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 C-Blast Furnace Stoves exhaust. The compliance program was conducted to evaluate emissions of filterable and condensable particulate (PM, PM_{10}, and $PM_{2.5}$); metals [lead (Pb), mercury (Hg), and manganese (Mn)]; carbon monoxide (CO); and nitrogen oxide (NO_X). Three 2-hour sampling runs were conducted for each method. The assumption was made that all PM CPM collected was $PM_{2.5}$ and PM_{10}. 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	C-Blast Furnace Stoves	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, Hg, and Mn	EPA Method 29

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/EGLE	Agency Review of Process and Sampling Procedures
Doug Allen/EQM	Project Manager
Chris Janzen/EQM	Field sampling crew
Ron Kolde/EQM	Field sampling crew
Jeremy Gallagher/EQM	Field sampling crew
Nick Pharo/EQM	Field sampling crew
Eric Zang/EQM	Field sampling crew

2. SUMMARY OF TEST RESULTS

The emission measurement program was performed on August 11, 2020. Table 2-1 presents the average results and limit comparison. Table 2-2 presents a summary of stack gas conditions. Table 2-3 presents total particulate concentrations and mass emission rates. Table 2-4 presents manganese concentrations and mass emission rates. Table 2-5 presents lead concentrations and mass emission rates. Table 2-6 presents mercury concentrations and mass emission rates. Table 2-7 presents 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 the test protocol and regulatory letter regarding the test effort.

Table 2-1. Average Results and Limit Comparison

Pollutant	C-Blast Furnace Stoves Limits[a]	Test Results
Filterable PM (lb/hr)	6.98	**4.38**
Total PM_{10} (lb/hr)	19.72	**8.94**
Total $PM_{2.5}$ (lb/hr)	19.72	**8.94**
Mn (lb/hr)	0.012	**0.004**
Lead (lb/hr)	0.011	**0.0003**
Mercury (lb/hr)	0.003	**0.0001**
NO_x (lb/hr)	106.3	**4.5**
CO (lb/hr)	1,756	**1,425**

[a] Limits as provided in Permit MI-ROP-A8640-2016a.

Table 2-2. Stack Gas Conditions
C-Blast Furnace Stoves

August 11, 2020 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	8/11/2020 0842-1111	42.3	199,417	106,028	411	11.9	24.2	3.9
2	8/11/2020 1135-1348	44.1	208,006	106,622	432	13.0	22.6	4.3
3	8/11/2020 1428-1643	43.4	204,380	105,421	438	11.9	22.2	4.8
Average		**43.3**	**203,934**	**106,023**	**427**	**12.3**	**23.0**	**4.3**
Method 5/29 Test Runs (Metals)								
1	8/11/2020 0823-1045	47.2	222,427	113,409	432	13.5	24.2	3.9
2	8/11/2020 1135-1348	51.7	243,839	122,417	449	13.2	22.6	4.3
3	8/11/2020 1428-1643	51.2	241,278	122,725	449	12.1	22.2	4.8
Average		**50.0**	**235,848**	**119,517**	**443**	**12.9**	**23.0**	**4.3**

[a] Feet per second.

[b] Actual cubic feet per minute.

[c] Dry standard cubic feet per minute.

Table 2-3. Total Particulate Emissions
C-Blast Furnace Stoves

August 11, 2020 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	8/11/2020 0842-1111	1.76E-02	15.99	6.97E-03	6.34	1.06E-02	9.65
2	8/11/2020 1135-1348	4.12E-03	3.76	2.57E-03	2.34	1.55E-03	1.42
3	8/11/2020 1428-1643	7.83E-03	7.08	4.94E-03	4.47	2.89E-03	2.61
Average		**9.85E-03**	**8.94**	**4.83E-03**	**4.38**	**5.02E-03**	**4.56**

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

Table 2-4. Front-Half and Back-Half Manganese and Total Manganese Emissions
C-Blast Furnace Stoves

August 11, 2020 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	8/11/2020 0823-1045	10.1	4.30E-03	5.3	2.25E-03	15.5	6.55E-03
2	8/11/2020 1135-1348	3.6	1.65E-03	4.6	2.12E-03	8.2	3.77E-03
3	8/11/2020 1428-1643	3.0	1.39E-03	1.2	5.62E-04	4.3	1.95E-03
Average		**5.6**	**2.45E-03**	**3.7**	**1.64E-03**	**9.3**	**4.09E-03**

[a] Micrograms per dry standard cubic meter.
[b] Pounds per hour.
Note: Detection Limits are used in the runs denoted in *italics*.

