991 \times 100.8 \times 0.983}{297}$$

$$= 0.972 \text{m}^3$$

Therefore the volume of the gas sample is 0.972 m^3 at 298K and 101.3 kPa.

Note: In comparing the calculated values of $V_{m(ref)}$ in this example and in Part E (Method ON-4), there is a slight discrepancy which is explained by the fact that it is permissible to use $P_m = P_{bar}$ for moisture determination for Method ON-4, whereas for this method P_m must be the true value which is $P_{bar} + 0.098\Delta H$. However, the slight difference between the two values does not significantly alter the value of B_{wo} or M_s.

Particulate matter concentration:

$$C_s = \frac{M_p}{V_{m(ref)}}$$

$$= \frac{34.7}{0.972}$$

= 35.7 mg/STD m^3

Particulate matter emission rate:

$$ER_p = \frac{C_s Q_s}{1000 \text{ mg/g}}$$

$$= \frac{35.7 \times 30.21}{1000}$$

$$= 1.08 \text{ g/s}$$

Percentage isokinetic sampling rate:

$$\%I = \left(\frac{T_s \left(\frac{DGMV}{3} \right) \gamma \left(\frac{1}{1 - B_{wo}} \right) \left(P_{bar} + 0.098 \, \Delta H \right)}{\left(4.71 \times 10^{-3} \right) T_m \, P_s \, U_s \, D_n^2} \right) \times 100$$

For the first point, first reading:

$$\%I = \left(\frac{507 \times \left(\frac{62.9 \times 10^{-3}}{3} \right) \times 0.991 \times 1.21 \times 100.8}{0.00471 \times 297 \times 100.6 \times 15.1 \times (0.775)^2} \right) \times 100$$

$$= 100.7\%$$

Listed in Table 5-3 are the calculated velocities and percentage isokinetic for the sample points.

9.0 APPENDICES TO METHOD ON-5

9.1 APPENDIX 5A: Determination of Nozzle Size and Setting Isokinetic Sampling Rates

As stated in this method, it is necessary to sample at a rate such that the velocity of the gas entering the sampling nozzle equals the velocity of the undisturbed gas at the

sampling point. The ratio of nozzle to stack gas velocity must be 100% ±10%. This ratio is calculated using the stack gas conditions at the time of sampling.

Since some of these conditions, such as moisture content, can only be determined after the test, it is necessary to estimate them as closely as possible for the purposes of choosing the proper nozzle size.

9.1.1 Nozzle Size Determination

A nozzle size must be determined so that it is neither too large, i.e., beyond the ability of the train to draw sample isokinetically at high ΔP's, nor too small, i.e., requiring an impractical small ΔH setting at low ΔP's. The smallest (practical) nozzle is 4.763 mm in diameter.

One method for determining the proper nozzle size is as follows:

for true isokineticity,

$$\frac{\text{velocity in nozzle}}{\text{velocity in stack}} = 1$$

from that:

$$\Delta H = \left(\frac{60 \times 128.6\, \pi\, {D_n}^2\, C_p}{4 \times 10000} \right)^2 \times \left(\frac{(1 - B_{wo})^2\, M_d\, T_{m(avg)}\, P_s\, \Delta P}{{K_o}^2\, M_s\, T_{s(avg)}\, P_m} \right)$$

Eq. 5-6

where:

ΔH = orifice pressure differential, cm H_2O

ΔP = stack gas velocity pressure head, cm H_2O

D_n = nozzle diameter, cm

C_p = Pitot tube coefficient

B_{wo} = moisture content

M_d = dry stack gas molecular weight, kg/kg-mole

M_s = stack gas molecular weight, kg/kg-mole

$T_{m(avg)}$ = average temperature at orifice, K

$T_{s(avg)}$ = average stack gas temperature, K

P_s = absolute stack gas pressure, kPa

P_m = absolute orifice pressure, kPa

K_o = orifice coefficient

These values are estimated or calculated, usually being based on experimental values from a preliminary survey (the nozzle used for that test is picked by approximation). By substituting numerical values for all of the variables of the equation except ΔH, D_n and ΔP, a value for K in the following equation may be determined:

$$\Delta H = \Delta P K D_n^{\,4}$$

Eq. 5-7

Having determined K, to obtain the correct nozzle diameter:

1. Choose for ΔH the maximum ΔH obtainable or readable from the sampling train.
2. Choose for ΔP the maximum ΔP obtained or expected based on the preliminary survey.
3. By rearranging the above equation so that:

$$D_n = \left(\frac{\Delta H}{K \, \Delta P} \right)^{1/4}$$

Eq. 5-8

and substituting accordingly, D_n may be calculated.

4. The nozzle size next smaller to the calculated D_n is the appropriate size.

9.1.2 Isokinetic Sampling Rate Determination

There are several methods used to determine isokinetic sampling rates. One method is as follows:

1. if the variables of the above equations are determined at a particular instant the following relationship is found:

$$\Delta H = \frac{k' \Delta P T_m}{T_s}$$

Eq. 5-9

where:

$$k' = \frac{T_{s(avg)} K D_n^{\,4}}{T_{m(avg)}}$$

T_m = instantaneous absolute meter temperature, K

T_s = instantaneous absolute stack gas temperature, K

ΔH = orifice pressure differential, cm H_2O

ΔP = stack gas velocity pressure head, cm H_2O

2. Calculate k'.

3. If $k'' = k'(T_m / T_s)$ by substituting expected values of T_m and T_s, a table of values for k" may be prepared.

4. The above equations simplify to:

$$\Delta H = k'' \Delta P$$

Eq. 5-10

Another common method is the use of nomographs, usually commercially prepared. Nomographs are easy to operate and are reasonably accurate. However, most nomographs are pre-set for a pitot coefficient of 0.85 and manufacturers instruction on the use of these nomographs can be modified so that the location of pivot point will correspond to true coefficient; ΔP is multiplied by $C_p/0.85$ and the new ΔP used to set the pivot point. As well, the nomograph must be readjusted during sampling as the meter temperature and stack gas temperature change.

9.2 APPENDIX 5B: Gas Streams having Significant Concentrations of Substances with Dew Point Greater than 120°C

There is an almost infinite variety of sources and components of gas streams. Some components may have dew points above 120°C, i.e., above the probe and filter heater temperature. The concentration of the component is significant if the component condenses on the filter and this condensate causes such a high pressure drop that the pump is unable to draw at isokinetic rates.

To overcome this problem, the probe and filter must be maintained above the dew point of the component. However, increasing the temperature may volatilize some or all of the particulate matter thus allowing it to pass through the filter to be caught in the impingers. In such cases it may be necessary to install an additional backup filter after the impingers and include the impinger catch and the particulate matter on the backup filter in the calculation of the emission rate.

Another problem possibly encountered with increasing the filter temperature is that reactions may occur on the filter itself which may result in a non-representative particulate matter sample.

The Source Assessment Specialist should be contacted where there is a problem of condensible components so that an appropriate sampling methodology can be agreed upon.

9.3 APPENDIX 5C: Non-Continuous Sources

Some sources are non-continuous by their nature, e.g., batch processes. As well, some processes slow down or stop at certain times, e.g., lunch break or process interruptions. When this type of problem occurs it is necessary to halt sampling, remove the probe from the gas stream and seal the nozzle tip. Recommence sampling when the process operations return to their usual level.

Since non-continuous processes pose problems with respect to sampling and cannot be generalized, the Source Assessment Specialist should be contacted to discuss the particular situation.

9.4 APPENDIX 5D: Particulate Matter Sampling in Cyclonic Flow

Particulate matter emission sampling in stacks or ducts with cyclonic flow patterns present significant problems in obtaining representative measurements of concentrations and flow rates. Difficulties also arise in establishing the correct velocity for determining the isokinetic sampling rate.

Cyclonic flow has two angle components identified as the “yaw” and “pitch” angle. The yaw angle is a measure of the degree of tangential flow in the stack. The Ministry uses the yaw angle as the reference to determine if the flow is cyclonic. If the average yaw (based on absolute values) is greater than 15°, the flow is considered cyclonic.

The pitch angle is a measure of the degree of radial flow in the stack. The pitch angle can be visualized as the extent (angle) of stack gas flow towards or away from a person standing (facing) the stack.

A 3-dimensional (3-D) Pitot tube is used to accurately measure the axial stack gas velocity (and volumetric flow rate) in stacks with both yaw angle and pitch angle components. The sampling point determination is done similar to the non-cyclonic sampling point selection approach (equal area method). Refer to US EPA 40CFR60

Method 2F for the procedures to determine stack gas velocity and volumetric flow rate with 3-D probes.

For the particulate matter sample collection approach, a null Pitot tube is attached to the typical probe setting used in Method ON-5 trains (Figure 5-1). The face of the null Pitot tube is oriented at right angles to the face of the probe's S-type Pitot tube. To minimize flow disturbances, the tips of the null Pitot tube are located approximately 5 cm above (downstream) and 10 cm beyond the tips of the probe's S-type Pitot tube.

This typical probe setting with the null Pitot tube attached measures the yaw angle and, the velocity pressure at that angle, at each point during isokinetic sampling. This approach is suitable only to align the probe nozzle with the obtained yaw angle for collecting the particulate matter sample. The stack gas velocity and flow rate is to be determined using the 3-D Pitot tube.

The position of the nozzle with respect to the yaw angle is determined by rotating the probe/Pitot tube on its axis until the pressure differential across the null Pitot tube is zero. The yaw angle is measured with a protractor with readability of 0.5°. The protractor needs to be solidly fixed to the probe so that when the protractor is reading 0°, the faces of the null Pitot tube are parallel to the axis of the stack or duct.

The rest of the sampling train has the same configuration of the standard Method ON-5 sampling train.

10.0 REFERENCES

1. American Society for Testing and Materials, D6331-98(2005): Standard Test Method for Determination of Mass Concentration of Particulate Matter from Stationary Sources at Low Concentrations (Manual Gravimetric Method), 2005.

2. Connor Pacific Environmental Technologies Inc., INCO Super Stack Source Testing Report, Copper Cliff, Ontario, May 2000.

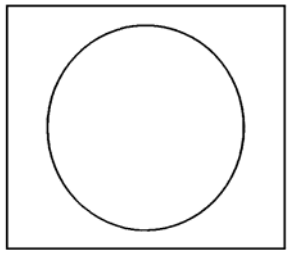
3. Environment Canada, Reference Method EPS 1/RM/8, Reference Methods for Source Testing: Measurement of Releases of Particulates from Stationary Sources, December, 1993.

4. Ministry of Environment and Energy, Province of Ontario, Source Testing Code, Version 2, Report # ARB-66-80, November 1980.

5. United States Environmental Protection Agency, Code of Federal Regulations, Title 40 Part 60, Appendix A, July 1. 1994.

TABLE 5-1: FIELD SAMPLING REPORT (EXAMPLE)

Schematic of Stack Cross-section



Plant*:
Location*:
Date*:
Operators
Run No.*:
Pitot Coefficient*: 0.850
Dry Gas Meter (γ) Factor*: 0.991
Initial Leak Check (m^3/min):
Final Leak Check (m^3/min):

Ambient Temperature (°C): 23
Barometric Pressure (kPa)*: 100.5
Assumed Moisture Content (%):
Static Pressure (mmH_2O)*: 10.9
Stack Diameter (m)*: 2.30
Nozzle Diameter (mm): 7.75
Probe Length (m):
Probe Liner:
Gas Stack Molecular Weight (kg/kgmol): 29.66

Traverse Number and Direction – 1, N-S

Sampling Point Number*	Sampling Time* (Min.)	Stack Temp. T_s (°C)	Velocity Head ΔP (mm H_2O)	Orifice Pressure 'Drop ΔH' (cm H_2O)	Dry Gas Meter Reading (Litres)	Dry Gas Meter Temp.		Sample Box Temp. (°C)	Impinger Outlet Temp. (°C)	Probe Temp. (°C)	Vacuum (mm Hg.)
						Inlet T_m in (°C)	Outlet T_m out (°C)				
1	0	234	1.09	3.56	000.00	19	19	120	18	118	76
	3	236	1.09	3.56	062.90	22	19	120	18	120	76
2	6	236	1.09	3.56	124.90	21	21	120	19	120	76
	9	237	1.07	3.56	186.60	21	21	120	19	117	76
3	12	237	1.17	3.81	247.80	23	22	120	20	125	76
	15	237	1.14	3.81	312.70	24	22	120	19	120	76
4	18	237	1.14	3.81	377.30	24	22	120	19	120	76
	21	237	1.19	3.81	441.90	25	23	120	18	119	76
5	24	237	1.02	3.05	506.50	27	23	120	19	120	76
	27	238	1.02	3.30	564.60	27	24	120	20	118	76
6	30	238	1.02	3.56	623.80	28	24	120	19	119	89
	33	238	1.02	3.56	685.00	28	25	120	19	117	89
7	36	238	1.02	3.56	745.90	28	26	120	20	120	89
	39	238	0.99	3.43	806.80	29	27	120	19	121	89
8	42	238	0.94	3.30	867.10	29	28	120	18	120	89
	45	237	0.97	3.30	925.20	29	28	120	18	122	89
	48				983.50						
		avg. 237	avg. 1.06	avg. 3.53		avg. 26	avg. 23				

* Information required for Method 5

TABLE 5-2: MOISTURE AND PARTICULATE MATTER CATCH DATA (EXAMPLE)

	Final wt.(mg)	Tare wt.(mg)	Particulate wt.(mg)
(a) Filter	756.3	738.1	18.2
(b) Beaker containing washing from nozzle, probe, cyclone (if used) and front half of filter holder	104709.7	104693.2	16.5
(c) Cyclone collection flask	----	----	----
(d) Beaker containing impinger contents and washing from impingers and back half of filter holder	101385.0	101368.2	16.8
Weighing room relative humidity:	pre-test = 42% post-test = 39%	total wt. of particulate (excluding impinger contents)	= 34.7 mg
	Final wt.(g)	Tare wt.(g)	Wt. of H_2O (g)
Impinger #1:	828.4	696.3	132.1
Impinger #2:	447.0	436.2	10.8 0.2
Impinger #3:	417.7	417.5	4.1
Impinger #4:	685.7	681.6	
Desiccant saturation level = <1/4		total wt. of H_2O	= 147.2 g

TABLE 5-3: CALCULATED VELOCITIES AND PERCENTAGE ISOKINETIC

Sampling Point Number	Velocity (m/s)	%I
1	15.3 15.3	100.8 99.2
2	15.3 15.1	98.8 99.0
3	15.8 15.7	100.3 100.9
4	5.7 16.0	100.9 98.8
5	14.8 14.8	96.2 98.1
6	14.8 14.8	101.3 100.8
7	14.8 14.6	100.8 101.2
8	14.2 14.4	100.0 99.2
	AVG. 15.1	**AVG. 99.8**

(EXAMPLE)

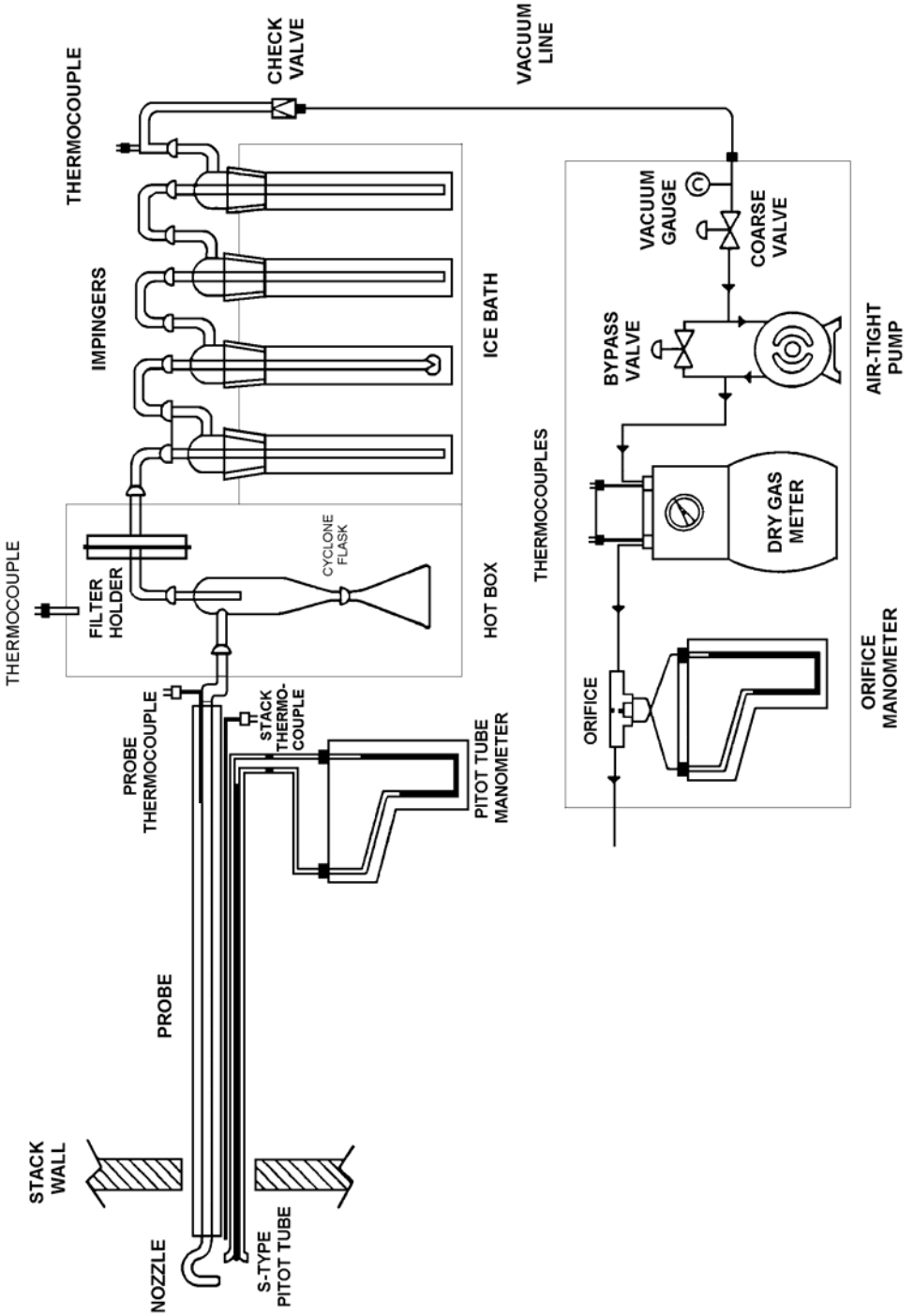


FIGURE 5-1: PARTICULATE MATTER SAMPLING TRAIN

Part G

Method ON-6: Determination of Odour Emissions from Stationary Sources

1.0 INTRODUCTION

This chapter outlines three traditional methods of sampling for odours (dynamic pre-dilution, evacuated lung and flux chamber methods) and one modified method specific to sampling open bed biofilters. Assessors must choose the most appropriate sampling method based on a preliminary assessment of each individual source. Certain source parameters may dictate that a non-traditional method may be required to ensure accurate, representative data. Several non-traditional methods that have been successfully applied in the past are outlined in the appendix of this chapter. When developing and/or using a non-traditional method, it is necessary that the Source Assessment Specialist be contacted to discuss sampling strategies.

Methods for quantifying fugitive odour concentrations and emission rates have not been outlined in this document. Fugitive odours can be a major contributor to a facility's aggregate odour impact; as such, these emissions are required to be addressed. The unique nature of facilities and the way in which fugitive odours may be emitted requires that the sampling strategy for sampling fugitive odour emissions be dealt with on an individual basis.

2.0 PURPOSE

This method is intended to determine the odour concentration and emission rate of undefined mixtures of gaseous odorants of a gas stream in a stack, duct and area source. The samples are collected by dynamic dilution with neutral gas, undiluted by evacuated lung, or via flux chamber sampling procedures and are evaluated using dynamic olfactometry with a panel of human assessors (odour panel evaluation technique).

3.0 LIMITATIONS

The methodology outlined within this chapter is not applicable to measuring odours from solid odour emitting particles or droplets of odorous fluids within a “supersaturated” gas stream. The Source Assessment Specialist should be contact to discuss sample strategies when it is deemed that a customized (non-traditional) sampling strategy is necessary.

4.0 DEFINITIONS

Listed in this chapter are the more frequently referenced definitions. For a complete list of definitions, refer to the European Standard EN 13725: 2003 Determination of Odour Concentration by Dynamic Olfactometry or its most recent version.

Detection threshold (Sample)	Dilution factor at which the sample has a 50% probability of being detected by a human assessor.
Dilution factor	The ratio between sample flow or volume after dilution (Total Sample Volume) and the flow or volume of the odorous gas (“Undiluted” Sample Volume).
Dynamic dilution	Dilution achieved by mixing two known flows of gas; odorous sample and neutral gas, respectively. The rate of dilution is calculated from the flow rates.
Field Blank	odourless air sample collected at the sampling site, treated as a sample in all respects, including contact with the sampling devices and exposure to sampling site conditions, storage, preservation, and all

	analytical procedures.
Flux Chamber	A device used to isolate a surface area for collecting gaseous emissions being generated as neutral gas is being passed over the enclosed area.
Maximum dilution factor	Maximum achievable dilution factor of the olfactometer; an instrument property.
Minimum dilution factor	Minimum achievable dilution factor of the olfactometer; an instrument property.
Neutral gas (diluent)	Air or nitrogen that is treated in such a way that it is as odourless as technically possible (nitrogen of 4.8 Grade or higher is recommended) and that does, according to panel members, not interfere with the odour under investigation. **SAFETY WARNING:** Nitrogen is only used to predilute the sample itself. For the olfactometer, the neutral gas which is used to dilute the sample and present a reference shall be air.
Odour emission rate	The quantity of odour units (ou) which crosses a given surface divided by time. It is the product of the odour concentration C_{od}, and the wet reference volumetric flow rate (at standard temperature and standard atmospheric pressure, 298 K and 101.3 kPa respectively). It is typically expressed as ou/s.

