SOURCE TESTING REPORT
COMPLIANCE TESTING
BOF ESP OUTLET
AK STEEL DEARBORN WORKS
DEARBORN, MICHIGAN

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AIR QUALITY DIV.

Prepared for:

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1. INTRODUCTION

Environmental Quality Management, Inc. (EQM) was retained by AK Steel Dearborn Works to plan and conduct a compliance air sampling program at the BOF ESP exhaust. The compliance program was conducted to evaluate emissions of filterable and condensable particulate (PM, PM_{10}, and $PM_{2.5}$); metals—lead (Pb), manganese (Mn), and mercury (Hg); carbon monoxide (CO); nitrogen oxide (NO_X); and visible emissions (VEs). Three sampling runs (at least 2 heats long) were conducted for each method except for visible emissions. One 1-hour run was conducted for visible emissions concurrently with the PM/CPM sampling runs. EPA-approved sampling methods and laboratory analysis procedures were used to meet the objectives of the sampling program.

An outline of the test program is presented in Table 1-1. Project participants and responsibilities are presented in Table 1-2.

Table 1-1. Sampling Requirements for AK Steel Dearborn, Michigan

Test Point No.	Test Point Name	Parameter Tested	Test Method
1	BOF ESP Exhaust	Flow	EPA Method 2
		Moisture	EPA Method 4
		PM/Condensables	EPA Method 5/202
		O_2, CO_2, CO, NO_X	EPA Method 3A, 7E & 10
		Metals: Pb, Mn, Hg	EPA Method 5/29
		Opacity	EPA Method 9

Table 1-2. Project Participants

Name/Company	Responsibility
David Pate/AK Steel	Coordinate process operation and sampling activities Site/Process preparation Process information
Mark Dziadosz/DEQ Katherine Koster/DEQ	Agency Review of Process and Sampling Procedures
Dan Scheffel/EQM	Project Manager
Doug Allen/EQM	Field sampling crew
Ben Fern/EQM	Field sampling crew
Gary Drexler/EQM	Field sampling crew
Nick Pharo/EQM	Field sampling crew
Eric Zang/EQM	Field sampling crew
Robert Bingham/Smoke Reader LLC	VE observations

2. SUMMARY OF TEST RESULTS

The emission measurement program was performed from September 27-28, 2016. Table 2-1 presents the average results and limit comparison. Table 2-2 presents the summary of stack gas conditions. Table 2-3 presents the total particulate concentrations and mass emission rates. Table 2-4 presents the manganese concentrations and mass emission rates. Table 2-5 presents the lead concentrations and mass emission rates. Table 2-6 presents the mercury concentrations and mass emission rates. Table 2-7 presents the nitrogen oxides (NO_x) and carbon monoxide (CO) concentrations and mass emission rates.

Appendix A summarizes emission and example calculations, Appendix B presents field data, Appendix C presents laboratory results, Appendix D presents calibration data, Appendix E presents process data, and Appendix F presents visible emissions data. Appendix G presents the test protocol and regulatory letter regarding the test effort.

Table 2-1. Average Results and Limit Comparison

Pollutant	BOF ESP	Limits[a]
PM (lb/hr)	15.6	62.6
PM_{10} (lb/hr)	21.0	47.5
$PM_{2.5}$ (lb/hr)	20.96	46.85
Mn (lb/hr)	0.082	0.10[b]
Lead (lb/hr)	0.0296	0.067[b]
Mercury (lb/hr)	0.00283	0.0086[b]
NO_x (lb/hr)	27.7	52.9
CO (lb/hr)	2999	7048
VE	8%[c]	20%[d]

[a] Limits as provided in Permit to Install No. 182-05C.
[b] Limit is for the ESP and SEC Baghouse combined.
[c] Calculated as highest observed 6-minute average.
[d] 6-minute average.

