

## Source Test Method **ST-15**

### **PARTICULATE**

(Adopted January 20, 1982)

**REF: Regulations 6-310, 6-311, 10-1-301**

#### **1. APPLICABILITY**

1.1 This method is used to quantify particulate emissions. It determines compliance with Regulations 6-310, 6-311, and 10-1-301.

#### **2. PRINCIPLE**

2.1 Stack gases are drawn isokinetically through glass fiber filters at stack conditions. The weight of particulate matter, including any material that condenses at or above the stack temperature, is determined gravimetrically after the removal of uncombed water.

#### **3. RANGE**

3.1 The minimum particulate emissions measurable by this procedure is .001 gr/SDCF.

#### **4. APPARATUS**

5.1 Probe Nozzle. The probe nozzle shall be equivalent to the nozzle shown in Figure 15-1. The probe nozzle shall be constructed of borosilicate glass, quartz, or stainless steel.

5.2 Filter Holder. Use filter tubes equivalent to the one shown in Figure 15-1 and constructed of borosilicate glass or quartz.

5.3 Filter Tube Holder. Use a filter tube holder which will contain three filter tubes and the probe nozzle in a leak-free manner. Figure 15-2 shows an acceptable filter tube holder configuration.

5.4 Filter Medium. Use borosilicate glass wool, or equivalent. Corning Glass Works Glass, Catalogue #3950 is acceptable.

5.5 Connections. The connection between the filter and the first impinger must be able to withstand stack temperatures. Vinyl tubing is acceptable in making all other connections.

5.6 Pitot Tube. Use a Stauscheibe (Type-S), or equivalent, with a known coefficient which is constant within  $\pm 5\%$  over the entire working range. The pitot tube coefficient is determined by placing both the S-type and the standard pitot tube in a gas stream and measuring the pressure head with both over the entire velocity range of interest. Calculate the coefficient of the Type-S pitot tube as follows:

$$C_{p_s} = C_{p_{std}} \left[ \frac{\Delta P_{std}}{\Delta P_s} \right]^{\frac{1}{2}}$$

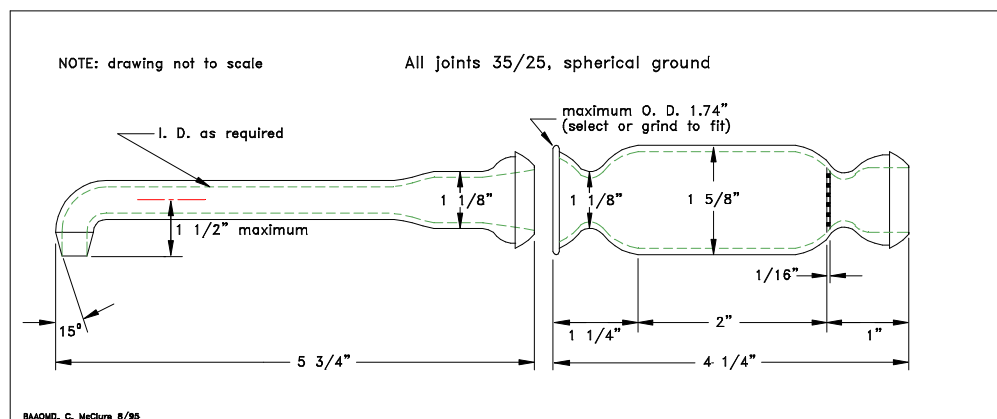
where:

- $C_{p_s}$  = Type-S pitot tube coefficient  
 $\Delta P_s$  = Pressure head, Type-S pitot tube  
 $\Delta P_{std}$  = Pressure head, standard pitot tube  
 $C_{p_{std}}$  = Standard pitot tube coefficient

- 5.7 Temperature Measuring Device. Use a Chromel-Alumel thermocouple accurate to  $\pm 15^{\circ}\text{F}$ , connected to a temperature compensated null type potentiometer, or equivalent, to measure stack temperatures.