Odour concentration	Number of odour units per volume of gas at wet standard conditions. It is typically expressed as ou (m^3 basis).
Odour unit (O.U Dimensionless)	Number of unit volumes of odourless gas required to dilute one unit volume of odorous gas (under standard conditions) to reach the odour panels detection threshold. The accepted reference value is equivalent to 123 µg n-butanol (CAS 71-36-3). Evaporated in 1 cubic metre of neutral gas (at standard conditions) this produces a concentration of 0.040 µmol/mol.
Odour Panel	Composed of 8 assessors who are qualified to judge samples of odorous gas using dynamic olfactometry. Each assessor must be appropriately screened and meet the selection criteria outlined in the EN 13725:2003 standard.
Pre-Dilution	Drawing a sample of stack gas while simultaneously diluting it with neutral gas for the purpose of preventing condensation and/or sorption of odours upon sample collection and to reduce sample gas temperature.
Sample	The amount of gas which is assumed to be representative of the gas mass or gas flow under investigation and which is examined for odour concentration.

Standard Conditions for Olfactometry	Room temperature (298K) and normal atmospheric pressure on a wet basis.
Sweep gas	Neutral gas which is introduced at a low velocity into a flux chamber.

5.0 DYNAMIC PRE-DILUTION SAMPLING

Source parameters may result in the necessity to "pre-dilute" a sample prior to collection in a sample container. In all cases pre-dilution of stack gas is required if:

1. It is determined that the stack gas temperature may degrade the sample container;
2. The moisture content of the stack gas will result in condensation forming in the sample container;
3. It is determined that the odour intensity is great enough that it results in a positive response at the highest dilution factor of the olfactometer.

5.1 Apparatus

The odour sample collection system must be capable of dynamically pre-diluting the stack gas with odour free purified nitrogen. The quantity of nitrogen shall be sufficient to prevent condensation and sorption of odours upon sample collection and cooling to ambient temperatures.

A sketch of an acceptable dynamic pre-dilution odour sample collection system is shown in Figure 6-1a. Other odour sample collection systems may be used, provided it can be demonstrated that they are effective in preventing condensation upon sample collection and cooling to ambient temperature.

(a) Probe – structurally stable stainless steel, Teflon®, borosilicate or quartz glass. The distance between the probe and the sample container shall be kept to a minimum.

(b) Velocity & Flow Measurement Device – with a resolution of 0.01 m/s such as an anemometer or pitot-tube; reference should be made to Method ON-2 concerning pitot tube configuration and calibration.

(c) Temperature Sensor – thermocouple or other calibrated device capable of measuring stack gas temperature with a maximum acceptable error of 1.5%. The sensor must be checked according to the procedure outlined in Method ON-2 (Chapter 7.5, Appendix 2E).

(d) Differential Pressure Gauges – to use with Pitot tube and orifice meter. Inclined manometer or devices of equivalent sensitivity, readable to the nearest 0.10 mm water column for differential pressure (ΔP) values between 0.10 mm and 25 mm WC, and readable to the nearest 1.3 mm WC for ΔP values greater than 25 mm WC; a more sensitive unit will be required if a ΔP reading is found to be less than 5 smallest scale divisions, see Method ON-2 (Chapter 7.3, Appendix 2C).

(e) Sample Line – made of Teflon®, stainless steel or glass; the distance between the probe and the sample container shall be kept to a minimum. All fittings shall be clean and odour free and preferably of Telfon® or stainless steel composition.

(f) Sample Containers – material of construction shall be Tedlar®, Teflon® or any other materials (such as Nalophan®) which will not compromise the integrity of the sample. When such other materials are proposed, approval from the Source Assessment Specialist is required. The sample container shall be of sufficient volume to carry out a minimum of an eight member odour panel evaluation.

(g) Heated Sample Box – a heated enclosure (or heated probe assembly) shall be used to maintain the temperature of the stack gas, up to a maximum temperature of 120ºC, from the point at which it is drawn from the stack, to the point when it has been diluted with pre-purified nitrogen. Maintaining the sample gas stream at the stack temperature prevents the formation of condensation within the sample apparatus prior to the point of dilution.

(h) Valves – capable of metering the dilution air flow and the sample flow; material of construction shall be Teflon®, glass or stainless steel.

(i) Orifice Meters – capable of accurately measuring the flow ranges required for pre-dilution flow, sample flow and total flow. The material of construction shall be glass, Teflon® or stainless steel.

(j) Pre-Dilution Odourless Gas – nitrogen (4.8 grade or higher).

5.2 Preparation

1. The Pitot tube and orifice meters must be maintained in accordance with the standard accepted procedures and calibrated prior to testing, in accordance with Method ON-2 (Chapter 7.1, Appendix 2A) and Method ON-4 (Chapter 6.2, Appendix 4B). The orifices shall be calibrated in the flow ranges required for the tests.

2. The probe and the sample transfer line must be clean and free of residual odour. If any contamination is observed on the sample transfer line, the sample transfer line must be replaced. A new and/or clean odour free sample line should be used for each source being measured.

3. The sample containers are required to be preconditioned by heating to 70°C (158°F) and flushed continuously with odourless air for a minimum of 8 hours. All containers should be checked for residual odours prior to use. Note that materials other than Tedlar® and Telfon® may not require such preconditioning. However, guidance in this issue is required from the Source Assessment Specialist.

4. The sampling site or location should be selected where odours are expected to be uniform, well mixed and in gaseous form, but note that the flow measurements need to be conducted at a location that meets the minimum requirements listed in Method ON-1.

5. The odour collection system must be calibrated for its complete range of pre-dilution ratios, across the units' range of operating temperatures, using a tracer gas and a flame ionization detector (FID). This calibration shall be completed at a minimum frequency of 6 months (see Hydrocarbon Calibration procedure in Chapter 10.1, Appendix 6A). Prior to utilizing equipment in the field, complete flow checks on each sample collection system and compare the results to data collected during most recent tracer gas calibration. Anomalies shall be flagged and the system shelved until it is recalibrated.

   All calibration data must be available on request prior to or during the actual testing, and must be submitted with the final report.

6. The odour sampling collection system must be leak-checked prior to mobilization to ensure sample integrity and is performed according to the following procedure:

Odour Sampling Leak-Check

a) Plug both the inlet to the probe and the dilution gas inlet.

b) Using a metering system comprised of a vacuum gauge, leak-free pump, and a calibrated dry gas meter (or calibrated pump) draw a vacuum of 380 mm Hg.

c) Maintain the vacuum for at least 1 minute. A leakage rate of 4% of the undiluted sample flow or greater is unacceptable and if found, the sampling train should be dismantled and reassembled until the leak is adequately reduced or eliminated.

5.3 Volumetric Flow Rate Determination

Volumetric flow rate must be determined in accordance with Method ON-2. Molecular weight and stack gas moisture determination should be completed following Method ON-3 and ON-4 respectively.

The exhaust gas stream should be checked for stratification. Please see the chapter titled “Stratification Test Procedure” in Environment Canada’s Report EPS 1/PG/7, December 2005 (or the most recent version) if further guidance is required.

If stack gas stratification is identified, contact the Source Assessment Specialist to discuss the most appropriate strategy for sample collection.

5.4 Pre-Dilution Ratio Determination

The odour sample is “pre-diluted” with odourless gas (nitrogen) during sampling to prevent condensation and absorption of odours upon sample collection and transport; therefore, preliminary tests must be carried out at the source(s) to determine the required pre-dilution ratio.

When an odour sample is collected from a source that exhausts gas containing water vapour, there is the potential for this water vapour to condense. The condensed water, called dew has the potential to absorb odorous compounds in the sample gas and negatively bias the odour analysis results.

The sample "dew point" is the temperature at which the gaseous sample becomes saturated with water vapour. If the sample temperature is maintained at a level higher than the dew point temperature, water vapour remains gaseous. If the sample cools to a temperature below the dew point, water vapor will condense and the odour sample is deemed invalid. Pre-diluting the gas sample with dry nitrogen will lower the total moisture content in the sample container, therefore lowering the dew point temperature. This procedure is used to avoid the formation of condensation which can occur as the sample gas cools after being extracted from the exhausts gas stream.

The following procedure defines the method for calculating the pre-dilution ratio (dry nitrogen to stack gas) necessary to prevent the formation of condensation in a sample container and is based on the measured stack gas moisture content and the lowest temperature at which the gaseous sample is expected to reach during transport and analysis.

5.4.1 Procedure for Calculation of the Pre-Dilution Ratio

1. Determine the stack gas moisture content following the procedures outlined in Part E, Method ON-4. Record the sample volume (m^3 of dry exhaust gas) and total condensed moisture collected (mL or g) and calculate the moisture content in g/m^3.

2. Determine the lowest temperature that the sample gas will reach during transport and/or analysis (i.e. ambient temperature or the odour evaluation laboratory temperature), and record the temperature of the exhaust gas.

3. From Table 6-1 obtain the amount of water in air (g/m^3), assuming 100% relative humidity, for the ambient temperature or the expected temperature of the odour evaluation laboratory; which ever is lower.

4. If the total condensed moisture per cubic metre obtained in Step 1 (g/m^3) exceeds that obtained in Step 3 (g/m^3) sample pre-dilution is required.

Note: For supersaturated gas streams, it is necessary to use the actual water condensate volume collected;

5. To determine the optimum pre-dilution ratio, divide the measured stack gas moisture content (g/m^3) from Step 1 by the amount of water in air at the dew point temperature selected in Step 3.

For example, if the stack gas moisture content is measured to be 45 g/m^3 and the lowest temperature the sample will reach is assumed to be that of the ambient temperature of 18˚C; based on Table 6-1 the stack gas sample must be diluted to contain a maximum of 15.4 g of water per cubic metre of air to prevent condensation. By dividing the stack gas moisture condensate of 45 g/m^3 by the water content at the selected dew point temperature (15.4 g/m^3), the dilution ratio required to prevent condensation is estimated at 3 volumes of nitrogen by 1 volume of exhaust gas sample.

6. The pre-dilution ratio used in the field should be a maximum of 20% or 10 dilution factors higher than that calculated based on this methodology. A dilution level lower than that calculated shall not be used, as it is likely to result in the formation of condensation. Sample teams should strive to use dilution factors as close as possible to the calculated optimum pre-dilution ratio.

7. In cases when the odour concentration is high enough to elicit a positive response from panelists when the olfactometer is diluting the odour sample in its upper dilution range, the odour assessment results are rejected as inconclusive. A new set of samples need to be collected, making sure that a suitable pre-dilution ratio is selected that will accommodate the minimum number of dilution step presentations required by the odour evaluation facility. Preliminary source assessment data may be presented in the pre-test plan for prior approval from the Source Assessment Specialist to increase the dilution ratio beyond the pre-dilution ratio limits outlined above.

5.4.2 Alternate Methods for the Determination of the Optimum Pre-Dilution Rates

The following procedures may be used to determine the dew point of odour samples for the purposes of setting pre-dilution rates. They can be used in lieu of Method ON-4's moisture determination, if stack gas temperature is less than 100°C, and the gas stream does not contain water droplets. Deviation from the 100°C criteria may be considered acceptable however pre-consultation with the Source Assessment Specialist is necessary.

5.4.2.1 Relative Humidity

The relative humidity is the ratio of the actual water vapour pressure to the saturation water vapour pressure (100% humidity) at a selected temperature. Using a commercially available electronic sensor relative humidity can be easily measured.

In order to use relative humidity measurements for pre-dilution ratio determination, the following steps are required:

1. Using an electronic sensor measure the relative humidity of the stack gas (following the manufacturer's instructions).
2. Measure the stack gas temperature; T_s (refer to Method ON-2).
3. Obtain the amount of water in air (g/m^3), assuming 100% relative humidity, at the stack gas temperature.
4. Multiply the water in air value (obtained from Step 3) by the percent relative humidity (obtained from Step 1). This will determine the stack gas moisture content (g/m^3).
5. From Table 6-1 obtain the amount of water in air (g/m^3), assuming 100% relative humidity, for the ambient temperature or the expected temperature of the odour evaluation laboratory; which ever is lower.
6. If the total condensed moisture per cubic metre obtained in Step 4 (g/m^3) exceeds that obtained in Step 5 (g/m^3) sample pre-dilution is required.
7. Follow Steps 5 to 7 of the pre-dilution determination procedure (Chapter 5.4.1) to calculate the required dilution rate.

5.4.2.2 Psychrometer (Wet and Dry Bulb Thermometer)

Wet and dry bulb thermometer technique can be used if:

(i) stack gas temperature greater than 0°C and less than 100°C;

(ii) the gas stream velocity is greater than 5 m/s; and

(iii) the gas stream does not contain water droplets or acid mist.

In order to use the wet and dry bulb thermometer technique, for pre-dilution determination, the following steps are required:

1. Measure the dry stack gas temperature (refer to Method ON-2).
2. Simultaneously measure the wet bulb stack gas temperature.
3. Based on the stack gas wet and dry bulb temperatures, use a psychrometric chart to determine the volume of water vapour in the stack gas.

4. From Table 6-1 obtain the volume of water in air (g/m^3), assuming 100% relative humidity, for the ambient temperature or the expected temperature of the odour evaluation laboratory; which ever is lower.

5. If the total condensed moisture per cubic metre obtained in Step 3 (g/m^3) exceeds that obtained in Step 4 (g/m^3) sample pre-dilution is required.

6. Follow Steps 5 to 7 of the pre-dilution determination procedure (Chapter 5.4.1) to calculate the required dilution rate.

The results of the pre-dilution ratio determination must be made available upon request during collection of the "optimum dilution" ratio samples and shall be included in the final report.

If uncertain on what approach to use to determine the "optimum dilution" ratio, the Ministry's Source Assessment Specialists need to be contacted for guidance.

5.5 Sampling Procedure (Non-Stratified Gas Stream)

1. Assemble the odour sample collection system. Place the probe at a single point near the centre of the stack or duct. If the stack or duct exceeds 2.0 m in diameter, the sample probe can be placed at any single point, greater than 1.0 m away from the stack or duct wall.

2. Ensure that all sample ports, including the area around the sample probe, are covered to prevent the dilution of the gas stream.

3. Heat the front end of the sample apparatus (between the stack and the point of dilution) to the temperature of the stack gas, or 120ºC whichever is lower. To prevent the formation of condensation in the sample line prior to the stack gas being diluted with nitrogen, the sample apparatus must be heated to a temperature equal to or no more than 20% higher than the measured stack temperature; not to exceed 120 ºC.

4. To condition the sample container, start the flow of nitrogen and adjust the stack gas sample flow rate to obtain the proper predetermined pre-dilution ratio. Fill the sample container with the pre-diluted stack gas, and then empty the sample container. Repeat the procedure. The sample container is now conditioned for the collection of an odour sample.

5. Adjust the sample flow rate such that the sample container is filled over a 10 minute sampling period. Connect the sample container, obtain sample and record all data according to Table 6-2.

6. The operator must watch over the sampling trains flow/pressure measuring device(s) throughout the entire test period to ensure a consistent pre-dilution rate is being achieved for the duration of the test.

7. A minimum of three separate samples shall be collected from each source at the optimum dilution rate.

5.6 Sample Recovery

After completion of the ten (10) minute sample collection, the sample container is immediately sealed, labelled and shielded from direct sunlight. To protect from photo-chemical degradation samples shall be placed in an opaque container for storage and transport.

Samples shall be analyzed within 24 hours of sample collection by an odour analysis laboratory that is acceptable to the Source Assessment Specialist.

Note: Caution should be taken when using stickers, tapes or other adhesive/solvent based products to label sample containers as there is the potential for odours to migrate into the sample container.

6.0 UNDILUTED – EVACUATED LUNG SAMPLING PROCEDURE

In the case that stack temperatures and moisture content are low and if it is determined that the stack gas odour concentration is within the dilution range of the olfactometer, the evacuated lung sampling procedure may be utilized.

6.1 Apparatus

The odour sample collection system must be capable of drawing a sample at a steady sampling rate spanning a 10 minute sample period. A pump is used to evacuate a rigid leak-free vessel creating negative pressure which draws a sample of stack gas from the gas stream, through a sample probe, into a sample bag contained within the vessel.

A sketch of an acceptable evacuated lung odour sample collection system is shown in Figure 6-1b. Other odour sample collection systems may be used, provided it can be

demonstrated that they are effective in obtaining a sample with minimal possibility of contamination.

(a) See Chapter 5.1 (a – f).

(b) Sample Lung – rigid vessel or container, capable of maintaining a vacuum sufficient to pull the sample from the exhaust stream, within the time required.

(c) Pump – Leak free diaphragm-type pump (with adjustable flow) or equivalent, which is capable of delivering at least 1 litre/minute under a steady sampling rate lasting 10 minutes.

Note: When sampling a stack or duct with significant negative pressure, a pump with a higher capability will be required.

(d) Flow meter - 0 to 5 litre flow range

6.2 Preparation

See Chapter 5.2 (Steps 1 to 4).

6.3 Volumetric Flow Rate Determination

See Chapter 5.3.

6.4 Sample Procedure

1. Assemble the odour sample collection system. Place the probe at a single point near the centre of the stack or duct. If the stack or duct exceeds 2.0 m in diameter, the sample probe can be placed at any single point, greater than 1.0 m away from the stack or duct wall.

2. Ensure that all sample ports, including the area around the sample probe, are covered to prevent the dilution of the gas stream.

3. To condition the sample container, connect the sample container to the sample line, seal the rigid vessel and start the pump. Fill the sample container with the stack gas. Empty the sample container and repeat the above procedure. The sample container is now conditioned for the collection of odour samples.

4. Reconnect the conditioned sample container, seal the rigid vessel and begin sampling by starting the pump; adjusting the sample flow rate such that the sample container is filled over a 10 minute sampling period. Record all data according to Table 6-2.

5. If sampling a gas stream of negative static pressure, it is important to disconnect and seal the sample container immediately following sample collection to ensure the sample is not drawn back into the stack or duct. When sampling a stack or duct with a high negative pressure it may be necessary to incorporate a clean odour free stainless steel needle valve between the sample probe and sample container. This valve can be closed immediately following sample collection to prevent sample loss.

6. A minimum of three separate samples shall be collected from each source.

6.5 Sample Recovery

See Chapter 5.6.

7.0 AREA SOURCE – FLUX CHAMBER SAMPLING PROCEDURE

This method is applicable to sampling for odours from area sources with no induced flow, including but not limited to: waste water lagoons, sewage treatment settling tanks/clarifiers, landfills and compost piles. This method is not applicable to open bed biofilters.

Area sources are rarely homogeneous in nature. As a result, it is important that a well developed sampling strategy is employed to ensure that the samples collected provide a fair representation of the odour emission potential of the source as a whole. This may require sampling to be completed at multiple locations, for each individual source.

A sketch of an acceptable area source odour sample collection system is shown in Figure 6-1c. Other odour sample collection systems and procedures may be used, provided it can be demonstrated that they are suitable for their intended purpose and have been approved by a Source Assessment Specialist.

Note that sampling using this approach is not to be conducted on rainy days (or when rain occurs within 24 hours prior to the scheduled sampling); as the rain will interfere with the normal generation and release of the odorous emissions (odour scrubbing effect).

7.1 Apparatus

(a) Sample Line – made of Teflon®, or glass; the distance between the probe and the sample container shall be kept to a minimum. All fittings shall be clean and odour free and preferably of Telfon® or stainless steel composition.

(b) Sample Containers – material of construction shall be Tedlar®, Teflon® or any other materials (such as Nalophan®) which will not compromise the integrity of the sample. When such other materials are proposed, approval from the Source Assessment Specialist is required. The sample container shall be of sufficient volume to carry out a minimum of an eight member odour panel evaluation.

(c) Sample Lung – rigid vessel or container, capable of maintaining a vacuum sufficient to pull the sample from the exhaust stream, within the time required.

(d) Pump – Leak free Teflon® coated diaphragm-type pump (with adjustable flow) or equivalent, which is capable of delivering at least 1 litre/minute under a steady sampling rate lasting 10 minutes.

(e) Flow meter – Two (2) flow meters with a 0 to 5 litre flow range.

(f) Odourless Gas – Nitrogen (4.8 grade or higher).

(g) Flux Chamber – Enclosure with a cylindrical shaped base and a spherical top, constructed of stainless steel or plexiglass. The unit shall be equipped with odour free fittings which will allow for the introduction of neutral (sweep) gas, the extraction of a gaseous sample and the relief of sweep gas pressure (i.e. with a bleed valve). See Figure 6-2 for a diagram. The flux chamber may be equipped with a floatation device for sampling liquid surfaces.

7.2 Preparation

1. The sample containers are required to be preconditioned by heating to 70°C (158°F) and flushed continuously with odourless air for a minimum of 8 hours. All containers should be checked for residual odours prior to use. Note that materials other than Tedlar® and Telfon® may not require such preconditioning. However, guidance in this issue is required from the Source Assessment Specialist.

2. The flux chamber shall be clean and free of residual odour prior to each use.

3. The sample transfer line must be clean and free of residual odour. If any contamination is observed on the sample transfer line, the sample transfer line must be replaced. A new and/or clean odour free sample line should be used for each source being measured.

7.3 Sample Procedure

1. Assemble the odour sample collection system and place the flux chamber over the surface area to be tested. Ensure that the cylindrical walls of the flux chamber are slightly below the sampling surface thereby preventing the introduction of ambient air into the chamber.

2. Start the flow of metered sweep gas into the flux chamber. The flow rate shall be metered at 0.00064 m^3/s based on one square metre of coverage. Using an EPA style flux chamber with a diameter of 40.6 cm and area coverage of 0.13 m^2, sweep gas flow rates shall be metered at 5 L/min.

   Flux chambers covering a larger surface area will require a higher sweep gas flow rate. In such cases, the sweep gas flow rate results will need to be normalized to 0.00064 m^3/s based on one square metre of coverage.

3. Allow a minimum of 4 air exchanges to occur within the chamber prior to drawing a sample. Each air exchange represents passing a volume of sweep gas into the flux chamber that is equal to the chamber volume.

4. To condition the sample container, connect it to the sample line within the rigid vessel. Seal the vessel and start the pump. Fill the sample container and stop the pump. Empty the sample container and repeat the above procedure. The sample container is now conditioned for the collection of odour samples.

5. Reconnect the conditioned sample container to the sample line within the rigid vessel, seal the vessel and begin sampling by starting the pump. The sample flow rate is required to be such that the sample container is filled over a 10 minute sampling period. The sweep gas volumetric flow rate must exceed that of the sample flow rate. Record all data according to Table 6-3.

6. A minimum of three separate samples shall be collected from each source; but as indicated previously, area sources are rarely homogeneous in nature. The number of separate samples may be higher than three; depending on the number of selected locations that will provide a fair representation of the odour emission potential, of the source as a whole.

Note that when using the flux chamber approach, for collecting odour samples, the odour flux (ou/s/m^2) is calculated based on the sweep gas rate. See Equations 6-3 and 6-4.