Table 2-2. Stack Gas Conditions
BOF ESP Exhaust Stack

September 27-28, 2016								AK Steel, Dearborn Works
Run No.	**Date/Time**	**Stack Gas Velocity, fps**[a]	**Volumetric Flow Rate**		**Stack Temperature, °F**	**Moisture Content, % H_2O**	**CO_2, %**	**O_2, %**
			acfm[b]	**dscfm**[c]				
Method 5/202 Test Runs (Total Particulate)								
1	9/27/2016 0906-1202	61.6	839,143	541,976	217	16.8	3.4	18.6
2	9/27/2016 1258-1525	58.9	802,261	521,170	214	16.7	3.3	18.8
3	9/28/2016 0831-1058	58.6	798,042	527,768	207	16.1	3.2	18.8
Average		**59.7**	**813,149**	**530,304**	**213**	**16.5**	**3.3**	**18.7**
Method 5/29 Test Runs (Metals)								
1	9/27/2016 0906-1202	60.6	825,159	529,837	218	17.2	3.4	18.6
2	9/27/2016 1258-1525	59.4	809,216	522,334	220	16.6	3.3	18.8
3	9/28/2016 0831-1058	57.8	786,617	510,985	211	17.1	3.2	18.8
Average		**59.3**	**806,997**	**521,052**	**216**	**17.0**	**3.3**	**18.7**

[a] Feet per second.

[b] Actual cubic feet per minute.

[c] Dry standard cubic feet per minute.

Table 2-3. Total Particulate and Total Manganese and Total Lead Emissions
BOF ESP Exhaust Stack

September 27-28, 2016 AK Steel – Dearborn Works

Run No.	Date/Time	Total Particulate Matter Concentration, gr/dscf[a]	Total Particulate Matter Mass Rate, lb/hr[b]	Filterable Particulate Matter Concentration, gr/dscf[a]	Filterable Particulate Matter Mass Rate, lb/hr[b]	Condensable Particulate Matter Concentration, gr/dscf[a]	Condensable Particulate Matter Mass Rate, lb/hr[b]
1	9/27/2016 0906-1202	4.38E-03	20.35	3.36E-03	15.62	1.02E-03	4.73
2	9/27/2016 1258-1525	4.52E-03	20.21	3.29E-03	14.70	1.23E-03	5.51
3	9/28/2016 0831-1058	4.93E-03	22.31	3.63E-03	16.42	1.30E-03	5.89
Average		**4.61E-03**	**20.96**	**3.43E-03**	**15.58**	**1.18E-03**	**5.38**

[a] Grains per dry standard cubic foot.
[b] Pounds per hour.

Table 2-4. Front-Half and Back-Half Manganese and Total Manganese Emissions
BOF ESP Exhaust Stack

September 27-28, 2016 AK Steel – Dearborn Works

Run No.	Date/Time	Front Half Manganese Concentration, µg/dscm[a]	Front Half Manganese Mass Rate, lb/hr[b]	Back Half Manganese Concentration, µg/dscm[a]	Back Half Manganese Mass Rate, lb/hr[b]	Total Manganese Concentration, µg/dscm[a]	Total Manganese Mass Rate, lb/hr[b]
1	9/27/2016 0906-1202	46.3	9.17E-02	2.9	5.84E-03	49.3	9.76E-02
2	9/27/2016 1258-1525	35.6	6.95E-02	1.5	2.86E-03	37.0	7.23E-02
3	9/28/2016 0831-1058	38.7	7.40E-02	1.1	2.13E-03	39.9	7.61E-02
Average		**40.2**	**7.84E-02**	**1.8**	**3.61E-03**	**42.1**	**8.20E-02**

[a] Micrograms per dry standard cubic meter.
[b] Pounds per hour.
Note: Metals data was blank corrected.

Table 2-5. Front-Half and Back Half-Lead and Total Lead Emissions BOF ESP Exhaust Stack

September 27-28, 2016 AK Steel – Dearborn Works

Run No.	Date/Time	Front Half Lead		Back Half Lead		Total Lead	
		Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]	Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]	Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]
1	9/27/2016 0906-1202	16.8	3.33E-02	0.8	1.64E-03	17.6	3.49E-02
2	9/27/2016 1258-1525	13.0	2.54E-02	0.7	1.42E-03	13.8	2.68E-02
3	9/28/2016 0831-1058	13.8	2.64E-02	0.2	4.72E-04	14.1	2.69E-02
Average		**14.6**	**2.84E-02**	**0.6**	**1.18E-03**	**15.2**	**2.96E-02**

[a]Micrograms per dry standard cubic meter.
[b]Pounds per hour.
Note: Metals data was blank corrected.

