Background Report Reference

AP-42 Section Number: 11.26

Background Chapter: 4

Reference Number: 7

Title: Emission Test Report--Plant A, Test No. 4, February 1994

US EPA

June 1995
STACK EMISSIONS MEASUREMENTS

Prepared by:

New England Air Quality Testing
STACK EMISSIONS MEASUREMENTS

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</tbody>
</table>
STACK EMISSIONS MEASUREMENTS

1.0 INTRODUCTION

In January of 1994, New England Air Quality Testing (NEAQT) was contracted by C. to quantify Total Suspended Particulate (TSP) and metals (As, Cd, Cr-VI, Ni) emissions from the Gamma Mill baghouse exhaust air at the facility.

Stack emissions sampling was conducted by NEAQT on January 21, 1994. One sample was collected from the baghouse exhaust air and analyzed for the aforementioned constituents at Endyne, Inc., an EPA-certified laboratory. In addition, a sample of the crushed ore product and baghouse fines were collected and analyzed for the same constituents. The following report includes the results of the sampling event with detailed descriptions of the sampling and analytical methods used.

2.0 SOURCE DESCRIPTION

The facility in contains a Roller Mill which crushes ore into a fine powder. The powder is circulated pneumatically from the Roller Mill through ductwork where it is separated based on particle size. The larger particles are recirculated to be crushed further, while the remainder of the crushed ore passes through additional ductwork where it is either classified as product and removed from the loop or continues on to be recirculated to the roller mill or exhausted through a baghouse.
3.0 SAMPLING AND ANALYTICAL METHODS

Air sampling for TSP and metals (As, Cd, Cr-VI, Ni) was conducted in accordance with the provisions of EPA Method 17 - "Determination of Particulate Emissions from Stationary Sources: (In-Stack Filtration Method)" modified for metals sampling with the substitution of teflon components rather than stainless steel in the sampling train.

The mass of TSP collected during sampling was determined as defined in EPA Method 17, while the mass of metals was determined in accordance with the provisions of NIOSH Method 7300 - "Elements". Stack gas velocity and volumetric flowrates were determined in accordance with EPA Method 1 - "Sample and Velocity Traverses For Stationary Sources" and EPA Method 2 - "Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)". The EPA and NIOSH Methods are further described in the sections that follow. Copies of each of the aforementioned standardized methods are included in Appendix 3, pages 1-27.

Testing was conducted by the following New England Air Quality Testing personnel:

David E. Adams Project Engineer
Curtis J. Puisto Senior Air Quality Technician

Facility access, production schedule coordination, and operational information were arranged and overseen by Mr. Tim Hicks of Luzenac America, Inc.

3.1 Sample Location

The sampling locations as well as velocity traverse measurement points were selected according to guidelines set forth in Method 1. This method applies to stacks or ducts which are greater than 12 inches in diameter. Air sampling and velocity measurements were conducted at the same ports in the stack.

Samples were collected from a 19" diameter duct with a circular cross-section which exhausts air from the baghouse. The sample ports were located in a horizontal stretch of duct at a location greater than 8 diameters downstream and greater than 2 diameters upstream of the nearest flow disturbance.
3.2 Volumetric Flow

Velocity traverses and sample collection were performed at identical locations. In accordance with EPA Method 1, velocity traverses were performed at a site located greater than two duct diameters downstream and greater than a half diameter upstream from a flow disturbance. The sample port locations met the upstream and downstream distance from flow disturbance criteria. Therefore, sampling ports were accessed to perform velocity traverses. In addition, EPA Method 1 dictates that for the 19" duct sampled, a minimum of 16 velocity traverse points are required (2 transects, 90° opposed x 8 traverse points/transect). A cross-sectional view of the duct and the traverse point layout for the velocity measurements is shown on page 1 of Appendix 1. The volumetric flow of the gas stream was measured in accordance with Method 2. Velocity traverse data is shown on page 3 of Appendix 1.

Gas composition was assumed to be that of ambient air (79.1% N₂, 20.9% O₂, 0% CO₂).

3.3 Sampling Procedures

Sampling for TSP and metals (As, Cd, Cr-VI, Ni) was conducted in accordance with EPA Method 17 modified to allow for metals analysis. EPA Method 17 specifies that the sampling train be fitted with stainless steel equipment while collecting TSP samples. However, the use of stainless steel may bias sample results when analyzing for metals. Therefore, EPA Method 17 was modified through the use of teflon equipment to replace stainless steel in the sampling train. The sampling train set-up was identical to that specified in the Method, as illustrated in Appendix 3, page 5.

Samples were collected isokinetically to determine concentrations of TSP and metals during the test run. The test run was 320 minutes in duration and collected 98.097 dry standard cubic feet.

The Particulate Field Data Form is included on page 2 of Appendix 1. Information derived from a nomograph during sampling is included on page 4 in Appendix 1.
3.3.1 Calibration Procedure

Flowrates for sampling equipment used to collect samples were calibrated according to requirements as indicated in EPA's - "QA Handbook for Air Pollution Measurement Systems: Volume III. Stationary Sources Specific Methods" (EPA 600/4-77/027). The standard pitot tube used to determine the volumetric flow rate met all criteria outlined in EPA Method 2.

3.3.2 Sample Collection

Following modified EPA Method 17, a sample was withdrawn from the stack isokinetically through an in-stack teflon nozzle and teflon filter holder containing a tare weighed 47mm glass fiber filter. Gaseous metals which pass through the filter were collected in a teflon impinger train containing a nitric acid/hydrogen peroxide absorbing solution. The volume of stack gas sampled was metered through an Anderson console containing a rotary vane pump, a calibrated dry gas meter, and an orifice manometer to determine the flowrate required to maintain isokinetic sampling conditions.

3.4 Analytical Procedures

Total Suspended Particulate gravimetric analysis was conducted by NEAQT. Air sample analysis for metals was performed by Endyne, Inc., of Williston, VT. All samples were delivered by NEAQT personnel to Endyne, Inc.

3.4.1 Sample Analysis

Gravimetric analysis was performed by NEAQT following specifications outlined in EPA Method 17 to determine the mass of Total Suspended Particulate collected during each of the two sample runs. A Mettler AJ100 Balance was used for total mass determination. Sample and Tare Weight Data Sheets for filters and beakers used during sampling are included in Appendix 1, pages 5-7.

Sample analysis for metals (As, Cd, Cr-VI, Ni) was performed by Endyne, Inc. In addition, total chromium was reported by Endyne for each sample, as requested by NEAQT. Upon completion of gravimetric analysis for TSP determination at NEAQT's facility, samples were delivered to Endyne, Inc.
All metals analyses were performed in accordance with NIOSH Method 7300. NIOSH Method 7300 involves chemical filter digestion, followed by Inductively Coupled Plasma (ICP) analysis.

3.4.2 Quality Assurance

Analytical method precision and accuracy were monitored by laboratory control standards which included matrix spike, duplicate, and quality control analysis.

Laboratory analytical results and Chain of Custody are included in Appendix 2, pages 1-7.

4.0 RESULTS

Tables 1 - 5 included on the following pages of the text present a summary of the data collected and results obtained. Table 1 contains a summary of analytical results for metals detected in the product and baghouse fines. Table 2 illustrates the velocity and corresponding flowrate measured during the test run at the velocity traverse location. Table 3 lists emissions results. Table 4 provides a comparison between the average emission rates from the baghouse exhaust and the State of Vermont action levels for each constituent.

4.1 Calculations

Sample calculations are included on pages 8-11 of Appendix 1. The sample computations contain mass calculations for the metals and TSP. In addition, sample volume, volume of water vapor, stack moisture content, TSP and metals concentrations, stack gas velocity and volumetric flowrate, isokinetic calculations, and mass emission rates calculations are included in the sample calculations section of Appendix 1.

4.2 Discussion

Samples of crushed ore product as well as baghouse fines were collected and analyzed for As, Cd, Cr, Cr-VI, and Ni to determine concentrations of each of these metals in the process stream, upstream of the baghouse exhaust.
**TABLE 1 - PRODUCT/BAGHOUSE FINES METALS**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Product Metal Concentrations (mg/kg)</th>
<th>Baghouse Fines Concentrations (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>1.55</td>
<td>3.32</td>
</tr>
<tr>
<td>Cd</td>
<td>0.408</td>
<td>0.339</td>
</tr>
<tr>
<td>Cr</td>
<td>6.53</td>
<td>12.6</td>
</tr>
<tr>
<td>Cr-VI</td>
<td>&lt;0.094&lt;sup&gt;1&lt;/sup&gt;</td>
<td>&lt;0.100&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ni</td>
<td>207</td>
<td>244</td>
</tr>
</tbody>
</table>

1. Value represents the lower analytic detection limit.

Table 1 illustrates the concentrations of metals present in the product and baghouse fines. Chromium-VI was not present at concentrations above the analytical detection limit of 0.094 mg/kg and 0.100 mg/kg for the product and baghouse fines, respectively. These results illustrate that the hexavalent form of Cr (Cr-VI) is less than 1.4% of the total chromium present in the product, and less than 0.8% in the baghouse fines.

**TABLE 2 - VELOCITY/FLOWRATE MEASUREMENTS**

<table>
<thead>
<tr>
<th>Test Run</th>
<th>Velocity (ft/sec)</th>
<th>Flowrate (scfm,dry)</th>
<th>% Isokinetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>54.10</td>
<td>4916.02</td>
<td>100.13</td>
</tr>
</tbody>
</table>

The measured velocity and corresponding stack flowrate for Test Run 1-1 are indicated in Table 2. The %isokinetic results are also included in Table 2.

**TABLE 3 - TEST RUN 1-1 RESULTS**

<table>
<thead>
<tr>
<th>Run Time (min)</th>
<th>Analyte</th>
<th>Mass (ug)</th>
<th>Volume (dscf)</th>
<th>Actual Conc. (gr/dscf)</th>
<th>Emission Rate (lb/8-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>320</td>
<td>TSP</td>
<td>0.0218 g</td>
<td>98.10</td>
<td>0.00343</td>
<td>0.144 lb/hr</td>
</tr>
<tr>
<td>320</td>
<td>As</td>
<td>0</td>
<td>98.10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>320</td>
<td>Cd</td>
<td>0.477</td>
<td>98.10</td>
<td>7.503 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
<td>2.530 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>320</td>
<td>Cr</td>
<td>0.94&lt;sup&gt;1&lt;/sup&gt;</td>
<td>98.10</td>
<td>1.479 x 10&lt;sup&gt;-7&lt;/sup&gt;</td>
<td>4.986 x10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>320</td>
<td>Cr-VI</td>
<td>&lt;1.94&lt;sup&gt;2&lt;/sup&gt;</td>
<td>98.10</td>
<td>&lt;3.051 x 10&lt;sup&gt;-7&lt;/sup&gt;</td>
<td>&lt;1.029 x10&lt;sup&gt;-4&lt;/sup&gt;</td>
</tr>
<tr>
<td>320</td>
<td>Ni</td>
<td>13.4&lt;sup&gt;1&lt;/sup&gt;</td>
<td>98.10</td>
<td>2.108 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
<td>7.105 x10&lt;sup&gt;-4&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Corrected to account for the presence of the analyte in the blank.

<sup>2</sup> Value represents the lower analytical detection limit.

NEAQ/
The Test Run 1-1 sample results are summarized in Table 3. A 98.097 dscf volume sample was collected during a 320-minute period. The concentration and mass emission rate for each of the metals and TSP are shown in Table 3. The mass of Chromium-VI collected on the sampling media was not present in quantities above the analytical detection limit of 1.94 ug. Based on the volume sampled and the stack gas flowrate, the Cr-VI analytical detection limit represents an emission rate of $1.029 \times 10^4$ lb/8-hr.

The mass of As, Cd, and Ni reported in Table 3 have been corrected to account for analytes present in the field blank (see the field blank laboratory report - Appendix 2, page 3).

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Emission Rate (lb/8-hr)</th>
<th>Action Level (lb/8-hr)</th>
<th>% of Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP</td>
<td>0.144 lb/hr</td>
<td>12.50 lb/hr</td>
<td>1.2</td>
</tr>
<tr>
<td>As</td>
<td>0</td>
<td>0.000019</td>
<td>0</td>
</tr>
<tr>
<td>Cd</td>
<td>$2.530 \times 10^5$</td>
<td>0.000047</td>
<td>.53.8</td>
</tr>
<tr>
<td>Cr</td>
<td>$4.986 \times 10^5$</td>
<td>0.01</td>
<td>0.5</td>
</tr>
<tr>
<td>Cr-VI'</td>
<td>$&lt;1.029 \times 10^4$</td>
<td>0.0000071</td>
<td>&lt;1449</td>
</tr>
<tr>
<td>Ni</td>
<td>$7.105 \times 10^4$</td>
<td>0.00026</td>
<td>273.3</td>
</tr>
</tbody>
</table>

'Cr-VI was not detected in the sample; see discussion on page 8.