The flux chamber sweep gas flow rate and its normalization are used for convenience to standardize the sampling strategy and emission rate calculations. In actuality the rate of odorant release from a surface area will depend upon many parameters, some of which include: temperature and porosity of the surface, ambient temperature and relative humidity, substance chemical and physical composition, surface tension between the odorant and the surface area as well as the sweeping effect of the wind on the surface area. The flux chamber sampling method is being adopted to assist in standardizing sampling strategies and providing repeatable results.

7.4 Sample Recovery

See Chapter 5.6.

8.0 OPEN BED BIOFILTER SAMPLING METHOD

Open bed biofilters have characteristically low air flow velocities over a large surface area. It is this induced air flow that makes sampling using area source odour sampling methods (i.e flux chamber sampling) unsuitable. If used, a flux chamber would trap air exiting the biofilter and build positive pressure within the chamber. This positive pressure at the surface of the biofilter would disturb the natural flow of the unit diverting air around the chamber in the path of least resistance. This would in-turn result in an inaccurate, non-representative odour samples.

This sample method utilizes a passive sampling hood designed to produce minimal resistance to the biofilters natural air flow, while funnelling the gas stream through a diameter of ducting small enough to produce measureable flow rates. An evacuated lung sampling apparatus is used in conjunction with the sampling hood to draw odour samples from its exhaust duct.

A sketch of an acceptable open bed biofilter odour sample collection system is shown in Figure 6-1d. Other odour sample collection systems and procedures may be used,

provided it can be demonstrated that they are suitable for their intended purpose and have been approved by a Source Assessment Specialist.

8.1 Apparatus

A well designed sampling hood is essential to the success of this procedure. The following three items need to be considered when constructing the sample hood:

(i) The size of the capture hood and diameter of its exhaust duct needs to be sufficient to provide measureable velocity readings.

(ii) The angle of the capture hood (inverted funnel) must provide minimal resistance to the natural flow of the biofilter exhaust.

(iii) The entry angle from the capture hood to the exhaust duct needs to be designed to provide a smooth transition, minimizing the possibility of positive pressure build-up in the capture hood.

It is imperative that the sample hood is designed to minimize the loss of gas stream velocity and prevent the build up of pressure as the biofilter emissions pass through the apparatus. A high positive pressure within the sampling hood (created by a poorly designed sampling apparatus) has the potential to alter the natural air flow of the bed; providing inaccurate non-representative sampling results. Pressure build-up within the sample hood, resulting in entry losses, will vary depending on the angle of the capture hood in relation to the biofilter bed. It is recommended that a hood height to base diameter ratio of 3 to 1 be used.

In addition to limiting losses due to the potential pressures and disturbances between the biofilter bed, capture hood and exhaust duct, the duct should be designed to allow gas velocity readings of 0.2 m/s or higher. Velocity readings can typically be measured accurately at levels as low as 0.2 m/s by commercially available air velocity meters.

8.2 Sampling

Odour sampling locations are established by conducting an initial airflow survey over the surface area being assessed. This survey should be completed by obtaining flow

measurements using twelve (12) or more equal area quadrants. This survey will reveal any airflow trends; preferential air flow, possible breakthrough zones, dead spots or relative uniformity across the bed.

If the biofilter displays relative uniformity across the bed (considered to be less than 20% variance from the average measured velocity) sampling should be completed at a minimum of three separate locations across the bed.

If there is significant variance in measured velocity (> +/-20%), sampling zones need to be established. These zones are based on quadrants with similar flow characteristics. The number of sampling zones defined will be subject to the amount of flow variation and the flow patterns observed. A minimum of three odour samples should be collected from each of the defined zones.

Odour samples and temperature/flow measurements are taken from the straight vertical section of duct extending above the capture hood (see figure 6-1d for a sketch of the apparatus). An evacuated lung sampling system is used to draw the odour sample into the sample container (see Chapter 6). A pre-dilution sampler may be needed if high moisture levels and/or very high odour concentrations are encountered (see Chapter 5).

The resultant odour concentration is assigned to each quadrant within the defined sample zone. The product of the zones average velocity (calculated to reflect that of the bed surface), total area and the resulting odour concentration provides the odour emission rate. Emission rates for biofilters are typically entered into the air dispersion model as a point source. If there is significant variation in the biofilter velocity profile and numerous sample zones are identified, it may be necessary to model the biofilter as more than one point source – utilizing a diameter of equal area – and assigning relative emission rates and flow characteristics.

If the velocity profile of the biofilter is relatively uniform an inlet flow measurement is preferred for calculating volumetric flow rates and surface velocity, as it is likely to be more accurate. If this method is employed it is necessary to adjust the flow rate to

reflect the temperature and moisture characteristics of the gas flow as it exits the biofilter (typically at saturation).

Note that sampling using this approach is not to be conducted on rainy days (or when rain occurs within 24 hours of the scheduled sampling); as the rain will interfere with the normal generation and release of the odorous emissions (odour scrubbing effect).

9.0 FIELD BLANKS

Field blanks are required to be collected immediately prior to commencing source sampling. A minimum of one field blank is required for each test date.

Field blank samples are collected to determine the existence and magnitude of contamination problems and to assess the level of quantification of the sampling system and analytical procedure.

Blanks reflect the amount of contamination introduced into the odour samples during sample collection, transfer or analysis. They are used to determine whether (1) equipment-cleaning protocols adequately remove residual/background contamination from the sampling trains and containers, (2) equipment handling and transport periods introduce contamination, and (3) sampling, transport and sample-processing procedures result in contamination.

The procedure for obtaining a field blank requires that the blank be exposed to the same environmental conditions as all other odour samples. The basic steps for the collection of a field blank follow:

1. At the sampling site (and immediately prior to drawing samples from the exhaust) connect an odour-free air source to the end of the sample probe.
2. Connect the sample container to the odour sampler.
3. Obtain a sample “blank” following the same procedures used when collecting other odour samples. The sampling apparatus must draw air from the supplied odour-free source, through the entire sample train and into the sample container.

4. Record the field blank collection information in the field data sheets. Label the field blank appropriately with the time, date and sample ID prior preparing it for transport. Field blanks should be shipped in the same manner and at the same time as the other samples collected.

5. Analytical procedures for field blanks shall be identical to those used for all other odour samples.

Note: The odour samples associated with each blank (laboratory and field blanks) shall not be corrected for blank contamination.

10.0 ODOUR EVALUATION

Evaluation of odour concentrations of gaseous samples should be completed following the European Standard EN 13725: 2003 (or its most recent version) with the following exceptions:

- A minimum of an 8 member panel is required for odour analysis in Ontario.
- Analysis is not required to be completed twice for each sample.
- Analysis is required to be completed within 24 hours of sample collection.

Besides the above mentioned deviations all other criteria, as outlined in the EN 13725 document needs to be followed.

11.0 APPENDICES TO METHOD ON-6

11.1 APPENDIX 6A: Hydrocarbon Calibration Method – Calibrating Pre-Dilution Sampling Apparatus

1. Assemble the pre-dilution sampling apparatus without sample container or sample lung.

2. Attach the sample inlet of the pre-dilution sampling apparatus probe to a hydrocarbon source of known concentration, i.e., certified calibration gas (Propane or Methane).

Note: hydrocarbon concentration should be sufficiently high so as not to exceed the detection limit of continuous analyzers equipped with a flame ionization detector at the highest pre-dilution ratio anticipated for the tests.

3. Assemble a continuous hydrocarbon analyzer (flame ionization detector) to draw a slip stream from the pre-dilution apparatus sample collection outlet. Hydrocarbon concentrations shall be recorded on a continuous basis (1 second intervals) and logged electronically via data acquisition system across a range of dilution settings. The hydrocarbon analyzer and data acquisition system shall be maintained and operated according the manufacturer's specifications and the analyzer shall meet the performance criteria outlined in the US EPA 40CFR60 Method 25A.

4. Start the flow of neutral gas and adjust the sample apparatus to achieve the desired pre-dilution ratio. Record the data according to Table 6-2, excluding the stack temperature. Maintain this operation for a minimum of 1 minute. Record the undiluted hydrocarbon concentration on the data sheet and calculate the actual dilution factor based on the analyzer readings for each dilution setting. Readings obtained during the 1 minute interval should be stable. Differences exceeding ±5% during the 1 minute reading indicates that the sampling system is faulty and is in need of repair.

Repeat Step 4 over the range of pre-dilution ratios and at unit temperature increments anticipated to be used during field testing. The acceptable linear response over the operating range of the pre-dilution sampling apparatus is set at ±5 percent.

11.2 APPENDIX 6B: Equations and Sample Calculations

11.2.1 Stratification (%) Equation

$$ST_i = \left(\frac{C_i - C_{avg}}{C_{avg}} \right) \times 100$$

Eq. 6-1

where:

ST_i = stratification (%)

C_i = concentration of the measured species at point

C_{avg} = geometric average of all measured concentrations

The flow in the stack or duct is considered to be stratified if any calculated value using Equation 6-1 exceeds 10%.

11.2.2 Point Source - Odour Emission Rate Equation

$$ER = \overline{DT} \times Q_w$$

Eq. 6-2

where:

$\overline{DT}$ = Average Detection Threshold Value (geometric average odour concentration value defined by geometric average of triplicate odour sample analysis)

Q_w = Stack gas volumetric flow rate - wet basis at reference conditions (25ºC and 101.3 kPa)

ER = Source Emission Rate (ou/s)

11.2.3 Area Source - Odour Emission Rate Equation

$$OF = \left(\frac{\overline{DT} \times SG}{CA} \right)$$

Eq. 6-3

where:

$\overline{DT}$ = Average Detection Threshold Value (geometric average odour concentration value - defined by geometric average of triplicate odour sample analysis)

SG = Sweep Gas Flow Rate (m^3/s)

CA = Chamber Area (m^2)

OF = Odour Flux ($ou/s/m^2$)

$$ER = OF \times SA$$

Eq. 6-4

where:

SA = Total Source Area (m²)

ER = Source Emission Rate (ou/s)

11.2.4 Pre-Dilution Ratio Determination Equation

$$R = \frac{W_w}{V_m}$$

Eq. 6-5

where:

W_w = weight of moisture collected by the condenser (g)

V_m = volume of dry gas sample (m³)

R = stack gas moisture content (g/m³)

$$PD = \frac{R}{D_p}$$

Eq. 6-6

where:

PD = pre-dilution ratio (volume of dry nitrogen to stack gas)

D_p = ambient temperature moisture content at saturation (g/m³)

Moisture content data for this calculation is based on the data used in the sample calculation in Method ON-4. This data can be seen in Part E (Tables 4-1 and 4-2).

11.2.4.1 Pre-Dilution Ratio Sample Calculation

W_w = 146.6 g

V_m = 0.975 m³

By using Equation 6-4, we obtain:

$$R = \frac{146.6}{0.975}$$

$$R = 150.3\,\text{g/m}^3$$

For the purpose of finding D_p we will assume that that lowest temperature that the sample will reach is an ambient temperature of 18°C. D_p is then defined using Table 6-1.

D_p = 15.4 g/m³

$$PD = \frac{150.3}{15.4}$$

$$PD = 9.8:1$$

Based on the calculation, the pre-dilution ratio used would be 10**:**1 (10 parts dry nitrogen to 1 part stack gas) by volume.

11.3 APPENDIX 6C: Conditional Odour Sampling Methods

This chapter describes some of the successful non-traditional odour sampling methods that have been applied in the past. These “Conditional Odour Sampling Methods” are intended to provide some guidance in dealing with some non-traditional odour sources. Please note that this chapter is for guidance purposes only. It is necessary to contact the Source Assessment Specialist prior to implementing these methods for compliance testing purposes.

11.3.1 Sampling Truck Trailers and Bins

Sampling large area sources such as a truck trailer or a large bin presents several challenges. The following is a brief description of a sampling method which has been successfully applied in the past.

To facilitate the measurement of odours coming from truck trailers or bins, build an enclosure to accommodate the largest truck trailer or bin of raw material. Equip this enclosure with a passive air intake at one end and an exhaust system used for the venting of odorous air at the other end. The air inlet should be placed above the odour source and the outlet should be placed lower for the purpose of inducing a cross draft. The exhaust will discharge odorous air from within the enclosure through a straight section of a duct which will provide an ideal sampling location for both odour and volumetric flow rate. Refer to Figure 6-3 for a view of the enclosure.

Once the truck trailer or bin is placed within the enclosure and the door tightly closed, the exhaust system is activated. Fresh air is allowed to enter the opposite end of the enclosure through the passive air intake, which is an opening equivalent in diameter to the exhaust duct diameter. The enclosure is allowed to stabilize for a period sufficient to give at least two (2) air exchanges prior to sample collection.

Once the enclosure is stabilized, odour samples are collected from the exhaust duct with an evacuated lung sampling system (see Chapter 6). Care must be taken to ensure

that samples are not collected while there are ambient odours around the enclosures, as this will bias the results.

At the beginning and at the end of each sampling day, a sample is collected while the enclosure is empty to evaluate background levels.

11.3.2 Fugitive Odour Sampling

When assessing a facility's aggregate odour impact it is necessary to address the issue of fugitives. Fugitive sources of odour are elusive and difficult to identify, such as leaky valves, flanges or passive ventilation apertures. These sources may even release quantities of odorants intermittently making them even more difficult to quantify.

In certain instances fugitive sources may comprise the majority of a facility's aggregate odour emission rate; as such, it is essential that these sources are quantified and included in a site-wide assessment of potential odour impacts.

There are several sampling methods which can be used to quantify fugitive odours. Due to the unique nature of odour emitting facilities, it is often necessary to adapt one or more of these methods to best suit each individual situation. Having a qualified person develop a comprehensive strategy for quantifying fugitive odour emissions is a key element to completing a successful odour assessment. A Source Assessment Specialist should always be contacted to discuss proposed sampling strategies prior to initiating a program.

12.0 REFERENCES

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Table 6-1
Amount of Water in Air at Saturation
(Using Standard Atmospheric Pressure 101.325 Kpa)

Temperature (°C)	Vapour Conc. (g/m³)	Temperature (°C)	Vapour Conc. (g/m³)	Temperature (°C)	Vapour Conc. (g/m³)	Temperature (°C)	Vapour Conc. (g/m³)
-20	0.9	1	5.2	22	19.4	43	59.3
-19	1.0	2	5.6	23	20.6	44	62.2
-18	1.1	3	5.9	24	21.8	45	65.3
-17	1.2	4	6.4	25	23.0	46	68.6
-16	1.3	5	6.8	26	24.4	47	71.9
-15	1.4	6	7.3	27	25.8	48	75.4
-14	1.5	7	7.7	28	27.2	49	79.0
-13	1.7	8	8.3	29	28.7	50	82.8
-12	1.8	9	8.8	30	30.3	51	86.7
-11	2.0	10	9.4	31	32.0	52	90.8
-10	2.1	11	10.0	32	33.8	53	95.1
-9	2.3	12	10.7	33	35.6	54	99.5
-8	2.5	13	11.3	34	37.6	55	104
-7	2.8	14	12.1	35	39.6	60	130
-6	3.0	15	12.8	36	41.7	65	160
-5	3.2	16	13.6	37	43.9	70	197
-4	3.5	17	14.5	38	46.2	75	240
-3	3.8	18	15.4	39	48.6	80	291
-2	4.1	19	16.3	40	51.1	85	350
-1	4.5	20	17.3	41	53.7	90	419
0	4.8	21	18.3	42	56.4		

2009 ASHRAE Handbook, Fundamentals, Chapter 1, Psychrometrics

The satuaration pressure over ice for the temperature range of -100 to 0 Deg C is given by:

$$\ln p_{ws} = C_1 / T + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln T$$

where:

C_1 = -5.674 535 9 E+03
C_2 = 6.392 524 7 E+00
C_3 = -9.677 843 0 E -03
C_4 = 6.221 570 1 E -07
C_5 = 2.074 782 5 E -09
C_6 = -9.484 024 0 E -13
C_7 = 4.163 501 9 E+00

The satuaration pressure over liquid water for the temperature range of 0 to 200 Deg C is given by:

$$\ln p_{ws} = C_8 / T + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln T$$

where:

C_8 = -5.800 220 6 E+03
C_9 = 1.391 499 3 E+00
C_{10} = -4.864 023 9 E -02
C_{11} = 4.176 476 8 E -05
C_{12} = -1.445 209 3 E -08
C_{13} = 6.545 967 3 E +00

T = absolute temperature, K
p_{ws} = saturation pressure, Pa

TABLE 6-2: ODOUR SAMPLE DATA SHEET TEMPLATE

SAMPLE ID:

SOURCE: SAMPLE DATE:

TIME START: FINISH:

STACK TEMP (ºC): AMBIENT TEMP (ºC):

STACK GAS MOISTURE CONTENT (g/m^3):

VAPOUR CONC. (SATURATION) AT LOWEST ANTICIPATED TEMP (g/m^3):

PREDILUTION RATIO:

EVALUATION DATE: ED_{50}:

SAMPLE LINE		DILUTION LINE		DILUTION RATIO	P	STACK TEMP.	PROBE TEMP.
Hs	FLOWRATE	H_D	FLOWRATE				

TABLE 6-3: FLUX CHAMBER ODOUR SAMPLE DATA SHEET TEMPLATE

SOURCE: Pbar:

SAMPLE DATE: Ambient Temp:

SAMPLE LOCATION:

FLUX CHAMBER AREA:

EVALUATION DATE:

Sample #	Sweep Gas Flow Rate (L/min)	Sweep Gas Start Time	Sampler Temp (°C)	Sample Flow Rate (L/min)	Sample Start Time	Sample Finish Time

FIGURE 6-1a: SKETCH OF AN ACCEPTABLE SAMPLING TRAIN FOR ODOUR SAMPLING (Dynamic Dilution Approach)

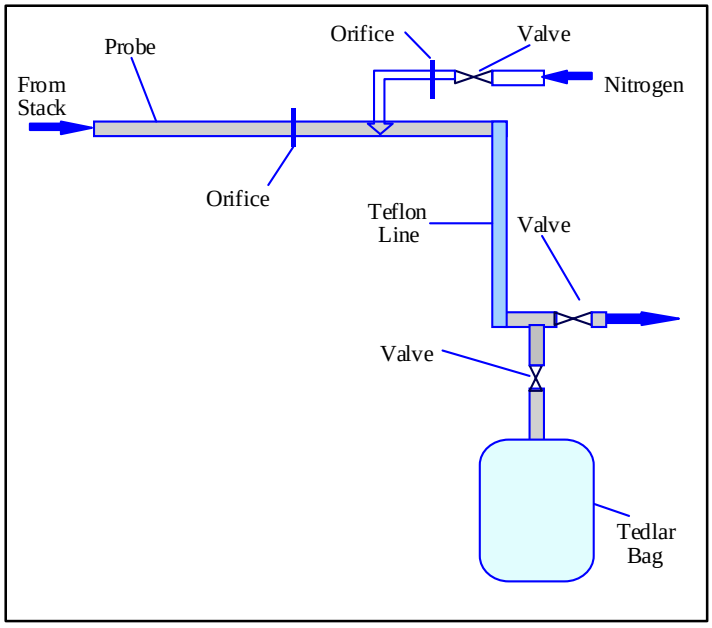


FIGURE 6-1b: SKETCH OF AN ACCEPTABLE SAMPLING TRAIN FOR ODOUR SAMPLING (Evacuated Lung Approach)

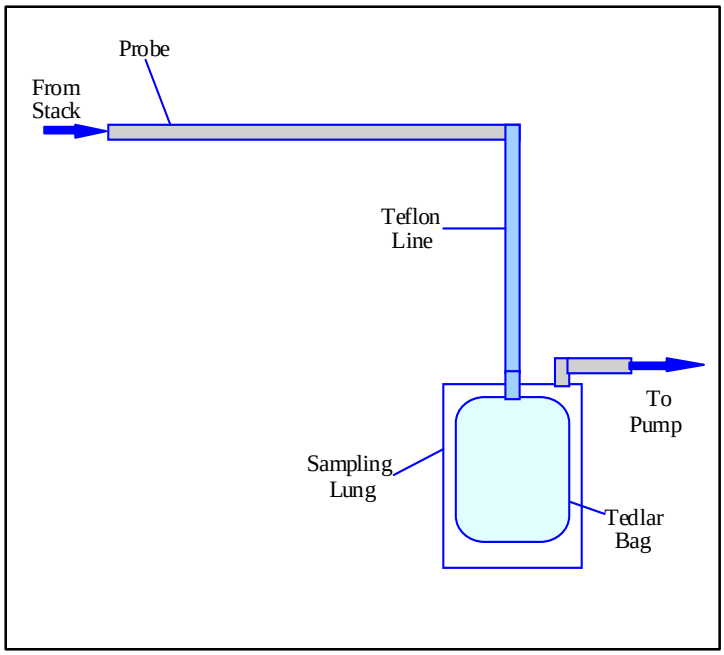
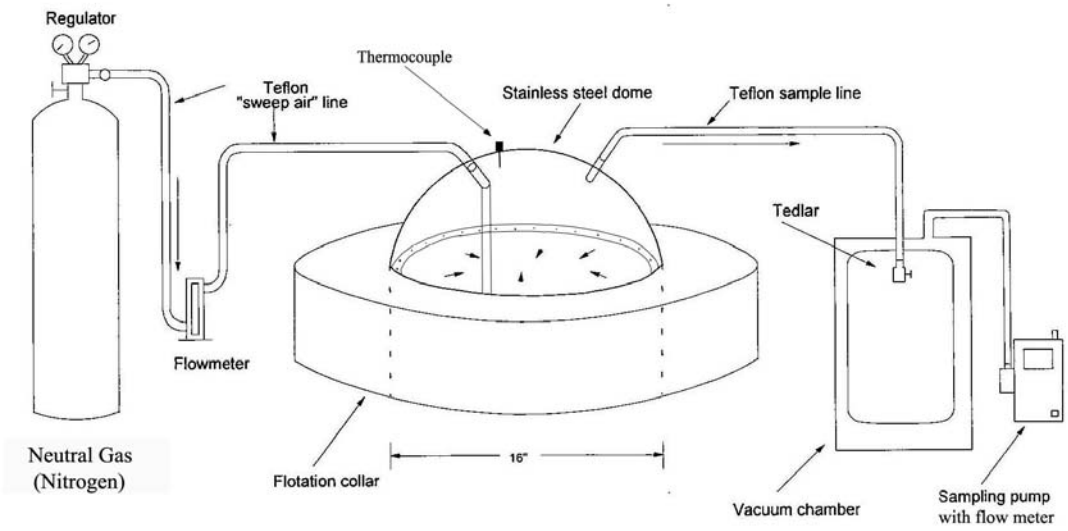


FIGURE 6-1c: SKETCH OF AN ACCEPTABLE SAMPLING TRAIN FOR ODOUR SAMPLING (Flux Chamber Approach)



Source - Diagram modified for Ontario specifications based on the following document:
Murphy, Scott (2009) Missoula Odor Characterization Study. Morrison-Maierle Inc. & Bowker & Associates Inc.