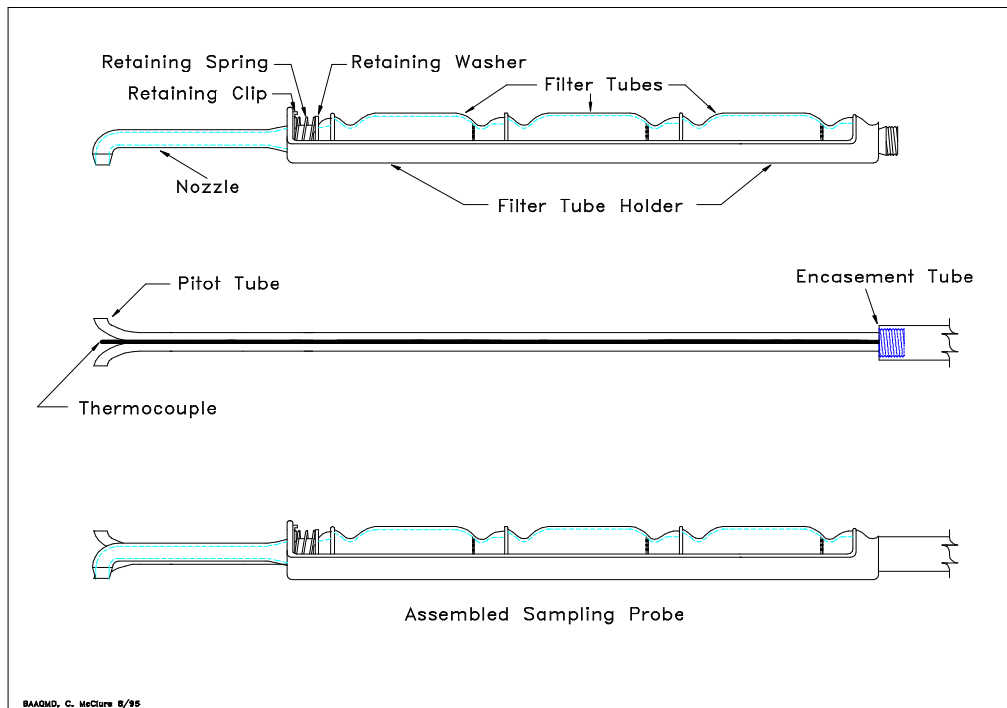
**Figure 15-1**

**Nozzle and Filter Tube**



- 5.8 Encasement tube. Assemble the items in 5.3, 5.6 and 5.7 in a pipe as shown in Figure 15-2 to facilitate handling. To prevent the pitot tube from interfering with the gas flow stream-lines approaching the sample nozzle, position the pitot tube and sample nozzle not closer together than 0.75 inches.
- 5.9 Condensers. Use three Greenberg-Smith impingers. The third impinger shall be modified by removing the impaction plate and attaching a thermometer to the inlet stem.
- 5.10 Cooling System. Use an ice bath to contain the impingers.
- 5.11 Sample Pump. Use a leak-free vacuum pump capable of maintaining a 1.0 CFM flow rate at 15 inches of mercury. The pump must have a sample rate control valve and a vacuum gauge attached to the inlet.
- 5.12 Silica Gel Tube. Use approximately 500 cc of silica gel, (with Drierite indicator) to insure that the gas entering the dry test meter is free of  $\text{H}_2\text{O}$ .

- 5.13 Dry Test Meter. Use a 175 CFH dry test meter accurate within  $\pm 2\%$  of the true volume and equipped with a thermometer to measure the outlet temperature. The working pressure across the meter shall not exceed one inch water column.
- 5.14 Rotameter. Use a calibrated rotameter to measure the sampling rate.
- 5.15 Pressure Gauge. Use a Magnehelic differential pressure gauge, or equivalent, in the same range as the velocity and static pressures being measured in the stack.
- 5.16 Analytical Balance. An analytical balance accurate to within  $\pm 0.5$  mg to measure filter weights. An analytical balance capable of measuring condensate weights to the nearest 0.1 gram is acceptable.
- 5.17 Barometer. Use a barometer that is accurate to within  $\pm 0.2$  inches of mercury.

**Figure 15-2****Filter Tube Assembly****6. PRE-TEST PROCEDURES**

- 6.1 Filter Preparation. Pack three labeled filter tubes for each run with borosilicate glass wool so as to produce a 10 inch H<sub>2</sub>O pressure drop across each filter tube at 0.5 CFM flow. Dry the filter tubes in an oven at 105°C for 24 hours, cool them in a desiccator. Weigh each filter tube on an analytical balance to the nearest 0.5 mg. Record each weight on the lab data sheet shown in Form 15-1.