Table 2-5. Front-Half, Back-Half, and Total Lead Emissions
C-Blast Furnace Stoves

August 11, 2020 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	8/11/2020 0823-1045	*0.46*	*1.96E-04*	*0.2*	*1.00E-04*	*0.70*	*2.96E-04*
2	8/11/2020 1135-1348	*0.42*	*1.93E-04*	0.2	1.09E-04	0.66	3.02E-04
3	8/11/2020 1428-1643	*0.42*	*1.94E-04*	*0.2*	*9.91E-05*	*0.64*	*2.93E-04*
Average		***0.44***	***1.94E-04***	**0.2**	**1.03E-04**	**0.67**	**2.97E-04**

[a]Micrograms per dry standard cubic meter.
[b]Pounds per hour.
Note: Detection Limits are used in the runs denoted in *italics*.

Table 2-6. Total Mercury Emissions
C-Blast Furnace Stoves

August 11, 2020 AK Steel, Dearborn Works

Run No.	Date/Time	Total Mercury	
		Concentration, µg/dscm[a]	**Mass Rate, lb/hr[b]**
1	8/11/2020 0823-1045	0.30	1.26E-04
2	8/11/2020 1135-1348	0.32	1.47E-04
3	8/11/2020 1428-1643	0.24	1.09E-04
Average		**0.29**	**1.28E-04**

[a]Micrograms per dry standard cubic meter.
[b]Pounds per hour.
Note: Detection Limits are used in the runs denoted in *italics*.

Table 2-7. NOx and CO Emissions
C-Blast Furnace Stoves

August 11, 2020 AK Steel, Dearborn Works

	Nitrogen Oxides			**Carbon Monoxide**		
Run Date/Time	**Concentration, ppm[a]**	**Mass Rate**		**Concentration, ppm[a]**	**Mass Rate**	
		lb/hr[b]	**lb/MMcf[c]**		**lb/hr[b]**	**lb/MMcf[c]**
8/11/2020 0823-1022	4.9	3.99	1.43	2,089	1,033.3	300.65
8/11/2020 1135-1334	5.2	4.53	1.50	3,797	2,027.2	589.83
8/11/2020 1428-1627	5.5	4.86	1.61	2,269	1,214.6	353.40
Average	**5.2**	**4.46**	**1.51**	**2,718**	**1,425.1**	**414.63**

[a] Parts per million, dry basis.

[b] Pounds per hour.

[c] Pounds per MMcf of Blast Furnace Gas.

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, 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 C-Blast Furnace Stoves exhaust. 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 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 stoves 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.