Table 2-6. Front-Half and Back Half-Mercury and Total Mercury Emissions BOF ESP Exhaust Stack

September 27-28, 2016 AK Steel – Dearborn Works

Run No.	Date/Time	Front Half Mercury		Back Half Mercury		Total Mercury	
		Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]	Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]	Concentration, µg/dscm[a]	Mass Rate, lb/hr[b]
1	9/27/2016 0906-1202	ND	ND	1.1	2.16E-03	1.1	2.17E-03
2	9/27/2016 1258-1525	ND	ND	1.5	2.96E-03	1.5	2.97E-03
3	9/28/2016 0831-1058	ND	ND	1.7	3.34E-03	1.8	3.35E-03
Average		**ND**	**ND**	**1.5**	**2.82E-03**	**1.5**	**2.83E-03**

[a]Micrograms per dry standard cubic meter.
[b]Pounds per hour.
Note: Metals data was blank corrected.

Table 2-7. NOx and CO Emissions
BOF ESP Exhaust Stack

September 27-28, 2016 AK Steel – Dearborn Works

Run Date/Time	Nitrogen Oxides			Carbon Monoxide		
	Concentration, ppm[a]	Mass Rate		Concentration, ppm[a]	Mass Rate	
		lb/hr[b]	lb/ton[c]		lb/hr[b]	lb/ton[c]
9/27/2016 0907-1202	7.2	27.43	0.080	1159.0	2678.4	7.81
9/27/2016 1258-1525	7.2	26.91	0.086	1900.6	4330.3	13.84
9/28/2016 0831-1057	7.9	28.81	0.095	892.3	1988.7	6.56
Average	**7.4**	**27.72**	**0.087**	**1317.3**	**2999.1**	**9.40**

[a] Parts per million, dry basis.
[b] Pounds per hour.
[c] Pounds per ton.

3. SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures used in this test program conform to EPA Reference Methods 1 through 4, 5, 7E, 9, 10, 29, and 202, as published in the Federal Register.

3.1 Location of Measurement Sites

EPA Method 1, "Sample Velocity Traverses for Stationary Sources," was used to select representative measurement sites. The sampling location was at the exhaust of the BOF ESP. A schematic of the test location is shown in Figure 4-1 in Section 4.

3.2 Stack Gas Volumetric Flow Rate

EPA Method 2, "Determination of Stack Gas Velocity and Volumetric Flow Rates," was used to determine stack gas volumetric flow rates. Type "S" pitot tubes meeting the EPA specifications and an inclined manometer were used to measure velocity pressures. A calibrated Type "K" thermocouple attached directly to the pitot tube was used to measure stack gas temperature. The stack gas velocity was calculated from the average square root of the stack gas velocity pressure, average stack gas temperature, stack gas molecular weight, and absolute static pressure. The volumetric flow rate is the product of velocity and stack cross-sectional area.

3.3 Stack Gas Dry Molecular Weight

The ESP sampling location was sampled continuously for CO_2 and O_2 by using non-dispersive infrared analyzers (CO_2) or paramagnetic analyzers (O_2); gaseous pollutants were measured according to EPA Reference Method 3A, "Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)." Figure 3-1 is a schematic of the sampling system.