- 6.2 Impinger Preparation. Fill each of two unmodified Greenberg-Smith impingers with approximately 100 ml of distilled water. Weigh and record the weights on the data sheet as shown in Form 15-2.
- 6.3 Nozzle Size Determination.
- 6.3.1 Determine the number and location of the stack traverse points in accordance with ST-18.
- 6.3.2 Conduct a velocity traverse in accordance with ST-17 and measure the stack gas temperature.
- 6.3.3 Determine the moisture content of the stack gases in accordance with ST-23.
- 6.3.4 Nozzle diameter:

$$D_n = 13.7 \left[ \frac{T_s}{V_s(100 - H_2O)} \right]^{\frac{1}{2}}$$

Where:

- $D_n$  = Nozzle diameter, mm
- $T_s$  = Stack gas temperature, °R
- $H_2O$  = Stack gas moisture concentration, %
- 13.7 = A constant based on an assumed meter rate of 0.5 CFM, meter temperature 70°F, and a molecular weight of 28.8.
- $V_s$  = Stack Gas Velocity fps

- 6.4 Assemble the sampling train as shown in Figure 15-3.
- 6.5 The entire sampling train must be leak-checked before each test run. Plug the sampling probe, start the pump, and adjust the pump vacuum to 380 mm Hg (15" Hg). A leak rate through the meter which exceeds 0.57 lpm (0.02 CFM) is unacceptable.

## 7. SAMPLING

- 7.1 Each test run shall be of 50 minute duration when testing emissions from continuous operations. Each test run at batch process operations shall be for 90% of the batch time or 50 minutes, whichever is less.
- 7.2 Sample at the traverse points determined in accordance with ST-18.
- 7.3 The sampling rate at each traverse point must be isokinetic. Measure the stack velocity and stack temperature at each point and adjust the meter flow rate according to the following equation:

$$Q_m = \frac{2.638 \times 10^{-3} (100 - \%H_2O) D_n^2 V_s}{T_s}$$

Where:

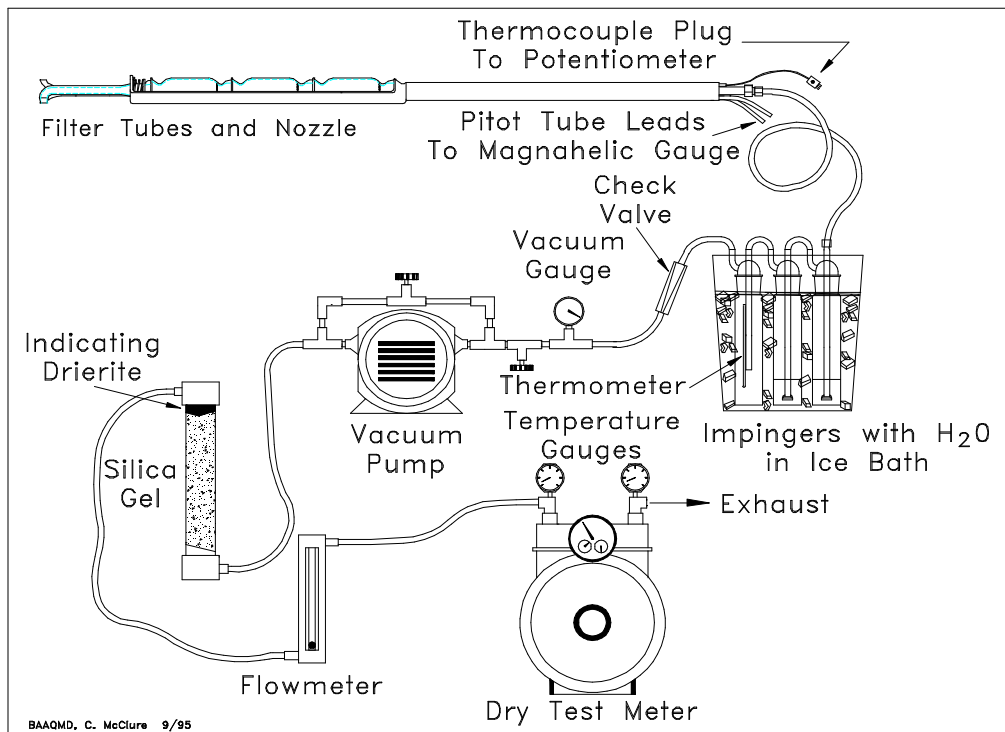
- $Q_m$  = Isokinetic Sampling Rate, ACFM
- $T_s$  = Stack Temperature, °R

$$\%H_2O = \text{Stack Gas Moisture content (from 6.3.3)}$$

- 7.4 When inserting the probe into the stack rotate the nozzle so it points down stream to avoid particulate collection prior to sampling. Immediately before sampling, rotate the probe so the nozzle points upstream.