Table 4 contains values for the Gamma Mill emission rates, State of Vermont action levels (VT - Air Pollution Control Regulations: August 13, 1993), and % of the action level measured for each of the analytes in question. Action levels for each of the metals are designated in units of lb/8-hr. However, the regulatory discharge level for TSP must be reported in units of lb/hr, and is determined based on the input process weight (lb/hr). Mr. Tim Hicks indicated that the average input process weight for the Gamma Mill is 7 tons/hour. This corresponds to a maximum discharge weight of 12.50 lb/hr (see Table 1 of the aforementioned Regulations).

Sampling parameters, including sample volume (98.097 dscf) and run time (320 minutes) were increased during the January 21, 1994 sampling event relative
to prior sampling conducted by NEAQT at the Luzenac-Ludlow facility. In addition to collecting a larger sample volume, NEAQT worked with Endyne to reduce detection limits in an effort to quantify mass emission rates at or below Vermont action levels. As indicated in Table 4, detectable quantities of As, Cd, Cr, and TSP were measured at values below Vermont regulatory levels. Nickel was detected at 273.3 percent of the action level.

Chromium-VI was not detected in the exhaust gas. Total chromium concentrations are reported to provide additional information regarding chromium emissions, due to the fact that the Cr-VI detection limit is above the action level. As indicated in Table 1, less than 0.8% of the total Cr present in the baghouse fines is in the hexavalent form (Cr-VI). A direct correlation between the baghouse fines Cr-VI/Cr ratio and the known mass emission rate of total chromium yields an emission rate for Cr-VI. Total Cr is emitted from the facility at a rate of $4.986 \times 10^5$ lb/8-hr. With a less than 0.8% Cr-VI/Cr ratio, the Cr-VI emission rate is less than $3.99 \times 10^7$ lb/8-hr which is 5.6% of the Cr-VI action level ($7.1 \times 10^6$ lb/8-hr).

Based on the results of the January 21, 1994 emissions test at the Luzenac-Ludlow facility, nickel is the only test constituent present in the Gamma Mill exhaust at concentrations above State of Vermont action levels.
## PARTICULATE FIELD DATA FORM

<table>
<thead>
<tr>
<th>Plant</th>
<th>CITY</th>
<th>DATE</th>
<th>SOURCE</th>
<th>TEST/RUN</th>
<th>OPERATOR</th>
<th>STACK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gamma</td>
<td>CD/DA</td>
<td></td>
<td>19&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meter Box ID</th>
<th>Meter Factor</th>
<th>Meter dH</th>
<th>Pitot Factor</th>
<th>Bar. Press.</th>
<th>Nozzle Size</th>
<th>Leak Check Pre</th>
</tr>
</thead>
<tbody>
<tr>
<td>392-644</td>
<td>0.99</td>
<td>1.72</td>
<td>0.99</td>
<td>20.72</td>
<td>0.25D</td>
<td>0.15 &amp; 16&quot; Hg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.002 &amp; 10&quot; Hg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pitot Check Pre</th>
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<tbody>
<tr>
<td></td>
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</tbody>
</table>

---

### Traverse Point Number

<table>
<thead>
<tr>
<th>Point Number</th>
<th>Time clk/smpl</th>
<th>Vel. Head ΔP &quot;H2O</th>
<th>Orifice Press Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Inlet**

<table>
<thead>
<tr>
<th>Meter Vol. cu ft</th>
<th>Stack Temp °F</th>
<th>Probe Temp °F</th>
<th>Dry Gas Meter Temperature °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

**Outlet**

<table>
<thead>
<tr>
<th>Inlet</th>
<th>Outlet</th>
<th>Oven Temp °F</th>
<th>Imp Temp °F</th>
<th>Pump Vac &quot;Hg</th>
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<tbody>
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</tr>
</tbody>
</table>

---

**New England Air Quality Testing**

*Rest at 1600 W | Vol = 25,800*

Pump problems 0.3 ΔH IV way
### VELOCITY TRAVERSE DATA SHEET

**PLANT CITY**
**SOURCE**
**DATE** 1/21/94
**RUN** 1-1
**PITOT ID**
**COEFFICIENT** 0.99
**BAR PRESSURE** 28.72
**OPERATORS** CP/DA

<table>
<thead>
<tr>
<th>Traverse Point #</th>
<th>Velocity Head &quot;H₂O&quot; ΔP</th>
<th>Stack Temp °F</th>
<th>Cyclonic Flow Angle °</th>
<th>Static Pressure &quot;H₂O&quot;</th>
<th>√ΔP</th>
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</thead>
<tbody>
<tr>
<td>Side 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>0.38</td>
<td>179</td>
<td>NA</td>
<td>+0.24</td>
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<tr>
<td>2</td>
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<td>3</td>
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<td>8</td>
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<tr>
<td>1</td>
<td>0.50</td>
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<tr>
<td>2</td>
<td>0.54</td>
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<tr>
<td>3</td>
<td>0.58</td>
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<td>0.58</td>
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<tr>
<td>8</td>
<td>0.45</td>
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</tbody>
</table>

**AVG:** 0.63

NEW ENGLAND AIR QUALITY TESTING

CA
### NOMOGRAPH DATA FORM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibrated Orifice Pressure Differential (H_2O)</td>
<td>1.77</td>
</tr>
<tr>
<td>Meter Temperature Average °F</td>
<td>160</td>
</tr>
<tr>
<td>Moisture in Gas Stream %</td>
<td>2</td>
</tr>
<tr>
<td>Barometric Pressure (Hg)</td>
<td>28.72</td>
</tr>
<tr>
<td>Stack Static Pressure (H_2O)</td>
<td>0.24</td>
</tr>
<tr>
<td>Static/Barometric Pressure Ratio (P_s/P_b)</td>
<td></td>
</tr>
<tr>
<td>Stack Temperature Average °F</td>
<td>178</td>
</tr>
<tr>
<td>Velocity Head Average (H_2O)</td>
<td>0.53</td>
</tr>
<tr>
<td>Velocity Head Maximum (H_2O)</td>
<td>0.62</td>
</tr>
<tr>
<td>C Factor</td>
<td>0.99</td>
</tr>
<tr>
<td>Calculated Nozzle Diameter &quot;</td>
<td>0.225</td>
</tr>
<tr>
<td>Actual Nozzle Diameter &quot;</td>
<td></td>
</tr>
<tr>
<td>Reference (\Delta p) (H_2O)</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**NEW ENGLAND AIR QUALITY TESTING**

\[
\sqrt{\frac{2.5}{1.77}} \times 0.75 = 0.89 \text{ CFM}
\]
# TARE WEIGHT LOG SHEET

**Project:**

**Facility:** YV-Y-7A5k

**Filter size:** 250 µm

<table>
<thead>
<tr>
<th>FILTER/BEAKER NUMBER</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC Blanks 3/1</td>
<td>1/24 0800</td>
<td>1/25 0830</td>
<td>1/25 1430</td>
<td>1/26 0815</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100.00000</td>
<td>100.00000</td>
<td>98.99999</td>
<td>100.00000</td>
<td>100.00000</td>
</tr>
<tr>
<td>GC Blanks 2/6</td>
<td></td>
<td></td>
<td>1/25</td>
<td>1/25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>104.4393</td>
<td>104.4499</td>
<td>104.4420</td>
</tr>
<tr>
<td>*Sample 25/4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>101.3107</td>
<td>101.3080</td>
<td>101.3106</td>
<td>101.3081</td>
<td></td>
</tr>
<tr>
<td>*Red Blk 25/5</td>
<td></td>
<td></td>
<td>1/25</td>
<td>1/25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100.2762</td>
<td>100.2737</td>
<td>100.2760</td>
<td>100.2739</td>
<td></td>
</tr>
</tbody>
</table>

*Void A.M.*
SAMPLE WEIGHT LOG SHEET

Project: Task 2
Facility: Task 2
Beaker/Filter size: 250 ml

<table>
<thead>
<tr>
<th>FILTER/ BEAKER NUMBER</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
</tr>
<tr>
<td>QC Blank 23</td>
<td>100.0020</td>
<td>100.0019</td>
<td>100.0016</td>
<td>0.00036</td>
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</tr>
<tr>
<td></td>
<td>104.4420</td>
<td>104.4421</td>
<td>104.4417</td>
<td>0.00972</td>
<td></td>
</tr>
<tr>
<td>Field blank 5</td>
<td>100.2760</td>
<td>100.2764</td>
<td>100.2760</td>
<td>0.00009</td>
<td></td>
</tr>
</tbody>
</table>

NEW ENGLAND AIR QUALITY TESTING
SAMPLE WEIGHT LOG SHEET

Project: task 2
Facility:
Beaker/Filter size: 47 mm Glass Fiber Filter

<table>
<thead>
<tr>
<th>FILTER/BEAKER NUMBER</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
<th>DATE/TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
<td>mass g</td>
</tr>
<tr>
<td>47-07</td>
<td>0.025</td>
<td>0.1012</td>
<td>0.1012</td>
<td>0.0121</td>
<td></td>
</tr>
</tbody>
</table>

NEW ENGLAND AIR QUALITY TESTING
Metal mass calculations:

T/R 1.11

a. As: $1.48 - 1.72 < 0 \mu g$

b. Cd: $0.477 \mu g$

c. Cr: $2.55 - 1.61 = 0.94 \mu g$

d. Cr III: $< 1.94 \mu g$

e. Ni: $19.7 - 6.30 = 13.4 \mu g$

* Mass corrected to account for blank contamination

Product:

a. As: $1.55 \text{ mg/kg}$

b. Cd: $0.408 \text{ mg/kg}$

c. Cr: $6.53 \text{ mg/kg}$

d. Cr VI: $< 0.094 \text{ mg/kg}$

e. Ni: $207 \text{ mg/kg}$

Baghouse Fines:

a. As: $3.32 \text{ mg/kg}$

b. Cd: $0.337 \text{ mg/kg}$

c. Cr: $12.6 \text{ mg/kg}$

d. Cr VI: $< 0.100 \text{ mg/kg}$

e. Ni: $344 \text{ mg/kg}$
**TSP mass calculations**

\[ \text{TSP} = \frac{\text{Filter mass (final - tare)}}{1} + \frac{\text{Beaker mass (final - tare)}}{1} \]

\[ = \left(0.1012 - 0.0891\right) + \left(101.3203 - 101.3104\right) \]

\[ \text{TSP} = 0.0218 \text{ g} \]

\[ \text{BLANK} = 0.0000 \text{ g} \]

**Additional calculations**

**I. Standard meter volume**

Eq. 5-10

\[ V_m(s) = K \frac{V_m P_m}{T_m} = K \frac{V_m}{T_{m,avg}} \left(\frac{P_{bar} + A H_{ale}/13.6}{T_{m,avg}}\right) \]

\[ \text{where } K = \frac{17.64^{\circ}R}{1 \text{ in Hg}} \]

\[ V_m(s) = \left(17.64^{\circ}R\right) \left(108.344 \text{ ft}^3\right) \left(\frac{28.72 + 0.33/13.6}{100 + 460 \cdot R}\right) = 98.047 \text{ ft}^3 \]

**II. Volume of H₂O vapor**

Eq. 5-2

\[ V_{m}(s) = K \left(V_t - V_i\right) \]

\[ \text{where } K = 0.04707 \text{ ft}^3/\text{ml} \]

\[ V_{m}(s) = \left(0.04707 \text{ ft}^3/\text{ml}\right) \left(69 \text{ ml}\right) = 3.248 \text{ ft}^3 \]

**III. % Moisture in stack gas**

Eq. 5-3

\[ B_{w,s} = \frac{V_{m}(s)}{V_{m}(s) + V_{w}(s)} = \frac{3.248}{3.248 + 2.246} = 0.632 \]
IV. Concentration of metals and TSP

Eq. 5-6: \[ C_\text{S} = \frac{(0.00193)}{\text{mg}} \times \left( \frac{M_{\text{As}}}{\text{g}} \right) \times \left( \frac{5.43 \text{mg}}{V_{\text{m,\text{std}}}} \right) = \text{grains/dscf} \]

a. As: 0.0193 mg = 0 grains/dscf
b. Cd: 0.000477 mg = 7.503 \times 10^{-8} \text{ grains/dscf}
c. Cr: 0.00094 mg = 1.479 \times 10^{-7} \text{ grains/dscf}
d. Cr: 0.000944 mg = 3.051 \times 10^{-7} \text{ grains/dscf}
e. Ni: 0.0134 mg = 2.108 \times 10^{-6} \text{ grains/dscf}
f. TSP: 21.8 mg = 3.429 \times 10^{-3} \text{ grains/dscf}

V. Stack gas velocity

Eq. 2-9: \[ V_\text{s} = \frac{K \cdot C_p \cdot (\Delta P \text{kin})}{T_s \left( \text{mg} \right) / P_s \cdot M_s} \]

where \( K = 85.49 \)

Eq. 2-5: \( M_s = M_d \left( 1 - \frac{B_{\text{ws}}}{18.0} \right) + 18.0 \cdot B_{\text{ws}} = 29 (1 - 0.032) + 18.0 \cdot 0.032 = 28.65 \)

where \( M_d = 29.0 \)