FIGURE 6-1d: SKETCH OF AN ACCEPTABLE SAMPLING TRAIN FOR ODOUR SAMPLING (Biofilter Bed Sample Train)

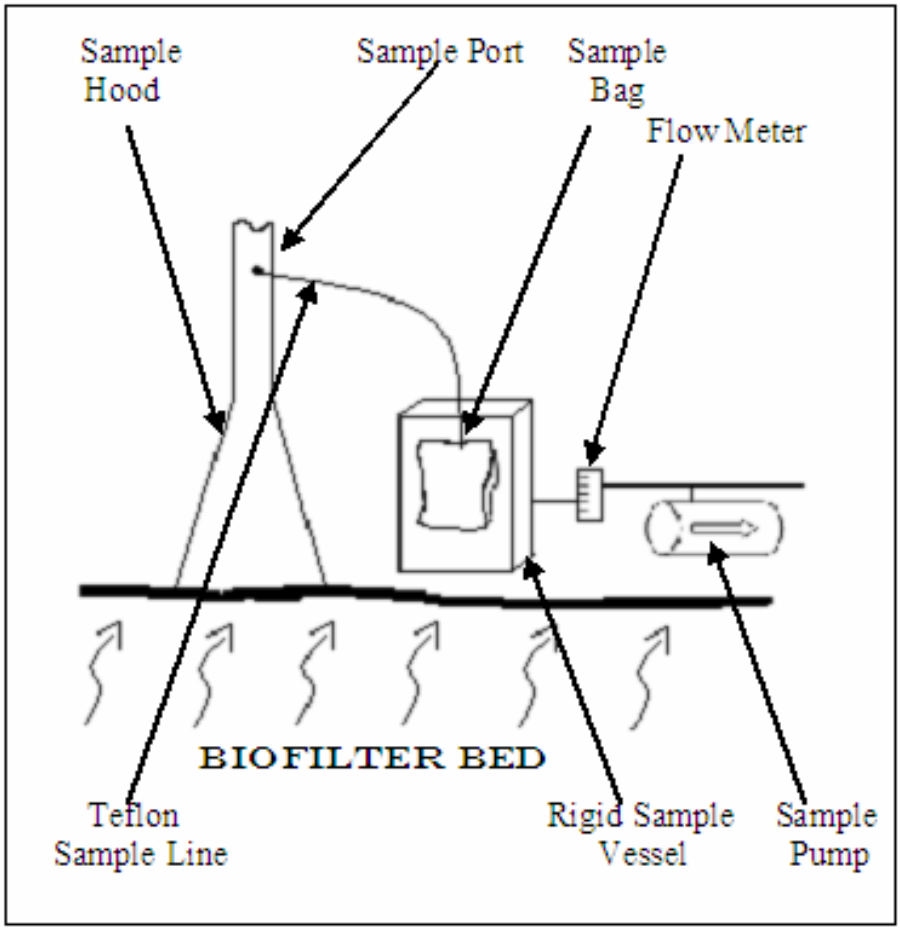
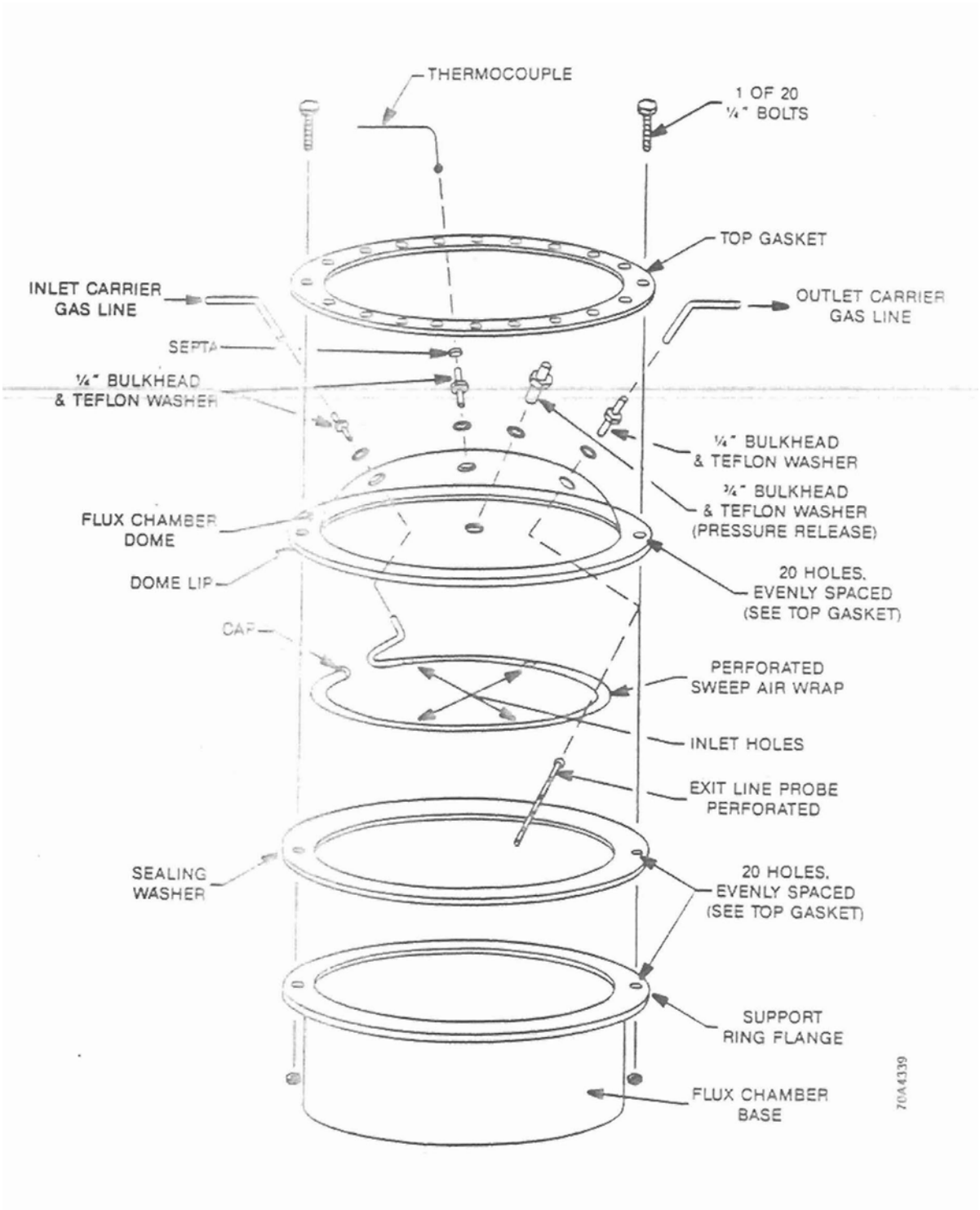
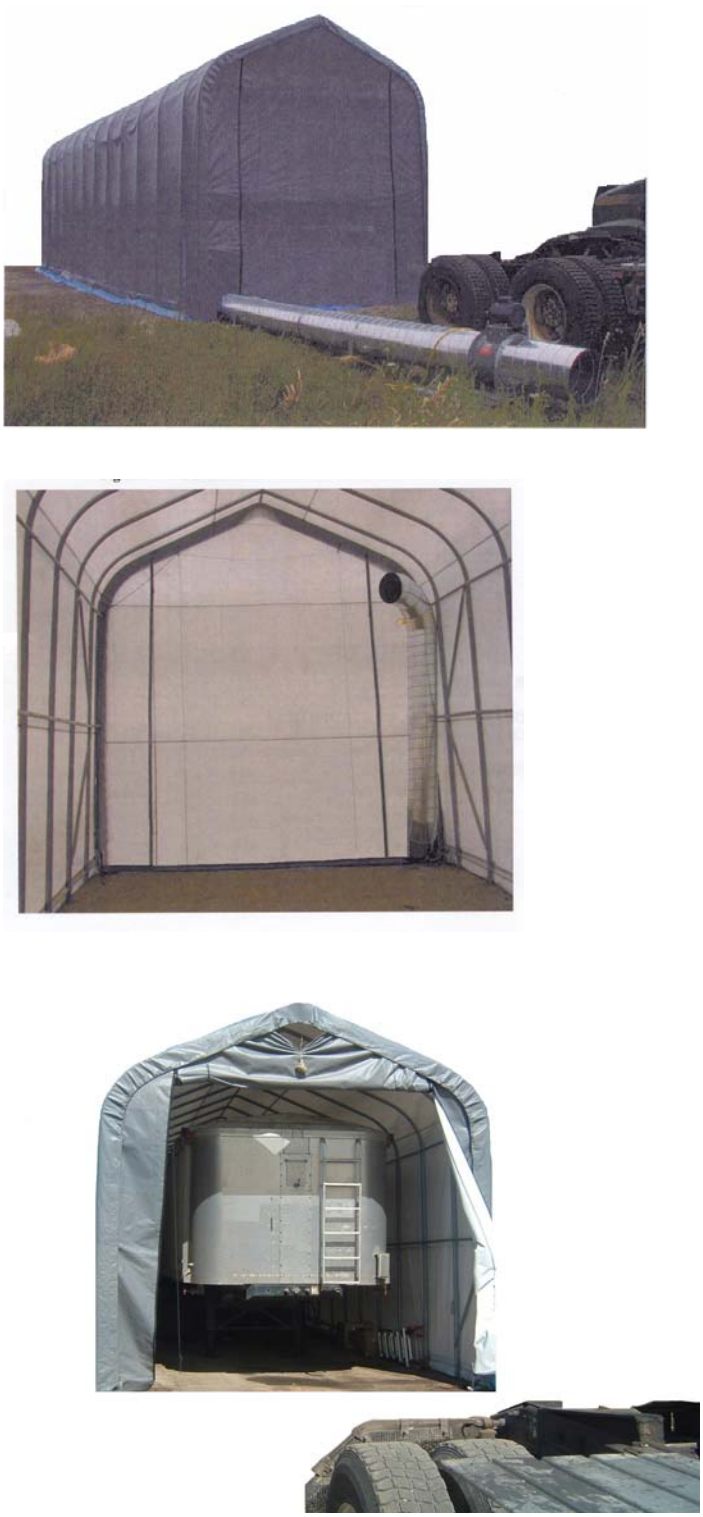


FIGURE 6-2: ODOUR SAMPLING FLUX CHAMBER CONFIGURATION



Source: U.S. Environmental Protection Agency (1986). Measurement of gaseous emission rates from land surfaces using isolation flux chamber - user's guide.

FIGURE 6-3: TRUCKS ODOUR SAMPLING STATION



Part H

Method ON-7: Determination of Size Distribution of Particulate Matter from Stationary Sources

ACKNOWLEDGEMENT

This document is based on the State of California's Air Resources Board - Method 501 (Determination of Size Distribution of Particulate Matter from Stationary Sources). It has been adapted to reflect requirements specific to Ontario.

1.0 PURPOSE

To determine the size distribution of particulate matter of a gas stream in a stack or duct, withdrawn under isokinetic conditions, segregated by size through inertial separation (cascade impactor) and determined gravimetrically.

2.0 PRINCIPLE

An aerosol stream passes through a nozzle and impacts upon collection plates. Particles in the aerosol stream having large enough inertia will impact upon the collection plates while the other particles will follow the airflow through the impaction region.

Impaction occurs when the particle's inertia overcomes the aerodynamic drag. Otherwise, the particle remains in the air stream and proceeds to the next stage. To keep the cut-point for each stage constant, the impactor is operated at a constant flow rate. At each stage, the particle impacts on a desiccated, tared glass fibre mat.

Each stage gives a cut-point based on aerodynamic diameter of the particle and the flow rate/face velocity. Aerodynamic diameter is defined as the diameter of a sphere of unit density (1.0 g/cm^3) that attains the same terminal settling velocity as the actual particle under consideration.

Following sampling, the samples are cooled in a dessicator and weighed to 0.1 mg.

Note that for mathematical modeling purposes, it is convenient to express the behaviour of an irregularly shaped particulate specimen as if it were a spherical particle. Use of such common denominators makes it easier to predict, compare and correlate various materials. The Stokesian, or Equivalent Diameter is the diameter of a sphere having the same terminal settling velocity and density as the particle under consideration. Typically, the density of a particulate sample is not known during field sampling. All calculations in the field are therefore performed assuming unit particle density (1 g/cm^3).

The assumed most significant negative bias with this approach is that spheres have the unique feature of being the most compact shape for the volume or surface area they possess. More irregular shaped (normal) particles will possess more surface than the sphere and will therefore fall more slowly because of the increased drag than their equivalent spherical diameter.

3.0 APPLICABILITY

This method is applicable to ducted source sampling environments with:

(i) a particulate mass concentration range of 0.00001 g /m^3 (10 ug/m^3) to 100 g/m^3 (based on a pressure range between 125 to 500 mm of water gauge);

(ii) a temperature range between 0°C and 450°C; and,

(iii) a velocity between 3.0 and 30 m/s.

In general, the applicable range of solid particle separation using cascade impactors is between 0.30 and 20 microns in diameter.

This method is **not applicable** to high temperature, moisture saturated gas streams or fibrous material.

This method may be used as a screening tool for the determination of filterable PM_{10} and $PM_{2.5}$ while conducting standard Method ON-5 sampling for total suspended

particulate matter determination. The mass fractions obtained (from the cascade impactor sampling) are multiplied by the total PM emissions (minus the residual PM obtained from the back filter and probe/filter holder sample recovered).

Note: This variation of Method ON-5 accounts only for the PM_{10} and $PM_{2.5}$ filterable fraction, and not the condensable fraction. For the condensable fraction, the US EPA Method 202 needs to be followed.

When using this method for PM_{10} and $PM_{2.5}$ compliance testing, the Source Assessment Specialist needs to be contacted to approve its use.

Alternatively, the primary reference for PM_{10} and $PM_{2.5}$ determination are the US EPA methods based on cut off cyclones to determine the filterable fractions, and the US EPA method 202 for the PM condensable fraction.

4.0 APPARATUS

4.1 Sampling Train

A schematic diagram of the source test sampling train is presented in Figure 7-1. This train is similar to the Method ON-5 particulate sampling train. The schematic diagram shows the basic parts of the sampling train, including the right angle pre-collector and the cascade impactor mounted on a modified probe of a Method ON-5 sampling probe.

(a) Right Angle Pre-collector – serves to turn the sample stream through a 90° angle and help prevent overloading of first impactor stage. The curved nozzles used with Method ON-5 are not acceptable for use with particle sizing devices because of high particulate losses in the nozzle. Figure 7-2 shows a view of a right angle pre-collector.

(b) Cascade Impactor – consists of a threaded cylindrical casing, with up to 11 impaction jet stages, particle collection plate, threaded inlet and outlet sections, and a filter holder in the outlet section (for a 47 mm diameter final filter). It provides for up to 12 particle size classifications.

The preferred configuration is to use the single jet inlet followed by six (6) multi-jet stages with the collection plates and a filter.

Figure 7-3 shows a cross-section of the University of Washington 11-stage impactor, and Figure 7-4 illustrates the individual parts of a 7-stage impactor.

(c) Probe – Structurally stable, lined corrosion resistant metal liner, long enough to traverse at least half of the stack diameter, and capable of maintaining a gas temperature of 120°C at the exit end during sampling and including a probe temperature sensor.

(d) Pitot tube and Differential Pressure Gauge – S-type (Stausscheibe or reverse type) or standard type with tubing to connect the two pressure taps to inclined manometers or devices of equivalent sensitivity, readable to the nearest 0.10 mm H_2O for ΔP values between 0.10 and 25 mm H_2O. Velocity profile information is obtained prior to the sampling run by performing a velocity traverse using Method ON-2. The sampling flow rate, nozzle and sampling points are selected based on this velocity traverse.

(e) Temperature Sensors – Thermocouple or other calibrated device capable of measuring stack gas temperature to within 1.5% of the minimum temperature. Temperature sensor is used to measure the impactor exit gas temperature, the stack gas temperature, and the temperature of the gas in last impinger of the sampling train.

(f) Condenser – comprised of four impingers connected in series with leak-free fittings (e.g., ground glass). The first, third and fourth impingers are of the Greenburg-Smith design modified by replacing the tip with 1.3 cm I.D. glass tubing extending to about 1.3 cm from the bottom of the flask. The second impinger is of the standard Greenburg-Smith design. Known volumes of water are placed in the first and second impingers and a known weight of desiccant is placed in the fourth impinger. The impingers are maintained in an ice bath.

(g) Metering System – comprised of a vacuum gauge, leak-free pump with coarse and fine control valves, calibrated dry gas meter capable of measuring volume to within 2% and including an inlet and an outlet temperature sensor capable of measuring temperature to within 1°C or temperature compensation and a calibrated orifice meter.

(h) Barometer – mercury aneroid or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg. Alternatively, the daily atmospheric pressure is provided by Environment Canada may be used with an altitude adjustment for the sampling site at the rate of minus 2.5 mm per 30 meters of elevation increase or vice versa for elevation decrease.

(i) Gas Composition Determination Equipment – see Parts D and E (Methods ON-3 and ON-4)

4.2 Sample Recovery and Analysis Equipment

(a) Brushes – sized and shaped to clean out probe and nozzle; nylon bristles with stainless steel wire handle and extensions of stainless steel, Nylon, Teflon, or other inert material.

(b) Wash Bottles – glass or polyethylene; acetone should not be stored in polyethylene bottles for longer than one month.

(c) Liquid Sample Storage Containers – glass or polyethylene (500 or 1000 ml) with leak-free acetone resistant caps. Acetone samples should not be stored in polyethylene longer than one month.

(d) Storage Cylinder – for taking plates and stages from impactor.

(e) Petri Dishes – glass or polyethylene, large enough to hold unfolded substrate.

(f) Graduated Cylinder – with subdivisions no greater than 2 ml.

(g) Balance – capable of weighing impingers to the nearest 0.1 g.

(h) Dessicator.

(i) Analytical Balance – capable of weighing to the nearest 0.1 mg.

5.0 REAGENTS AND MATERIALS

5.1 Sample Collection

The following items are required for sample collection:

(a) Cascade Substrate – substrate material used depends on the sampling situations and the type of impactor used. The most commonly used are bare metal, greased metal, polypropylene coated metal, fibreglass and quartz.

Glass or quartz fibre mats are generally the Ministry's preferred substrate choice. These mats provide a light-weight impaction surface, reducing re-entrainment due to particle bounce.

In hot gases containing sulphur oxides, glass fibre often exhibits gains in weight due to reaction with sulphur oxides and the formation of sulphates. In this case, (sulphuric) acid treated substrates need to be used. The manufacturer should be contacted when these filters are needed or the glass fibre mat can be acid

treated following the procedure outlined in the State of California's Air Resources Board - Method 501 (Chapter 4.1.2.3).

(b) Water – distilled or deionized. Run blank prior to field use to eliminate a high background on test samples.

(c) Silica Gel – new or fully regenerated, 6 to 16 mesh indicating type. To regenerate silica gel, dry at 175°C for 2 hours.

(d) Crushed Ice.

5.2 Sample Recovery

The following items are required for sample recovery:

(a) Acetone – reagent grade, 0.001% residue, in glass bottles.

(b) Water – distilled or deionized. Run blank prior to field use to eliminate a high background on test samples.

5.3 Sample Analysis

The following items are required for sample analyses:

(a) Acetone – reagent grade, 0.001% residue, in glass bottles.

(b) Desiccant – new or fully regenerated, self-indicating, e.g., 6 to 16 mesh silica gel.

6.0 PROCEDURE

6.1 Sampling Equipment Preparation

1. The Pitot tube, dry gas meter and orifice meter must be maintained in accordance with standard accepted procedures and calibrated prior to testing, in accordance with the procedures specified in Part C (Method ON-2, Chapter 7.1, Appendix 2A) and Part E (Method ON-4, Chapter 6.2 and Appendix 4B). Such calibration data must be available on request, prior to or during the actual testing and also must be submitted with the final report.

2. Glass and quartz fibre substrates are checked visually against a light for irregularities and flaws or pinhole leaks. They are identified by appropriate labelling of their shipping containers (Petri dishes).

3. Substrates are desiccated at 20°C ±6°C and ambient pressure for at least 24 hours and then weighed at intervals of at least 6 hours to a constant weight, i.e., 0.5 mg change from the previous reading. Weight of substrates is recorded to the nearest 0.1 mg. Record the substrates weighing room relative humidity which must not exceed 50% during weighing. The filter should not be exposed to the ambient atmosphere for longer than 2 minutes.

4. Clean all parts of the cascade impactor of any dirt and soiling material, and inspect the material for plugged jets by holding the jet stage up to the light to determine if plugging exists. Then, assemble the impactor to check for missing parts.

6.2 Preliminary Survey

1. Select the sampling site location and number of sampling points in accordance with Part B (Method ON-1).

2. Determine gas flow parameters in order to prepare for actual sampling at isokinetic rates. Gas temperature, molecular weight, static pressure and the velocity profile (including cyclonic and reverse flow checks) are required parameters for this purpose. It is also important to know the range of particulate matter loading so that a sampling period can be established.

   The parameters noted above can be determined by performance of methods outlined in Parts C to F (Methods ON-2 to ON-5). For this purpose Method ON-5 may be modified. For example, total sampling time may be reduced by decreasing the number of sampling points or the sampling time per point.

   The information learned from such a test would include the gas temperature, velocity profile, moisture content and particulate matter loading. From this information, assuming the parameters of the source remain constant, isokinetic sampling rates can be calculated and the proper nozzle size determined. Also, the sampling period can be determined so as to meet the minimum criteria for particulate matter catch or total gas volume sampled.

   The recommended isokinetic error limit for the above procedure is that each point sampled by an impactor should have a point velocity that is within 20% of the impactor inlet velocity. Each of the traverse points which would be used in a standard Method ON-5 run should be sampled. If the ratio of the minimum velocity to the maximum velocity is greater than 1.5, multiple impactor runs are required.