**Figure 15-3**

**Particulate Sampling Train**



- 7.5 Record the following information at five-minute intervals or whenever changing sampling locations on a field data sheet as shown in Form 15-3.

Stack Velocity Head  
 Sample time  
 Sample Rate  
 Cumulative Sample Volume  
 Impinger Saturation Temperature  
 Stack Gas Temperature  
 Impinger Vacuum  
 Dry Test Meter Temperature

- 7.6 At the conclusion of each run, stop the pump, remove the probe from the stack and record the final meter reading. Point the probe upward and purge the sample train with ambient air.
- 7.7 Conduct three consecutive test runs.

**8. POST-TEST PROCEDURES**

- 8.1 Remove the nozzle and filters as a unit and seal both ends. This must be done in a clean dry location to avoid sample contamination.
- 8.2 Stopper the impingers to minimize sample losses.
- 8.3 Clean the exterior of the nozzle and filter tubes and dry then in an oven for 24 hours at 105°C. Allow to cool in a desiccator and weigh to the nearest 0.5 mg. Repeat the desiccation and weighing process daily until constant weights are recorded.
- 8.4 After weighing the nozzle containing particulate matter, clean, dry and weigh the nozzle to obtain its tare weight.
- 8.5 Weigh each impinger to the nearest 0.1 g.

**9. AUXILIARY TESTS**

- 9.1 Determine the CO<sub>2</sub>, O<sub>2</sub> and CO concentrations simultaneously with each particulate run in accordance with ST-5, ST-14, and ST-6. An Orsat analysis (ST-24) is also acceptable.

**10. CALCULATIONS**

- 10.1 Standard Dry Sample Volume

$$V_o = \frac{17.71V_m P_b}{T_m}$$

Where:

- $V_o$  = Standard dry sample volume, SDCF @ 70 °F and 29.92 inches Hg
- $V_m$  = Actual Metered Volume, ft<sup>3</sup>
- $P_b$  = Barometric Pressure, Inches Hg
- $T_m$  = Average Meter Temperature, °R
- 17.71 = Constant correcting to 70 °F and 29.92 inches Hg

- 10.2 Water Vapor Content

$$\%H_2O = \frac{(0.0474W_c) + \frac{V_o P_{sat}}{P_b - P_i - P_{sat}}}{V_o + (0.0474W_c) + \frac{V_o P_{sat}}{P_b - P_i - P_{sat}}} \times 100$$

Where:

$W_c$	=	Total condensate weight, all impingers, grams
$P_{sat}$	=	Water saturation pressure in the impingers, inches Hg.
$P_b$	=	Barometric pressure, inches Hg
$P_i$	=	Pump inlet vacuum, inches Hg
%H <sub>2</sub> O	=	Percent water vapor, by volume
0.0474	=	Cubic feet of vapor resulting from 1 cubic centimeter of liquid H <sub>2</sub> O

### 10.3 Stack Gas Molecular Weight

$$MW = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO) + 0.18 (\%H_2O)$$

Where:

MW	=	Molecular Weight
%CO <sub>2</sub>	=	Percent Carbon Dioxide by volume (dry basis)
%O <sub>2</sub>	=	Percent Oxygen by volume (dry basis)
%CO	=	Percent Carbon Monoxide by volume (dry basis)
%H <sub>2</sub> O	=	Percent Moisture by volume
%N <sub>2</sub>	=	Percent Nitrogen by volume (dry basis - determine by difference)

### 10.4 Stack Gas Flow Rate. Determine in accordance with ST-17.

### 10.5 Corrected Particulate Weight. Calculate using the third filter net weight as blank:

$$W_p = (W_1 + W_2) - \frac{W_3}{F_3}(F_1 + F_2)$$

Where:

$W_p$	=	Corrected weight of particulate catch, grams
$W_1$	=	Weight gain in 1st filter, grams
$W_2$	=	Weight gain in 2nd filter, grams
$W_3$	=	Weight gain in 3rd filter, grams
$F_1$	=	Weight of wool in 1st filter, grams
$F_2$	=	Weight of wool in 2nd filter, grams
$F_3$	=	Weight of wool in 3rd filter, grams

### 10.6 Particulate Weight Concentration:

$$G = 15.43 \frac{W_p}{V_o}$$

Where:

- G = Particulate concentration, grains/SDCF  
 W<sub>p</sub> = Weight of particulate catch, grams  
 V<sub>o</sub> = Standard dry sample volume, SDCF  
 15.43 = Grains/gram