Eq. 2-6: \( P_s = P_{\text{bar}} + P_\text{g} = 28.32 + 0.34/0.31 = 28.73 \text{ in H}_2 \text{O} \)

\[ V_s = \sqrt{\frac{85.49 \cdot 0.99 \cdot 0.726 \cdot (178 + 460)(128.73)(28.73)}{28.73 \cdot 28.65}} \]

\[ V_s = 54.096 \text{ ft/sec} \]

VI. Stack Volumetric Flow

Eq. 2-10: \[ Q_{\text{std}} = 60 \left( 1 - B_{\text{ws}} \right) \cdot V_s \cdot A \cdot \left( \frac{T_s}{520 \text{ (deg F)}} \right) \cdot \left( \frac{14.7 \text{ psi}}{P_{\text{std}}} \right) \]

\[ Q_{\text{std}} = 60 (1 - 0.032) \left( 54.096 \text{ ft}^3 / \text{sec} \right) \left( \frac{19.2}{12} \right) \left( \frac{520}{760 \text{ (deg F)}} \right) \left( \frac{28.73}{29.52} \text{ (psi)} \right) = 4316.02 \text{ dscfm} \]
VII. % IsoKinetic

\[ I = \frac{K_u \cdot T \cdot V_m(\text{STD})}{P_s \cdot V_s \cdot A_n \cdot \Theta \cdot (1 - B_w)} \]

where \( K_u = 0.09450 \)

\[ I = \frac{(0.09450) \cdot (178 \cdot 966^2 \cdot 98.691 \text{ dscf})}{(28.93 \cdot 4 \cdot (54.096 \cdot \frac{1}{12}) \cdot (\frac{0.152}{12}) \cdot (320 \text{ mm}) \cdot (1 - 0.082)} \]

\[ I = 100.12 \% \]

VIII. Emission Rate

\[ C_6 \times \frac{16}{7000 \text{ grains}} = \frac{\text{lb}}{\text{dscf}} \]

\[ \frac{16}{\text{dscf}} \times Q_{\text{std}} \times \frac{480 \text{ min}}{8 \text{ hr}} = \frac{\text{lb}}{\text{hr}} \]

\[ Q_{\text{STD}} = 4916.02 \text{ dscf/hr} \]

a. As : 0

b. Cd : 7.503 \times 10^6 \text{ grains/dscf} = 1.072 \times 10^{11} \text{ lb/dscf} = 2.530 \times 10^{10} \text{ lb/hr}

c. Cr : 1.479 \times 10^7 \text{ grains/dscf} = 2.113 \times 10^{11} \text{ lb/dscf} = 4.986 \times 10^{10} \text{ lb/hr}

d. Cr-\text{VI} : < 3.051 \times 10^7 \text{ grains/dscf} = < 4.359 \times 10^{11} \text{ lb/dscf} = < 1.029 \times 10^4 \text{ lb/hr}

e. Ni : 2.108 \times 10^6 \text{ grains/dscf} = 3.011 \times 10^{10} \text{ lb/dscf} = < 7.105 \times 10^4 \text{ lb/hr}

f. TSP : 3.429 \times 10^3 \text{ grains/dscf} = 4.899 \times 10^7 \text{ lb/dscf} = 0.114 \text{ lb/hr}
Enclosed please find the results of the analyses performed for the samples referenced on the attached chain of custody record.

Chain of custody indicated the samples were not preserved.

All samples were prepared and analyzed by requirements outlined in the referenced methods and within the specified holding times.

All instrumentation was calibrated with the appropriate frequency and verified by the requirements outlined in the referenced methods.

Sample results reflect adjustments made regarding slight blank contamination observed for total chromium only. For other metals, blank contamination was not observed at levels affecting the analytical results.

Analytical method precision and accuracy was monitored by laboratory control standards which included matrix spike, duplicate and quality control analyses. These standards were determined to be within established laboratory method acceptance limits.

Reviewed by,

Harry B. Locker, Ph.D.
Laboratory Director

enclosures
LABORATORY REPORT

CLIENT: NEAQT
PROJECT NAME: 
REPORT DATE: 1/7/94
DATE SAMPLED: January
DATE RECEIVED: 1/20/94

PROJECT CODE: NEAQ3755
REF.#: 56146
STATION: A525 Sample
TIME SAMPLED: Not Indicated
SAMPLER: C. Puisto

Tested parameters are reported in micrograms. Digestion was performed by NIOSH Method 7300. Hexavalent chromium was digested by EPA Method 3060.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration</th>
<th>EPA Method</th>
<th>Analysis Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Arsenic</td>
<td>1.48</td>
<td>7060</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Cadmium</td>
<td>0.477</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium</td>
<td>2.55</td>
<td>6010</td>
<td>2/2/94</td>
</tr>
<tr>
<td>Total Chromium VI</td>
<td>&lt;1.94</td>
<td>7196A</td>
<td>2/2/94</td>
</tr>
<tr>
<td>Total Nickel</td>
<td>19.7</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
</tbody>
</table>
LABORATORY REPORT

CLIENT: NEAQT
PROJECT NAMF
REPORT DATE: 
DATE SAMPLED: 
DATE RECEIVED 

PROJECT CODE: NEAQ3755
REF.#: 56,147
STATION: A526 Field Blank
TIME SAMPLED: Not Indicated
SAMPLER: C. Puisto

Tested parameters are reported in micrograms. Digestion was performed by NIOSH Method 7300. Hexavalent chromium was digested by EPA Method 3060.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration</th>
<th>EPA Method</th>
<th>Analysis Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Arsenic</td>
<td>1.72</td>
<td>7060</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Cadmium</td>
<td>&lt;0.210</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium</td>
<td>1.61</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium VI</td>
<td>DU¹</td>
<td>7196A</td>
<td>2/2/94</td>
</tr>
<tr>
<td>Total Nickel</td>
<td>6.30</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
</tbody>
</table>

Notes:

1 Data unavailable because analysis did not meet laboratory QA/QC standards.
Laboratory Services
32 James Brown Drive
Williston, Vermont 05495
(802) 879-4333
FAX 879-7103

LABORATORY REPORT

CLIENT: NEAQT
PROJECT NAME: 
REPORT DATE: 
DATE SAMPLED: 
DATE RECEIVED: January 23, 1994

PROJECT CODE: NEAQ3755
REF.#: 56,148
STATION: A527 Baghouse Fines
TIME SAMPLED: Not Indicated
SAMPLER: C. Puisto

Tested parameters are reported in milligrams per kilogram, dry weight. Digestion was performed by EPA Method 3050. Hexavalent chromium was digested by EPA Method 3060.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration</th>
<th>EPA Method</th>
<th>Analysis Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Arsenic</td>
<td>3.32</td>
<td>7060</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Cadmium</td>
<td>0.339</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium</td>
<td>12.6</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium VI</td>
<td>&lt;0.100</td>
<td>7196A</td>
<td>2/2/94</td>
</tr>
<tr>
<td>Total Nickel</td>
<td>244.</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
</tbody>
</table>
LABORATORY REPORT

CLIENT: NEAQT
PROJECT CODE: NEAQT3755
PROJECT NAME: NEAQT3755
REF.#: 56,149
STATION: AS28 Product
DATE SAMPLED: 2/2/94
TIME SAMPLED: Not Indicated
SAMPLER: C. Puisto

Tested parameters are reported in milligrams per kilogram, dry weight. Digestion was performed by EPA Method 3050. Hexavalent chromium was digested by EPA Method 3060.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration</th>
<th>EPA Method</th>
<th>Analysis Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Arsenic</td>
<td>1.55</td>
<td>7060</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Cadmium</td>
<td>0.408</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium</td>
<td>6.53</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
<tr>
<td>Total Chromium VI</td>
<td>&lt;0.094</td>
<td>7196A</td>
<td>2/2/94</td>
</tr>
<tr>
<td>Total Nickel</td>
<td>207.0</td>
<td>6010</td>
<td>2/3/94</td>
</tr>
</tbody>
</table>
LABORATORY REPORT

MATRIX SPIKE AND DUPLICATE LABORATORY CONTROL DATA

CLIENT: NEAQT  
PROJECT CODE: NEAQ3755

PROJECT NAME: 
REPORT DATE: 
DATE SAMPLED:

SPIKE QA/QC DATA:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ref.#</th>
<th>Sample (mg/L)</th>
<th>Spike (mg/L)</th>
<th>% Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>56,149</td>
<td>0.160</td>
<td>0.100</td>
<td>87.8</td>
</tr>
<tr>
<td>Cadmium</td>
<td>56,149</td>
<td>0.042</td>
<td>0.200</td>
<td>83.5</td>
</tr>
<tr>
<td>Chromium</td>
<td>56,149</td>
<td>0.673</td>
<td>0.400</td>
<td>117.</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>56,149</td>
<td>&lt;0.020</td>
<td>0.100</td>
<td>109.</td>
</tr>
<tr>
<td>Nickel</td>
<td>56,149</td>
<td>0.213</td>
<td>0.800</td>
<td>88.3</td>
</tr>
</tbody>
</table>

DUPLICATE QA/QC DATA:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ref.#</th>
<th>Dup 1 (mg/kg)</th>
<th>Dup 2 (mg/kg)</th>
<th>Avg % Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>56,148</td>
<td>3.21</td>
<td>3.43</td>
<td>3.</td>
</tr>
<tr>
<td>Cadmium</td>
<td>56,148</td>
<td>0.312</td>
<td>0.365</td>
<td>8.</td>
</tr>
<tr>
<td>Chromium</td>
<td>56,148</td>
<td>13.5</td>
<td>11.6</td>
<td>8.</td>
</tr>
<tr>
<td>Chromium VI</td>
<td>56,148</td>
<td>&lt;0.099</td>
<td>&lt;0.100</td>
<td>ND¹</td>
</tr>
<tr>
<td>Nickel</td>
<td>56,148</td>
<td>236.</td>
<td>252.</td>
<td>3.</td>
</tr>
</tbody>
</table>

Notes:

1 None Detected
### CHAIN-OF-CUSTODY RECORD

<table>
<thead>
<tr>
<th>Lab #</th>
<th>Sample Location</th>
<th>Matrix</th>
<th>GRA</th>
<th>COM</th>
<th>Date/Time</th>
<th>Sample Containers</th>
<th>Field Results/Remarks</th>
<th>Analysis Required</th>
<th>Sample Preservation</th>
<th>Rush</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/11/6</td>
<td>AS25 SAMPLE</td>
<td>1/21/94</td>
<td>2</td>
<td>Iron + Bakker to be combined + digested.</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/11/7</td>
<td>AS26 Field Blank</td>
<td>1/21/94</td>
<td>2</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/11/8</td>
<td>AS27 Baghouse Bines Dust</td>
<td>1/22/94</td>
<td>1</td>
<td>Dust</td>
<td>30</td>
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<td></td>
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</tr>
<tr>
<td>6/11/9</td>
<td>AS28 Product Dust</td>
<td>1/22/94</td>
<td>1</td>
<td>Dust</td>
<td>30</td>
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**Requested Analyses**

<table>
<thead>
<tr>
<th>#</th>
<th>Analysis</th>
<th>Method/Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>6 TKN</td>
</tr>
<tr>
<td>2</td>
<td>Cl o r e</td>
<td>7 Total P</td>
</tr>
<tr>
<td>3</td>
<td>A m m o n i a N</td>
<td>8 Total D as. P</td>
</tr>
<tr>
<td>4</td>
<td>N i t r i c N</td>
<td>9 BOD</td>
</tr>
<tr>
<td>5</td>
<td>N i t r a t e N</td>
<td>10 Alkalinity</td>
</tr>
<tr>
<td>29</td>
<td>TCLP (Specify: volatiles, semi-volatiles, metals, pesticides, herbicides)</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Other (Specify)</td>
<td>Hg, Cr, Cd, Cr VI, N</td>
</tr>
</tbody>
</table>

**Analysis of Sample:**
- **Received by:** Signature
- **Date/Time:** 1/28/94 1355
- **Relinguished by:** Signature
- **Date/Time:** 1/28/94 1355
METHOD I—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. Principle and Applicability

1.1 Principle. To aid in the representative measurement of pollutant emissions and a total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and fumes. The method cannot be used when: (1) flow is cyclic or variable (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m² (113 in.²) cross-sectional area, or (3) the measurement site is less than two stack diameters downstream or less than a half diameter upstream from any flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured. Failure to do so may result in subsequent adjustments to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. Procedure

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (Dₑ) shall be calculated from the following equation to determine the upstream and downstream distances:

\[ Dₑ = \frac{LW}{L+W} \]

where \( L \) = length and \( W \) = width.

An alternative procedure is available for determining the acceptability of a measurement location by locating the criteria above. This procedure determination of gas flow angles at the sampling point and comparing the results with accepability criteria, is described in Section 2.2.

2.2 Determining the Number of Traverse Points.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.), (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.), (3) three, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that correspond to: (1) the number of stack diameters upstream, and (2) the number of stack diameters downstream.