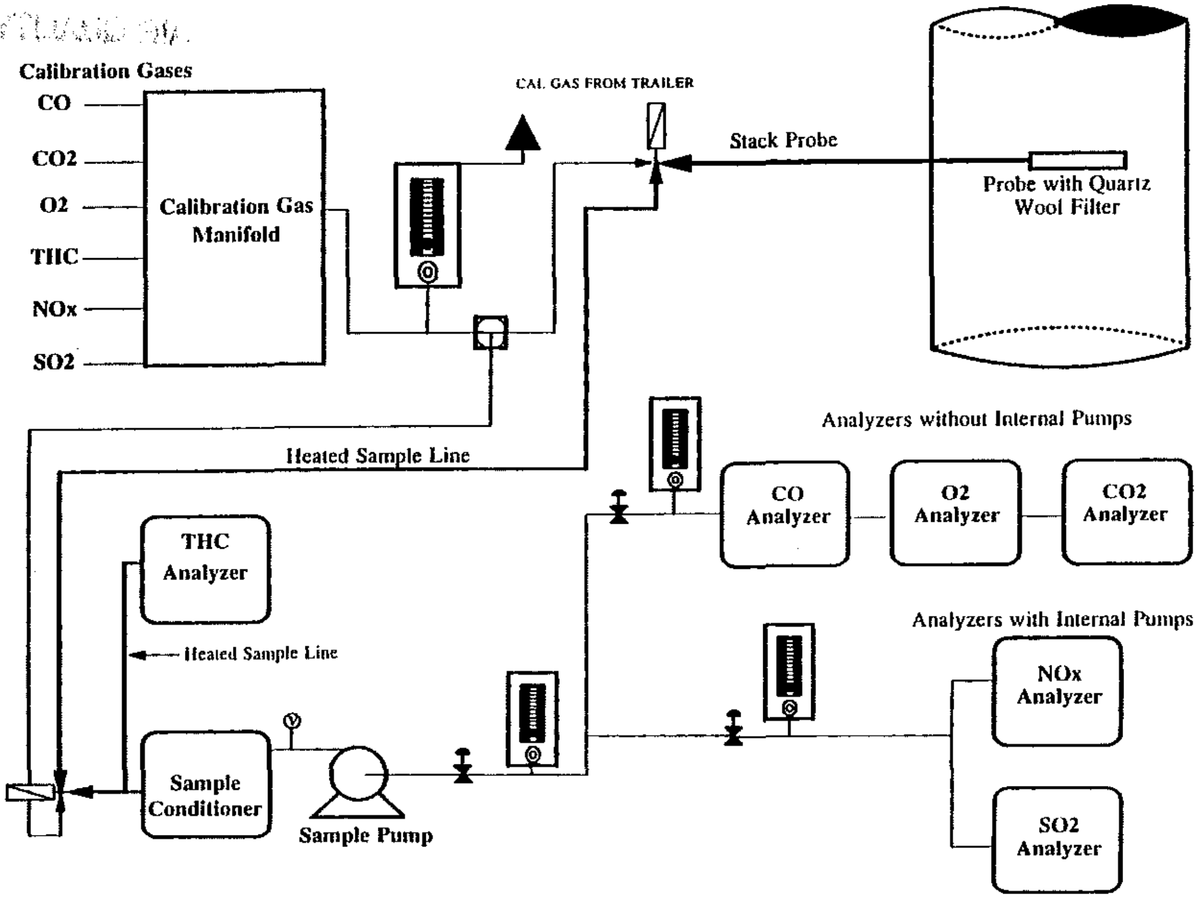


Figure 3-1. CEM Sample Flow and Calibration System
Note: This study used the CO, NO_X, CO_2, and O_2 analyzers.

3.4 Stack Gas Moisture Content

EPA Reference Method 4, "Determination of Moisture Content in Stack Gases," was used to determine stack gas moisture content. This method was conducted as part of each particulate and metals measurement run. The initial and final contents of all impingers were determined gravimetrically.

3.5 Filterable Particulate and Condensable

EPA Method 5/202 were used to measure the concentration and mass emission rate of total filterable particulate matter. Particulate matter of less than 10 microns (PM_{10}) and particulate matter of less than 2.5 microns ($PM_{2.5}$) were determined as the sum of the filterable and condensable fractions. Three 3-4 heat sampling runs and a blank were collected at the ESP stack outlet location. Figures 3-2 and 3-3 present schematics of the sampling trains for Method 5 and Method 202, respectively.