10.7 Particulate Mass Emission Rate:

$$M = \frac{G Q_o}{116.7}$$

Where:

- M = Particulate mass emission rate, lbs/hr  
 Q<sub>o</sub> = Standard dry stack flow rate, SDCFM  
 116.7 = Conversion factor for grains to pounds and minutes to hours

10.8 Correction to 12% Carbon Dioxide:

$$G' = \frac{12.0(G)}{C_{CO_2}}$$

Where:

- G' = Particulate concentration, grains/SDCF at 12% CO<sub>2</sub>  
 C<sub>CO<sub>2</sub></sub> = Percent Carbon Dioxide in stack gas (dry basis)  
 12.0 = CO<sub>2</sub> standard, mole fraction  
 G = Particulate concentration, grains SDCF

10.9 Auxiliary Fuel Correction Factor. If the test results are applied to Regulation 6-310.1 and if auxiliary fuel is used, a correction for the carbon dioxide shall be calculated as:

$$G'' = \frac{(0.12)[Q_o - (10.24)(Q_g)]}{\left[ \frac{(Q_o)(C_{CO_2})}{100} \right] - [1.11(Q_g)]} (G)$$

Where:

- G'' = Particulate concentration, grains/SDCF at 12% and corrected for auxiliary fuel usage  
 Q<sub>o</sub> = Stack flowrate, SDCFM  
 Q<sub>g</sub> = Natural gas flowrate, SDCFM



- 1.11 = Average cubic feet of CO<sub>2</sub> produced by combusting 1 cubic foot of natural gas
- 10.24 = Average cubic feet of air required to combust 1 cubic foot of natural gas

10.10 Isokinetic Ratio. Calculate for each traverse point as:

$$R_i = \frac{(T_{si})(V_{mi})(100)}{(V_{si})(t_i)(T_{mi})(A_n)(60)(100 - \%H_2O)}$$

Where:

- R<sub>i</sub> = Isokinetic ratio at point i
- T<sub>si</sub> = Stack temperature at point i, °R
- V<sub>mi</sub> = Metered volume at point i, ft<sup>3</sup>
- V<sub>si</sub> = Stack gas velocity at point i, FPS
- t<sub>i</sub> = Sample time at point i, minutes
- T<sub>mi</sub> = Dry Test Meter temperature at point i, °R
- A<sub>n</sub> = Cross-sectional area of nozzle, Ft<sup>2</sup>
- %H<sub>2</sub>O = Water Vapor in gas stream, percent
- 100 = Conversion from percent to mole fraction
- 60 = Conversion from seconds to minutes

10.11 Overall Isokinetic Ratio. Calculate from complete stack traverse as:

$$R_i = \frac{(T_s)(V_o)(29.92)(100)}{(V_s)(t)(A_n)(P_s)(100 - \%H_2O)(60)(530)}$$

Where:

- R<sub>i</sub> = Overall Isokinetic Ratio for the traverse
- T<sub>s</sub> = Stack temperature, °R
- V<sub>o</sub> = Standard dry sample volume, SDCF
- V<sub>s</sub> = Average stack gas velocity, FPS
- t = Total sampling time, minutes
- A<sub>n</sub> = Cross-sectional area of nozzle, Ft<sup>2</sup>
- P<sub>s</sub> = Absolute stack gas pressure, "Hg
- %H<sub>2</sub>O = Water Vapor in gas stream, percent
- 29.92 = Standard absolute pressure, inches Hg
- 60 = Conversion from seconds to minutes
- 100 = Conversion from percent to mole fraction
- 530 = Standard absolute temperature, °R

## 11. REPORTING

11.1 The data and information indicated in Form 15-4 shall be reported.

**Bay Area Air Quality Management District**

Form 15-1

Source Test Laboratory Data Sheet

**Filter Tube and Nozzle Weightings**

Plant Name: _____	Plant Number: _____
Source Operation: _____	Test Date: _____
Source Test #: _____	Page: 1 of _____
Impinger Solution: _____	Initial: _____

Tube I. D. #	Tare Weight (g)	Packed Weight (g) (A)	Final Weight (g) (B)	Catch Weight (g) (B) - (A)

Nozzle I. D. #	Tare Weight (g) (A)	Final Weight (g) (B)	Catch (g) (B) - (A)