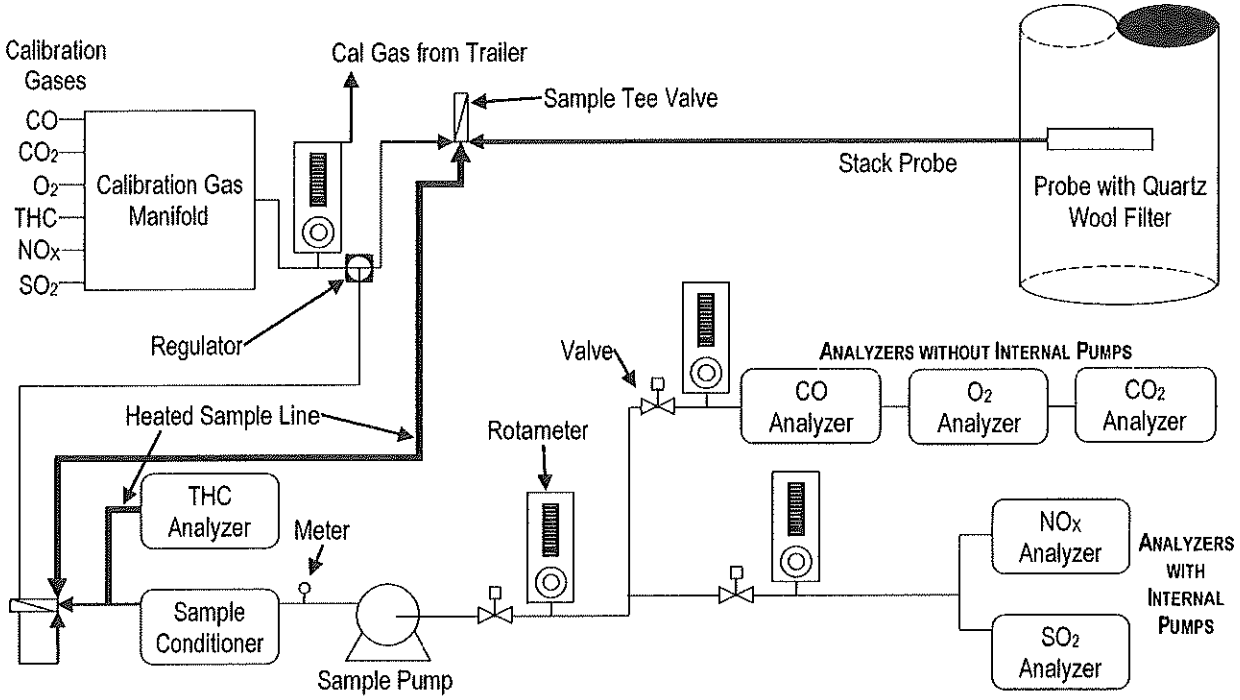


Figure 3-1. CEM Sample Flow and Calibration System
Note: This study used the CO, NO_X, CO_2, and O_2 analyzers.

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 and Condensable Particulate

EPA Methods 5/202 were used to measure the concentration and mass emission rate of 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. Total suspended solids (TSP) particulate matter was determined only as the total filterable particulate matter. Three sampling runs and a blank were collected at the stoves exhaust location. Figures 3-2 and 3-3 present schematics of the sampling trains for Method 5 and Method 202, respectively.