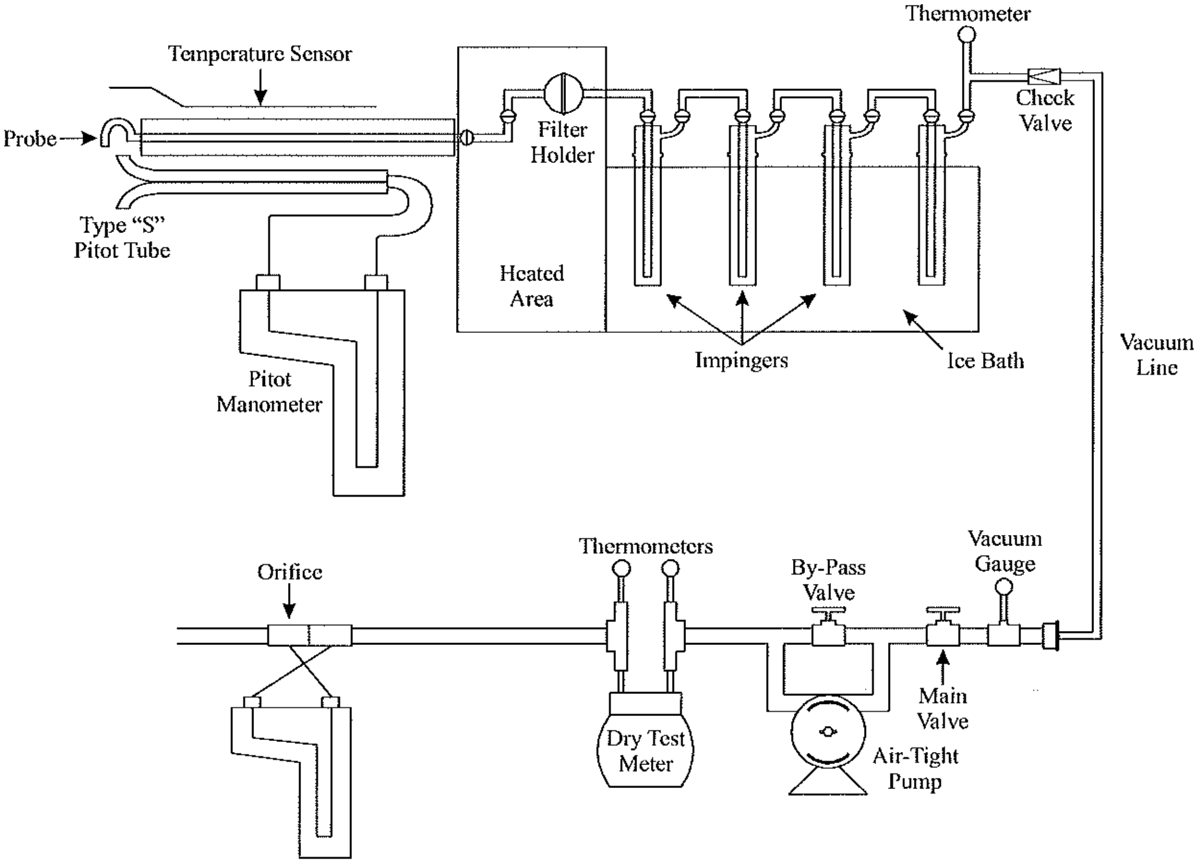


Figure 3-2. Method 5 Front-half of Sampling Train

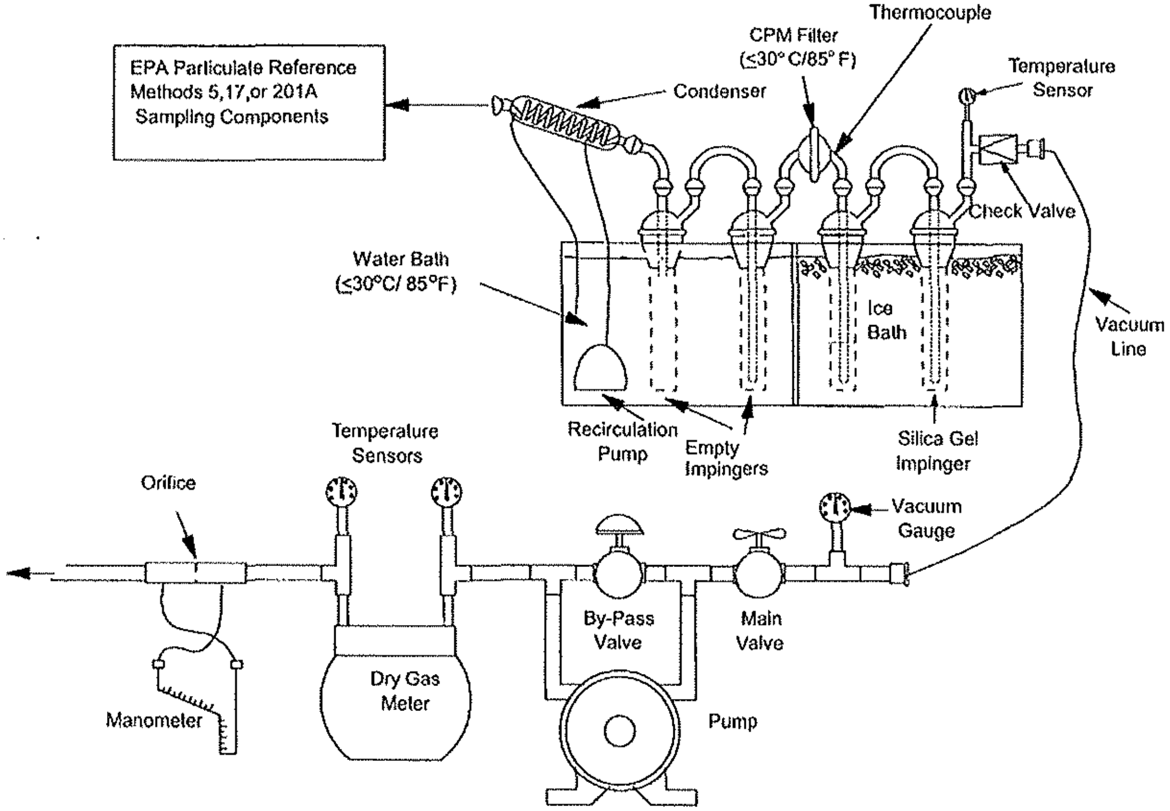


Figure 3-3. Method 202 Sampling Train

3.6 Nitrogen Oxides (NO$_X$)

Nitrogen oxide concentrations were analyzed following the procedures of EPA Reference Method 7E, "Determination of Nitrogen Oxide Emissions from Stationary Sources by Instrumental Analyzer Technique." The sampling system consists of a stainless steel probe, a glass fiber filter for particulate matter removal, a heated Teflon sampling line, and a sample gas conditioner to remove moisture prior to the gas entering the chemiluminescent analyzer. A zero gas and two Protocol One calibration gases were used to calibrate the instrument. Data was recorded on a data-logging system recording 1-minute averages of pollutant data. Figure 3-1 is a schematic of the continuous emission analyzer system.

3.7 Carbon Monoxide (CO)

Carbon monoxide concentrations were sampled and analyzed continuously following the procedures of EPA Method 10, "Determination of Carbon Monoxide Emissions from Stationary

Sources by Instrumental Analyzer Technique." The same sampling system that was used for the other continuous analyzers was used for the CO analyzer. The instrument used is a non-dispersive infrared analyzer manufactured by Thermo Environmental.

A zero gas and two calibration gases were used to calibrate the instrument. Figure 3-1 is a schematic of the sampling system.

3.8 Metals

EPA Method 29 was used to determine metals (Pb, Mn, and Hg) emissions. The test apparatus consisted of a glass nozzle, a heated glass-lined probe, a heated 83-mm quartz fiber filter, seven chilled impingers, and a metering console. The samples were withdrawn isokinetically from the source. Particulate emissions were collected in the probe and on the heated filter, and the gaseous emissions were then collected in an aqueous acidic solution of hydrogen peroxide in order to measure lead and manganese. The last two impingers contained acidified potassium permanganate ($KMnO_4$) in 10% sulfuric acid for the collection of mercury. The recovered samples were digested and analyzed at the laboratory. Three 3-4 heat test runs were performed at the ESP stack outlet. Figure 3-4 is a schematic of the Method 29 sampling train.