**Bay Area Air Quality Management District**

**Form 15-2**

Source Test Laboratory Data Sheet

**Impinger Weightings**

Plant Name: _____	Plant Number: _____
Source Operation: _____	Test Date: _____
Source Test #: _____	Page: <u>1</u> of _____
Impinger Solution: _____	Initial: _____

Impinger I. D. #	( A ) Tare Weight (g)	( B ) Filled Weight (g)	( C ) Final Weight (g)

Impinger I. D. #	( C-A ) Sample Weight (g)	( C-B ) Condensate Wt. (g)	Condensate Weight / Run (g)
			Run A
			Run B
			Run C
			Run D

# Bay Area Air Quality Management District

939 Ellis Street, San Francisco, CA 94109

## Form 15-3 Source Test Data Sheet

Plant # \_\_\_\_\_  
 Source I.D. \_\_\_\_\_  
 Sample Type \_\_\_\_\_  
 Process Cycle \_\_\_\_\_  
 Duct Size \_\_\_\_\_  
 Duct Shape \_\_\_\_\_  
 Duct Pressure \_\_\_\_\_  
 Assumed %H<sub>2</sub>O \_\_\_\_\_

Run # \_\_\_\_\_  
 Temp Meter # \_\_\_\_\_  
 Mag. Gauge # \_\_\_\_\_

Date: \_\_\_\_\_  
 Box ΔH@ \_\_\_\_\_  
 Meter (Y) \_\_\_\_\_

\_\_\_\_\_ Nozzle Diameter  
 \_\_\_\_\_ Pitot Tube I.D., Cp  
 \_\_\_\_\_ Gas System  
 \_\_\_\_\_ Pbar, Barometer  
 \_\_\_\_\_ Leak Test Rate  
 \_\_\_\_\_ Time @ Point  
 \_\_\_\_\_ # of Points  
 \_\_\_\_\_ Time/Run (Min.)

Sampling Train: Probe # \_\_\_\_\_ Filter # \_\_\_\_\_ Imp. # \_\_\_\_\_ Imp. # \_\_\_\_\_ Pump/Box # \_\_\_\_\_

Initial Traverse Data					Sampling Data									
Trav. Point I.D.	Dist. from Wall	Duct Temp. °F	ΔP "H <sub>2</sub> O	Angle of Flow	Traverse Point I.D.	ΔP "H <sub>2</sub> O	Duct Temp. °F	Vs FPS	Time (minutes)	Meter Rate CFH	Meter Temp. °F	Meter Volume Ft <sup>3</sup>	Train Vacuum "Hg	Sat'd Gas Temp. °F

Post Run Impinger Catch (ml) = \_\_\_\_\_  
 Assumed O<sub>2</sub> = \_\_\_\_\_  
 Assumed CO<sub>2</sub> = \_\_\_\_\_  
 Post Run Calculated %H<sub>2</sub>O = \_\_\_\_\_

Source Test Team

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

## Form 15-4

<b>Distribution:</b>  Firm Permit Services Enforcement Services Technical Services Planning Requester DAPCO	<b>BAY AREA                  AIR QUALITY MANAGEMENT DISTRICT</b>  <i>939 Ellis Street                  San Francisco, California 94109                  (415) 771-6000</i>  <b>Summary of                  Source Test Results</b>	Report No.: _____ Test Date: _____ <b>Test Times:</b> Run A: _____ Run B: _____ Run C: _____
<b>Source Information</b>		<b>BAAQMD Representatives</b>
Firm Name and Address	Firm Representative and Title  Phone No. (     )	Source Test Engineers
Permit Conditions:	Source:  Plant No.                      Permit No. Operates	Permit Services Division/Enforcement Division  Test Requested By:
Operating Parameters:		
<b>Applicable Regulations:</b>		<b>VN Recommended:</b>

**Source Test Results and Comments:**

<u>METHOD</u>	<u>TEST</u>	<u>RUN A</u>	<u>RUN B</u>	<u>RUN C</u>	<u>AVERAGE</u>	<u>LIMIT</u>
ST-17	Stack Volume Flowrate, SDCFM Stack Gas Temperature, °F					
ST-23	Water Content, Volume %					
ST-14	Oxygen, Volume %					
ST-5	Carbon Dioxide, Volume %					
ST-6	Carbon Monoxide, ppmv Carbon Monoxide, lb/hr					
ST-15	Particulate, gr/SDCF Particulate, lb/hr Isokinetic Ratio, act./theo.					

Air Quality Engineer II	Date	Supervising Air Quality Engineer Date	Approved by Air Quality Engineering Manager
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