3. Select a nozzle size and adjust the initial guess at the impactor flow rate so as to obtain the required sampling velocity for each traverse region.

4. Make a preliminary guess for the impactor flow rate by calculating the time to collect a total sample of 50 mg particulate (sum of precollector, all stages and filter weights). The following equation is used for this calculation:

$$T_{50mg} = \frac{0.83335}{Q_i G_a}$$

Eq. 7-1

where:

Q_i = actual impactor flow rate (m^3/s)

G_a = mass loading (mg/m^3)

When possible, 1-hour test-runs should be conducted; but, the minimum criteria for the actual testing period depends on the mass loading of the stack gas, the size distribution of the particles, and the gas flow rate in the sampler. If the results of a mass test are available, the mass loading can be obtained from them. If not, an estimate should be made based on the pre-test survey or other information. Given the mass concentration, an estimate of the sampling time for initial tests can be obtained from the nomograph shown in Figure 7-5.

The desired particle deposition on each of the collection plate substrate needs to be sufficient to weight (not less than 0.05 mg), but not too much that the particles overload the substrate (not more than 20 mg). The amount of particles that can be collected on a collection plate depends on the type of particles and the particle diameter. The larger particles are more likely to bounce or re-entrain.

5. Depending on the gas stream particulate loading, multi-stage impactors can be assembled adding a pre-collector to knock out large diameter particles. Note that the pre-collector should only be used when heavy particulate loading is expected.

   Select the stages that will give the desired stage cuts at this flow rate without resulting in particle bouncing or a very low Reynolds number. Most commercially available impactors come with fixed set of stages which are used at all times and no decision as to which stages to use is required. In some

cases, a variety of stages are available and those most suitable to the sampling condition should be used.

If data regarding a particular particle diameter is desired, the cut point of two stages should bracket this diameter for reliable interpolation of the mass less than this diameter. If the target diameter is large, the cut point of the largest stage should be as close to the desired diameter as possible to reduce extrapolation errors.

6.3 Sampling Train Preparation

1. Place about 100 ml of distilled or deionized water in each of the first 2 impingers and weigh each of the first three impingers and record to the nearest 0.5 g or measure the volume of water in each impinger to the nearest 1.0 ml.

2. Place 200 to 300 g of desiccant in the fourth impinger, the weight being taken either directly or as the tared weight of desiccant and impinger and recorded to the nearest 0.5 g.

3. Assemble the impactor with the selected impact plates and pre-weighed, numbered substrate (in a clean sheltered area). Attach to the impactor the calibrated nozzle and the precollector (if applicable). Conduct a preliminary leak check of the impactor/precollector combination. This leak check is optional. The purpose of this leak check is to catch and correct any leaks before sampling.

4. Assemble the sampling train, keeping all openings where contamination could occur covered until just prior to assembly or until sampling is about to begin.

5. A pre-test leak-check is required and it is performed according to the following procedure:

   Pre-Test Leak-Check

   a) Plug the nozzle or inlet to the probe.

   b) Draw a vacuum of 380 mm Hg or the highest vacuum anticipated to occur during the test. The recommended procedure for drawing a vacuum is to start the pump with the bypass valve fully open and the coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the bypass valve until the desired vacuum is reached. Do not reverse direction of the bypass valve; this will cause water to back up into the filter holder.

   c) Slowly remove the plug from the nozzle and immediately turn off the vacuum pump. This prevents the water in the impingers from being forced into the filter holder and silica gel from being entrained into the third impinger.

6. Mark the probe with heat-resistant tape or other suitable means to enable to exact positioning of the probe at the sampling points.

7. Clean the portholes prior to the test run to minimize the chance of sampling deposited material.

6.4 Sampling Train Operation

1. Start the probe and heating system. Before commencing the test, verify that the heating system maintains a temperature of 120°C. Place crushed ice around the impingers (if this type of condensing apparatus is used).

2. Remove any protective covering from the nozzle and position the nozzle at the first sampling point, ensuring that all components of the probe assembly are properly oriented with respect to the gas stream, i.e., nozzle and Pitot tube face opening planes are perpendicular to the direction of flow. Block off openings around the probe and porthole to prevent dilution of the gas stream.

3. Immediately start the pump and adjust the flow rate to the pre-determined sampling rate. If the stack is under significant negative pressure (several centimetres of H_2O) take care to close the coarse adjust valve before inserting the probe into the stack to prevent water from backing into the filter holder. If necessary, the pump may be turned on with the coarse adjust valve closed.

4. Ensure that the probe nozzle does not make contact with the stack wall or ports, thus minimizing the chance of extracting deposited material.

5. For each traverse, data are recorded according to the format shown in Part F (Method ON-5, Table 5-1). These data shall be recorded for each sampling point or velocity region selected (constant sampling rate with a nozzle chosen to be isokinetic, ±20%).

   The dry gas meter volume is recorded at the start of the test and at the end of each of these time periods. The other information in the various columns is recorded at some time during each of the periods. Periodically check the gas flow rate through the test period to ensure isokinetic flow. To do this, record the gas meter volume and divide by the test-time. The gas sampling flow rate through the cascade impactor should remain constant during the test-run

6. During the test run, ensure that the probe and filter bypass (or filter housing) are maintained at 120°C and that the temperature at the outlet of the impingers is less than 20°C. It may be necessary to add more ice and possibly salt to attain the required temperature. Periodically check the level and the zero of the manometer.

7. If the pressure drop across the sampling train becomes too high, stop the test. Check for potential overloaded substrate. If it is suspected that the filter is overloaded, reject the test and repeat the test-run. A leak-check must be conducted before disassembling the train.

8. At the end of the test-run, face the impactor downstream and close the course adjust valve, record the final dry gas meter reading. Remove the probe making sure not to bump the impactor against the stack wall or sampling ports. Turn off the pump.

   Note: No leak check should be performed after the particle sizing has been completed, as it will likely change the particle distribution in the fractionation head due to sudden changes in pressure and velocity.

6.5 Sample Recovery

1. Upon removing the probe from the port, allow the sampling train to cool until it can be safely handled.

2. Wipe off all external particulate matter near the tip of the probe nozzle, pre-collector and impactor. Place a cap over the nozzle probe to prevent the loss or contamination of the sample. The probe tip should not be tightly capped while the sampling train is cooling as this would create a vacuum in the filter bypass, thus drawing water from the impingers into the impactor.

3. Remove the probe from the sampling train and cover the exposed end, being careful not to lose any sample in the probe. Remove the umbilical cord.

4. The probe and impactor-impinger assembly should be removed to a clean and sheltered area; making sure that the impactor is maintained and transported in an upright position to avoid loss or shifting of PM among the unit stages.

5. Inspect the components. Note and report any damage or abnormalities.

6. Remove the nozzle-precollector and impactor from the probe. Carefully remove the plates or inserts using a pair of tweezers and clean disposable surgical gloves, and place them in Petri dishes. Label and seal each Petri dish.

7. If it is desired to determine the moisture content of the exhaust gas, disassemble the impinger train. Weigh the impingers and their contents or seal the impingers for later weighing. Note and report the condition of the silica gel (i.e., the extent of saturation).

8. Measure and record the amount of liquid caught in the first three impingers to the nearest 0.5 g or 1.0 ml.

6.6 Laboratory Analysis

1. Transfer each collection plate inserts from the Petri dishes to a tared weighing dish. Desiccate for 24 hours at 20°C ± 6°C and ambient pressure. Then weigh them at intervals of at least 6 hours to a constant weight (report the weights to the nearest 0.1 mg.). Record the weighing room relative humidity, which must not exceed 50%. Samples should not be exposed to the ambient atmosphere for longer than 2 minutes.

   If the sampled particulate matter is hygroscopic, a constant weight may be impossible to achieve. If this situation is encountered, the dry weight may be determined by weighing the sample at specific time intervals after removal from the dessicator (e.g., every 30 seconds), plotting the weight versus the time from removal and then extrapolating the graph to time zero to determine the desiccated weight.

2. Retain all samples for at least 6 months after the test series. They are to be made available upon request by the Ministry.

3. Calculate the change in weight for each collection plate insert. Add up the difference to get the total particulate matter collected by the cascade impactor. Divide the amount collected on each plate insert by the total amount collected, to find what percentage of the total particle weight was collected on each plate insert.

4. For known materials, if using Stokes diameter, the particle density may be calculated from handbook values of the specific gravity of the material. For unknown materials, the particle density may be assumed to be 1.0 g/cm^3 and the particle sizes reported as the equivalent aerodynamic diameter.

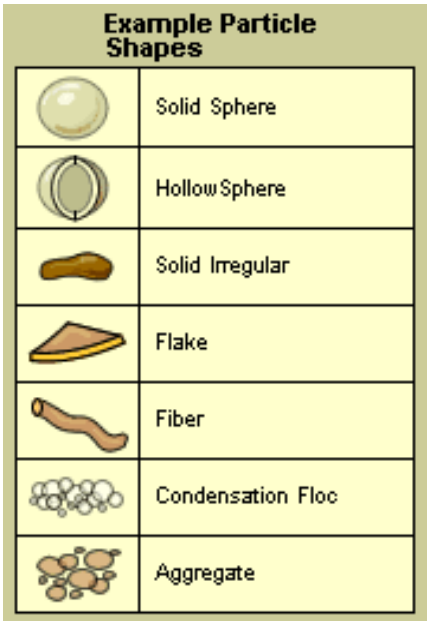
5. Graph the results on log probability paper with the particle diameter (d) as the ordinate and cumulative percent by weight as the abscissa. It is recommended to draw the particle size distribution line through each of the data points (rather than trying to draw a straight or curved line) because this presents the data in an unedited format.

7.0 THEORETICAL FRAMEWORK ON PARTICLES

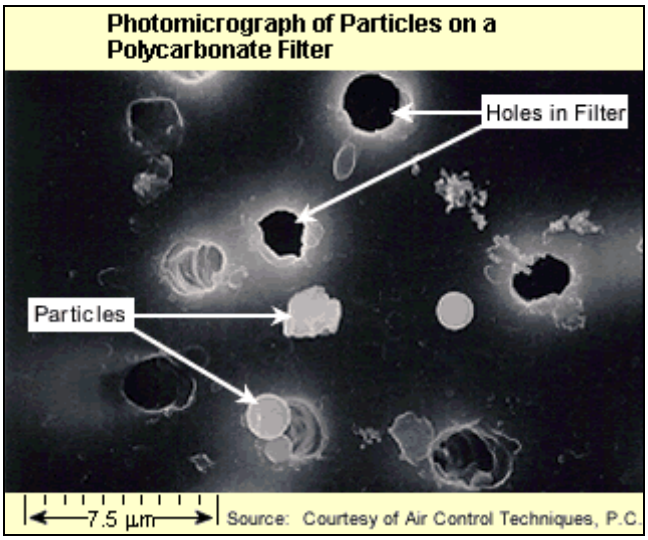
The following information is aimed at providing a better understanding on particles and their characterization. This information was transcribed from the US EPA's Training module on Basic Concepts in Environmental Sciences.

7.1 Aerodynamic Diameter

Particles emitted from air pollution sources and formed by natural processes have a number of different shapes and densities as indicated in the following diagram.



The photomicrograph below shows a variety of spherical particles and irregularly shaped particles collected on a polycarbonate filter.



Defining particle size for spherical particles is easy; it is simply the diameter of the particle. For non-spherical particles, the term "diameter" does not appear to be strictly applicable. For example, what is the diameter of a flake of material or a fibre? Also, particles of identical shape can be composed of quite different chemical compounds and, therefore, have different densities. The differences in shape and density could introduce considerable confusion in defining particle size.

In air pollution control, it is necessary to use a particle size definition that directly relates to how the particle behaves in a fluid such as air. The term "aerodynamic diameter" has been developed by aerosol physicists in order to provide a simple means of categorizing the sizes of particles having different shapes and densities with a single dimension. The **aerodynamic diameter** is the diameter of a spherical particle having a density of 1 gm/cm^3 that has the same inertial properties in the gas as the particle of interest.

The aerodynamic diameter for all particles greater than 0.5 micrometer can be approximated using the following equation (Eq. 7-2). Refer to aerosol textbooks to determine the aerodynamic diameter of particles less than 0.5 micrometer.

$$dpa = Dps\sqrt{\rho_p}$$

Eq. 7-2

where:

dpa = Aerodynamic particle diameter (µm)

Dps = Stokes diameter (µm)

ρ_p = Particle density (g/cm^3)

Particle density affects the motion of a particle through a fluid and is taken into account in Equation 7-2. The Stokes diameter for a particle is the diameter of the sphere that has the same density and settling velocity as the particle. It is based on the aerodynamic drag force caused by the difference in velocity of the particle and the

surrounding fluid. For smooth, spherical particles, the Stokes diameter is identical to the physical or actual diameter.

Inertial sampling devices such as cascade impactors are used for particle sizing. These sampling devices determine the aerodynamic diameter. The term "aerodynamic diameter" is useful for all particles including fibres and particle clusters. It is not a true size because "non-spherical" particles require more than one dimension to characterize their size.

Particles that appear to have different physical sizes and shapes can have the same aerodynamic diameter as illustrated below.

Aerodynamic Diameters of Differently Shaped Particles

	Solid sphere	ρ_p = 2.0 gm/cm^3 d_{ps} = 1.4 µm	d_{pa} = 2 µm
	Hollow sphere	ρ_p = 0.5 gm/cm^3 d_{ps} = 2.8 µm	
	Irregular shape	ρ_p = 2.4 gm/cm^3 d_{ps} = 1.3 µm	

Note: ρ_p = Particle density
d_{ps} = Stokes particle diameter
d_{pa} = Aerodynamic diameter

Conversely some particles that appear to be visually similar can have somewhat different aerodynamic diameters as illustrated below.

Aerodynamic Diameters of Particles with Different Densities			
	Low-density particle	ρ_p = 1 gm/cm^3 d_{ps} = 2 µm	d_{pa} = 2.0 µm
	Medium-density particle	ρ_p = 2 gm/cm^3 d_{ps} = 2 µm	d_{pa} = 2.8 µm
	High-density particle	ρ_p = 3 gm/cm^3 d_{ps} = 2 µm	d_{pa} = 3.5 µm

Note: ρ_p = Particle density
d_{ps} = Stokes particle diameter
d_{pa} = Aerodynamic diameter

7.2 Particle Size Categories

7.2.1 Particle Size Terminology

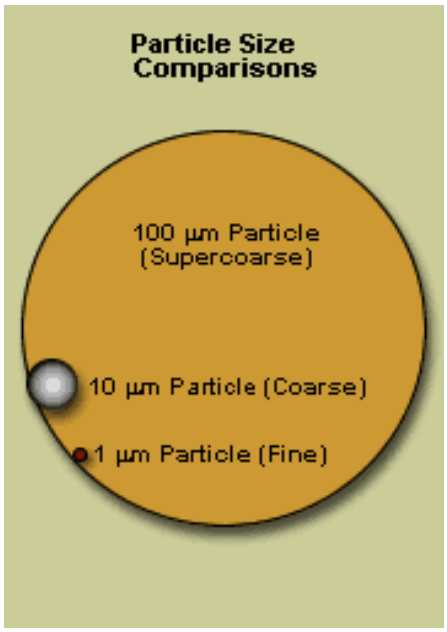
Since the range of particle sizes of concern for air emission evaluation is quite broad it is beneficial to divide this range into smaller categories. Defining different size categories is useful since particles of different sizes behave differently in the atmosphere and the respiratory system.

The following table displays the particle size terminology along with the corresponding particle sizes.

Terminology for Particle Sizes	
Description	**Particle Size**
Super-coarse	$d_{pa} > 10$ µm
Coarse	2.5 µm $< d_{pa} \leq$ 10 µm
Fine	0.1 µm $< d_{pa} \leq$ 2.5 µm
Ultra-fine	$d_{pa} \leq$ 0.1 µm

The following diagram provides a visual comparison of the size of a fine particle (1.0 µm), coarse particle (10 µm), and a super-coarse particle (100 µm). There is a

substantial difference in size between these particles, all of which are considered moderate-to-large in air pollution control.



7.2.2 Particulate Matter Categories

In addition to the terminology provided in the previous table, the particles are categorized as follows:

(i) Total Suspended Particulate Matter (TSP);

(ii) PM_{10};

(iii) $PM_{2.5}$; and,

(iv) Condensable Particulate Matter.

7.2.2.1 Total Suspended Particulate Matter

Particles ranging in size from 0.3 micrometer to about 40 micrometer in diameter are referred to as total suspended particulate matter (TSP). TSP includes a broad range of particle sizes including fine, coarse, and super-coarse particles.

7.2.2.2 PM_{10}

PM_{10} is defined as the sum of both the filterable particulate matter fraction with an aerodynamic diameter of 10 micrometers and less, and the condensable particulate matter fraction.

PM_{10} is considered a specific type of contaminant because this size range is considered respirable. In other words, particles less than approximately 10 micrometers can penetrate into the lower respiratory tract. The particle size range between 0.1 and 10 micrometers is especially important in air pollution studies. A major fraction of the particulate matter generated in some industrial sources is in this size range.

7.2.2.3 $PM_{2.5}$

$PM_{2.5}$ is defined as the sum of both the filterable particulate matter fraction with an aerodynamic diameter of 2.5 micrometers and less, and the condensable particulate matter fraction.

$PM_{2.5}$ particles settle quite slowly in the atmosphere relative to coarse and supercoarse particles. Normal weather patterns can keep $PM_{2.5}$ particles airborne for several hours to several days and enable these particles to cover hundreds of miles. $PM_{2.5}$ particles can cause health problems due to their potentially long airborne retention time and the inability of the human respiratory system to defend itself against particles of this size.

In addition, the chemical makeup of $PM_{2.5}$ particles is quite different than for coarse and supercoarse particles. US EPA data indicate that $PM_{2.5}$ particles are composed primarily of sulphates, nitrates, organic compounds, and ammonium compounds. The US EPA also determined that $PM_{2.5}$ particles often contain acidic materials, metals and other contaminants believed to be associated with adverse health effects.

7.2.2.4 Condensable Particulate Matter

Particulate matter that forms from condensing gases or vapours is referred to as condensable particulate matter. Condensable particulate matter forms by chemical reactions as well as by physical phenomena.

Condensable particulate matter is usually formed from material that is not particulate matter at stack conditions but which condenses and/or reacts upon cooling and dilution in the ambient air to form particulate matter. The formation of condensable particulate matter occurs within a few seconds after discharge from the stack.

From a health standpoint, condensable particulate matter is important because it is almost entirely contained in the $PM_{2.5}$ classification.

7.3 Particle Size Distribution

7.3.1 Interpretation of Raw Data

Particulate matter for size distribution evaluation is measured in a variety of ways. The data must be measured in a manner whereby it can be classified into successive particle diameter size categories.

In the case of cascade impactors, particulate matter is separated into diameter size categories within the impactor head during sampling. The mass of particulate matter contained within each size range is recovered and determined gravimetrically.

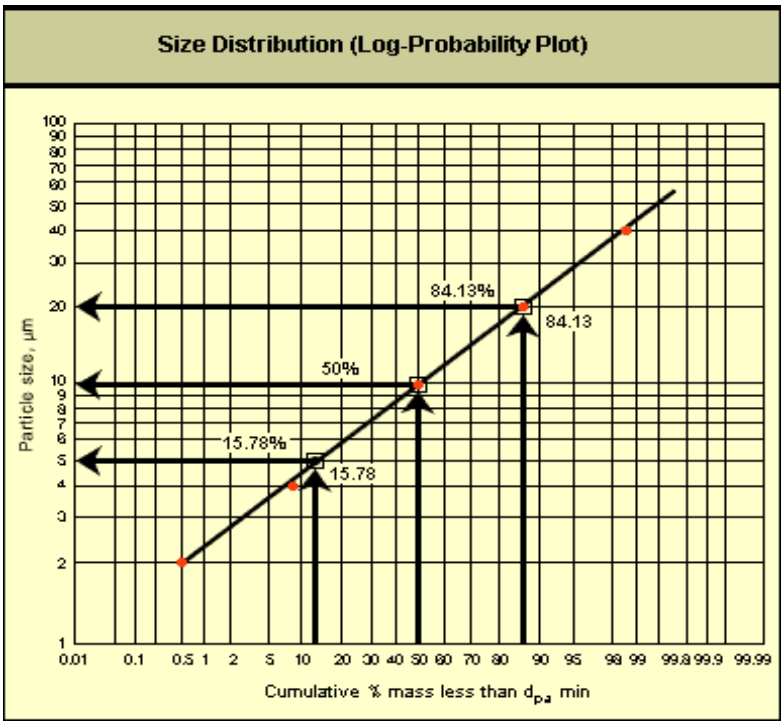
7.3.2 Sample Calculations

Calculation of both the mass median particle diameter and the geometric standard deviation for the following lognormal distribution data.

Particle Size Data				
Size Range (µm)	**d_{pa} min (µm)**	**Concentration (µg/m^3)**	**% Mass in Size Range**	**Cum. % Mass < d_{pa} min**
0 - 2	-	1.0	0.5	-
2 - 4	2	14.5	7.25	0.5
4 - 6	4	24.7	12.35	7.75
6 - 10	6	59.8	29.90	20.1
10 - 20	10	68.3	34.15	50.0
20 - 40	20	28.9	14.45	84.13
> 40	40	2.8	1.4	98.6
		Total = 200.0		100.0

Procedure:

1. Plot the distribution data from the above table on log-probability paper, as illustrated below:



The straight line indicates that the particle size data set is lognormal.