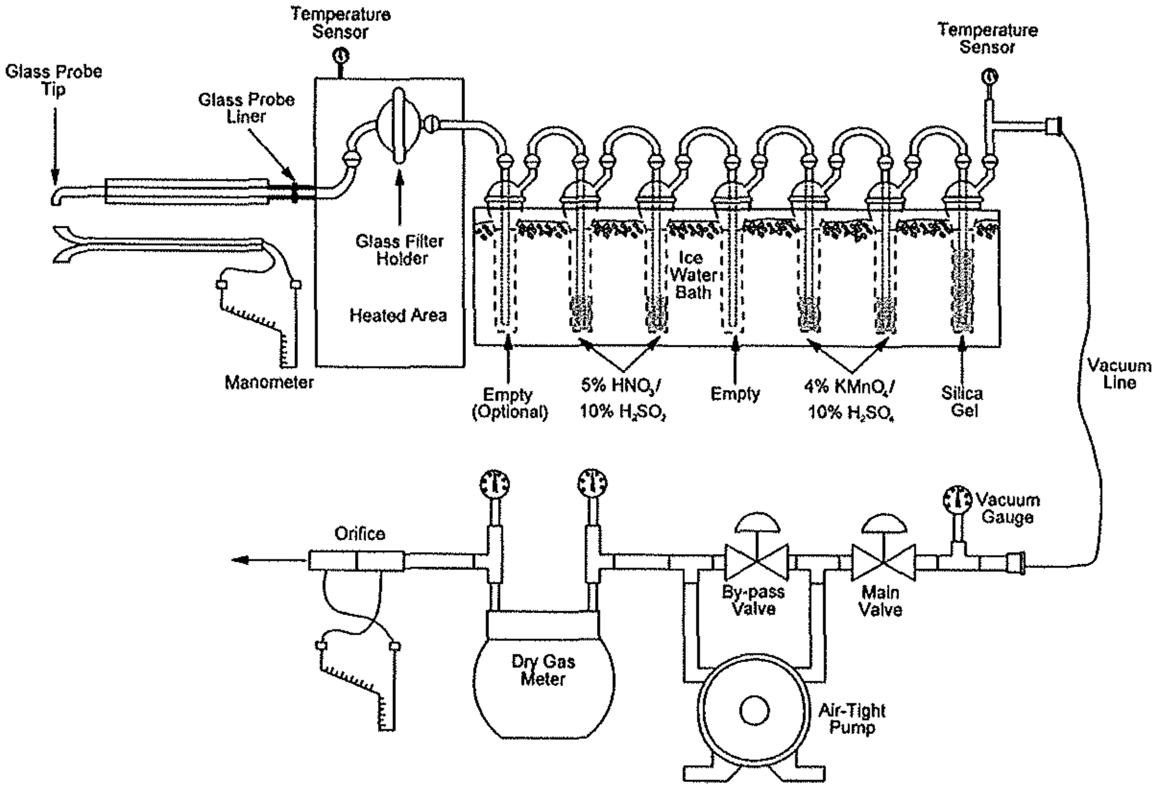


Figure 3-4. Method 5/29 Sampling Train

3.9 Opacity

EPA Method 9, "Visual Determination of the Opacity of Emissions from Stationary Sources," was used to measure visible emissions from the BOF ESP exhaust for the test program. During each particulate measurement run, plume opacity was recorded every 15 seconds or four readings per minute, for 60 minutes.

3.10 Test Comments

After consultation with the MDEQ, it was agreed that no port changes would take place while oxygen blowing was taking place. When it was time for a port change, the probe was left at the point until the completion of the oxygen blow. Once the blow was completed, the probe was moved to another port and was placed at the point that corresponded to where it would have been had the port changes been performed solely based on the time. Due to this, during some of the runs, a few of the points were not sampled. MDEQ and AK agreed that this did not have a significant bias on the sampling results.

After the initial analysis of the samples, EQM requested that the lab reanalyze the samples as the manganese results were higher than expected. The second analytical set of results was used to calculate the manganese emissions.

The lab also submitted results for a mercury audit. Of the two fractions, one passed the audit, but the second fraction (the aqueous fraction) had failed. Upon checking the calculations, the lab reissued acceptable results for the fraction. The lab had used an incorrect dilution volume in their calculations.

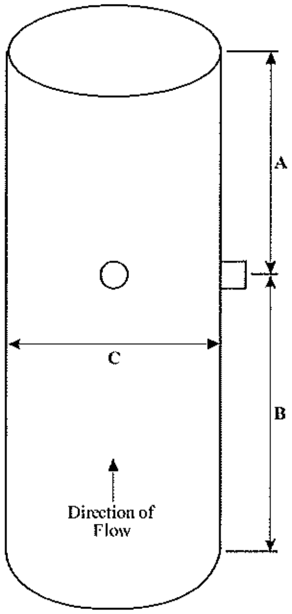
4. PROCESS DESCRIPTION/SAMPLING LOCATIONS

Scrap steel is charged into the BOF vessel and then molten iron is charged into the vessel on top of the scrap. Fluxing agents are also added during the steelmaking process. Oxygen is blown into the molten iron/scrap mixture, causing the scrap to melt; iron is refined into steel by reducing the carbon content (which results in emissions of CO). The heat for the steelmaking process comes from the reaction of oxygen with the dissolved carbon in the molten iron.