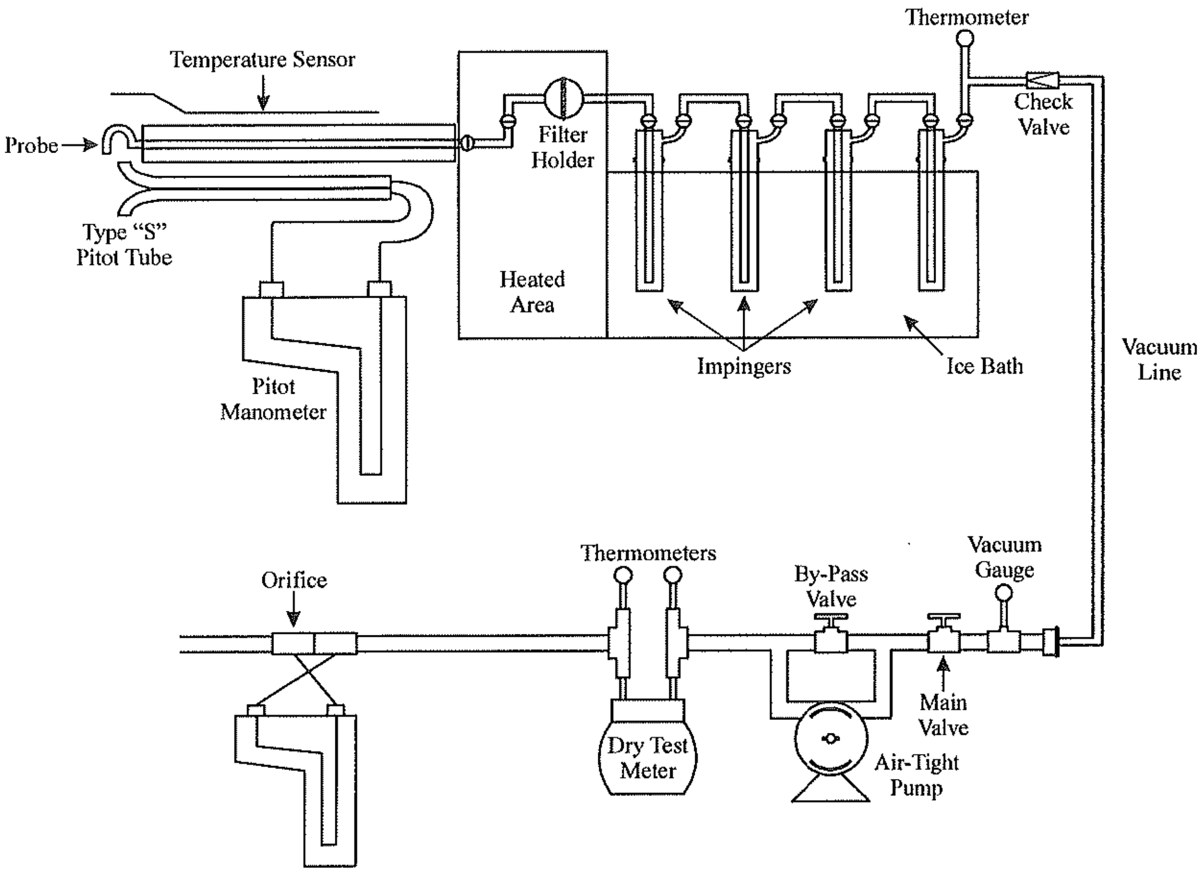


Figure 3-2. **Method 5 Front-half of Sampling Train**

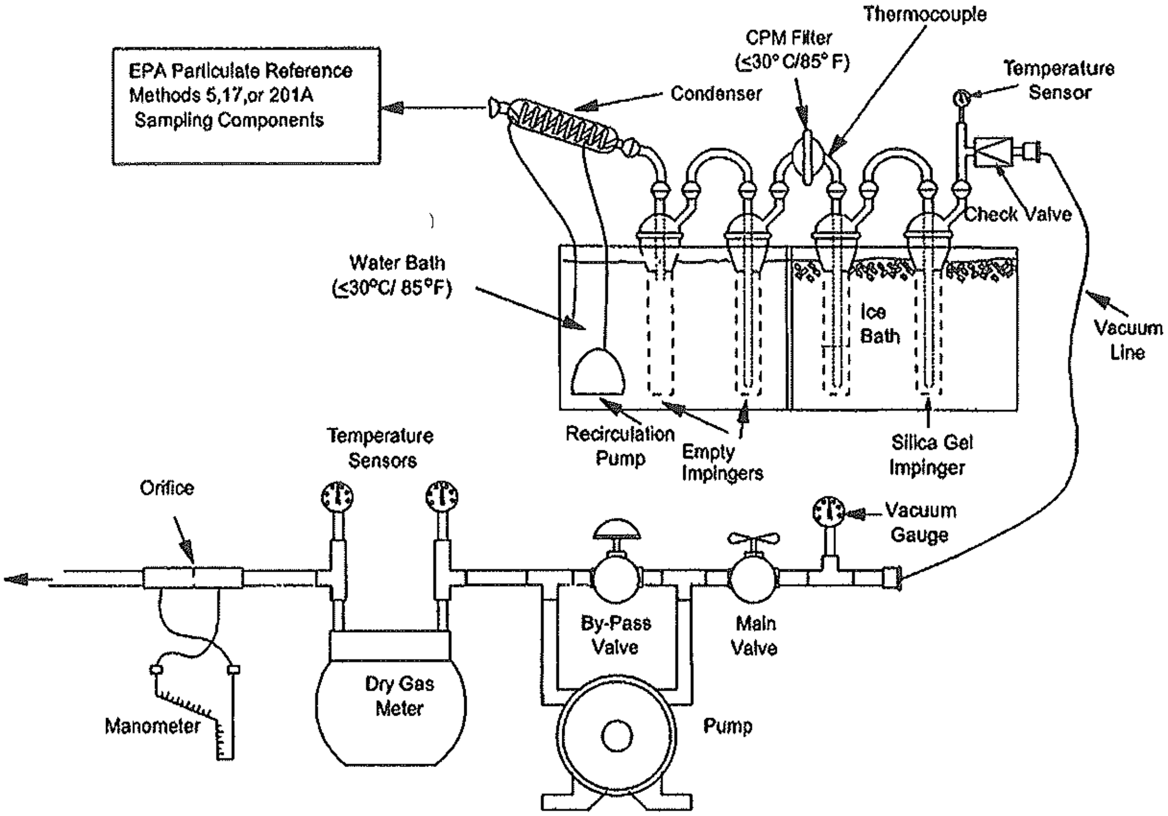


Figure 3-3. Method 202 Sampling Train

3.6 Nitrogen Oxides (NOx)

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. An NO_2-NO_x converter efficiency test was conducted according to EPA Method 7E. An NO_2 calibration gas with a value of 49.4 ppm was introduced to the analyzer. The response observed was 47.13 ppm, which is an efficiency of 95.4%. This result is above the 90% converter efficiency that is required. Results are provided in Appendix B.

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 contain potassium permanganate ($KMnO_4$) for the collection of mercury. The recovered samples are digested and analyzed at the laboratory. Three test runs were performed at the stoves exhaust. Figure 3-4 is a schematic of the Method 29 sampling train.