The number of traverse points for circular stacks is based only on the number of circular stack diameters. For rectangular stacks, the number is the product of the number of circular stack diameters and the number of duct diameters (or equivalent diameters) in the stack.

Table 1-1. Cross-Section Layout for Rectangular Stacks

<table>
<thead>
<tr>
<th>Number of Traverse Points</th>
<th>Minimum Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
</tr>
</tbody>
</table>

The cross-section layout for rectangular stacks is shown in Figure 1-1.

2.2.2 Velocity Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.), (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.), (3) three, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-2. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-2 the minimum number of traverse points that correspond to: (1) the number of stack diameters upstream, and (2) the number of stack diameters downstream.

The number of traverse points for circular stacks is based only on the number of circular stack diameters. For rectangular stacks, the number is the product of the number of circular stack diameters and the number of duct diameters (or equivalent diameters) in the stack.

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2.2.2 Velocity (Non-Particulate) Traverse. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-1 may be used instead of Figure 1-7.

2.3 Cross-sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for example, see Equations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation. After this line, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls.

To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). When any of the traverse points is located in Section 2.3.1 (all within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls by (1) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as two separate traverse points, both in the sampling (or velocity measurement) procedures, and in recording the data.

---

**Fig. 1.3. Example showing circular stack cross section divided into 12 equal areas with location of traverse points indicated.**

**Table 1-2. Location of Traverse Points in Circular Stacks**

<table>
<thead>
<tr>
<th>Traverse point number on a traverse</th>
<th>Number of traverse points on a traverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>5</td>
<td>4.0</td>
</tr>
<tr>
<td>6</td>
<td>4.7</td>
</tr>
<tr>
<td>7</td>
<td>5.4</td>
</tr>
<tr>
<td>8</td>
<td>6.1</td>
</tr>
<tr>
<td>9</td>
<td>6.8</td>
</tr>
<tr>
<td>10</td>
<td>7.5</td>
</tr>
<tr>
<td>11</td>
<td>8.2</td>
</tr>
<tr>
<td>12</td>
<td>8.9</td>
</tr>
<tr>
<td>13</td>
<td>9.6</td>
</tr>
<tr>
<td>14</td>
<td>10.3</td>
</tr>
<tr>
<td>15</td>
<td>10.9</td>
</tr>
<tr>
<td>16</td>
<td>11.6</td>
</tr>
<tr>
<td>17</td>
<td>12.3</td>
</tr>
<tr>
<td>18</td>
<td>12.9</td>
</tr>
<tr>
<td>19</td>
<td>13.6</td>
</tr>
<tr>
<td>20</td>
<td>14.3</td>
</tr>
<tr>
<td>21</td>
<td>14.9</td>
</tr>
<tr>
<td>22</td>
<td>15.6</td>
</tr>
<tr>
<td>23</td>
<td>16.3</td>
</tr>
<tr>
<td>24</td>
<td>16.9</td>
</tr>
</tbody>
</table>
2.3.2 Stacks With Diameters Equal to or Less Than 0.1 m (4 in.). Follow the procedure in Section 2.3.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.) or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

2.4. If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one of the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4 x 4 "minimum number of points matrix were expanded to 8 points, the final matrix could be 4 x 4 or 12 x 12, and would not necessarily have to be 8 x 8. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

2.5. The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.6. Verification of Absence of Cyclic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

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**Figure 1-4. Example showing rectangular stack cross section divided into nine elemental areas, with a traverse point at centroid of each area.**

---

2.5 Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at the traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0" reference. Note the differential pressure (ps) reading at each traverse point. If a null (zero) pitot reading is obtained at "0" reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at "0" reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α and assign a values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 20°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

2.7 The alternative procedure described in Section 2.5 may be used to determine the rotation angle (α) to the nearest degree as described above. The limit of acceptability for the average value of α would remain 20°.

2.8 Alternative Measurement Site Selection Procedure. This alternative applies to sources where measurement locations are less than 2 equilibrium stack or duct diameters downstream or less than 4 duct diameters upstream from a flow disturbance. The alternative should be limited to ducts larger than 46 cm in diameter where blockage and wall effects are minimal. A directional flow-sensing probe is used to measure pitch and yaw angles of the gas flow at 40 or more traverse points; the resultant angle is calculated and compared with acceptable criteria for mean and standard deviation.

Note: Both the pitch and yaw angles are measured from a line passing through the traverse point and parallel to the stack axis. The yaw angle is the angle of the gas flow component in the plane that includes the traverse line and is parallel to the stack axis. The yaw angle is the angle of the gas flow component in the plane that is perpendicular to the traverse line and is measured from the line passing through the traverse point and parallel to the stack axis.

2.9.1.1 Directional Probes. Any directional probe, such as United Sensor Type DA Three-Dimensional Directional Probe, capable of measuring both the pitch and yaw angles of gas flows is acceptable. (Note: Mention of trade name or specific product does not constitute endorsement by the U.S. Environmental Protection Agency.) Assign an identification number to the directional probe, and permanently mark or engrave number on the body of the probe. The pressure holes of directional probes are susceptible to plugging when used in particulate-laden gas streams. Therefore, system for cleaning the pressure holes by "back-purging" with pressurized air is required.

2.9.1.2 Differential Pressure Gauges. Inclined manometers, U-tube manometers, other differential pressure gauges (e.g., magnehelic gauges) that meet the specifications described in Method 2.2.1 are acceptable if both negative and positive pressure readings shall be calibrated at a minimum of three points as specified in Method 2.2.1.2

2.9.2 Traverse Points. Use a minimum of 40 traverse points for circular ducts and 40 points for rectangular ducts for the gas flow and angle determinations. Follow §2.2.1 and Table 1-1 or 1-2 for the location and layout of the traverse points. If the measurement location is not to be accessible according to the criteria in this alternative procedure, the same traverse point number and location for sampling and velocity measurements are required.

2.9.3 Measurement Procedure. Follow the procedure for differential pressure gauges as recommended by the manufacturer. Capillary tubing or surge tanks may be used to dampen pressure fluctuations. It is recommended, but not required, that a pressure leak check be conducted. To perform a leak check, pressurize or use suction on the impact opening until a reading of at least 7.6 cm H2O is recorded. Remove the pressure gauge, then plug the impact opening. The pressure of a leak-free system will remain stable for at least 15 seconds.

2.9.3.3 Level and zero the manometer. Select the manometers level and zero may be because of vibrations and temperature changes, periodically check the level and zero during the traverse.

2.9.3.4 Position the probe at the approximate gas stream, rotate until zero deflection is indicated for yaw angle pressure gauge. Determine and record the yaw angle. Record the pressure gauge readings for the pitch angle, and determine the pitch angle from the calibration curve. Repeat this procedure for each traverse point. Complete a "back-purge" of the pressure lines and the impact opening prior to measurements of each traverse point.

A post-test check as described in §2.3 is required. If the criteria for a leak-free system are not met, repair the equipment and repeat the flow angle measurements.

2.9.4 Calculate the resultant angle at traverse point, the average resultant angle and the standard deviation using the following equations. Complete the calculations retaining at least one extra significant figure beyond that of the least significant digit. Around the values after the final calculations.

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2.5.1 Calculate the resultant angle at each traverse point
\[ \theta = \arccos \left( \frac{\cos \alpha_1 \cos \beta_1 \sin \gamma}{\sin \alpha_1 + \cos \alpha_1 \cos \beta_1 \cos \gamma} \right) \]  
Eq. 1-2

Where:
- \( \theta \) = Resultant angle at traverse point \( i \).
- \( \alpha \) = Yaw angle at traverse point \( i \), degree.
- \( \beta \) = Pitch angle at traverse point \( i \), degree.

2.5.2 Calculate the average resultant for the measurement:
\[ \bar{\theta} = \frac{\sum_{i=1}^{n} \theta_i}{n} \]  
Eq. 1-3

where:
- \( \bar{\theta} \) = Average resultant angle, degree.
- \( n \) = Total number of traverse points.

2.5.3 Calculate the standard deviations:
\[ S_\theta = \sqrt{\frac{\sum_{i=1}^{n} (\theta_i - \bar{\theta})^2}{n-1}} \]  
Eq. 1-4

where:
- \( S_\theta \) = Standard deviation, degree.

2.6.1 The measurement location is acceptable if \( \bar{\alpha}, \bar{\beta}, \bar{\gamma} \) are within \( 2^\circ \) of each other.

2.6.2 Calibrate the flow system as described in Sections 4.1.1 and 4.1.2 of Method B. In addition, the flow system shall have the capacity to generate two test-section velocities, one between 655 and 730 m/min (2,000 and 2,400 ft/min) and the other between 730 and 1,100 m/min (2,400 and 3,600 ft/min).

2.6.3 Cut two entry ports in the test section. The axes through the entry ports shall be perpendicular to the central axis of the test section to the centroid of the test section. The ports should be elongated slots parallel to the central axis of the test section and of sufficient length to allow measurement of pitch angles while maintaining the probe head position at the test-section centroid. To facilitate alignment of the directional probe during calibration, the test section should be constructed of Plexiglas or some other transparent material. All calibration measurements should be made at the same point in the test section, preferably at the centroid of the test section.

2.6.4 To ensure that the gas flow is parallel to the entrance of the test section, follow the procedure in Section 2.4 for cyclone flow determinations to measure the gas flow angle at the centroid of the test section from two test ports located 90° apart. The gas flow angle measured in each port must be \( \pm 2^\circ \) of 0°. Straightening vanes should be installed, if necessary, to meet this criterion.

2.6.5 Pitch Angle Calibration. Perform a calibration traverse according to the manufacturer's recommended protocol in 5° increments for angles from \(-60^\circ\) to \(+60^\circ\) at one velocity in each of the two ranges specified above. Average the pressure ratio values for each port, each angle, in two flow ranges, and plot a calibration curve with the average values of the pressure ratio or other suitable measurement factor as recommended by the manufacturer versus the pitch angle. Draw a smooth line through the data points. Plot also the data values for each traverse point. Determine the differences between the measured data values and the angle from the calibration curve at the same pressure ratio. The difference at each comparison must be within 2° for angles between 0° and 40° and within 3° for angles between 40° and 60°.

2.6.6 Yaw Angle Calibration. Mark the three-dimensional probe to allow the determination of the yaw position of the probe. This is usually a line extending the length of the probe and aligned with the impact opening. To determine the accuracy of measurement of the yaw angle, only the zero or null point may be calibrated as follows: Place the directional probe in the test section, and rotate the probe until the zero position is found. With a protractor or angle measuring device, measure the angle indicated by the zero or null point on the three-dimensional probe. This should be within 2° of 0°. Repeat this measurement for any other points along the length of the probe where yaw angle measurement could be read in order to account for variations in the probe. The markings used to indicate pivot head positions should be made at the same point in the test section, preferably at the central axis of the test section.
METHOD 3—DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. Principle and Applicability

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Schaefer-Ade or reverse type) pitot tube.

1.2 Applicability. This method is applicable for measurement of the average velocity of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1. Section 2.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams. Section 3.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, subject to the approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically; or (3) to move to another measurement site at which the flow is acceptable.

2. Apparatus

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g., stainless steel). It is recommended that the external tubing diameter (dimension D, Figure 2-2a) be between 0.48 and 0.89 centimeters (0.19 and 0.35 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions F and P, Figure 2-2b); it is recommended that this distance be between 1.00 and 1.50 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4. An identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

![Figure 2-1. Type S pitot tube manometer assembly.](image-url)
Figure 2-2. Properly constructed Type S pilot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and diameters coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pilot tubes constructed this way.
Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of \( \beta_s \) so long as \( \beta_s \) and \( \phi_s \) are 10°, \( \beta_s \) and \( \phi_s \) are 5°, \( x \) is 0.32 cm (1/8 in.) and \( y \) is 0.68 cm (1/4 in.) (see Table II in Bibliography).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.1 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head \( (\Delta p) \) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another \( \Delta p \) reading. If the \( \Delta p \) readings made before and after the air purge are the same (±5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if \( \Delta p \) at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative \( \Delta p \) readings shall be...
taken, as above, for the last two back purges at which suitably high ap readings are observed.

2.3 Differential Pressure Gage. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (lower column) inclined-vertical manometer, having 0.01 in. H.O. divisions on the 0- to 1-in. inclined scale, and 0.1-in. H.O. divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gage of equivalent sensitivity) is satisfactory for the measurement of ap values as low as 1.3 mm (0.05 in.) H.O. However, a differential pressure gage of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all ap readings at the traverse points in the stack is less than 1.5 mm (0.06 in.) H.O.; (2) for traverses of 13 or more points, more than 10 percent of the individual ap readings are below 1.3 mm (0.05 in.) H.O.; (3) for traverses of fewer than 13 points, more than one ap reading is below 1.3 mm (0.05 in.) H.O. Citation 18 in bibliography describes commercially available instrumentation for the measurement of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gage:

\[
T = \frac{\sum_{i=1}^{n} \sqrt{ap_i} + K}{\sum_{i=1}^{n} \sqrt{ap_i}}
\]

where:

- ap = Individual velocity head reading at a traverse point, mm H.O. (in. Hg)
- n = Number of traverse points
- K = 0.33 mm H.O. when metric units are used and 0.009 in. H.O. when English units are used.