Particulate emissions consisting of iron oxides and various other metal oxides are also produced. In order to remove the large amounts of particulate, the flue gas is controlled by a 32-field electrostatic precipitator (ESP). The ESP is considered the "primary" control device in the steel making process at AK Dearborn's BOF shop. The dust-laden gases enter the ESP and the dust particles are electrically energized (negative charge) prior to entering the ESP. The charged particles then migrate over the positively charged collector plates, where the particulate matter is collected. Rappers are used to vibrate both the discharge electrodes and the collection plates to dislodge the accumulated dust. The clean gases pass through the ID fans and are discharged out of the stack passing through the COM light pathway.

In addition to the ESP, a secondary emission control baghouse (BOF baghouse) is in operation at the facility. This BOF baghouse collects and controls particulate emissions during the hot metal charging and tapping operations that occur at the BOF vessels during the steel making heats. This baghouse also controls emissions generated by the iron reladling operations.

A diagram of the sampling location is shown in Figure 4-1.



Location	Upstream A	Downstream B	Inside Diameter C
ESP Exhaust Stack	>240 inches	>480 inches	204 inches
4 total ports, 6 sample points per port, 24 sample points			
Sample Point 1	4.3 inches from inside of port		
Sample Point 2	13.7 inches from inside of port		
Sample Point 3	24.1 inches from inside of port		
Sample Point 4	36.1 inches from inside of port		
Sample Point 5	51.0 inches from inside of port		
Sample Point 6	72.6 inches from inside of port		

Figure 4-1. Sampling Location

5. QUALITY ASSURANCE AND QUALITY CONTROL

The field sampling quality assurance for this project included the use of calibrated source sampling equipment, reference test methods, and traceability protocols for recording and calculating data. The analytical quality assurance includes use of validated analytical procedures, calibration of equipment, and analysis of control samples and blanks. The calibration and quality control procedures used for this test program are described in the following subsection.

5.1 Calibration Procedures and Frequency

All manual stack gas sampling equipment is calibrated before the start of the test program in accordance with the procedures outlined in the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III*, EPA-600/4-72-027B. Table 5-1 is a summary of the stack gas sampling equipment calibrations that are performed in preparation for this project. The meter boxes are re-calibrated after the test.

Table 5-2 lists the additional calibration checks that are performed on the sampling equipment on site, just prior to the testing, to ensure that equipment was not damaged during transport. Table 5-3 details the field checks conducted on the continuous emission monitoring systems before and during the test program.

Table 5-1. Field Equipment Calibration Summary[a]

Equipment	Calibrated Against	Allowable Error
Method 5 meter box	Reference test meter	Y ±0.02 Y ΔH@ ±0.20 ΔH@ post-test Y ±0.05 Y
Pitot tube	Geometric specifications	See EPA Method 2
Thermocouple	ASTM-3F thermometer	±1.5%
Impinger (or condenser thermometer)	ASTM-3F	±2°F
Dry gas meter thermometer	ASTM-3F	±5°F
Probe nozzles	Caliper	±0.004 in.
Barometer	NBS traceable barometer	±0.1 in. Hg

[a] As recommended in the *Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III. Stationary Source-Specific Methods*. EPA-600/4-77-027b, August 1977.

Table 5-2. Field Checks of Sampling Equipment

Equipment	Checked Against	Allowable Difference
Pitot tube	Inspection	No visible damage
Thermocouples	ASTM 2F or 3F	±1.5%
Probe nozzles	Caliper	±0.004 in.

Table 5-3. Field Checks of O_2, CO_2, CO, and NO_X Analyzers

Calibration	Instrument Check	Acceptable Limit
Initial Calibration	O_2, CO_2, CO, and NO_X Calibration Error, % Span	±2%
	Sampling System Bias	±5% of Span
Daily Calibration	O_2, CO_2, CO, and NO_X Calibration Error, % Span	±2%
	O_2, CO_2, CO, and NO_X Drift, % Span	±3% of Span