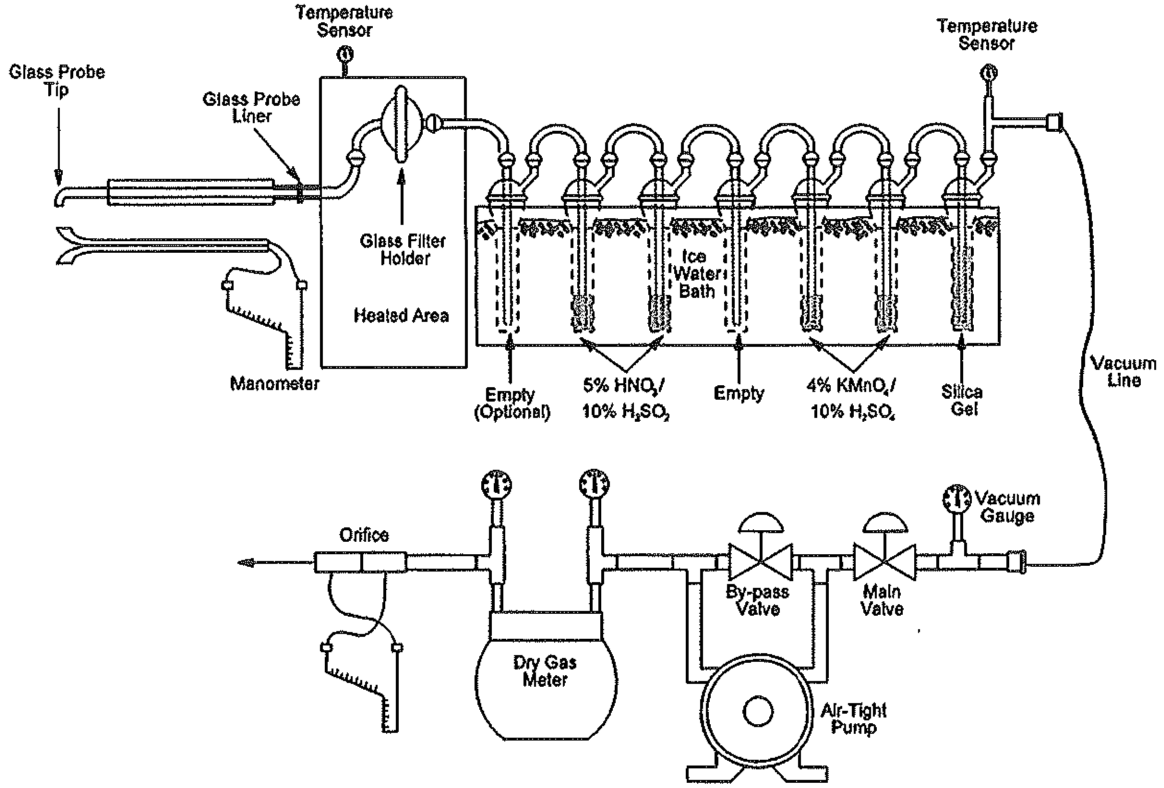


Figure 3-4. Method 5/29 Sampling Train

3.9 Test Comments

1. The analysis of the samples included the audit samples for lead, mercury, and manganese. The audit results were within the acceptable range and are presented in Appendix C.

2. Emission rates for CO and NOx were calculated using the flows from the metals runs. This calculation is conservative as the flows measured from the metals runs was higher than the flows measured by the PM/CPM runs.

3. During runs 1 and 2 for both the particulate and metals sampling runs, data was collected at ten minute increments rather than the 5-minute increment required by the test methods. This was due to miscommunication between the test team members. Run 3 was conducted in accordance with the test methods. There was very little discrepancy in the three runs so it is EQM's belief that the first two sampling runs provided representative data. This discrepancy was discussed with the onsite EGLE inspector prior to the conclusion of the test.

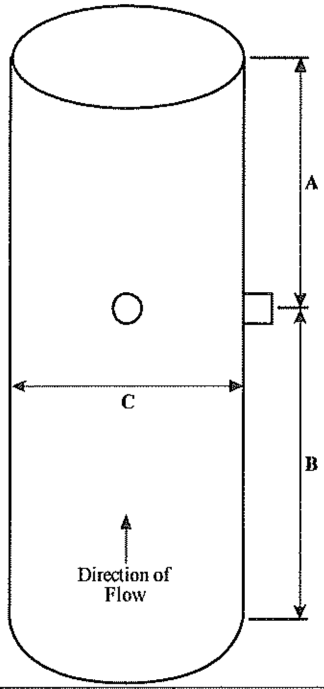
4. The analytical report for metals in appendix C only contains the analytical results which is presented within the first 66 pages of the report. The remainder of the analytical report is available on request from AK Steel.

4. PROCESS DESCRIPTION/SAMPLING LOCATIONS

The blast furnace stoves provide "hot blast" air for injection into the blast furnace. Blast furnace gas (BFG) produced by the furnace is cleaned, and then recycled to the blast furnace stoves to be used as fuel. The BFG, along with a small amount of natural gas (NG), is fired in the stove burners and used to heat checker brick within the stoves. The stoves are cycled between periods of heating up ("on gas") while firing BFG and NG, and periods of supplying hot blast air to the furnace ("on blast"). During firing, the checker brick is being heated up with no air passing through the stoves.

When the stove reaches the desired temperature, the stove is put "on blast," at which time air supplied by the blower passes through the heated checker brick, creating the hot blast air, which is injected into the furnace through the tuyeres. Typically, only one stove is supplying hot blast at any given time; however, sometimes two stoves supply hot blast depending on the circumstances of the process and stove performance.

A diagram of the sampling location is shown in Figure 4-1. Blast furnace production ranged between 290.3 and 305.1 tons/hour during the testing.



Location	Upstream A	Downstream B	Inside Diameter C
C Furnace Stove Stack	>240 inches	>960 inches	120 inches
4 Sample Ports	Three Traverse Points per Port		12 Total Sample Points
Traverse Pt 1: 5 ¼”	Traverse Pt 2: 17 ½”		Traverse Pt 3: 35 ½”

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 additional calibration checks 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, & NO_X Calibration Error, % Span	±2% ±5%
	Sampling System Bias	±5% of Span
Daily Calibration	O_2, CO_2, CO, & NO_X Calibration Error, % Span	±2% ±3%
	O_2, CO_2, CO, & NO_X Drift, % Span	±3% of Span