If \( T \) is greater than 1.08, the velocity head data are unacceptable and a more sensitive differential pressure gage must be used.

Note: If differential pressure gauges other than inclined manometers are used (e.g., the aneroid barometer), the calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare ap readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing the range of ap values in the stack. If, at each point, the values of ap are equal, the gauge-oil manometer agrees to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. If the readings shall be either be voided, or procedures to adjust the measured ap values and final results shall be used subject to the approval of the Administrator.

2.4 Temperature Gage. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature shall be used. The temperature gauge shall be attached to the probe such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the probe and temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more than 1 percent in the absolute pressure measurement is introduced, the temperature gauge need not be attached to the probe; this alternative is subject to the approval of the Administrator.

2.5 Pressure Probe and Gage. A piezometer- or water-filled U-tube manometer capable of measuring stack pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard Type 5 pressure probe or one leg of a Type 5 pressure probe with the face opening at the same altitude as the probe shall also be used as the pressure probe.

2.6 Barometer. A mercury aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value is inserted into the equation (which the absolute barometer pressure) shall be requenced and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 20-meter (100 foot) elevation increase or vice-versa for elevation decrease.

2.7 Calibration Pitot Tube. When calibration of the Type 5 pitot tube is necessary (see Section 4), a standard pitot tube shall be used as a reference. The standard pitot tube shall, preferably, have a known coefficient obtained either (1) directly from the National Bureau of Standards, Route 370, Quantico, Quantico, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.1.1 through 2.1.3 below and illustrated in Figure 4-1 (see also Citations 7, 8) or "Bibliography" may be used. Pitot tube design shall be accepted only if the measurements provide a baseline coefficient of about 0.95 ± 0.01.

2.7.1 Hemispherical (shown in Figure 4-1), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon D, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the exhaust pipe, following the 90-degree bend.
Figure 2-4. Standard pitot tube design specifications.

3. Procedure

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen air fluctuations. It is recommended, but not required, that a post-test leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 1.6 cm (6 in.) H.O.

velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 1.6 cm (6 in.) H.O. Other leak-check procedures, subject to the approval of the Administrator, may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-3).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of A voltage encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the A and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.
### 3.8 Determine the stack gas dry molecular weight

For combustion processes or processes that emit essentially CO, CO₂, and N₂, use Method 1. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 28.8. For other processes, other methods, subject to the approval of the Administrator, must be used.

### 3.7 Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 8.

### 3.6 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimensions rather than using blueprints.

### 4.1 Type 3 Pilot Tube. Before its initial use, carefully examine the Type 3 pilot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-3 or 2-4. The pilot tube shall not be used if it fails to meet these alignment specifications.

After verifying the face opening alignment, measure and record the following dimensions of the pilot tube: (a) the external tube diameter (dimension D, Figure 2-2); and (b) the face-to-face plane distances (dimensions P₁ and P₂, Figure 2-3). If D is between 0.46 and 0.96 cm (1/8" and 3/8") and P₁ and P₂ are equal and between 1.06 and 1.56 D, there are two possible options: the pilot tube may be calibrated inside the procedure outlined in Sections 4.1.3 through 4.1.5 below, or (2) a baseline (heated tube) coefficient value of 0.84 may be assigned to the pilot tube. Note, however, if if the pilot tube is part of an assembly, blower may still be required, despite k value being outside the baseline coefficient values (Section 4.1.1).

If D, P₁, and P₂ are outside the test limits, the pilot tube must be calibrated outlined in 4.1.3 through 4.1.5 below.

---

**Figure 2-5. Velocity traverse data.**

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4.1.1 Type S Pitot Tube Assembly. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling nozzle, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Getlein 8 in bibliography; therefore an assumed otherwise known baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-8 through 2-14 illustrate interference-free component arrangements for Type S pitot tubes having external tube diameters between 0.48 and 0.95 cm (9/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-8 through 2-14 shall be calibrated according to the procedure outlined in Sections 4.1.3 through 4.1.6 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-sample nozzle) shall be measured and recorded.

Note: Do not use any Type S pitot tube assembly which is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the nozzle (see Figure 2-6b).

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A and the other B. Calibration shall be done in a flow system having the following essential design features:

Figure 2.7. Proper thermocouple placement to prevent interference; D<sub>t</sub> between 0.48 and 0.95 cm (9/16 and 3/8 in.).

Figure 2.8. Minimum pitot-sample probe separation needed to prevent interference; D<sub>t</sub> between 0.48 and 0.95 cm (9/16 and 3/8 in.).
4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, either circular or rectangular. For circular cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.); for rectangular cross-sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

4.1.2.2 The cross-sectional area of the confluence duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

\[ D = \frac{4LW}{L + W} \]

Equation 2-1

where:
- \( D \) = Equivalent diameter
- \( L \) = Length
- \( W \) = Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the site must be located at least 1.5 times the duct diameter downstream and 2.0 times the duct diameter upstream from the nearest disturbances.

Note: The eight- and two-diameter criteria are not absolute; other test section locations may be used (subject to approval of the administrator), provided that the flow at the test site is stable and demonstrably parallel to the duct axis.

4.1.3.3 The flow system shall have the capacity to provide a test-section velocity around 118 m/min (200 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type B pitot tube coefficients obtained by single-velocity calibration at 118 m/min (200 ft/min) will generally be valid to within ±2% for the measurement of velocities above 250 m/min (400 ft/min) and within ±3% for the measurement of velocities below 250 m/min (400 ft/min). If a more precise correlation between G and velocity is desired, the flow system shall have the capacity to generate at least four distinct time-varying test-section velocities covering the velocity range from 50 to 175 m/min (1000 to 3000 ft/min), and calibration data shall be taken at steady velocity intervals over this range (see Chapters 8 and 14 in the bibliography for details).

4.1.3.4 Two entry ports, one each for the standard and Type B pitot tubes, shall be cut in the test section: the standard pitot entry port shall be located slightly downstream of the Type B port, so that the standard and Type B impact openings will lie in the same cross-sectional plane during calibration. To facilitate alignment of the pitot tubes during calibration, it is advisable that the test section be constructed of stainless steel or some other transparent material.

4.1.3.6 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.3.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the calibration tube, proceed as follows:

4.1.3.6.1 Make sure the manometer is properly filled and that the air is free from contamination and is of the proper density. Then and later check all pitot tubes; repair or replace if necessary.

4.1.3.8 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type B entry port.

4.1.3.9 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.3.1), and align the tube so that its tip is pointed directly into the flow. Particular care should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.10 Read \( A_{cal} \) and record its value in a data table similar to the one shown in Figure 2-8. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.11 Connect the Type B pitot tube to the manometer, open the Type B entry port. Check the manometer level and zero. Insert and align the Type B pitot tube so that its A side impact opening is at the same point as was the standard pitot tube pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.12 Read \( A_{cal} \) and enter its value in the calibration data table. Remove the Type B pitot tube from the duct and disconnect it from the manometer.

4.1.3.13 Repeat steps 4.1.3.3 to 4.1.3.12 above three pairs of \( A_{cal} \) have been obtained.

4.1.3.14 Read \( A_{cal} \), and record its value in the data table similar to the one shown in Figure 2-8. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.15 Repeat steps 4.1.3.3 to 4.1.3.12 above for the B side of the standard pitot tube.

4.1.3.16 Perform calculations, as done in Section 4.1.3 below, to obtain the Type B pitot tube coefficient as follows:

4.1.4.1 For each of the six pairs of readings (i.e., three from side A and three from side B) obtained in Section 4.1, calculate the value of the Type B pitot tube coefficient as follows:
where:

- \( C_{mA} \) = Type B pitot tube coefficient
- \( C_{mB} \) = Standard pitot tube coefficient
- \( e_{mA} \) = Velocity head measured by the standard pitot tube, cm H.O. (in. H2O)
- \( e_{mB} \) = Velocity head measured by the Type B pitot tube, cm H.O. (in. H2O)

Equation 2-2

\[
C_{mB} = C_{mA} \sqrt{\frac{e_{mA}}{e_{mB}}}
\]

4.1.4.2 Calculate \( C_{m} \) (side A), the mean of the three \( A \)-side coefficients, and \( C_{s} \) (side B), the mean of the \( B \)-side coefficient; calculate the difference between these two average values.

4.1.4.3 Calculate the deviation of each of the three \( A \)-side values of \( C_{mA} \) from \( C_{m} \) (side A), and the deviation of each \( B \)-side value of \( C_{mB} \) from \( C_{m} \) (side B). Use the following equation:

\[
\text{Deviation} = C_{mA} - C_{mB} (A \text{ or } B)
\]

Equation 2-3

4.1.4.4 Calculate \( s \), the average deviation from the mean, for both the \( A \) and \( B \) sides of the pitot tube. Use the following equation:

\[
s (\text{side A or B}) = \frac{1}{3} \sum |C_{mA} - C_{m}(A \text{ or } B)|
\]

4.1.4.5 Use the Type B pitot tube only if the values of \( s \) (side A) and \( s \) (side B) are less than or equal to 0.01 and if the absolute value of the difference between \( C_{mA} \) (side A) and \( C_{mB} \) (side B) is 0.01 or less.

4.1.5 Special considerations

4.1.5.1 Selection of calibration point

4.1.5.1.1 When the isolated Type B pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedure outlined in Sections 4.1.3 and 4.1.4 above. The Type B pitot coefficients so obtained, i.e., \( C_{mA} \) (side A) and \( C_{mB} \) (side B), will be valid so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 3-6 through 3-8).

4.1.5.1.2 For Type B pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 3-6 and 3-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe shaft into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 5 in Bibliography). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe shaft, is 3 percent or less of the duct cross-sectional area for assemblies with external shafts (Figure 2-10a), and 3 percent or less for assemblies with external shafts (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specifications illustrated in Figure 3-8a), the value of \( C_{mA} \) depends upon the amount of free space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-point calibration technique is acceptable for this purpose, even though the larger nozzle sizes (> 0.889 cm or 3/4 in.) are not ordinarily used for isokinetic sampling at velocities around 515 m/min (1,000 ft/ min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 18 in Section 4).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-3 or 2-4, however, and must have an average deviation \( s \) value of 0.01 or less (see Section 4.1.4.4).
METHOD 17-DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES (IN-STACK FILTRATION METHOD)

Introduction

Particulate matter is not an absolute quantity; rather, it is a function of temperature and pressure. Therefore, to prevent variability in particulate matter emissions regulations and/or associated test methods, the temperature and pressure at which particulate matter is to be measured must be carefully defined. Of the two variables (temperature and pressure), temperature has the greater effect upon the amount of particulate matter in an effluent gas stream; in most stationary source categories, the effect of pressure appears to be negligible.

In Method 5, 250°F is established as a nominal reference temperature. Thus, where Method 5 is specified in an applicable subpart of the standards, particulate matter is defined with respect to temperature. In order to maintain a collection temperature of 250°F, Method 5 employs a heated glass sample probe and a heated filter holder. This equipment is somewhat cumbersome and requires care in its operation. Therefore, where particulate matter concentrations (over the normal range of temperature associated with a specified source category) are known to be independent of temperature, it is desirable to eliminate the glass probe and heating systems, and sample at stack temperature.

This method describes an in-stack sampling system and sampling procedures for use in such cases. It is intended to be used only when specified by an applicable subpart of the standards, and only within the applicable temperature limits (if specified), or when otherwise approved by the Administrator.

1. Principle and Applicability

1.1 Principle. Particulate matter is withdrawn isothermally from the source and collected on a glass fiber filter maintained at stack temperature. The particulate mass is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method applies to the determination of particulate emissions from stationary sources for determining compliance with new source performance standards, only when specifically provided for in an applicable subpart of the standards. This method is not applicable to stacks that contain liquid droplets or are saturated with water vapor. In addition, this method shall not be used if the projected cross-sectional area of the probe extension-filter holder assembly covers more than 8 percent of the stack cross-sectional area (see Section 6.1.2).

2. Apparatus

2.1 Sampling Train. A schematic of the sampling train used in this method is shown in Figure 17-1. Construction details for many, but not all of the train components are given in APTD-0041 (Citation 2 in Bibliography). For changes from the APTD-0041 document and for allowable modifications to Figure 17-1, consult with the Administrator.

The operating and maintenance procedures for many of the sampling train components are described in APTD-0078 (Citation 3 in Bibliography). Since correct use is important in obtaining valid results, all users should read the APTD-0078 document and adopt the operating and maintenance procedures outlined in it, unless otherwise specified herein. The sampling train consists of the following components:

2.1.1 Probe Nozzle. Stainless steel (316) or glass, with sharp, tapered leading edge. The angle of taper shall be 30° and the taper shall be the outside to preserve a constant internal diameter. The probe nozzle shall be of the button-hook or elbow design, unless otherwise specified by the Administrator. If made of stainless steel, the nozzle shall be constructed from seamless tubing. Other materials of construction may be used subject to the approval of the Administrator.