2. Using the graph, determine the approximate particle size at 15.78%, 50%, and 84.13% probability.

3. Determine the mass median particle diameter:

   Mass median particle diameter = d_{50} = 10 µm

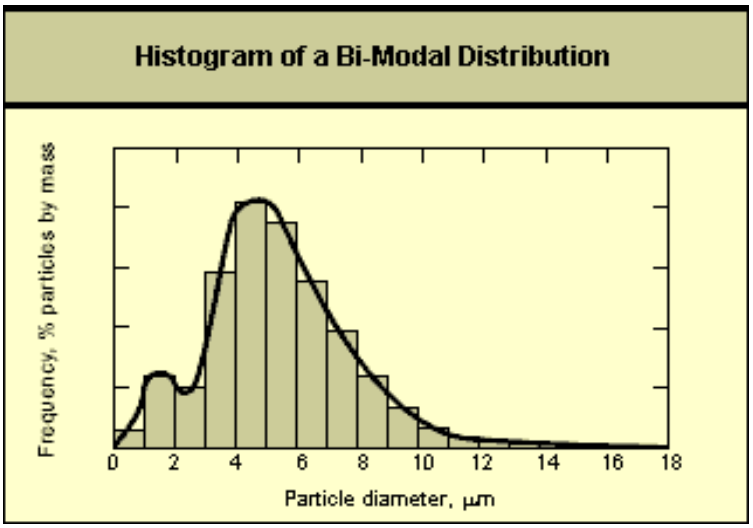
4. Determine the geometric standard deviation of the particle mass distribution.

$$\sigma_g = \frac{d_{50}}{d_{15.78}} = \frac{10\,\mu m}{5\,\mu m} = 2.0$$

or:

$$\sigma_g = \frac{d_{84.13}}{d_{50}} = \frac{20\,\mu m}{10\,\mu m} = 2.0$$

Particle size distributions resulting from complex particle formation mechanisms or several simultaneous formation mechanisms may not be lognormal. As shown in the following diagram, these distributions may exhibit more than one peak (multi-modal).



In these cases, plots of the data on log-probability paper will not yield a straight line. In order to characterize this type of particle size data, it may be necessary to treat the data as two separate lognormal distributions.

8.0 REFERENCES

1. California Air Resources Board, Method 501 – Determination of Size Distribution of Particulate Matter Emissions from Stationary Sources, September 1990.

2. Marple, V.A. and K.L. Rubow, Chapter 4: Theory and Design Guidelines, Cascade Impactors: Sampling & Data Analysis, Eds. J.P. Lodge and T.L. Chan, A.I.H.A. 475 Wolf Ledges Parkway, Akron, OH 44331, 1986.

3. Pilat, M., Operations Manual Pilat (University of Washington) Mark 3 and Mark 5 Source Test Cascade Impactor, University of Washington, Seattle, January 1998.

4. United States Environmental Protection Agency, Education and Outreach, Basic Concepts in Environmental Sciences – Module 3: Characteristics of Particles, September 1990.

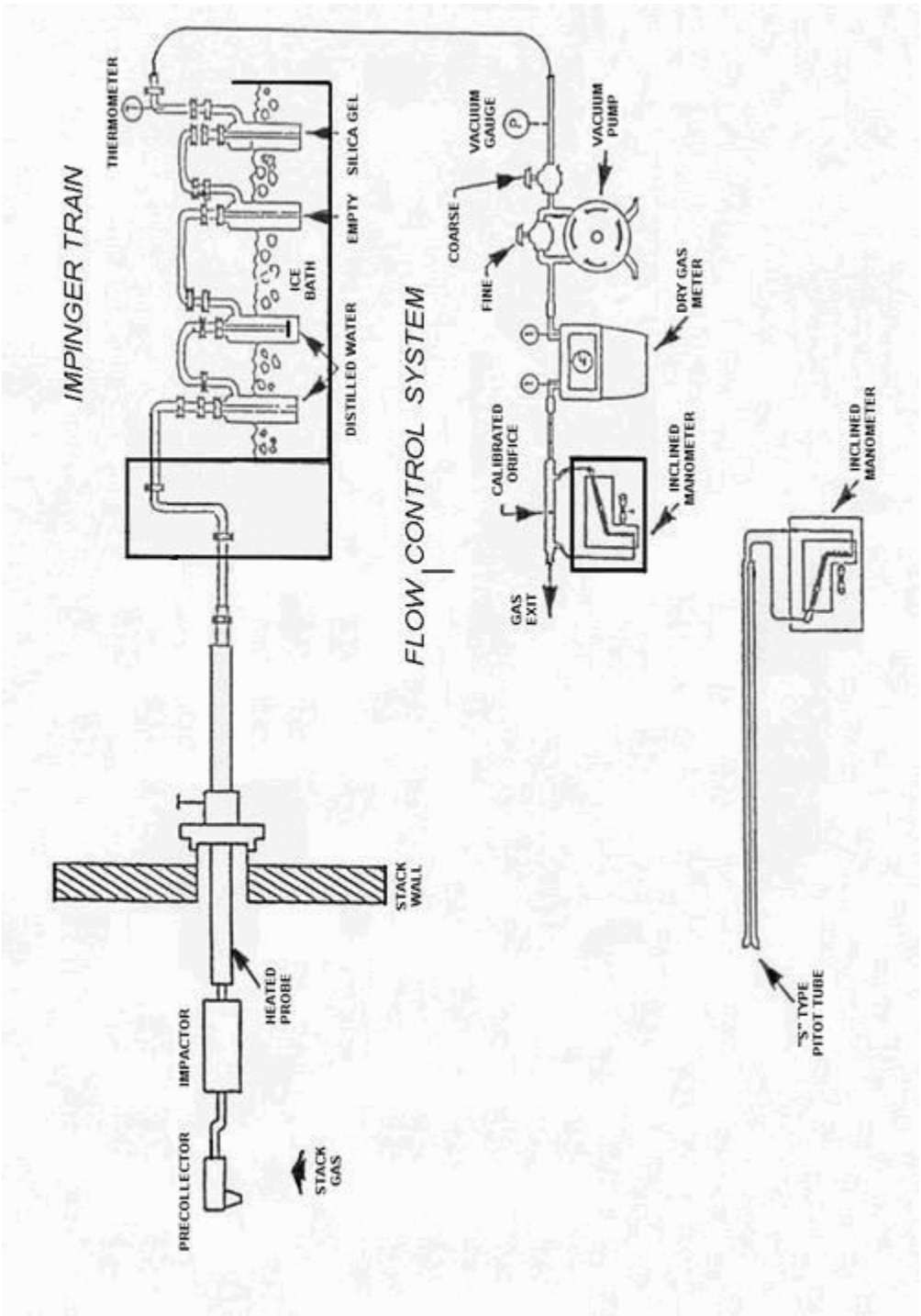


FIGURE 7-1: CASCADE IMPACTOR PARTICULATE SAMPLING TRAIN

FIGURE 7-2: VIEW OF A RIGHT ANGLE PRECOLLECTOR

FIGURE 7-3: CROSS SECTION OF A UNIVERSITY OF WASHINGTON MARK 5 CASCADE IMPACTOR

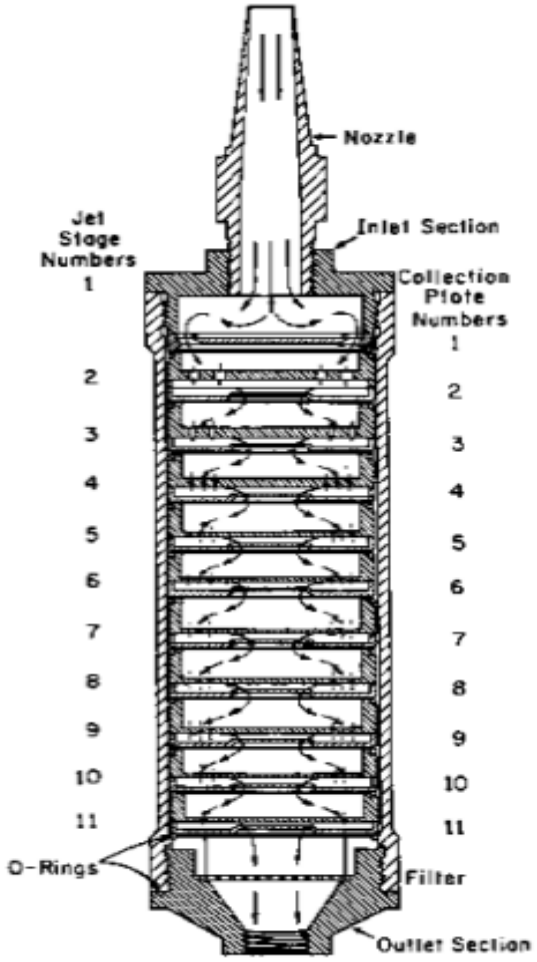


FIGURE 7-4: EXPANDED VIEW OF PARTS TO THE UNIVERSITY OF WASHINGTON SEVEN STAGE CASCADE IMPACTOR

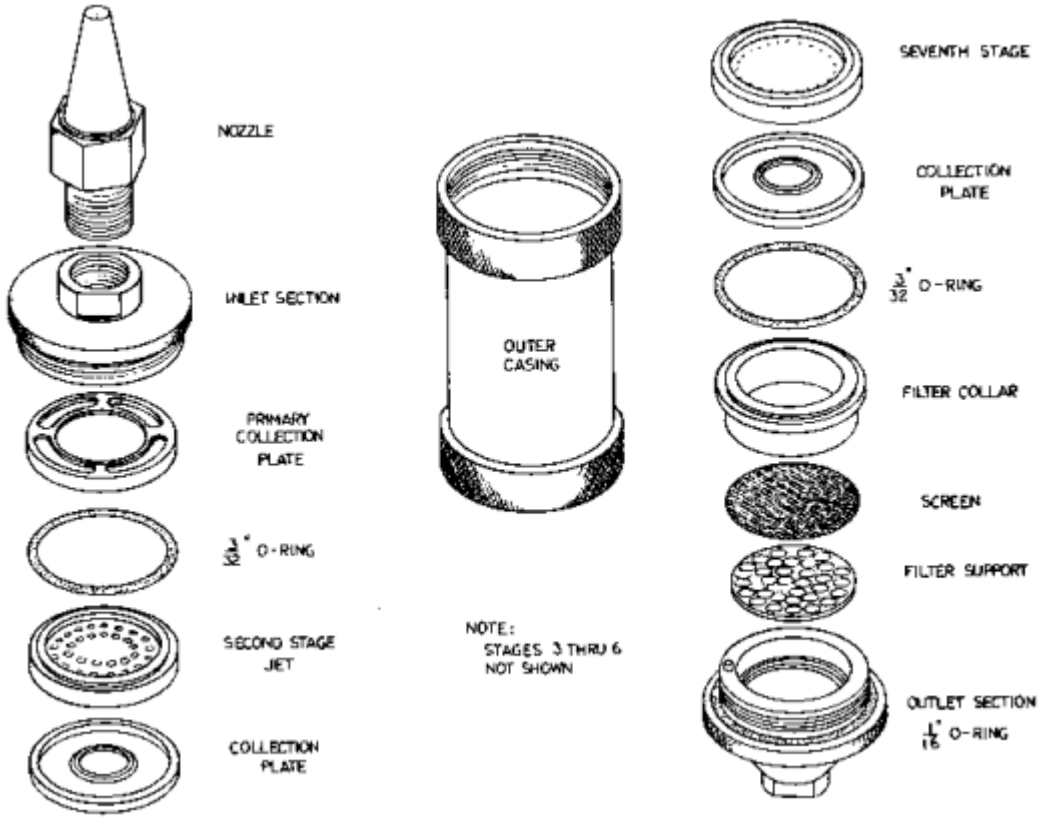
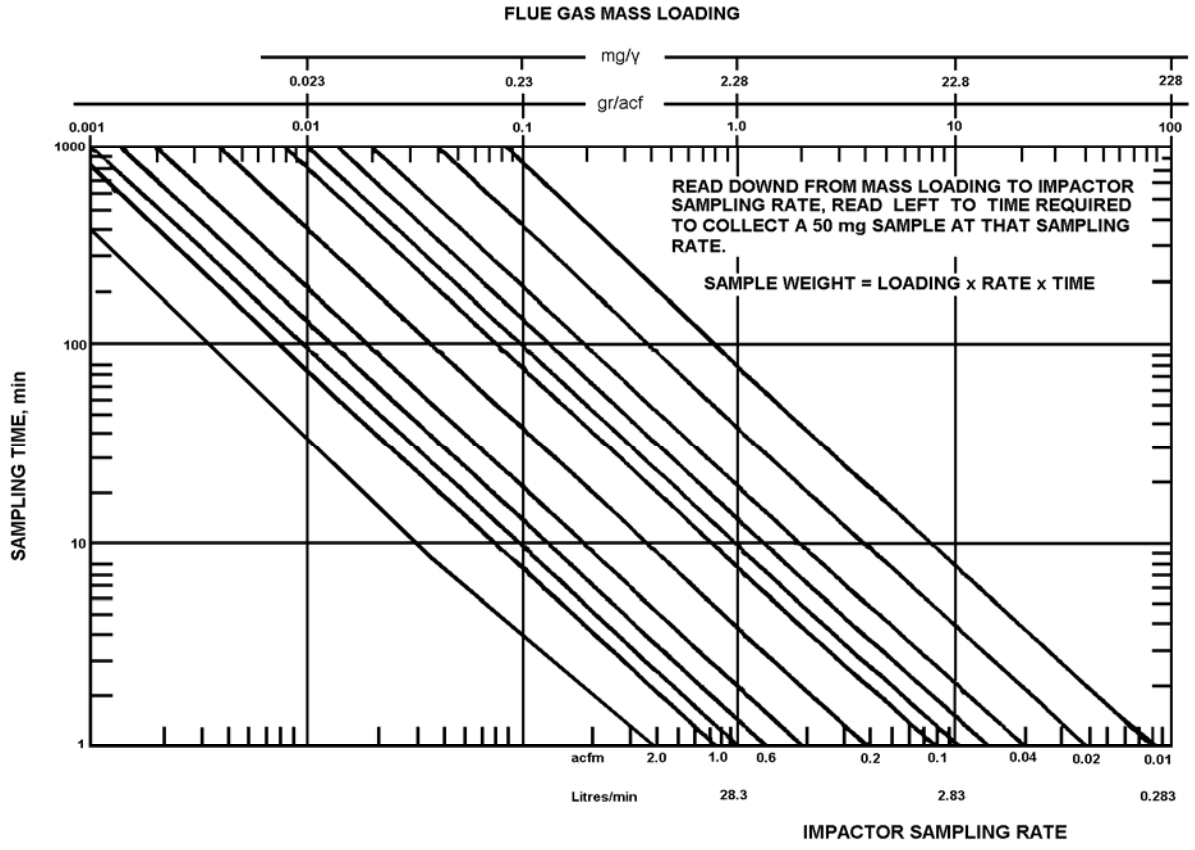


FIGURE 7-5: NOMOGRAPH FOR DETERMINING SAMPLING TIME (50 mg SAMPLE)



Attachment 1: Reference Source Testing Methods

This Attachment contains a list of acceptable methods for the measurement of emissions of air pollutants from stationary sources when such emission data are required for the purpose of determining compliance with the Environmental Protection Act of the Province of Ontario and the regulations thereunder.

These methods comprise the most up-to-date procedures available at the date of issue of this Code; however, as new and improved techniques become available, the most current version of the methods shall be used when conducting source testing.

The stack gas parameters determination are covered in detail in Parts B to E (Methods ON-1 to ON-4) of this code, and are commonly used for each stack gas test. However, these four methods are often performed simultaneously when using Method ON-5 or modified Method ON-5 sampling trains.

For contaminants without established reference test methods the proponent should demonstrate to the satisfaction of the Source Assessment Specialist that the stack gas sampling, sample recovery and analysis accurately represent what is being discharged to the atmosphere.

1. LIST OF REFERENCE SOURCE TESTING ASSESSMENT METHODS FOR CONTAMINANTS LISTED IN O.REG.419/05

Item	CAS No.	Contaminant	Reference Method (Source Testing)
1.	75-07-0	Acetaldehyde	CARB Method 430
2.	64-19-7	Acetic Acid	NIOSH Method 1603 - Modified
3.	67-64-1	Acetone	US EPA SW-846 Method 0030
4.	74-86-2	Acetylene	OSHA Chemical Sampling Information
5.	79-06-1	Acrylamide	OSHA Method 21 - Modified
6.	107-13-1	Acrylonitrile	US EPA SOP #1704
7.	7664-41-7	Ammonia	US EPA Method CTM-027
8.	7440-36-0	Antimony	US EPA 40CFR60 Method 29
9.	7784-42-1	Arsine	NIOSH Method 6001 - Modified
10.	7440-41-7	Beryllium and compounds	US EPA 40CFR60 Method 29
11.	7440-42-8	Boron	US EPA 40CFR60 Method 29
12.	10294-33-4	Boron Tribromide	OSHA CSI Method – Modified
13.	10294-34-5	Boron Trichloride	US EPA 40CFR60 Method 29, or US EPA 40CFR60 Method 26
14.	7637-07-2	Boron Trifluoride	OSHA CSI Method – Modified
15.	7726-95-6	Bromine	US EPA 40CFR60 Method 26
16.	7440-43-9	Cadmium	US EPA 40CFR60 Method 29

Item	CAS No.	Contaminant	Reference Method (Source Testing)
17.	1305-62-0	Calcium Hydroxide	US EPA 40CFR60 Method 29
18.	1305-78-8	Calcium Oxide	US EPA 40CFR60 Method 29
19.	1333-86-4	Carbon Black	OSTC Method ON-5
20.	75-15-0	Carbon Disulphide	Environment Canada Method EPS 1/RM/6
21.	630-08-0	Carbon Monoxide	US EPA 40CFR60 Method 10
22.	56-23-5	Carbon Tetrachloride	US EPA SW-846 Method 0030
23.	7782-50-5	Chlorine	US EPA 40CFR60 Method 26
24.	10049-04-4	Chlorine Dioxide	NCASI Technical Bulletin 520
25.	67-66-3	Chloroform	US EPA SW-846 Method 0030
26.	-	Chromium - Speciation	US EPA SW846 Method 0061
27.	7440-47-3	Chromium – Total	US EPA 40CRF60 Method 29
28.	7440-50-8	Copper	US EPA 40CFR60 Method 29
29.	1319-77-3	Cresols	NIOSH Method 2546 - Modified
30.	17702-41-9	Decaborane	OSHA CSI Method – Modified
31.	117-81-7	Di(2-ethylhexyl) Phthalate	NIOSH Method 5020 – Modified
32.	19287-45-7	Diborane	NIOSH Method 6006 – Modified
33.	131-15-7	Dicapryl Phthalate	OSHA Method 104 – Modified
34.	106-46-7	Dichlorobenzene, 1,4-	Environment Canada Method EPS 1/RM/2
35.	624-92-0	Dimethyl Disulphide	Environment Canada Method EPS

Item	CAS No.	Contaminant	Reference Method (Source Testing)
			1/RM/6
36.	75-18-3	Dimethyl Sulphide	Environment Canada Method EPS 1/RM/61/RM/6
37.	117-84-0	Di-n-Octyl Phthalate	OSHA Method 104 – Modified
38.	-	Dustfall	ASTM Method D1739-98 (2004)
39.	141-78-6	Ethyl Acetate	US EPA 40CFR60 Method 18 -Tedlar® Bag - GC-FID
40.	140-88-5	Ethyl Acrylate	NIOSH Method 1450 - Modified
41.	100-41-4	Ethyl Benzene	US EPA SW-846 Method 0030
42.	60-29-7	Ethyl Ether	NIOSH Method 1610 - Modified
43.	107-06-2	Ethylene Dichloride	US EPA SW-846 Method 0030
44.	1309-37-1	Ferric Oxide	US EPA 40CFR60 Method 29
45.	7664-39-3	Fluorides (as HF) - Gaseous (Growing Season)	US EPA 40CFR60 Method 13B
46.	7664-39-3	Fluorides (as HF) - Total (Growing Season)	US EPA 40CFR60 Method 13B
47.	7664-39-3	Fluorides (as HF) - Total (Non-Growing Season)	US EPA 40CFR60 Method 13B
48.	50-00-0	Formaldehyde	CARB Method 430
49.	64-18-6	Formic Acid	NIOSH Method 2011 - Modified
50.	98-01-1	Furfural	NIOSH Method 2529 - Modified

Item	CAS No.	Contaminant	Reference Method (Source Testing)
51.	98-00-0	Furfuryl Alcohol	NIOSH method 2505 - Modified
52.	7647-01-0	Hydrogen Chloride	US EPA 40CFR60 Method 26/26A
53.	7783-06-04	Hydrogen Sulphide	US EPA 40CFR60 Method 11
54.	15438-31-0	Iron (metallic)	US EPA 40CFR60 Method 29
55.	-	Isocyanates Speciation	US EPA CTM-036
56.	98-82-8	Isopropyl Benzene (cumene)	US EPA SW-846 Method 0030
57.	7439-92-1	Lead	US EPA 40CFR60 Method 29
58.	7439-93-2	Lithium	US EPA 40CFR60 Method 29
59.	7580-67-8	Lithium Hydrides	US EPA 40CFR60 Method 29
60.	1309-48-4	Magnesium Oxide	US EPA 40CFR60 Method 29
61.	74-93-1	Mercaptans	Environment Canada Method EPS 1/RM/6
62.	7439-97-6	Mercury (Hg)	US EPA 40CFR60 Method 29
63.	7439-97-6	Mercury (Hg)	US EPA 40CFR60 Method 30B
64.	7439-97-6	Mercury (as Hg) – alkyl compounds	US EPA 40CFR60 Method 101
65.	67-56-1	Methanol (Methyl Alcohol)	US EPA 40CFR60 Method 308
66.	96-33-3	Methyl Acrylate	NIOSH Method 2537 - Modified
67.	71-55-6	Methyl Chloroform (1,1,1-Trichloroethane)	US EPA SW-846 Method 0030

Item	CAS No.	Contaminant	Reference Method (Source Testing)
68.	78-93-3	Methyl Ethyl Ketone (2-Butanone)	US EPA SW-846 Method 0030
69.	108-10-1	Methyl Isobutyl Ketone	US EPA SW-846 Method 0030
70.	80-62-6	Methyl Methacrylate	NIOSH Method 2537 - Modified
71.	-	Milk Powder	OSTC Method ON-5
72.	-	Mineral Spirits (Naphthas)	NIOSH Method 1550 - Modified
73.	74-89-5	Monomethyl Amine	OSHA Method 40 – Modified
74.	142-82-5	n-Heptane	US EPA SW-846 Method 0030
75.	7440-02-0	Nickel	US EPA 40CFR60 Method 29
76.	13463-39-3	Nickel Carbonyl	NIOSH Method 6007 - Modified
77.	7697-37-2	Nitric Acid	US EPA Method CTM027 – Modified
78.	139-13-9	Nitrilotriacetic Acid	BC Laboratory Methods Manual
79.	10102-44-0	Nitrogen Oxides	US EPA 40CFR60 Method 7E
80.	10028-15-6	Ozone	OSHA Method 214 – Modified
81.	19624-22-7	Pentaborane	OSHA CSI Method - Modified
82.	108-95-2	Phenol	US EPA 40CFR60 Method 318
83.	75-44-5	Phosgene	US EPA Draft Method
84.	7664-38-2	Phosphoric Acids	CARB Method 421
85.	85-44-9	Phthalic Anhydride	OSHA Method 90 – Modified
86.	78-87-5	Propylene Dichloride	NIOSH Method 1013 - Modified