A range of nozzles suitable forokinetic sampling should be available, e.g., 0.50 to 1.27 cm (¼ to ½ in.) or larger (if higher volume sampling trains are used—inside diameter (ID) nozzles in increments of 0.16 cm (¼ in). Each nozzle shall be calibrated according to the procedures outlined in Section 6.1.

2.1.2 Filter Holder. The in-stack filter holder shall be constructed of borosilicate or quartz glass, or stainless steel. If a gasket is used, it shall be made of silicone, Teflon, or stainless steel. Other holder and gasket materials may be used subject to the approval of the Administrator. The filter holder shall be designed to provide a positive seal against leakage from the outside or around the filter.

---

Figure 17-1. Particulate Sampling Train, equipped with In-Stack Filter.
2.1.3 Probe Extension. Any suitable rigid probe extension may be used after the filter holder.

2.1.4 Pilot Tube. Type B is described in Section 2, or other type approved by the Administrator; the pilot tube shall be attached to the probe extension to allow constant monitoring of the stack gas temperature (see Figure 17-1). The pilot tube (in a stack or pressure) opening shall be on the probe at the same horizontal level as the sampling nozzle opening. The sampling nozzle opening shall not be more than 1 meter above the ground or floor level. The distance between the nozzle opening and the pilot tube opening shall be at least 0.1 meter. The sampling nozzle shall be of a type approved by the Administrator. The sampling nozzle shall be of the type approved by the Administrator.

2.1.5 Sampling Assemblies. The sampling assembly shall be of a type approved by the Administrator.

2.1.6 Condenser. It is recommended that the condenser be used in Method 2 to condense the moisture content of the stack gas. The condenser shall be of a type approved by the Administrator.

2.1.7 Metering System. Vacuum gage, leak-free pump, thermometer, and manometer shall be used to determine the temperature and pressure of the sample. The metering system shall be of a type approved by the Administrator.

2.2 Analysis.

2.2.1 Glass Weighing Balance. The balance shall be of a type approved by the Administrator.

2.2.2 Desiccator. The desiccator shall be of a type approved by the Administrator.

2.2.3 Analytical Balance. The balance shall be of a type approved by the Administrator.

2.2.4 Gas Analysis. The gas analysis shall be of a type approved by the Administrator.

2.2.5 Temperature. The temperature shall be of a type approved by the Administrator.

2.2.6 Humidity. The humidity shall be of a type approved by the Administrator.

2.2.7 Barometer. The barometer shall be of a type approved by the Administrator.

2.2.8 Pump. The pump shall be of a type approved by the Administrator.

2.2.9 Flowmeter. The flowmeter shall be of a type approved by the Administrator.

3.1 Sampling.

3.1.1 Filters. The filter shall be of a type approved by the Administrator.

3.1.2 Bag. The bag shall be of a type approved by the Administrator.

3.1.3 Gas. The gas shall be of a type approved by the Administrator.

3.1.4 Condenser. The condenser shall be of a type approved by the Administrator.

3.1.5 Desiccant. The desiccant shall be of a type approved by the Administrator.

3.1.6 Water. The water shall be of a type approved by the Administrator.

3.2 Sample Preparation.

3.2.1 Gas. The gas shall be of a type approved by the Administrator.

3.2.2 Liquid. The liquid shall be of a type approved by the Administrator.

3.2.3 Solid. The solid shall be of a type approved by the Administrator.
Check filters visually against light for irregularities and flaws or pinhole leaks. Label filters of the proper size on the back side with a label or sitckers using indelible ink. As an alternative, label the shipping containers (glass or plastic petri dishes) and keep the filters in these containers at all times except during sampling and weighing.

Desiccant the filters at 20±3°C (68±10°F) and ambient pressure for at least 24 hours and weigh them to nearest 0.1 mg. Weigh a sample of at least 4 hours to a constant weight, i.e., 0.1 mg change from previous weighing; record results to the nearest 0.1 mg. During each weighing, the filter must not be exposed to the laboratory atmosphere for a period greater than 2 minutes and a relative humidity above 50%. Alternatively, unless otherwise specified by the Administrator, the filters may be oven dried at 104°C (220°F) for 2 to 3 hours, desiccated for 2 hours, and weighed. Procedures other than those described, which account for relative humidity effects may be used, subject to the approval of the Administrator.

4.1.2 Preliminary Determinations. Select the sampling site and the minimum number of sampling points according to Method 1 or as specified by the Administrator. Make a projected area model of the probe extension-filter holder assembly, with the pitot tube face openings positioned along the centerline of the stack, as shown in Figure 17-1. Calculate the estimated cross-section blockage, as shown in Figure 17-2. If the blockage exceeds 5 percent of the duct cross-sectional area, the test has the following options:

1. A suitable out-of-stack filter method may be used instead of in-stack filtration.
2. A special in-stack arrangement, in which the sampling and velocity measurement sites are separate, may be used; for details concerning this approach, consult the Administrator.

4.1.3 Preparation of Collection Train. During preparation and assembly of the sampling train, keep all openings where contamination can occur covered until just prior to assembly or until sampling is about to begin.

If impingers are used to condense stack gas moisture, prepare them as follows: place 100 mL of water in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. More silica gel may be used, but care should be taken to ensure that it is not entrained and carried out from the impinger during sampling. Place the container in a clean place for later use in the sample recovery. Alternatively, the weight of the silica gel plus impinger may be determined to the nearest 0.1 g and recorded.

If some means other than impingers is used to condense moisture, prepare the condenser (and, if appropriate, silica gel for condenser outlet) for use.

Using a tweezers or clean disposable surgical gloves, place a labeled (identified) and weighed filter in the filter holder. Be sure that the filter is properly centered and the gasket properly placed so as not to allow the sample gas stream to circulate the filter. Check filter for tears after assembly is completed. Mark the probe extension with heat.

Figure 17-2. Projected area model of cross-section blockage (approximate average for a sample traverse) caused by an in-stack filter holder-probe extension assembly.
resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point.

Assemble the train as in Figure 17-1, using a very tight seal of silicone grease on all ground glass joints and sealing only the outer portion (see APTD-0578) to avoid possibility of contamination by the silicone grease. Place crushed ice around the impingers.

4.1.4 Leak Check Procedures.

4.1.4.1 Pretest Leak-Check. A pretest leak-check is recommended, but not required. If the latter opens to conduct the pretest, leak-check, the following procedure shall be used.

After the sampling train has been assembled, plug the inlet to the probe nozzle with a material that will be able to withstand the stack temperature. Insert the filter holder into the stack and wait approximately 5 minutes (or longer, if necessary) to allow the system to come to equilibrium with the temperature of the stack gas stream. Turn on the pump and draw a vacuum of at least 350 mm Hg (13 in. Hg); note that a lower vacuum may be used, provided that it is not exceeded during the test. Determine the leakage rate. A leakage rate in excess of 4 percent of the average sampling rate or 0.000017 m³/min (0.02 cfm), whichever is less, is unacceptable.

The following leak-check instructions for the sampling train described in APTD-0578 and APTD-0581 may be helpful. Start the pump with by-pass valve fully open and coarse adjust valve completely closed. Partially open the coarse adjust valve and slowly close the by-pass valve until the desired vacuum is reached. Do not reverse direction of by-pass valve. If the desired vacuum is exceeded, either leak-check at this higher vacuum or close the leak-check as shown below and start over.

When the leak-check is completed, first slowly remove the plug from the inlet to the probe nozzle and immediately turn off the vacuum pump. This prevents water from being forced backward and keeps silica gel from being entrained backward.

4.1.4.2 Leak-Checks During Sample Run. If, during the sampling run, a component (e.g., filter assembly or impinger) changes becomes necessary, a leak-check shall be conducted immediately before the change is made. The leak-check shall be done according to the procedure outlined in Section 4.1.4.1 above, except that it shall be done at a vacuum equal to or greater than the maximum value recorded up to that point in the test. If the leakage rate is found to be as greater than 0.000017 m³/min (0.02 cfm) or 4 percent of the average sampling rate (whichever is less), the results are unacceptable, and no correction will need to be applied to the total volume of dry gas measured if, however, a higher leakage rate is obtained, the latter shall either reset the leakage rate and plan to correct the sample volume as shown in Section 4.1.4.1 above, or shall void the sampling run.

Immediately after component changes, leak-checks are optional; if such leak-checks are done, the procedure outlined in Section 4.1.4.1 above shall be used.

4.1.4.3 Post-Test Leak-Check. A leak-check is mandatory at the conclusion of each sampling run. The leak-check shall be done in accordance with the procedure outlined in Section 4.1.4.1, except that it shall

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**Figure 17-3—Particulate Field Data**

**Scheme of Stack Cross Section**

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<tr>
<th>Traverse point number</th>
<th>Sampling time</th>
<th>Volume</th>
<th>Stack temperature (°F)</th>
<th>Velocity head (°F)</th>
<th>Pressure differential across orifice</th>
<th>Gas sample volume</th>
<th>Gas sample temperature at dry gas meter</th>
<th>Temperature of air moving through orifice or test sample</th>
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be conducted at a vacuum equal to or greater than the maximum value reached during the sampling run. If the leakage rate is found to be greater than 5 cm³/min (0.002 ft³/min) or 4 percent of the average sampling rate (whichever is less), the results are acceptable, and no correction need be applied to the sample. If no leakage is detected, continue sampling.

If, however, a higher leakage rate is obtained, the tester shall either record the leakage rate and correct the sample volume as shown in Section 6.3 of this method, or shall void the sampling run.

4.3.5 Particulate Tram Operation. During the sampling run, maintain a sampling flow rate of 20 to 50 liters per minute into the dust chamber filter and check the particulate meter at 20 percent of the true flow rate. The meter shall show a steady reading for at least 10 seconds. If the meter indicates a change in flow rate, the test shall be repeated.

4.3.6 Calculation of Percent Isokinetic. Calculate the percent isokinetic using the procedure set out in Section 4.3.1.1 to determine whether another test run should be made. If there is difficulty in maintaining isokinetic rates due to source conditions, the sampling run may be repeated with possible variance on the isokinetic rates.

4.3.7 Sample Recovery. Proper cleanup procedures for the probe extension assembly are removed from the test unit at the end of the sampling period. Allow the assembly to cool.

When the assembly is to be handcarried, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it to prevent losing or gaining particulate matter. Do not use the probe extension assembly.

4.3.8 Contamination. Contamination may be present in the sample container, due to mechanical, chemical, or biological sources. Clean the sample container, and rinse and dry with a clean, dry cloth. If necessary, use a solvent to clean the sample container.

4.4 Analysis. The analysis shall be performed by the procedure specified in this method. The sample is to be analyzed in duplicate.

If the material designates the sample container, it shall be analyzed in duplicate.

4.5 Results. The results shall be recorded in a manner specified by the administrator. The results shall be reported as the mean of the duplicate analyses.

4.6 Quality Control. Quality control procedures shall be performed as specified by the administrator. The results shall be reported as the mean of the duplicate analyses.

4.7 Reporting. The results shall be reported in accordance with the procedures specified by the administrator. The results shall be reported as the mean of the duplicate analyses.

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Condenser Water. Treat the condenser or implanter water as follows: make a notation of any color or film in the liquid. Measure the liquid volume to within ±1 ml by using a graduated cylinder or, if a balance is available, determine the liquid weight to within ±0.5 g. Record the total volume or weight of liquid present. This information is required to calculate the moisture content of the effluent gas. Discard the liquid after measuring and recording the volume or weight.

4.3 Analysis. Record the data required on the example sheet shown in Figure 17-4. Handle each sample container as follows:

Container No. 1. Leave the contents in the collection container or transfer the filter and any loose particulate from the container to a tared glass weighing dish. Desiccate for 24 hours in a desiccator containing anhydrous calcium sulfate. Weigh to a constant weight and report the results to the nearest 0.1 mg. For purposes of this section, the term "constant weight" means a difference of no more than ±0.3 mg or 0.1 percent of total weight less test weight, whichever is less, between two consecutive weighings, with no less than 6 hours desiccation time between weighings.

Alternatively, the sample may be oven dried at the average stack temperature or 105°C (220°F), whichever is less, for 2 to 3 hours, cooled in the desiccator, and weighed to a constant weight, unless otherwise specified by the Administrator. The test may also be oven dried at the average stack temperature or 105°C (220°F), whichever is less, for 2 to 3 hours, weigh the sample, and use this weight as a final weight.