Item	CAS No.	Contaminant	Reference Method (Source Testing)
87.	75-56-9	Propylene Oxide	NIOSH Method 1612 - Modified
88.	7440-22-4	Silver	US EPA 40CFR60 Method 29
89.	100-42-5	Styrene	US EPA SW-846 Method 0030
90.	7446-09-5	Sulphur Dioxide	US EPA 40CFR60 Method 6C
91.	7664-93-9	Sulphuric Acid	US EPA 40CFR60 Method 8
92.	-	Suspended Particulate Matter (< 44 µm Diameter)	OSTC Method ON-5
93.	13494-80-9	Tellurium (except hydrogen telluride)	US EPA 40CFR60 Method 29
94.	109-99-9	Tetrahydrofuran	NIOSH Method 1609 - Modified
95.	7440-31-5	Tin	US EPA 40CFR60 Method 29
96.	7440-32-6	Titanium	US EPA 40CFR60 Method 29
97.	108-88-3	Toluene	US EPA SW-846 Method 0030
98.	584-84-9	Toluene Di-isocyanate, 2,4-	US EPA CTM-036
99.	79-01-6	Trichloroethylene (TCE)	US EPA SW-846 Method 0030
100.	76-13-1	Trifluorotrichloroethane	US EPA SW-846 Method 0030
101.	7440-62-2	Vanadium	US EPA 40CFR60 Method 29
102.	75-01-4	Vinyl Chloride	US EPA 40CFR60 Method 106

Item	CAS No.	Contaminant	Reference Method (Source Testing)
103.	75-35-4	Vinylidene Chloride (1,1-Dichloroethene)	US EPA SW-846 Method 0030
104.	1330-20-7	Xylenes	US EPA SW-846 Method 0030
105.	7440-66-6	Zinc	US EPA 40CFR60 Method 29

O. Reg. 419/05; O. Reg. 605/05.

ASTM – The American Society for Testing and Materials

BC – British Columbia

CARB – State of California Air Resources Board

CSI – OSHA Chemical Sampling Information

NIOSH – US National Institute for Occupational Safety and Health

OSHA – US Occupational Safety & Health Administration

OSTC – Ontario Source Testing Code

SOP – Standard Operating Procedure

US EPA – United States Environmental Protection Agency

2. LIST OF REFERENCE SOURCE TESTING ASSESSMENT METHODS FOR CONTAMINANTS NOT LISTED IN O.REG.419/05

Item	Contaminant	Reference Method (Source Testing)
1.	Aldehydes	CARB Method 430
2.	Acetic Acid	NIOSH Method 1603 - Modified
3.	Acetone	US EPA SW-846 Method 0030
4.	Asbestos	CARB Method 427, or Environment Canada Method EPS 1-AP-75-1
5.	Benzene	CARB Methods 410A/410B
6.	Carbon Dioxide	US EPA 40CFR60 Method 3A
7.	Carbon Disulphide	US EPA 40 CFR60 Method 15
8.	Carbon Monoxide	US EPA 40CFR60 Method 10
9.	Carbonyl Sulphide	Environment Canada Method EPS 1/RM/2
10.	Chlorobenzene	Environment Canada Method EPS 1/RM/2
11.	Chlorophenol	Environment Canada Method EPS 1/RM/2*
12.	Chromium Speciation	US EPA SW846 Method 0061
13.	Chromium - Total	US EPA 40CRF60 Method 29
14.	Cyanide	CARB Method 426
15.	Dioxins	Environment Canada Method EPS 1/RM/2**

Item	Contaminant	Reference Method (Source Testing)
16.	Ethylene Oxide	CARB Method 431
17.	Furans	Environment Canada Method EPS 1/RM/2**
18.	Hydrogen Halides	US EPA 40CFR60 Methods 26/26A
19.	Hydrogen Sulphide	US EPA 40CFR60 Method 11
20.	Isocyanates Speciation	US EPA CTM-036
21.	Metals	US EPA 40CFR60 Method 29
22.	Mercury Speciation	ASTM Method D6784-02
23.	Microbial Survivability Test for Medical Waste Incinerator Emissions	US EPA Method CTM-026
24.	Odour	OSTC Method ON-6
25.	Opacity	US EPA 40CFR60 Method 9
26.	Orthophosphate	Alberta Method 45050/45051
27.	Oxygen	US EPA Methods 3A
28.	PM10	US EPA 40CFR60 Method 201A
29.	PM10/PM2.5	US EPA Method CTM-040
30.	Particulate Matter (Condensable)	US EPA 40CFR60 Method 202
31.	Polonium 210	US EPA 40CFR60 Method 111
32.	Polychlorinated Dibenzo-p-Dioxins	Environment Canada Method EPS 1/RM/2**

Item	Contaminant	Reference Method (Source Testing)
33.	Polychlorinated Dibenzo Furans	Environment Canada Method EPS 1/RM/2**
34.	Polychlorinated Biphenyls (PCBs)	Environment Canada Method EPS 1/RM/2
35.	Polynuclear Aromatic Hydrocarbons	Environment Canada Method EPS 1/RM/2***
36.	Total Gaseous Non-methane Organics	US EPA Method 25
37.	Total Gaseous Organics	US EPA Method 25A
38.	Total Reduced Sulphur (TRS) – Non-Speciated	US EPA Method
38.	Total Reduced Sulphur (TRS) - Speciated	Environment Canada Method EPS 1/RM/6
39.	Urea	Alberta Method 47575
40.	Volatile Organic Constituents****	US EPA SW-846 Method 0030

Alberta – Alberta Environment (Canada)

CARB – State of California Air Resources Board

US EPA – United States Environmental Protection Agency

OSTC – Ontario Source Testing Code

* This method must be used in conjunction with Environment Canada's Method 1/RM/3 and the Methodology for Organic Analysis - NITEP/Mid-Connecticut Combustion Test.

** This method must be used in conjunction with Environment Canada's Method 1/RM/3 and Report EPS 1/RM/23.

*** This method must be used in conjunction with Environment Canada's Methodology for Organic Analysis - NITEP/Mid-Connecticut Combustion Test.

****Refer to the reference method for a list of constituents that can be sampled with this method.

Attachment 2: Guidebook to Prepare a Pre-Test Plan Document

ACKNOWLEDGEMENT

This document is based on the U. S. Environmental Protection Agency's "Guidebook on the Preparation and Review of Site-Specific Test Plans". It has been adapted to reflect requirements specific to Ontario, e.g., references to Certificates of Approval.

PURPOSE AND USE OF GUIDEBOOK

The purpose of this guidebook is to provide a standard format for preparing pre-test plans for compliance source test programs such as those required by Certificates of Approval, Provincial Officers' Orders and notices issued by the Ontario Ministry of Environment.

The same guidebook format should be used for source test programs if the results are intended to be accepted as representative and accurate by the Ministry. Any tests done for these reasons and to this level of Quality Assurance/Quality Control (QA/QC) are referred to as being of "compliance quality."

A properly prepared pre-test plan should include written descriptions, summary tables, and figures that encompass all aspects in the planning of an emissions test program. The pre-test plan is to provide the information necessary to determine whether a testing organization understands the objectives of the test and whether the test includes appropriate procedures to accomplish these objectives.

The pre-test plan guidebook has been developed to facilitate the preparation of pre-test plans by outlining the information required. Following this guidebook will make the preparation of the pre-test plan easier and more effective.

SUMMARY OF SOURCE TESTING PROCEDURE

1. A compliance test is a source test conducted for the purpose of determining compliance with the Environmental Protection Act of Ontario or the regulations promulgated thereunder, performed and reported in accordance with the requirements of Part A of this code. The Ministry must be advised of any proposed compliance testing prior to testing and supplied with a term of reference which should include at least relevant process and test information.

   If required, a Ministry official must be allowed to tour the process, inspect the sampling site and witness the sampling tests. It must be demonstrated that the testing was performed at process conditions effecting the maximum pollutant emissions, e.g., at normal maximum production rates excluding process upsets, and that the test results truly represent the emissions from this source. A complete final report must be submitted to the Ministry.

2. Three replicate samples must be taken over a sufficient time to represent the source accurately. Refer to this Code's Parts A through F for specific requirements.

3. Under the Ministry's normal practice, compliance source testing may be witnessed by the Ministry, if deemed necessary.

4. Following the Ministry’s approval of the pre-test plan, the Company shall notify the Ministry in writing of the location, date and time of any impending Source Testing required for compliance, at least fifteen (15) days prior to the Source Testing.

5. In order to avoid unnecessary and unproductive time of witnessing staff on-site, it is important to keep this Ministry informed of any changes or delays in starting times for source tests. While downtime of equipment may be unforeseeable in some cases, an effort to minimize this during the time our staff is on-site would be greatly appreciated.

The appropriate regional office should be contacted to obtain the appropriate telephone number of Ministry staff looking after that specific plant or geographical area where the plant under study is located.

6. The emission test report resulting from the source testing should be submitted to the Ministry.

TABLE OF CONTENTS FOR PRE-TEST PLAN FORMAT

Following is the first element of the step-by-step guide to completing a pre-test plan. We suggest that this Table of Contents be retained with the appropriate page numbers filled in. If this Table of Contents is not used, all the necessary elements outlined in it should be contained in your pre-test plan.

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PRE-TEST PLAN FORMAT

1.0 INTRODUCTION

1.1 Summary of Test Program

In this chapter, write a brief summary that identifies or states, as applicable, the following in the order presented:

1. Responsible groups or organizations.
2. Overall purpose of the emission test.
3. Certificate of Approval Number/Control Order.
4. Industry.
5. Name of plant.
6. Plant location.
7. Processes of interest.
8. Air pollution control equipment, if applicable.
9. Emission points and sampling locations.
10. Pollutants to be measured in tabular form.
11. Method of Analysis for each pollutant.
12. Expected dates of test.

1.2 Previous Certificate of Approval Source Test and Results

1.3 Test Program Organization

1. Company Name (as in Certificate of Approval):

   Company Address:
   Plant Location:
   Plant Coordinator:
   Name:
   Position:
   Telephone No. Fax No.
   Directions and/or map to the test site.

2. Ministry of Environment and Energy District Office:

   Name of local Environmental Officer:
   Telephone No. Fax No.

3. Sampling Company:

   Project Co-ordinator:
   Telephone No. Fax No.
   Sampling Team:

4. Analytical Laboratory:

   Project Co-ordinator:
   Telephone Number: Fax No.

Provide all the above information for any other parties or organizations participating in the source testing program.

1.4 Organization Chart

Provide an organization chart.

Example of Test Program Organization Chart (Figure 1)

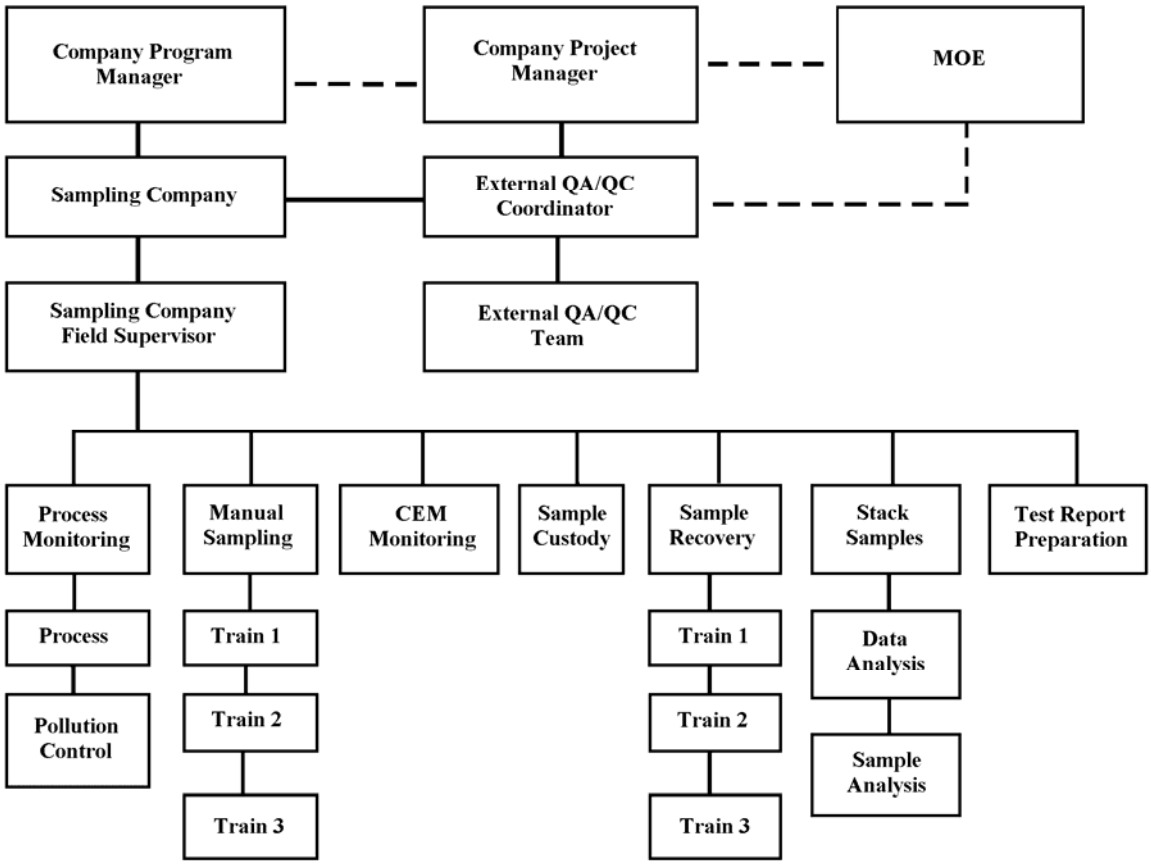


FIGURE 1: TEST PROGRAM ORGANIZATION CHART

2.0 SOURCE DESCRIPTION

2.1 Process Description

> All production rates and operating parameters should be at levels of maximum production within the approved operating range of the Equipment as required by the Certificate of Approval or Control Order (or at the operating level stated in the legal document used by the Ministry). If the production rates and operating parameters at which the test is run are at a lower rate, it may lead to reconsideration of the Certificate of Approval conditions.

In this chapter of the pre-test specify the North American Industry Classification System (NAICS) code (or codes) that apply to the facility, for classification of the emissions discharging from the facility.

This chapter consists of two parts: the process description and the process operation. The process description should familiarize the reader of the pre-test plan with the process and provide an insight understanding on how the unit operates. The process operation portion provides the reader with a general view of the process in terms of production and scheduling of processes.

2.1.1 Description of the process

State the plant's main line of product (or products) and its production rate. Give a brief description of the overall plant processes and operating areas. Provide a complete step-wise description of the process under study, including size and operating capacity of relevant units/equipment; nature of the source (i.e., batch, continuous, cyclic); identify fuels and feed materials used; identify by-products and final product; list design feed rates or batch sizes and actual feed and production rates; and indicate the relationship of the source or process under investigation to the overall or other plant process (i.e., other lines or processes that may affect the emissions of the source or process under investigation).

This subchapter should also include a flow diagram of the overall process (Figure 2), accompanied by an appropriate text describing the stages of the process. In this flow diagram, trace the process from the beginning to the end. Identify the major operations. Show only those gas, liquid, and solid flow streams that relate to the process under scrutiny. Indicate emission and process stream test points.

2.1.2 Process Operation

In the process operation subchapter, the normal plant operating schedule in hours per day, days per week, and weeks per year should be given. The overall plant design capacity and average operating rates should be given in terms of product, by-product, and feed rates of fuels and raw materials. Indicate peak operating capacity. Include summaries of estimated process information concerning rates of production and feed over the sampling periods. Include any factor or operating condition that might affect the testing or emissions.

List of key operating parameters:

1. Number of shifts at plant:
2. Shift hours:
3. Normal Operating hours for Equipment: hours/day
   days/week
   weeks/year
4. Warm-up Time for Equipment:
5. Total number of lines:
6. Normal number of lines operating simultaneously:
7. Maximum number of lines operating simultaneously:
8. Indicate if Process is: Batch/Cyclic
   Continuous
   Other

9. Components of Product:
10. Components of Feed:
11. Type of Product:
12. Type of Feed:
13. Certificate of Approval Maximum Feed Rate/Maximum Production Rate:
14. Production Rate of Product:
15. Production Rate of Feed:
16. Temperature (°C) of Process:
17. Any other Parameters Required by Certificate of Approval or relevant to the process.

Note: The sampling consultant must verify with the plant operator that the process is running under the required capacity (as per Certificate of Approval, Control Order or maximum operating capacity); that the monitoring, collection and recording of the process data is appropriate; and that the recorded and reported process data is representative of the process under study.

2.2 Control Equipment Description

In this chapter, familiarize the reader of the pre-test plan with the number, types and location of all the air pollution control units that pertain to the process under study. Include the configuration of the pollution control systems and provide an insight understanding on how each unit operates.

1. Discussion of typical control equipment operation and, include a schematic (Figure 3).
2. List of key operating parameters and physical configurations:

   a) Baghouse

      (i) Cleaning mode: reverse flow _____

      pulse jet flow _____

      mechanical _____

(ii) Filter media: type _____

Treatments _____

(iii) Filter bag dimensions: Length _____

Diameter _____

(iv) Type of bag support: cage _____

(v) Rings _____

(vi) Number of filter bags: _____

(vii) Cloth to air ratio: _____

(viii) Cleaning to filtering flow ratio: _____

(ix) Number of compartments: _____

(x) Frequency of cleaning: _____

(xi) Pressure drop: _____

(xii) Frequency of change of filter bags: _____

b) Scrubber

(i) General Type: wet: _____

Dry: _____

(ii) Specific Type: venturi: _____

centrifugal/cyclonic: _____

flow submersion: _____

conditioning tower: _____

other (specify): _____

(iii) Type of nozzles: _____

(iv) Pressure at the nozzles: _____

(v) Water flow rate: _____

(vi) Pressure drop: _____

(vii) Scrubber operating temperature: _____

(viii) Scrubbing solution: _____

(ix) Type of media (conditioning tower): _____

(x) Direction of the scrubbing solution with respect to the exhaust gas:

concurrent: _____

counter-current: _____

tangential: _____

(xi) pH of scrubbing solution: _____

(xii) Fixed or variable gas flow: _____

c) Cyclone

(i) Type: single:_____

Multiple: _____

(ii) ID fan amps: _____

(iii) FD fan amps: _____

(iv) Gas temperature: _____

(v) Pressure drop: _____

(vi) Material recovery time: _____

d) Electrostatic Precipitator

(i) Type: wet: _____

Dry: _____

(ii) Cleaning mode: _____

(iii) Number of compartments: _____

(iv) Primary voltage: _____

(v) Secondary voltage: _____

(vi) Primary amps: _____

(vii) Secondary amps: _____

(viii) Sparks per minute: _____

(ix) ID fan amps: _____

e) For each air pollution control unit/equipment (if applicable), provide the following information. Also list any existing or required continuous emission monitors.

(i) Temperature (As required by C of A): (°C): _____, actual:_____

(ii) Percent Oxygen:_____, actual:_____

(iii) Percent Carbon Monoxide:_____, actual:_____

(iv) Continuous Emission Monitors:_____, actual:_____

(v) Other C of A Requirements:_____, actual:_____

3. Normal operating ranges of key parameters

_____

2.3 Exhaust System Characteristics

This chapter consists of two parts: the exhaust system and the exhaust gas. The exhaust system description portion should familiarize the reader of the pre-test plan with

the exhaust system configuration. The exhaust gas characteristics portion provides the reader with a preliminary evaluation of the exhaust gas.

2.3.1 Exhaust Gas System

In this subchapter include a detailed description of the exhaust system, encompassing the type of exhaust fan and location, material of construction, flue orientation and number of flues, sampling ports orientation and location, stack height, building height, and any additional information that helps the reader better understand this part of the source under investigation.

2.3.2 Exhaust Gas System

In this subchapter include the following information:

1. Source of the data provided (data based on):
    (i) preliminary survey;
    (ii) engineering estimates;
    (iii) mass balance;
    (iv) emission factors; and
    (v) previous measurements

2. Date of above information.

3. Complete the Flow Characterization Table below:

	Present	Not Present
Reverse Flow		
Cyclonic Flow		
Stratification		

4. Velocity: _____ (m/s)
5. Moisture Content: _____ (%)
6. Expected Contaminant Concentration: _____ (mg/m^3)
7. Temperature: _____ (°C)
8. Velocity Pressure Head: _____ (mm)
9. Other Chemical Constituents Present: _____ (mg/m^3)

Note: Raw field data sheets, with the above information, are to be included in the appendix.

3.0 TEST PROGRAM

3.1 Objectives

In this chapter:

1. Restate the overall purpose of the test program.
2. List (in order of priority) the specific objectives for both emissions and process operation data.

3.2 Test Matrix

Include a table showing the following (include schematics, if helpful):

1. Sampling locations
2. Number of runs
3. Sample type/pollutant
4. Sampling method
5. Sample run time
6. Analytical method
7. Analytical laboratory

> It is not necessary that full test copies of methods be provided if the method to be used is included in Part G – Chapter 10 (Appendices to Method ON-6) of this Code. Include only a full reference containing the date of publication and the number of the method. For any other methods, a full test copy should be included. Always ensure that you are using the most current version of the method.

Example of Test Matrix (Table 1) and Measurements at each Test Location (Table 2)

3.2 TEST MATRIX

Table 1 presents the sampling and analytical matrix. Table 2 shows all the measurements being made at each test location.

TABLE 1: *[PLANT, LOCATION]* TEST MATRIX

Sampling Location	No. of Runs	Sample/Type Pollutant	Sampling Method	Sample Run Time (min)	Analytical Method	Analytical Laboratory
Location #1	3	Moisture Content	OSTC Method ON-4			
	3	Molecular Weight	OSTC Method ON-3			
	3	Velocity Traverse	OSTC Method 2			
	3	Particulate	OSTC Method ON-5			
Location #2						

TABLE 2: MEASUREMENTS AT EACH TEST LOCATION

RUNS 1, 2, AND 3	
Test Location 1	Test Location 2
RUNS 4, 5, AND 6	

RUN 1	RUN 2	RUN 3

Notes: 1. Indicate which tests are to be run concurrently.

2. Unless otherwise specified, all tests within the test matrix should be conducted within the same testing period.

4.0 SAMPLING LOCATIONS

4.1 Flue Gas Sampling Locations

Please provide a schematic of the exhaust system and the following information for each source.

1. Source:

2. Stack Height: _____ (m) above grade
   _____ (m) above roof

3. Stack Diameter: _____ (m)
   (Please provide dimensions and equivalent diameter if square duct)

4. Type of source: Virtual _____
   Point _____

5. Sampling ports location: _____ (m) above grade
   _____ (m) above roof

6. Diameter:

7. No. of Ports: _____
   Configuration/Orientation:
   Ideal: _____ Non-Ideal: _____
   Downstream from any disturbance: _____ stack diameters (m)
   Upstream from any disturbance: _____ stack diameters (m)

8. No. and Configuration of traverse points:

9. If the source is non-ideal, please give reasons and discuss effect on results.

10. Discuss any proposed special traversing or measurement schemes.

To accurately locate geographically the point of emissions of the sources to be tested, provide the locations on Earth of the sources to be tested. Two approaches can be used: latitude/longitude system or the Universal Traverse Mercator (UTM) system. The UTM system provides coordinates (in meters) on a world wide flat grid for easy computation; while, the latitude/longitude system provides the location (in angles, minutes or arcs, and seconds of arcs) based on the Prime Meridian (Greenwich) and the Equator as the reference planes.

4.2 Process Sampling Locations

If process stream samples will be taken, include the following:

(i) Schematic of locations (Figure 4), if helpful (location can be shown in Figure 3 in Chapter 2.2)

(ii) Description of each sampling or measurement location

(iii) Sampling rate and type of sample (single or composite)

(iv) Discussion on the representativeness of each of the process stream sampling locations

5.0 SAMPLING and ANALYTICAL PROCEDURES

5.1 Test Methods

In this chapter:

1. State the proposed sampling method for each pollutant of the test matrix.

2. Provide flow diagrams of the sample recovery (if different from proposed sampling method).

3. Provide flow diagrams of the sample recovery and of the sample analysis (if different from proposed sampling method).

4. Description of any deviation/modifications from the reference sampling method(s) and reasons for requiring them.

5. Discussion of any problematic sampling or analytical conditions

Example of Sample Recovery Flow Diagram (Figure 5)

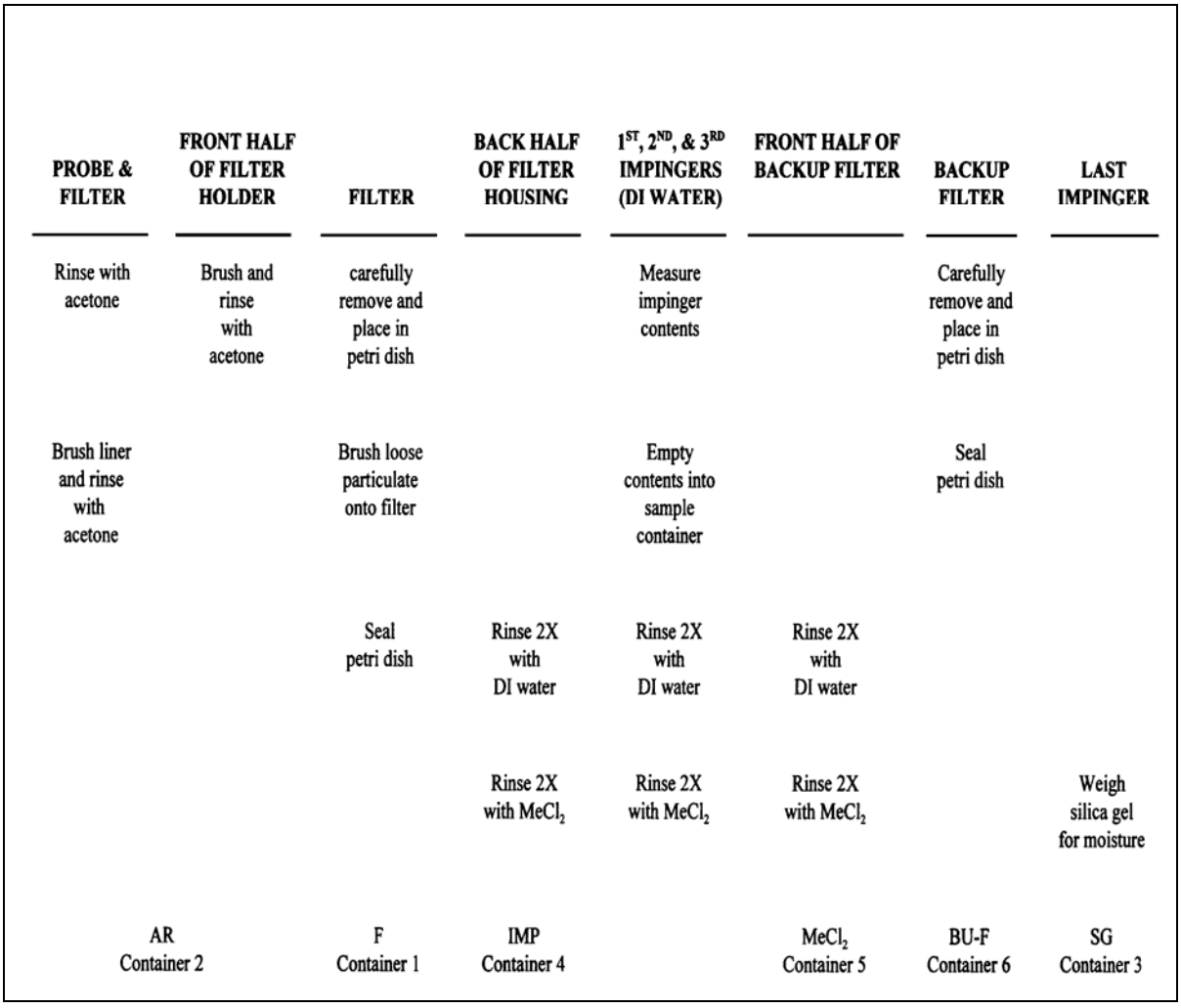


FIGURE 5: SAMPLE RECOVERY SCHEME FOR PARTICULATE/CONDENSIBLE SAMPLES

Example of Sample Analysis Flow Diagram (Figure 6)

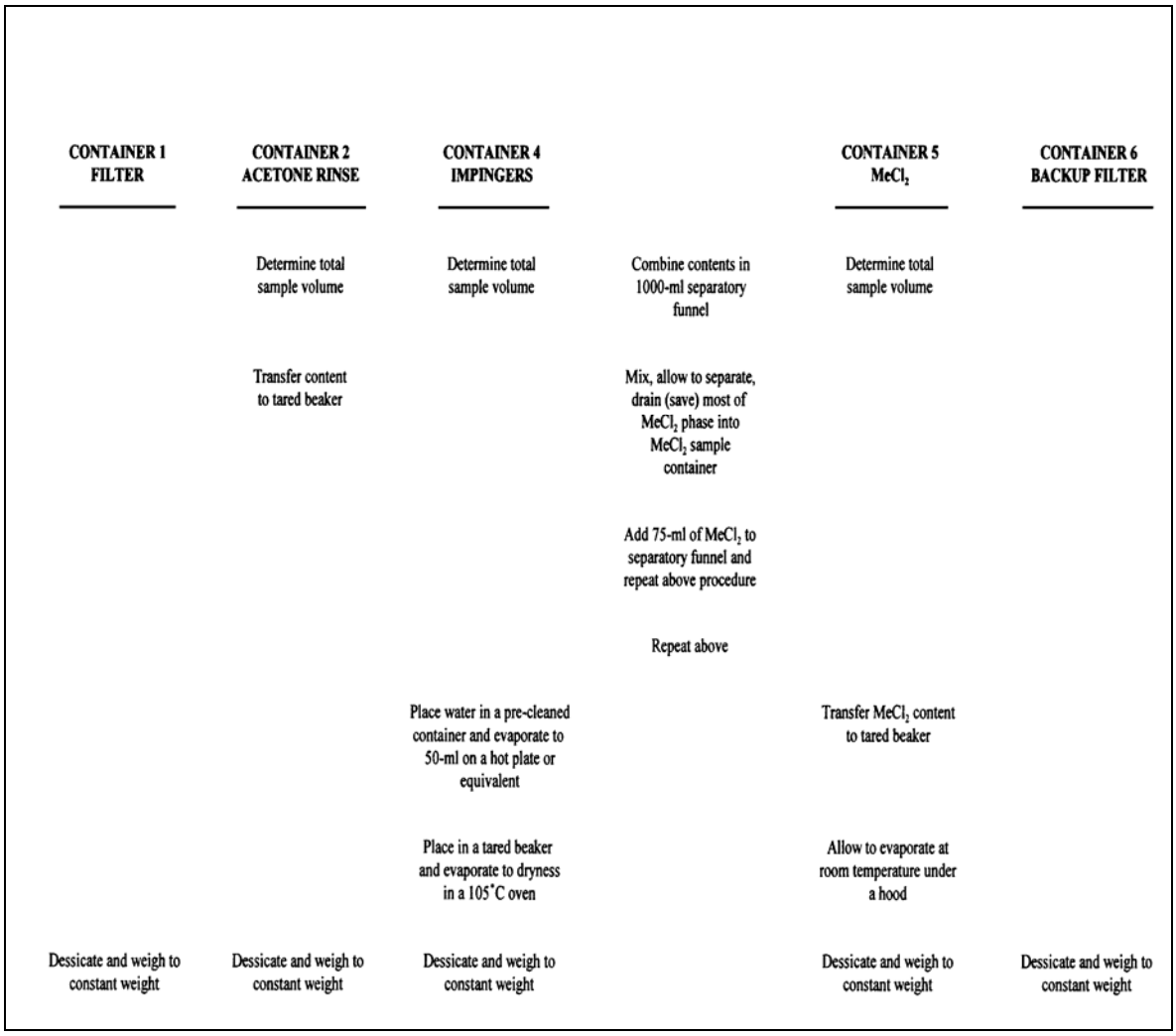


FIGURE 6 SAMPLE ANALYSIS FLOW DIAGRAM

5.2 Process Data

In this chapter, include the following:

1. Description of procedures for obtaining process stream and control equipment data.
2. Frequency of collection of this information.

Note: It is the responsibility of the sampling contractor to ensure the collection, accuracy and reporting of the process data. Source Testing reports without proper supporting process data may be rejected by the Ministry's Regional Director.

Example of Process Data Discussion (Chapter 5.2)

5.2 PROCESS DATA

The following process operation data will be collected:

(a) Number of press loads during EFB inlet/outlet testing;

(b) Number of press loads during press vent testing;

(c) Dryer inlet and outlet temperatures;

(d) Belt speed;

(e) EFB bed voltage and current; and

(f) EFB ionizer voltage and current.

The [Process Monitor] will count the number of press loads, and obtain the dryer data from the central control panel and the EFB data from the EFB control panel every 5 minutes.

6.0 INTERNAL QA/QC ACTIVITIES

6.1 QA/QC Procedures

In this chapter, provide the following for each test method:

1. Data sheets (see example on following page).

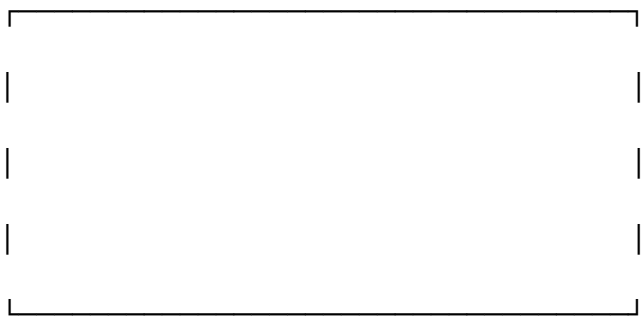
Example of Velocity Field Data Sheet (Figure 7)

Date: _____ Run No. _____

Plant _____ Start Time: _____

Test Location _____

Operator _____



Schematic: Cross-Section

Pitot ID No. _____

Pitot coeff: C_p = _____

Last calibrated Date: _____

Pitot condition: _____

Gauge sensitivity:

Req'd _____ mm H_2O

Port/ Traverse Pt.	Δp mm H_2O	Stack temp. °C

Actual _____ mm H_2O

Calibration:

Pre-test _____

Post-test _____

Leak check: (None)

Pre-test: _____

Post-test: _____

Temp. ID No. _____

Temp. calibration: (1.5% abs)

Pre-test _____

Post-test _____

Barometric pressure gauge calibration:

(1 in. Hg)

Pre-test _____

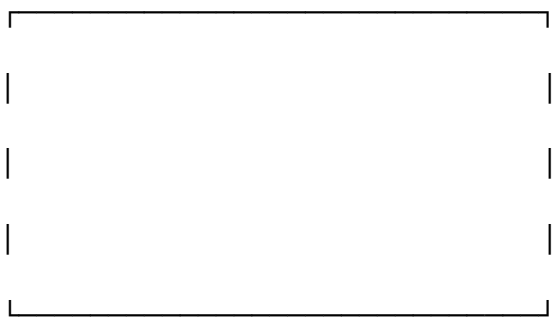
Post-test _____

Barometric pressure: P_b = _____ in. Hg

Static pressure: P_s = _____ in. Hg

Pitot configuration/assembly:

Sketch/dimensions



Checked for completeness by (Signature/Title) _____

6.2 QA/QC Check Lists

Example of a QA/QC Check List

- **Continuous Emission Monitors**
- **Measurement System Performance Specifications**:
- **Analyzer Calibration Error**: Less than ±2% of the span for the zero, mid-range, and high-range calibration gases
- **Sampling System Bias** Less than ±5% of the span for the zero, and mid- or high-range calibration gases
- **Zero Drift**: Less than ±3%of the span over the period of each run
- **Calibration Drift**: Less than ±3% of the span over the period of each run
- **Interference Check**: Less than ±7% of the modified Method ON-6 result for each run
- **Analytical Range**: The span of the monitoring system (range) shall be selected such that the pollutant gas concentration equivalent to the emission standard is not less than 30% of the span. The calibration gas shall be selected equivalent to mid-range of the span of the monitoring system.

In addition to the above, include discussion of any special QC procedures.

6.3 QA/QC Checks for Data Reduction and Validation

In this chapter, describe the following:

1. Procedure for assuring accurate transfer of raw data and accuracy of calculations
2. Data quality indicators, such as
    (i) Comparing process O_2 monitor and CEM O_2 data,
    (ii) Comparing flow rates by different sampling trains,
    (iii) Isokinetic checks,
    (iv) Comparing relative concentrations,
    (v) Comparing data with previous field test results (if applicable), and
    (vi) Running mass balances.

6.4 Sample Identification and Custody

1. Person responsible.
2. Sample identification and chain-of-custody procedure.
3. Sample identification label.
4. Chain-of-custody form.
5. Sample log sheet.

Note: The scheme for identifying samples should be logical and easily deciphered, e.g., 2I-Pa-F means Run No. 2, inlet, particulate matter sample and filter.

7.0 REPORTING AND DATA REDUCTION REQUIREMENTS

7.1 Report Format

In this chapter, include:

1. Table of Contents for the test report

Example Table of Contents for Test Report

7.1 REPORT FORMAT

The Table of Contents for the report will be:

TABLE OF CONTENTS

List of Figures

List of Tables

PAGE

1. Introduction

1.1 Summary of Test Program X

1.2 Key Personnel X

2. Source and Sampling Location Descriptions

2.1 Process Description X

2.2 Control Equipment Description X

2.3 Flue Gas and Process Sampling Locations X

3. Summary and Discussion of Results

3.1 Objectives and Test Matrix X

3.2 Field Test Changes and Problems X

3.3 Discussion of Results (at least one for each objective) X

3.4 Recommendations X

3.5 Conclusions X

4. Sampling and Analytical Procedures

4.1 Emission Test Methods X

4.2 Process Test Methods X

4.3 Sample Identification and Custody X

5. QA/QC Activities X

APPENDICES

A - Results and Calculations

B - Raw Field Data and Calibration Data Sheets

C - Production and Pollution Abatement Equipment Operating Data

D - Certificate of Approval

E - Sampling Log and Chain-of-Custody Records

F - Analytical Data Sheets

G - Audit Data Sheets

H - List of Participants

I - Additional Information

J - Qualifications of Sampling Team

7.2 Data Reduction and Summary

In this chapter, include:

1. Data summary tables; include units (e.g., kg/kJoule, kg/tonne of product, dscm corrected to 11% $O_{2)}$.

The example (on the following page) is for only one of the sets of measurements.

Similar tables should be made for all sets of data.

Example of Summary Table Format of Emission Data (Table 3)

7.2 DATA REDUCTION AND SUMMARY

Table 3 shows the format to be used to summarize the data.

Method/Compound	Units	EFB Inlet				EFB Outlet				Press Vents			
		Run 1	Run 2	Run 3	Avg	Run 1	Run 2	Run 3	Avg	Run 1	Run 2	Run 3	Avg
Method 5 Particulate Loading Condensibles	mg/dscm mg/dscm												
Method 25A, THC	ppm												
Method 25A TGNMO Condensibles Non-condensibles	ppm ppm ppm												
Method 25B TGNMO Condensibles Non-condensibles	ppm ppm ppm												
CARB 430 Formaldehyde	mg/dscm												
Method 3A O_2 CO_2	% %												
Method 10, CO	ppm												
Method 7E, NO_X	ppm												
TOC	ppm												

TABLE 3: SUMMARY TABLE FORMAT OF EMISSION DATA

8.0 PLANT SAFETY REQUIREMENTS

8.1 Safety Responsibilities

Identify the following individuals:

1. Person responsible for ensuring compliance with plant entry, health, and safety requirements

   Name:

   Position:

   Telephone Number:

2. Facility person or safety officer who has the authority to impose or waive facility restrictions

   Name:

   Position:

   Telephone Number:

3. Tester who has authority to negotiate with facility person any deviations from the facility restrictions

   Name:

   Position:

   Telephone Number:

8.2 Safety Requirements

1. Safety Equipment. Please indicate which of the following are required on-site:

	Required	Not Required
Head Protection		
Foot Protection		
Eye Protection		
Hearing Protection		
Safety Belt or Harness*		
Respiratory Equipment*		
Other Protective Clothing or Equipment		
Safety Training Session		
Date of Session if Required		

* To be provided by Company if required

2. Sampling Locations: _____ Outdoors; _____ Indoors
3. Approximate Temperature of Sampling Location Work Area:
4. Please indicate access to the sampling location:
   (i) Stairs,
   (ii) Fixed Ladder,
   (iii) Scaffolding,

(iv) Portable Ladder, and

(v) Crane/Lift.

5. Other Safety Requirements:

9.0 PERSONNEL RESPONSIBILITIES AND TEST SCHEDULE

9.1 Test Personnel Responsibilities and Detailed Schedule

In this sub-chapter:

1. Provide a list of sampling staff, clearly identifying the project manager and the field team leader.
2. Provide a table or text detailing the test schedule.

Example of List of Test Personnel and Responsibilities (Table 4)

TABLE 4: TEST PERSONNEL AND RESPONSIBILITIES

Responsibility	Test Personnel
1. Project Manager/Field Coordinator	*[Name of Individual]*
2. Sampling Team Leader	
3. Field Technician	
4. Field Technician	
5. CEM Operator	
6. Process Data Collector	

Example of Daily Test Schedule for Test Program (Table 5)

TABLE 5: PROPOSED DAILY TEST SCHEDULE FOR TEST PROGRAM

MONDAY July 29, 20__	TUESDAY July 30, 20__	WEDNESDAY July 31, 20__	THURSDAY August 1, 20__
1. Travel to site 2. Establish test team/ 3. Plant communications 4. Set up test locations 5. Conduct preliminary measurements 6. Set up lab for sample recovery	1. Complete 2 test runs	1. Complete 3rd test run 2. Pack up all but Methods 25 and 25A equipment 3. Conduct 2 additional Method 25/25A runs 4. Collect 2 evacuated cylinder samples 5. Rest of staff drive home 6. Afternoon: Contingency test day	1. Conduct 1 additional Method 25/25A run 2. Collect 1 evacuated cylinder sample 3. Restore sites 4. Remaining staff drive home 5. Contingency test day

9.2 Test Preparations

In this sub-chapter (if applicable), describe or identify the following:

1. Construction of special sampling and analytical equipment
    (i) Description
    (ii) Dates for completion of work
2. Modifications to the facility, e.g., adding ports, building scaffolding, installing instrumentation, and calibrating and maintaining existing equipment

(i) Description

(ii) Dates for completion

3. Services provided by the facility, such as electrical power, compressed air, and water

   (i) List of all services to be provided by the facility

   (ii) Description of modifications or added requirements, if necessary

4. Provide Access to sampling sites

   (i) If modifications are necessary, indicate the modifications

5. Provide Sample recovery area

   (i) Description

   (ii) If a mobile recovery area or laboratory is used, installation location, and dates for installation

10.0 REFERENCES

List any references used here.

Attachment 3:Recommended Qualifications for Stack Sampling Team

It is essential for the production of valid test data that the emissions measurement program be performed by qualified personnel using proper test equipment.

The source sampling team should consist of no less than two persons to perform the tests at the sampling site. A third person should be included when sampling variable rate processes, to correlate the sampling activity with the manufacturing process. For multi-stack sampling, the team should be increased accordingly.

One of the two persons shall be the source testing supervisor or leader, who will ensure that sampling is conducted properly and that the process is operating at the maximum or required production rate.

The source testing supervisor or leader must have sufficient experience and understanding of industrial processes and source testing to perform activities outlined in the introduction. The supervisor or leader must have an educational background in engineering, engineering technology or environmental science, or at least two (2) years of source testing field experience conducting source testing.

The remaining members of the source testing team should have sufficient experience to prepare and operate source sampling trains in a competent manner. He or she should have successfully completed in-house or external training on source testing and have previous field experience in source testing using the reference methods mentioned in this code.

Other stack testing team members with no previous experience in source testing must have successfully completed an in-house or external training on source testing, followed by at least two week period of source testing field observation. ASTM D7036 can be used as a general guide on determining personnel competency to carry out sampling and analysis of stationary source testing programs.

REFERENCES

1. Ministry of the Environment, Province of Ontario, Source Testing Code, Version 2, November 1980.

2. United States Environmental Protection Agency, Preparation and Review of Site-Specific Test Plans, December 1991.