### Table 17-4: Analytical Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Temp, °C</td>
<td>105°C</td>
</tr>
<tr>
<td>Average Wet Stack Temp, °C</td>
<td>105°C</td>
</tr>
<tr>
<td>Average Dry Stack Temp, °C</td>
<td>105°C</td>
</tr>
<tr>
<td>Average Moisture Temp, °C</td>
<td>105°C</td>
</tr>
<tr>
<td>Average Ambient Temp, °C</td>
<td>22°C</td>
</tr>
<tr>
<td>Average Pressure, psi</td>
<td>15</td>
</tr>
<tr>
<td>Average Flow Rate, cfm</td>
<td>200</td>
</tr>
</tbody>
</table>

### Contamination:

1.2.1 Probe Nozzle. Probe nozzles shall be calibrated before their initial use in the field. Using a micrometer, measure the inside diameter of the nozzle body and compare it to the nominal value. The diameter shall be the average of three measurements made on the same nozzle body. The diameter in millimeters and low numbers shall not exceed 0.023 mm (0.001 in.). When nozzles become nicked, dented, or corroded, they shall be replaced, recalibrated, and recalibrated before use. Each nozzle shall be permanently and uniquely identified.

1.2.2 Pilot Tube. If the pilot tube is placed in an interference-free arrangement with respect to the other probe assembly components, its baseline (isolated tube) coefficient shall be determined as outlined in Section 4 of Method 2. If the probe assembly is not interference-free, the pilot tube assembly coefficient shall be determined by calibration, using methods subject to the approval of the Administrator.

2.3 Metering System. Before its initial use in the field, the metering system shall be calibrated according to the procedure outlined in APTD-011. Instead of physically adjusting the dry gas meter dials to correspond to the meter readings, calibration factors may be used to mathematically correct the gas meter dials to the proper values.

After each field use, the calibration of the metering system shall be checked by performing three calibration runs at a single intermediate orifice setting (based on the previous field test), with the vacuum set at the maximum value reached during the test series. To adjust the vacuum, insert a valve between the wet test meter and the inlet of the metering system. Calculate the average value of the calibration factor. If the calibration has changed by more than ±0.5 percent, recalibrate the meter over the full range of orifice settings, as outlined in APTD-011.

A2 Alternative procedures, such as using the orifice meter coefficients, may be used subject to the approval of the Administrator.

Note: If the dry gas meter coefficient values obtained before and after a test series differ by more than 2 percent, the test series shall either be voided or recalculated, whichever meter coefficient value shall be used. The recalculated value shall be used. If the recalculated value is still within 2 percent of the initial value, the test series shall be considered satisfactory.

3.6 Temperature Gauges. Use the procedure in Section 4.3 of Method 2 to calibrate in-stack temperature gauges. Dial thermometers, such as are used for the dry gas meter and condenser outlet, shall be calibrated against mercury-in-glass thermometers.

3.8 Leak Check of Metering System. Shown in Figure 17-5, that portion of the sampling train from the pump to the orifice meter should be leak checked prior to initial use and after each shipment. Leakage after the pump will result in less volume being recorded than is actually sampled. The following procedures are suggested (see Figure 17-5).

Close the main valve on the meter box. Insert a one-hole rubber stopper with rubber tubing attached to the orifice expansion pipe. Disconnect and vent the low side of the orifice manometer. Close the low side orifice tap. Pressure the system to 15 to 20 psi (1 to 1.4 atm) and fill the manometer with glycerine, blowing air into the rubber tubing. Pinch off the tubing and observe the manometer for one minute. A loss of pressure on the manometer indicates a leak in the meter box; leak, if present, must be corrected.
5.6 Barometer. Calibrate against a mercury barometer.

6. Calculations. Carry out calculations, retaining at least one extra decimal figure beyond that of the summed data. Round off figures after the final calculation. Other forms of the equations may be used as long as they give equivalent results.

6.1 Nomenclature.

A. Cross-sectional area of nozzle, m² (ft²).

B. Water vapor in the gas stream, proportion by volume.

C. Acetone blank residue concentration, mg/L.

a. Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, g/m³ (g/ft³).

b. Percent of isokinetic sampling.

L. Maximum acceptable leakage rate for either a pressur leak check or for a leak check following a component change equal to 0.00087 m³/min (0.02 cfm) or 4 percent of the average sampling rate, whichever is less.

L₁. Individual leakage rate observed during the leak check conducted prior to the component change (i.e., L₁, L₂, L₃, …, Lₙ).

L₂. Leakage rate observed during the post-test leak check, m³/min (cfm).

m. Total amount of particulate matter collected, mg.

M. Molecular weight of water, 18.0 g/mol (6.015 lb/mole).

mₐ. Mass of acetone residue after evaporation, mg.

Pₐ. Barometric pressure at the sampling site, mm Hg (in. Hg).

Pₐ. Absolute stack gas pressure, mm Hg (in. Hg).

Pₐ. Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

P. Ideal gas constant, 0.08205 m³ mm Hg/mol K (litre·atm/mol·K).

T. Absolute gas temperature (see Figure 17-3), K (°R).

T₁. Absolute stack gas temperature (see Figure 17-4), °C (°R).


V. Volume of acetone blank, ml.

V. Volume of acetone used in wash, ml.

V. Total volume of liquid collected in impingers and silica gel (see Figure 17-4), ml.

Vₐ = Volume of gas sample as measured by dry gas meter, dcf.

Vₐ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dcf.

Vₐ = Volume of water vapor in the gas sample, corrected to standard conditions, dcf.

V = Black gas velocity, calculated by Method 2, Equation 3-9, using data obtained from Method 17, m/sec (ft/sec).

Wₐ = Weight of residue in acetone wash, mg.

Y = Dry gas meter calibration coefficient.

ΔP = Average pressure differential across the orifice meter (see Figure 17-3), mm H₂O (in. H₂O).

n = Density of acetone, mg/ml (see label on bottle).

n = Density of water, 0.9992 (g/ml or 0.003210 lb/ml).

Nₐ = Total sampling time, min.

Nₐ = Sampling time interval, from the beginning of a run until the first component change, min.

Nₐ = Sampling time interval, between two successive component changes, beginning with the interval between the first and second changes, min.

Nₐ = Sampling time interval, from the final (n) component change until the end of the sampling run, min.

θₙ = Specific gravity of mercury.

θₙ = Conversion to percent.

6.4 Volume of water vapor.

Vₐ = Volume of water vapor.

where:

Kₐ = 0.8556 cm²•mm Hg for metric units.

Kₐ = 17.64 ft²•in. Hg for English units.

Note: Equation 17-1 can be used written unless the leakage rate observed during any of the mandatory leak checks (i.e., the post-test leak check or leak checks conducted prior to component changes) exceeds L₁. If L₁ or L₂ exceeds L₉, Equation 17-1 must be modified as follows:

(a) Case I. No component changes made during sampling run. In this case, replace Vₐ in Equation 17-1 with the expression:

$$Vₐ = (L₁ - L₉) Nₐ$$

(b) Case II. One or more component changes made during the sampling run. In this case, replace Vₐ in Equation 17-1 by the expression:

$$Vₐ = (L₁ - L₉) Nₐ + (L₂ - L₉) N₂$$

Equation 17-1

$$Vₐ = (L₁ - L₉) Nₐ + (L₂ - L₉) N₂$$

where:

Kₐ = 0.8556 cm²•mm Hg for metric units.

Kₐ = 17.64 ft²•in. Hg for English units.

Equation 17-2

$$Vₐ = Vₐ + (Tₐ - T) \left( \frac{Vₐ}{Vₐ} \right) \left( \frac{T}{Tₐ} \right) \left( \frac{P_{bar} \cdot Vₐ}{P_{bar} \cdot Vₐ} \right)$$

where:

Kₐ = 0.9992 m³/ml for metric units.

Kₐ = 0.04707 ft³/ml for English units.
6.8 Moisture Content.

\[ E_m = \frac{V_{\text{wet}}}{V_{\text{dried}} + V_{\text{wet}}} \]

Equation 17-3

6.9 Acetone Blank Concentration.

\[ C_a = \frac{m_a}{V_{\text{ac}}} \]

Equation 17-4

6.7 Acetone Wash空白.

\[ W_a = C_a V_{\text{ac}} \]

Equation 17-5

6.9 Total Particulate Weight. Determine the total particulate mass from the sum of the weights obtained from containers 1 and 2 less the acetone blank (see Figure 17-4).

Note: Refer to Section 4.1.5 to assess in calculation of results involving two or more filter assemblies or two or more sampling trains.

6.10 Conversion Factors:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Factor</th>
<th>Equivalency</th>
</tr>
</thead>
<tbody>
<tr>
<td>g/l</td>
<td>10^-3</td>
<td>1.00000</td>
</tr>
<tr>
<td>g/l</td>
<td>10^-3</td>
<td>1.00000</td>
</tr>
<tr>
<td>g/m^3</td>
<td>1.209 x 10^{-6}</td>
<td>3.531</td>
</tr>
<tr>
<td>g/m^3</td>
<td>1.209 x 10^{-6}</td>
<td>3.531</td>
</tr>
</tbody>
</table>

6.11 Isokinetic Variation.

6.11.1 Calculation from Raw Data.

\[ 100 \frac{T_c}{T_a} = \left( \frac{T_c}{T_a} \right) \left( \frac{V_c}{V_a} \right) \left( \frac{P_a}{P_c} \right) \left( \frac{M_{12}}{M_{12}} \right) \]

Equation 17-6

where:

\[ M_{12} = 0.003484 \text{ mm Hg} \cdot \text{m}^3/\text{ml} \cdot \text{K} \text{ for metric units} \]

\[ M_{12} = 0.003489 \text{ in Hg} \cdot \text{ft}^3/\text{ml} \cdot \text{K} \text{ for English units} \]

6.11.2 Calculation from Intermediate Values.

\[ 100 \frac{T_c}{T_a} = \left( \frac{T_c}{T_a} \right) \left( \frac{V_c}{V_a} \right) \left( \frac{P_a}{P_c} \right) \left( \frac{M_{12}}{M_{12}} \right) \]

Equation 17-7

where:

\[ K_c = 0.003484 \text{ mm Hg} \cdot \text{m}^3/\text{ml} \cdot \text{K} \text{ for metric units} \]

\[ K_c = 0.003489 \text{ in Hg} \cdot \text{ft}^3/\text{ml} \cdot \text{K} \text{ for English units} \]

6.12 Acceptable Results. If 90 percent < T_c < 110 percent, the results are acceptable. If the results are low in comparison to the standard and T_c is beyond the acceptable range, or if T_c is less than 90 percent the Administrator may opt to accept the results. Use Citation 4 in bibliography to make judgments. Otherwise, reject the results and repeat the test.


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ELEMENTS (ICP)

M.W.: Table 1

OSHA/NIOSH/ACGIH: Table 1

PROPERTIES: Table 1

ELEMENTS: aluminum cobalt manganese silver tungsten arsenic copper molybdenum sodium vanadium beryllium iron nickel tellurium yttrium cadmium lead phosphorus thallium zinc calcium lithium platinum tin yttrium chromium magnesium selenium titanium

SYNONYMS: vary depending upon the compound.

<table>
<thead>
<tr>
<th>SAMPLING</th>
<th>MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLER: FILTER (0.8-μm, cellulose ester membrane)</td>
<td>TECHNIQUE: INDUCTIVELY COUPLED ARGON PLASMA, ATOMIC EMISSION SPECTROSCOPY</td>
</tr>
<tr>
<td>FLOW RATE: 1 to 4 L/min</td>
<td></td>
</tr>
<tr>
<td>VOL-MIN: Table 1</td>
<td>ASHING REAGENTS: conc. HNO₃, 4 mL; and conc. HClO₄, 1 mL</td>
</tr>
<tr>
<td>MAX: Table 1</td>
<td>CONDITIONS: room temperature, 30 min;</td>
</tr>
<tr>
<td>SHIPMENT: routine</td>
<td>150 °C to near dryness</td>
</tr>
<tr>
<td>SAMPLE STABILITY: stable</td>
<td></td>
</tr>
<tr>
<td>BLANKS: 2 to 10 field blanks per set</td>
<td>FINAL SOLUTION: 4% HNO₃, 1% HClO₄, 10 mL</td>
</tr>
</tbody>
</table>

ACCURACY

RANGE STUDIED: not studied

BIAS: none identified

OVERALL PRECISION (sₚ): not evaluated

APPLICABILITY: The working range of this method is 0.005 to 2.0 mg/m³ for each element in a 500-L air sample. This is simultaneous elemental analysis, not compound specific. Verify that the types of compounds in the samples are soluble with this ashing procedure.

INTERFERENCES: Spectral interferences are the primary interferences encountered in ICP-AES analysis. These are minimized by judicious wavelength selection, interelement correction factors and background correction [1,2].

OTHER METHODS: This method replaces P&GAM 351 [2] for trace elements. Atomic absorption spectroscopy (e.g., Methods 70XX) is an alternate analytical technique for many of these elements.

2/15/84

METHOD: 7300

ISSUED: 2/15/84

1 to 4 Urnin

Vol-Min: Table 1

ASHING REAGENTS: conc. HNO₃, 4 mL; and conc. HClO₄, 1 mL

CONDITIONS: room temperature, 30 min;

FINAL SOLUTION: 4% HNO₃, 1% HClO₄, 10 mL

WAVELENGTH: depends upon element; Table 2

BACKGROUND CORRECTION: spectral wavelength shift

CALIBRATION: elements in 4% HNO₃, 1% HClO₄

RANGE: 2.5 to 1000 µg per sample [1]

ESTIMATED LOD: 1 µg per sample [1]

PRECISION (sₚ): Table 2
ELEMENTS (ICP)

METHOD: 7300

REAGENTS:
1. Nitric acid, conc.
2. Perchloric acid, conc.*
   Mix 4 volumes conc. HNO₃ with 1 volume conc. HClO₄.
4. Calibration stock solutions, 1000 µg/mL. Commercially available, or prepared per instrument manufacturer's recommendation (see step 12).
5. Dilution acid, 4% HNO₃, 1% HClO₄.
   Add 50 mL ashing acid to 600 mL water; dilute to 1 L.
6. Argon.
7. Distilled, deionized water.

*See Special Precautions.

EQUIPMENT:
1. Sampler: cellulose ester membrane filter, 0.8-µm pore size, 37-mm diameter; in cassette filter holder.
2. Personal sampling pump, 1 to 4 L/min, with flexible connecting tubing.
3. Inductively coupled plasma–atomic emission spectrometer, equipped as specified by the manufacturer for analysis of elements of interest.
4. Regulator, two-stage, for argon.
5. Beakers, Phillips, 125-mL, or Griffin, 50-mL, with watchglass covers.*
6. Volumetric flasks, 10- and 100-mL.*
7. Assorted volumetric pipets as needed.*
8. Hotplate, surface temperature 150 °C.

SPECIAL PRECAUTIONS: Perform all perchloric acid digestions in a perchloric acid hood.

SAMPLING:
1. Calibrate each personal sampling pump with a representative sampler in line.
2. Sample at an accurately known flow rate between 1 and 4 L/min for a total sample size of 200 to 2000 L (see Table 1) for TMA measurements. Do not exceed a filter loading of approximately 2 mg total dust.

SAMPLE PREPARATION:
3. Open the cassette filter holders and transfer the samples and blanks to clean beakers.
4. Add 5 mL ashing acid. Cover with a watchglass. Let stand 30 min at room temperature.
   NOTE: Start a reagent blank at this step.
5. Heat on hotplate (120 °C) until ca. 0.5 mL remains.
   NOTE: Some species of Li, Mn, Mo, Sn, W, and Zr will not be completely solubilized by this procedure. Alternative solubilization techniques for most of these elements can be found elsewhere [2,3,4,5,6,7].
6. Add 2 mL ashing acid and repeat step 5. Repeat this step until the solution is clear.
7. Remove watchglass and rinse into the beaker with distilled water.
8. Increase the temperature to 150 °C and take the sample to dryness.
9. Dissolve the residue in 2 to 3 mL dilution acid.
10. Transfer the solutions quantitatively to 10-mL volumetric flasks.
11. Dilute to volume with dilution acid.

CALIBRATION AND QUALITY CONTROL:
12. Calibrate the spectrometer according to the manufacturers recommendations.
   NOTE: Typically, an acid blank and 10 µg/mL multielement working standards are used. The following multielement combinations are chemically compatible in 4% HNO₃/1% HClO₄:
   a. Ag, Ca, Co, Hg, Pb, V, Zn;
   b. Al, Be, Cd, La, Li, Ni, Ti;
   c. As, B, Ba, Mg, Mo, P, Sn;

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METHOD: 7300

Elements (ICP)

d. Cu, Fe, Na, Pt, Sr, Te, Y;
e. Cr, K, Sb, Se, Ti, Zr; and
f. Si, W (distilled water only)

13. Analyze a standard for every ten samples.
14. Check recoveries with at least two spiked media blanks per ten samples.

MEASUREMENT:
15. Set spectrometer to conditions specified by manufacturer.
16. Analyze standards and samples.

NOTE: If the values for the samples are above the range of the standards, dilute the solutions with dilution acid, reanalyze and apply the appropriate dilution factor in the calculations.

CALCULATIONS:
17. Obtain the solution concentrations for the sample, \( C_s \) (µg/mL), and the average media blank, \( C_b \) (µg/mL), from the instrument.
18. Using the solution volumes of sample, \( V_s \) (mL), and media blank, \( V_b \) (mL), calculate the concentration, \( C \) (mg/m³), of each element in the air volume sampled, \( V \) (L):

\[
C = \frac{C_s V_s - C_b V_b}{V}, \text{ mg/m}^3.
\]

EVALUATION OF METHOD:
Method P&CAM 351 was evaluated in 1981 [1, 2]. The precision and recovery data were determined at 2.5 and 1000 µg of each element per sample on spiked filters. The precision and recovery data, instrumental detection limits, sensitivity, and analytical wavelengths are listed in Table 2. The values in Table 2 were determined with a Jarrell-Ash Model 1160 ICP operated according to manufacturer's instructions.

REFERENCES:

METHOD REVISED BY: R. Delon Hull and Mark Millson, NIOSH/DPSE.
Table 1. Properties and sampling volumes.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Weight</th>
<th>MP, °C</th>
<th>Properties</th>
<th>Permissible Exposure Limits, mg/m³ TWA</th>
<th>Air Volume @ OSHA, L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>OSHA/NIOSH/ACGIH</td>
<td>MIN</td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td>107.87</td>
<td>961</td>
<td></td>
<td>0.01/ — / 0.1</td>
<td>250</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>26.98</td>
<td>660</td>
<td></td>
<td>— / — / 10.</td>
<td>5 (g)</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>74.92</td>
<td>817(*)</td>
<td></td>
<td>0.5/C 0.002/ 0.2</td>
<td>5</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>9.01</td>
<td>1278</td>
<td></td>
<td>0.002/ 0.0005/ 0.002</td>
<td>1250</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>40.08</td>
<td>842</td>
<td></td>
<td>5 (b)/ — / 2 (b)</td>
<td>5</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>112.40</td>
<td>321</td>
<td></td>
<td>0.2/ 0.04/ 0.05</td>
<td>13</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>58.93</td>
<td>1495</td>
<td></td>
<td>0.1/ — / 0.1</td>
<td>25</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>52.00</td>
<td>1890</td>
<td></td>
<td>1.0 (c)/ 0.025/ 0.5 (c)</td>
<td>5</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>63.54</td>
<td>1063</td>
<td></td>
<td>1.0/ — / 1.0</td>
<td>5</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>55.85</td>
<td>1353</td>
<td></td>
<td>10 (b)/ — / 5 (b)</td>
<td>5</td>
</tr>
<tr>
<td>Lithium (Li)</td>
<td>6.94</td>
<td>179</td>
<td></td>
<td>0.025 (d)/ — / 0.025 (d)</td>
<td>100</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>24.31</td>
<td>651</td>
<td></td>
<td>15 (b)/ — / 10 (b)</td>
<td>5</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>54.94</td>
<td>1244</td>
<td></td>
<td>C 5/ — / C 5</td>
<td>5</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>95.94</td>
<td>651</td>
<td></td>
<td>15 (e)/ — / 10 (e)</td>
<td>5</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>22.99</td>
<td>98</td>
<td></td>
<td>2 (f)/ C 2 (f)/ C 2 (f)</td>
<td>13</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>58.71</td>
<td>1453</td>
<td></td>
<td>1/ 0.015/ 1 (c)</td>
<td>5</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>30.97</td>
<td>44</td>
<td></td>
<td>— / — / 0.1</td>
<td>25 (g)</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>207.19</td>
<td>328</td>
<td></td>
<td>0.05/ 0.1/ 0.15</td>
<td>50</td>
</tr>
<tr>
<td>Platinum (Pt)</td>
<td>195.09</td>
<td>1769</td>
<td></td>
<td>0.002 (a)/ — / 1 (c)</td>
<td>1250</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>78.96</td>
<td>217</td>
<td></td>
<td>0.2/ — / —</td>
<td>13</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>118.69</td>
<td>323</td>
<td></td>
<td>2/ — / 2 (c)</td>
<td>5</td>
</tr>
<tr>
<td>Tellurium (Te)</td>
<td>127.60</td>
<td>450</td>
<td></td>
<td>0.1/ — / 0.1</td>
<td>25</td>
</tr>
<tr>
<td>Titanium (Ti)</td>
<td>47.90</td>
<td>1675</td>
<td></td>
<td>— / — / 10 (b)</td>
<td>5</td>
</tr>
<tr>
<td>Thallium (Tl)</td>
<td>204.37</td>
<td>304</td>
<td></td>
<td>0.1 (a)/ — / 0.1 (a)</td>
<td>25</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>50.94</td>
<td>1890</td>
<td></td>
<td>C 0.5/ 1 (c)/ 0.05 (V_2O_5)</td>
<td>5</td>
</tr>
<tr>
<td>Tungsten (W)</td>
<td>183.85</td>
<td>3410</td>
<td></td>
<td>— / 5 (e)/ 5 (e)</td>
<td>5 (g)</td>
</tr>
<tr>
<td>Yttrium (Y)</td>
<td>88.91</td>
<td>1495</td>
<td></td>
<td>1/ — / 1</td>
<td>5</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>65.37</td>
<td>419</td>
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<td>5 (b)/ 5 (b)/ 5 (b)</td>
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<tr>
<td>Zirconium (Zr)</td>
<td>91.22</td>
<td>1852</td>
<td></td>
<td>5/ — / 5</td>
<td>5</td>
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</tbody>
</table>

(a) soluble  
(b) oxide  
(c) metal  
(d) hydride  
(e) insoluble  
(f) hydroxide  
(g) at the ACGIH TLV
Table 2. Measurement procedures and data (a).

<table>
<thead>
<tr>
<th>Element</th>
<th>Wavelength (nm)</th>
<th>LOD (ng/mL)</th>
<th>Sensitivity (Intensity/μg/mL)</th>
<th>Recovery (%)</th>
<th>Precision (σ_r) (N = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>@ 2.5 μg/2.5 pg/filter</td>
<td>@ 1000 μg/25 pg/500 L air</td>
<td>@ 2.5 μg/2.5 pg/500 L air</td>
</tr>
<tr>
<td>Ag</td>
<td>328.3</td>
<td>26</td>
<td>0.65</td>
<td>111</td>
<td>91</td>
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<tr>
<td>Al</td>
<td>308.2</td>
<td>14</td>
<td>0.23</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>As</td>
<td>193.7</td>
<td>13</td>
<td>0.57</td>
<td>103</td>
<td>99</td>
</tr>
<tr>
<td>Be</td>
<td>313.0</td>
<td>1.5</td>
<td>1.29</td>
<td>107</td>
<td>90</td>
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<tr>
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<td>10</td>
<td>0.49</td>
<td>99</td>
<td>95</td>
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<td>1.6</td>
<td>0.83</td>
<td>107</td>
<td>99</td>
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<tr>
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<td>0.38</td>
<td>101</td>
<td>95</td>
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<td>106</td>
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<tr>
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<td>2.1</td>
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<td>0.13</td>
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<td>97</td>
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<td>105</td>
<td>106</td>
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<td>(c)</td>
<td>101</td>
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<td>105</td>
<td>97</td>
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<tr>
<td>P</td>
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<td>0.17</td>
<td>(c)</td>
<td>91</td>
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<td>15</td>
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<tr>
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<tr>
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<td>74</td>
<td>67</td>
</tr>
<tr>
<td>Te</td>
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<td>29</td>
<td>0.41</td>
<td>102</td>
<td>94</td>
</tr>
<tr>
<td>Ti</td>
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<td>1.2</td>
<td>0.55</td>
<td>96</td>
<td>100</td>
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<tr>
<td>Tl</td>
<td>190.9</td>
<td>17</td>
<td>0.22</td>
<td>103</td>
<td>99</td>
</tr>
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<td>0.88</td>
<td>99</td>
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<td>0.60</td>
<td>101</td>
<td>94</td>
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<tr>
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<td>1.9</td>
<td>0.88</td>
<td>75</td>
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</table>

(a) Values reported were obtained with a Jarrell-Ash Model 1160 ICP; performance may vary with instrument and should be independently verified.

(b) 2.5 μg/filter corresponds to 5 μg/m³ for a 500-L air sample.

(c) Blank levels too high to make accurate determinations.
<table>
<thead>
<tr>
<th>Source</th>
<th>Type of control</th>
<th>Pollutant</th>
<th>Run No.</th>
<th>Test Method</th>
<th>Isokinetic, %</th>
<th>Gas volume, DSCF</th>
<th>Volum. flow rate, DSCFM</th>
<th>Mass, g</th>
<th>Concen., gr/DSCF</th>
<th>Emission rate, lb/hr</th>
<th>Process rate, ton/hr</th>
<th>Emission factor</th>
</tr>
</thead>
<tbody>
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<td>fabric filter</td>
<td>filterable PM</td>
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<td>EPA 17</td>
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<td>98.10</td>
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<td>0.00343</td>
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<td>cadmium</td>
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<td>EPA 29</td>
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<td>4,916</td>
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</table>

Basis for rating: Data not rated because only one run was conducted and average process rates provided; run-by-run rates not specified.

Problems noted: Other notes: