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Research Triangle Park NC 27711

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Air

EPA

Iron and Steel (Coke Oven Battery Stack)

Emission Test Report Bethlehem Steel Sparrows Point, Maryland

COKE OVEN EMISSION TESTING

BETHLEHEM STEEL CORPORATION

SPARROWS POINT, MARYLAND

by
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CONTENTS

FIGURES

TABLES

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1. INTRODUCTION

In accordance with the U.S. Environmental Protection Agency's program for developing New Source Performance Standards, TRW Environmental Engineering Division participated in emission testing on a coke oven battery stack at Bethlehem Steel Corporation's Sparrows Point, Maryland facility. The testing was conducted the week of 9 July 1979. The results of this testing effort will be used in the development effort for supporting the New Source Performance Standards for Coke Oven Battery Stacks in the iron and steel industry.

Emission tests were conducted at the outlet of the battery stack to determine concentrations of the following constituents in the flue gas: particulate, benzo-α-pyrene (BαP), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), visible emissions, and sulfates (SO_4). Particulate and BαP trains were run simultaneously. Continuous monitors were run throughout the test to measure concentrations of O_2, CO and NO_x. In addition to continuous monitoring, integrated bag samples were obtained for measuring O_2, CO, CO_2, and N_2. This analysis was used for molecular weight determination. EPA Method 7 was performed to measure NO_x. Visible emissions were read for the duration of each test by the prescribed procedure in EPA Method 9. Sulfate analysis was performed on the particulate train filter and water (H_2O) impinger collection.

Bethlehem Steel's Sparrows Point facility, manufacturing iron and steel, employs mobile gunning for control of battery stack emissions. Emission tests were conducted at the 80 foot level of Coke Oven Battery Stack No. 2. The test locations are described in Section 4.

This report presents the results of the testing program. The following sections of the report contain: a summary of the results, descriptions of the sampling points, a description of the process, and delineation of the sampling and laboratory analytical procedures. The appendices contain field data, sample calculations and a daily activity log.

2. SUMMARY AND DISCUSSION OF RESULTS

The results of the testing program at the Sparrow's Point facility are summarized in Tables 2-1 through 2-8. Table 2-1 presents the coding system used for the testing program.

Table 2-2 presents the concentrations and emission rates of particulates and sulfates. The stack parameters and test conditions are also shown. The total particulate concentrations ranged from 0.19614 to 0.34397 gm/scm and averaged 0.27741 gm/scm. Emission rates for particulates ranged from 37.13 lb/hr (16.84 kg/hr) to 65.82 lb/hr (29.86 kg/hr) with an average of 54.43 lb/hr (24.69 kg/hr).

SO_2 concentrations ranged from 19.34 mg/scm to 51.98 mg/scm and averaged 35.66 mg/scm. Sulfate concentrations ranged from 63.43 mg/scm to 151.56 mg/scm and averaged 106.16 mg/scm.

Table 2-3 presents the concentrations and emission rates of Benzo-α-Pyrene (BαP) as well as the stack parameters and test conditions for these tests. BαP emission rates ranged from 77.29×10^{-6} lb/hr (35.07×10^{3} μg/hr) to 371.8×10^{-6} lb/hr (169.0×10^{3} μg/hr) and averaged 267.0×10^{-6} lb/hr (121.3×10^{3} μg/hr).

Tables 2-4 through 2-6 present the results of continuous monitoring for Oxygen (O_2), Carbon Monoxide (CO), and Oxides of Nitrogen (NO_X). The results for O_2 are expressed as percent (%), and the results for CO and NO_x are expressed as parts per million (ppm). Percent O_2 ranged from 9 to 13 for Test #1 with an average of 11.2. Percent O_2 ranged from 10 to 14 for Test #2 with an average of 11.9. Percent O_2 ranged from 10 to 12 for Test #3 with an average of 10.9.

All concentration levels reported were calculated on a dry basis.

Integrated bag samples were taken and analysis was performed on a Gas Chromagraph (G.C.) as well as an Orsat Analyzer for comparative results (see Figure 2-1). The continuous results for O_2 are slightly high in comparison with the GC results. The higher concentrations of O_2 reported by the continuous monitors are due to O_2 variations that resulted during Coke Oven pushing cycles. The Orsat results are lower than both continuous monitoring and GC analysis. The lower results produced by the Orsat are suspect and were the results of weak chemicals used in the Orsat analyzer. Figure 2-1 presents a comparison of gas analysis by the various methods.

The results of continuous monitoring for CO for test No.'s 1, 2, and 3 also are presented in Tables 2-4 through 2-6. CO concentrations ranged from 35 to 285 ppm for Test #1, with an average of 72 ppm. CO concentrations ranged from 75 to 310 ppm for Test #2 with an average of 141 ppm. CO concentrations ranged from 40 to 400 ppm for Test #3 with an average of 112 ppm.

The Orsat and G.C. are not capable of measuring concentrations in this range so no comparative data could be obtained. Figures 2-2 through 2-4 present the relationship of CO, NO_x, percent Opacity and percent O_2 for the duration of each test. Peaks of CO occurred during monitoring, as a result of oven push cycles, and the average concentrations are high as a result of these peaks.

The results of the three tests using continuous monitoring for NO_x are also presented in Tables 2-4 through 2-6. NO_x concentrations ranged from 25 to 130 ppm for Test #1, with an average of 70 ppm. NO_x concentrations ranged from 30 to 90 ppm for Test #2, with an average of 65 ppm. NO_x concentrations ranged from 50 to 105 ppm for Test #3, with an average of 79 ppm.

EPA Method 7 was used to determine NO_x, in addition to continuous monitoring. The results are presented in Table 2-7. NO_x concentrations averaged 40 ppm for Test #3. The EPA Method 7 results are less than the results obtained by monitoring on a continuous basis. This is the result of peaks that occurred during oven push cycles which are presented in Figures 2-2 through 2-4.

Problems occurred with the continuous NO_x monitor. The continuous monitor used operates on internal pumps. Extreme heat during the test resulted in lost voltage rendering the pumps inoperative. After brief cooling periods, the pumps were reset and continuous monitoring was resumed. This should not affect the results of the data obtained since the instrument responded to the correct calibration values at the end of each test.

Visible emissions were recorded for the duration of Tests #1 and #2. No visible emissions were recorded for Test #3 due to darkness. A graphic summary of opacities is presented in Figures 2-2 and 2-3. Additional visible emission data is included in Tables 2-9 through 2-11.

The sulfate analysis on the particulate train water impingers is expressed as SO_2. It is believed that not all of the SO_2 gas was caught in the water impingers; therefore, the SO_2 emissions reported are likely to be less than actual. This is because there was no oxidizing agent other than oxygen in the stack gas to create a more reactive form of sulfur oxide such as SO_3.

TABLE 2-1. SAMPLE COODING SYSTEM

For Particulate		Date	Time
Test Number	Sample Code		
1	CKO-15-M5-1	7-11-79	1518-2012
2	CKO-15-M5-2	7-12-79	1145-1820
3	CKO-15-M5-3	7-12-79	2010-0055
For BAP			
Test Number	Sample Code		
1	CKO-15-BAP-1	7-11-79	1516-2008
2	CKO-15-BAP-2	7-12-79	1145-1825
3	CKO-15-BAP-3	7-12-79	2010-0105
For NO_x			
Test Number	Sample Code		
1	CKO-15-M7-1	7-11-79	1530-1630
2	CKO-15-M7-2	7-12-79	1215-1315
3	CKO-15-M7-3	7-13-79	2040-2110

TABLE 2-2. PARTICULATE AND SULFATE ANALYSIS

RUN NUMBER	1 CKO-15-M5-1		2 CKO-15-M5-2		3 CKO-15-M5-3		AVERAGE	
	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS
I DATE	7-11-79	7-11-79	7-12-79	7-12-79	7-12-79	7-12-79		
II STACK PARAMETERS								
Pst - Static Pressure, "Hg (mmHg)	-0.09	(-2.29)	-0.09	(-2.29)	-0.09	(-2.29)	-0.09	(-2.29)
Ps - Stack Gas Pressure, "Hg Absolute (mmHg)	29.9	(759.5)	29.9	(759.5)	29.9	(759.5)	29.9	(759.5)
% CO_2 - Volume % Dry	4.0		3.6		3.6		3.7	
% O_2 - Volume % Dry	9.0		8.9		9.4		9.1	
% CO - Volume % Dry	NIL		NIL		NIL		NIL	
% N_2 - Volume % Dry	87.0		87.5		87.0		87.2	
Ts - Average Stack Temperature °F (°C)	562	(294.4)	565	(296.1)	567	(297.2)	565	(295.9)
% M - % Moisture in Stack Gas, By Volume	12.87		14.95		12.70		-13.51	
As - Stack Area, ft² (m²)	153.9	(14.30)	153.9	(14.30)	153.9	(14.30)	153.9	(14.30)
Mwd - Molecular Weight of Stack Gas, Dry Basis	29.000		28.932		28.952		28.96	
Mw - Molecular Weight of Stack Gas, Wet Basis	27.584		27.298		27.561		27.481	
Vs - Stack Gas Velocity, ft/sec, (m/sec)	12.184	(3.714)	12.652	(3.857)	13.334	(4.065)	12.723	(3.879)
Qa - Stack Gas Volumetric Flow at Stack Conditions, ACFM (m³/min)	112505	(3,186.2)	116833	(3,308.8)	123128	(3,487.0)	117489	(3,327.3)
Qs - Stack Gas Volumetric Flow at Standard Conditions, DSCFM (m³/min)	50590	(1,431.7)	51132	(1,447.0)	55202	(1,562.2)	52308	(1,480.3)
III TEST CONDITIONS								
Pb - Barometric Pressure, "Hg (mmHg)	30.0	(762.)	30.0	(762.)	30.0	(762.)	30.0	(762.)
Dn - Sampling Nozzle Diameter, in. (mm)	0.50	(12.7)	0.50	(12.7)	0.50	(12.7)	0.50	(12.7)
T - Sampling Time, min	128		160		160		149.3	
Vm - Sample Volume, ACF (m³)	67.085	(1.900)	82.037	(2.323)	88.627	(2.510)	79.250	(2.244)
Np - Net Sampling Points	32		32		32		32	
Cp - Pitot Tube Coefficient	0.85		0.85		0.85		0.85	
Tm - Average Meter Temperature °F (°C)	88	(31.1)	98	(36.7)	100	(37.8)	95	(35.2)
Pm - Average Orifice Pressure Drop, "H_2O (mmH_2O)	0.89	(22.6)	0.94	(23.9)	1.05	(26.7)	0.96	(24.4)
Vlc - Condensate Collected (Impingers and Gel), mls		(203.6)		(291.0)		(259.4)		(251.3)
IV TEST CALCULATIONS								
Vw_{gas} - Condensed Water Vapor, SCF (m³)	9.590	(0.272)	13.706	(0.388)	12.218	(0.346)	11.838	(0.335)
Vm - Volume of Gas Sampled at Standard Conditions, DSCF (m³)	64.925	(1.837)	77.982	(2.207)	83.968	(2.376)	72.625	(2.140)
% M - Percent Moisture, By Volume	12.87		14.95		12.70		13.51	
MW - Molecular Weight of Stack Gas, Wet Basis	27.584		27.298		27.561		27.481	
Vs - Stack Velocity, ft/sec (m/sec)	12.184	(3.714)	12.652	(3.857)	13.334	(4.065)	12.723	(3.879)
% I - Percent Isokinetic	112.8		107.5		107.2		109.2	
V ANALYTICAL DATA								
A) <u>Particulates Front Half</u>								
Probe, gr/DSCF (gm/m³)	0.01070	(0.02450)	0.00810	(0.01854)	0.00805	(0.01844)	0.00542	(0.02049)
Filter, gr/DSCF (gm/m³)	0.07038	(0.16116)	0.14021	(0.32109)	0.11657	(0.26695)	0.06699	(0.24973)
<u>Particulates Front Half Total</u>								
gr/DSCF, (mg/m³)	0.08107	(0.18566)	0.14831	(0.33963)	0.12462	(0.28539)	0.11800	(0.27023)
#/hr, (kg/hr)	35.14987	(15.94398)	64.98926	(29.47913)	58.95697	(26.74288)	53.03203	(24.05533)
B) <u>Particulates - Condensables</u>								
<u>Organic</u>								
gr/DSCF, (mg/m³)	0.00123	(0.00282)	0.00164	(0.00375)	0.00176	(0.00403)	0.00154	(0.00353)
#/hr, (kg/hr)	0.53476	(0.24256)	0.71826	(0.32580)	0.83295	(0.37782)	0.69532	(0.31539)
<u>Inorganic</u>								
gr/DSCF, (mg/m³)	0.00334	(0.00766)	0.00026	(0.00059)	0.00117	(0.00269)	0.00159	(0.00365)
#/hr, (kg/hr)	1.45001	(0.65772)	0.11250	(0.05103)	0.55530	(0.25188)	0.70594	(0.32021)
C) <u>Particulates - Total Condensables</u>								
gr/DSCF, (mg/m³)	0.00458	(0.01048)	0.00190	(0.00434)	0.00293	(0.00672)	0.00314	(0.00718)
#/hr, (kg/hr)	1.98476	(0.90029)	0.83075	(0.37683)	1.38824	(0.62971)	1.40125	(0.63561)
D) <u>Total Particulates</u>								
gr/DSCF, (mg/m³)	0.08565	(0.19614)	0.15020	(0.34397)	0.12756	(0.29211)	0.12114	(0.27741)
#/hr, (kg/hr)	37.13464	(16.84427)	65.82001	(29.85596)	60.34521	(27.37259)	54.43329	(24.69094)
E) <u>Sulfates</u>								
ppm SO_2, (mg/m³)	7.31	(19.34)	19.84	(51.98)	13.55	(35.50)	13.61	(35.66)
10^{-6} #/DSCF SO_2, (kg/m³)	1.22	(19.34)	3.28	(51.98)	2.24	(35.50)	2.25	(35.66)
ppm SO_4, (mg/m³)	25.96	(103.48)	15.92	(63.43)	38.03	(151.56)	26.64	(106.16)
10^{-6} #/DSCF SO_4, (kg/m³)	6.46	(103.5)	3.68	(63.4)	9.45	(151.6)	6.53	(106.2)

TABLE 2-3. BαP RESULTS

RUN NUMBER	1 CKO-15-BAP-1		2 CKO-15-BAP-2		3 CKO-15-BAP-3		AVERAGE	
	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS	ENGLISH UNITS	METRIC UNITS
I DATE	7-11-79	7-11-79	7-12-79	7-12-79	7-12-79	7-12-79		
II STACK PARAMETERS								
Pst - Static Pressure, "Hg (mmHg)	-0.08	(-2.03)	-0.09	(-2.29)	-0.09	(-2.29)	-.09	(-2.20)
Ps - Stack Gas Pressure, "Hg Absolute (mmHg)	29.9	(759.5)	29.9	(759.5)	29.9	(759.5)	29.9	(759.5)
% CO_2 - Volume % Dry	4.0		3.6		3.6		3.7	
% O_2 - Volume % Dry	9.0		8.9		9.4		9.1	
% CO - Volume % Dry	NIL		NIL		NIL		NIL	
% N_2 - Volume % Dry	87.0		87.5		87.0		87.2	
Ts - Average Stack Temperature °F (°C)	555.3	(290.7)	569.0	(298.3)	567.0	(297.2)	563.8	(295.4)
% M - % Moisture in Stack Gas, By Volume	12.87		14.95		12.70		13.51	
As - Stack Area, ft^2 (m^2)	153.9	(14.30)	153.9	(14.30)	153.9	(14.30)	153.9	(14.30)
Md - Molecular Weight of Stack Gas, Dry Basis	29.000		28.932		28.952		28.961	
Mw - Molecular Weight of Stack Gas, Wet Basis	27.586		27.296		27.561		27.481	
Vs - Stack Gas Velocity, ft/sec, (m/sec)	12.316	(3.755)	11.963	(3.647)	14.199	(4.329)	12.826	(3.910)
Qa - Stack Gas Volumetric Flow at Stack Conditions, ACFM (m^3/min)	113,730	(3,221)	110,469	(3,128)	131,111	(3,713)	118,437	(3354)
Qs - Stack Gas Volumetric Flow at Standard Conditions, DSCFM (m^3/min)	51,485	(1,457.0)	48,147	(1,362.6)	58,782	(1,663.5)	52,805	(1494.4)
III TEST CONDITIONS								
Pb - Barometric Pressure, "Hg (mmHg)	30.0	(762.0)	30.0	(762.0)	30.0	(762.0)	30.0	(762.0)
Dn - Sampling Nozzle Diameter, in. (mm)	0.50	(12.7)	0.50	(12.7)	0.50	(12.7)	0.50	(12.7)
T_t - Sampling Time, min	128		160		165		151	
Vm - Sample Volume, ACF (m^3)	67.42	(1.91)	80.81	(2.29)	97.51	(2.76)	81.91	(2.32)
Np - Net Sampling Points	32		32		32		32	
Cp - Pitot Tube Coefficient	0.85		0.85		0.85		0.85	
Tm - Average Meter Temperature °F (°C)	89		98		95		94	
Pm - Average Orifice Pressure Drop, "H_2O (mmH_2O)	0.86	(21.8)	0.80	(20.3)	1.12	(28.4)	0.93	(23.6)
IV TEST CALCULATIONS								
Vw_{gas} Condensed Water Vapor, SCF (m^3)								
Vm - Volume of Gas Sampled at Standard Conditions, DSCF (m^3)	65.125	(1.844)	76.789	(2.175)	93.232	(2.640)	79.049	(2.239)
% M - Percent Moisture, By Volume	12.87*		14.95*		12.70*		13.51*	
MW - Molecular Weight of Stack Gas, Wet Basis	27.584		27.298		27.561		27.481	
Vs - Stack Velocity, ft/sec (m/sec)	12.316	(3.755)	11.963	(3.647)	14.199	(4.329)	12.826	(3.910)
% I - Percent Isokinetic	111.2		112.4		108.2		110.6	
V ANALYTICAL DATA - BaP EMISSIONS								
Probe Rinse, (μg)		(0.185)		(0.468)		(0.440)		(0.364)
XAD-2 Adsorbent (μg)		(3.20)		(0.200)		(3.20)		(2.20)
Filter, (μg)		(0.180)		(0.265)		(0.585)		(0.343)
BaP Total (μg)		(3.565)		(0.933)		(4.225)		(2.908)
BaP Total, 10^{-6} #/hr (10^3 μg/hr)	371.8	(169.0)	77.29	(35.07)	351.9	(159.7)	267.0	(121.3)
BaP Total, #/year (kg/year)	3.26	(1.48)	0.676	(0.307)	3.08	(1.40)	2.34	(1.06)

*Taken directly from particulate sample train.

Table 2-4.

Continuous Monitoring Data
Bethlehem Steel
Battery Stack #2
Test #1

Time	OXYGEN (O_2) (%)	CARBON MONOXIDE (CO) (ppm)	OXIDES OF NITROGEN (NO_X) (ppm)
15:15	10.6	65	70
15:30	11.0	285	65
15:45	11.8	70	106
16:00	11.1	60	65
16:15	11.0	110	65
16:30	11.0	60	65
16:45	12.1	35	130
17:00	12.0	60	61
17:15	FLOW INTERRUPTION	--	--
17:30	11.6	50	87
17:45	13.0	55	80
18:00	11.6	85	70
18:15	11.4	50	85
18:30	11.2	90	40
18:45	11.1	70	50
19:00	12.0	45	60
19:15	11.2	40	65
19:30	9.2	95	65
19:45	11.0	40	25
20:00	10.0	35	75
20:15	10.0	46	70

Table 2-5.

Continuous Monitoring Data
Bethlehem Steel
Battery Stack #2
Test #2

Time	OXYGEN (O_2) (%)	CARBON MONOXIDE (CO) (ppm)	OXIDES OF NITROGEN (NOX) (ppm)
11:45	12.8	90	30
12:00	13.0	95	65
12:15	12.0	100	70
12:30	12.0	105	68
12:45	12.5	310	80
13:00	12.2	210	50
13:15	11.5	130	50
13:30	11.8	120	80
13:45	11.5	130	90
14:00	11.5	150	50
14:15	12.0	75	52
14:30	11.3	75	70
14:45	13.0	100	60
	← Process Problems-2 hrs. hold →		
16:45	14.0	90	*
17:00	10.8	120	60
17:15	12.4	225	70
17:30	10.0	110	80
17:45	10.5	290	80
18:00	11.0	150	60
18:15	11.5	0	70

* NO_x pump tripped

Table 2-6.

Continuous Monitoring Data
Bethlehem Steel
Battery Stack #2
Test #3

Time	OXYGEN (O_2) (%)	CARBON MONOXIDE (CO) (ppm)	OXIDES OF NITROGEN (NO_X) (ppm)
20:15	11.0	65	65
20:30	11.1	85	55
20:45	11.4	85	75
21:00	11.1	180	100
21:15	11.1	180	95
21:30	11.2	160	100
21:45	12.0	65	105
22:00	10.5	60	105
22:15	10.7	80	50
22:30	11.0	110	90
22:45	10.6	200	95
23:00	10.6	110	60
23:15	10.5	65	50
23:30	11.0	400	*
23:45	10.0	140	105
24:00	11.0	50	65
00:15	10.5	55	63
00:30	11.0	60	57
00:45	11.0	55	85
01:00	10.5	40	85

*NO_x pump tripped

TABLE 2-7. NOx METHOD 7 RESULTS

RUN NUMBER	CKO-15-M7-1	CKO-15-M7-2	CKO-15-M7-3
Flask A	23 ppm	103 ppm	17 ppm
Flask B	60 ppm	37 ppm	59 ppm
Flask C	19 ppm	58 ppm	48 ppm
Flask D	58 ppm	77 ppm	47 ppm
Average	40 ppm	69 ppm	40 ppm

TABLE 2-8. SULFATE RESULTS

RUN NUMBER	CK-15-M5-1	CKO-15-M5-2	CKO-15-MF-3
Vm (DSCF)	64.925	77.982	83.968
SO_2, ppm (dry)	7.31	19.84	13.55
SO_2, pound/DSCF	1.22×10^{-6}	3.28×10^{-6}	2.24×10^{-6}
SO_2, pound/hr	3.70	10.1	7.42
SO_4, ppm (dry)	25.96	15.92	38.03
SO_4, pound/DSCF	6.46×10^{-6}	3.68×10^{-6}	9.45×10^{-6}
SO_4, pound/hr	19.6	11.3	31.3

Table 2-9. FACILITY: SPARROWS POINT
SUMMARY OF VISIBLE EMISSIONS: TEST #1

Date: 7-11-79
Type of Plant: Coke Oven
Type of Discharge: Exhaust Gas
Location of Discharge: #2 Battery Stack
Height of Point of Discharge: ≈150'
Description of Background: Clouds
Description of Sky: Cloudy
Wind Direction: Variable
Color of Plume: White
Duration of Observation: 1525-1757

Distance from Observer to Discharge Point: ≈150'
Height of Observation Point: ≈40'
Direction of Observer from Discharge Point: North
Wind Velocity: 0-5 mph
Detached Plume: No

SUMMARY OF AVERAGE OPACITY

Set Number	Start	End	Sum	Average
1	10	10	415	17.3
2	15	25	500	20.8
3	15	0	55	2.3
4	5	0	60	2.5
5	0	0	60	2.5
6	0	25	195	8.1
7	25	25	575	24.0
8	0	0	0	0.0
9	0	0	270	11.2
10	0	25	365	15.2
11	20	0	230	9.6
12	0	30	555	23.1
13	20	0	45	1.9
14	0	0	15	0.6
15	0	0	0	0.0
16	0	0	0	3.54
17	0	0	0	1.67
18	0	0	0	0.0
19	0	0	0	0.0
20	0	0	0	0.0

SUMMARY OF AVERAGE OPACITY

Set Number	Start	End	Sum	Average
21	0	0	0	0.0
22	0	0	0	0.0
23	0	0	0	0.0
24	0	0	0	0.0
25	0	0	0	0.0
26	0	0	0	0.0
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

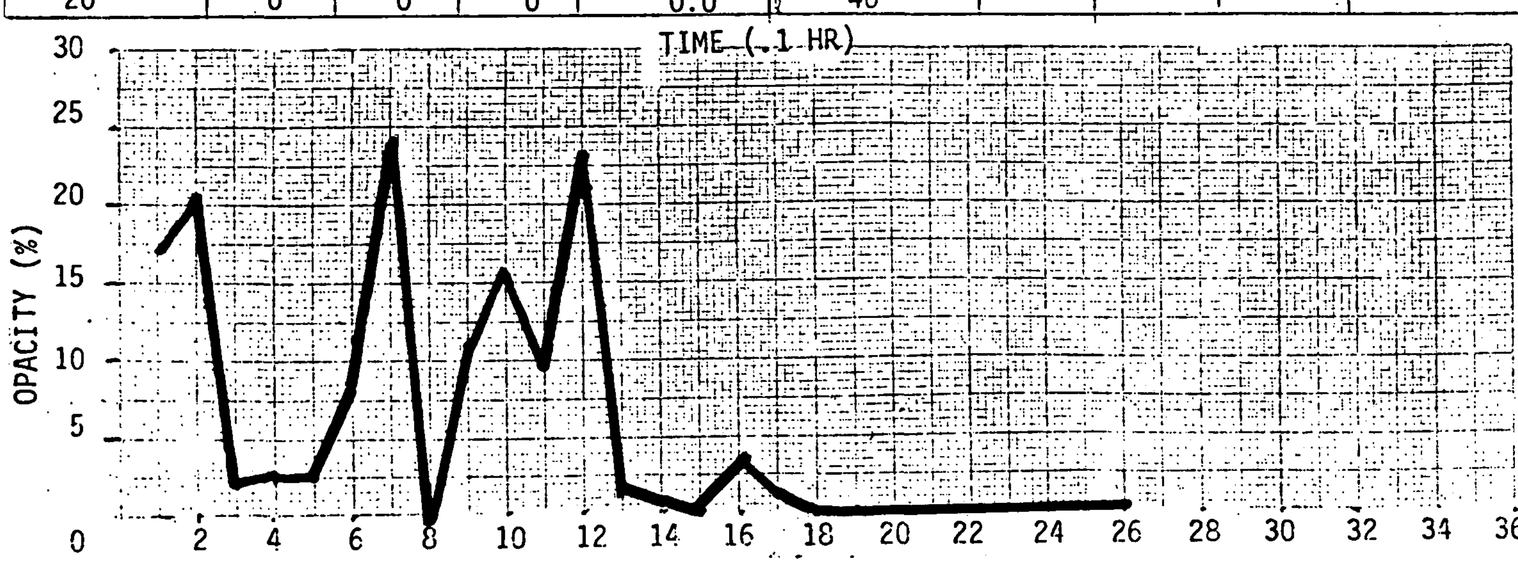


Table 2-10. FACILITY: SPARROWS POINT

SUMMARY OF VISIBLE EMISSIONS: TEST #2

Date: 7-12-79

Type of Plant: Coke Oven

Type of Discharge: Exhaust Gas

Location of Discharge: #2 Battery Stack

Height of Point of Discharge: ≈150'

Description of Background: Clouds

Description of Sky: Cloudy

Wind Direction: Variable

Color of Plume: White

Duration of Observation: 1135-1504

Distance from Observer to Discharge Point: ≈ 1[redacted]0'

Height of Observation Point: ≈ 40'

Direction of Observer from Discharge Point: No[redacted]

Wind Velocity: 0-5 mph

Detached Plume: No

First Half of Test #2

SUMMARY OF AVERAGE OPACITY

Set Number	Start	End	Sum	Average
1	20	15	270	11.2
2	15	0	60	2.5
3	0	0	75	3.1
4	0	0	0	0.0
5	0	0	0	0.0
6	0	0	0	0.0
7	0	10	105	4.4
8	10	10	110	4.6
9	5	5	55	2.3
10	0	10	130	5.4
11	10	0	40	1.7
12	0	0	0	0.0
13	0	5	55	2.3
14	5	0	70	2.9
15	0	0	0	0.0
16	0	0	0	0.0
17	0	0	0	0.0
18	0	0	0	0.0
19	0	0	0	0.0
20	5	10	175	7.3

SUMMARY OF AVERAGE OPACITY

Set Number	Start	End	Sum	Average
21	15	0	55	2.3
22	0	0	0	0.0
23	0	0	0	0.0
24	0	0	0	0.0
25	0	0	0	0.0
26	0	0	0	0.0
27	0	15	95	4.0
28	20	20	520	21.7
29	20	0	245	10.2
30	0	0	0	0.0
31	0	0	0	0.0
32	0	0	0	0.0
33	0	0	0	0.0
34	0	0	0	0.0
35	0	0	0	0.0
36	PLANT WENT DOWN			
37		↓		
38				
39				
40				

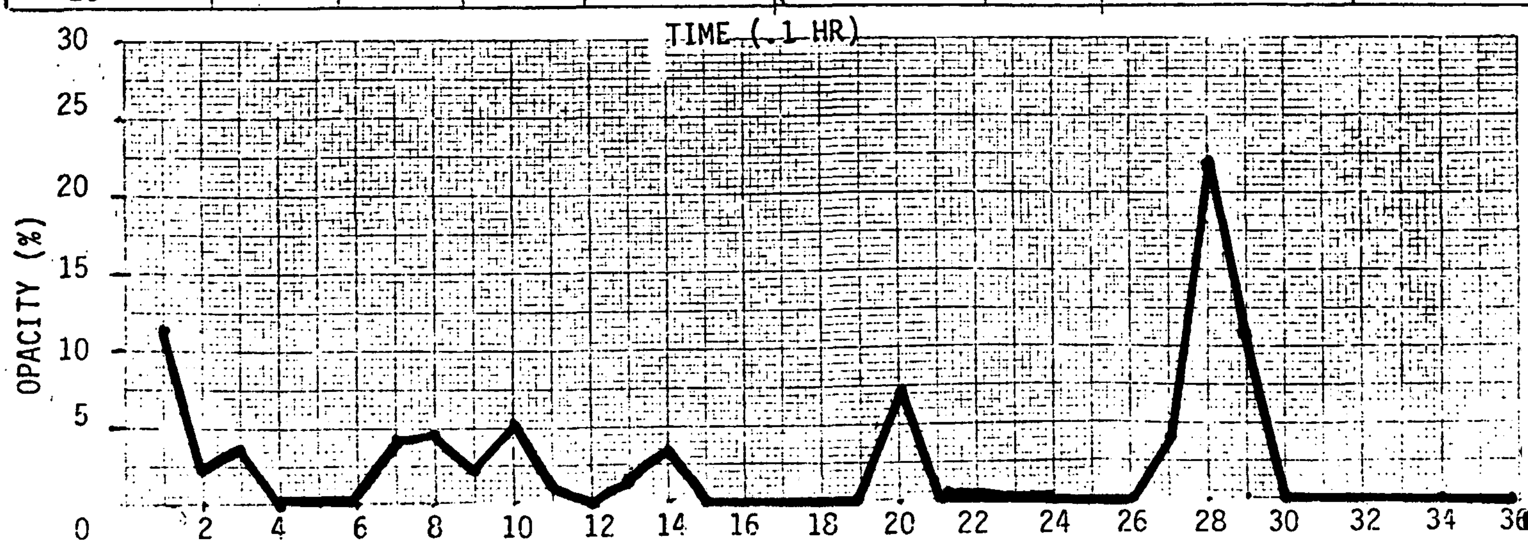


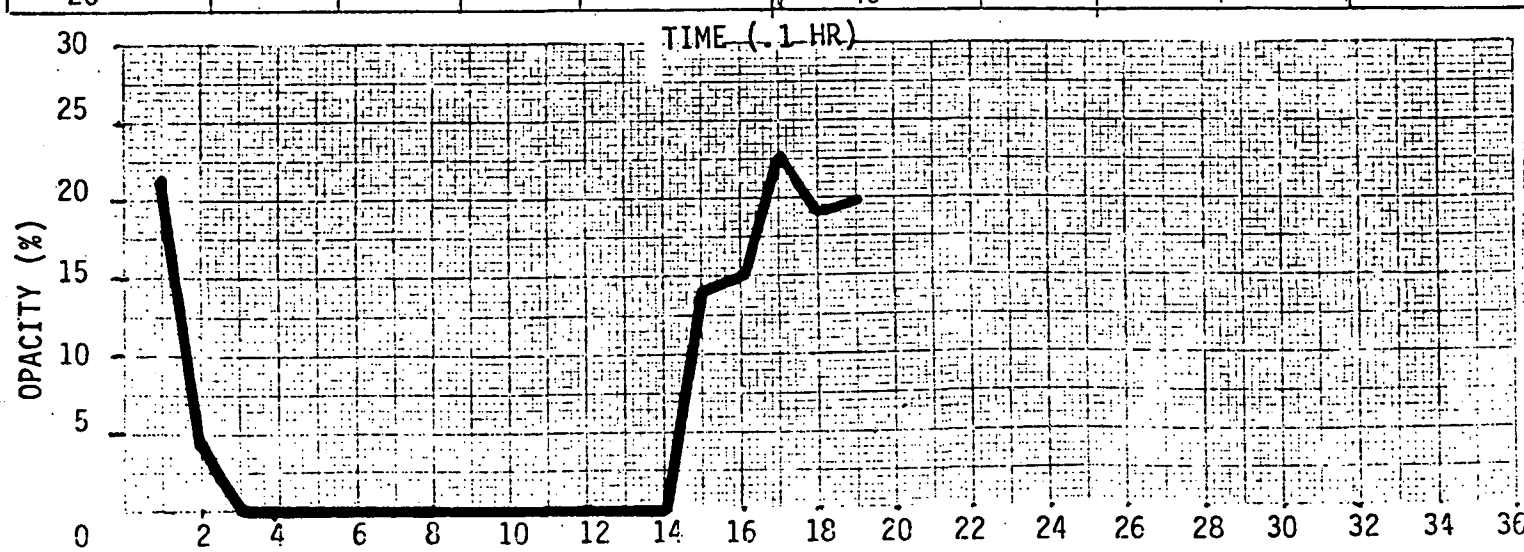
Table 2-11. FACILITY : SPARROWS POINT
SUMMARY OF VISIBLE EMISSIONS : TEST #2 (CONT.)

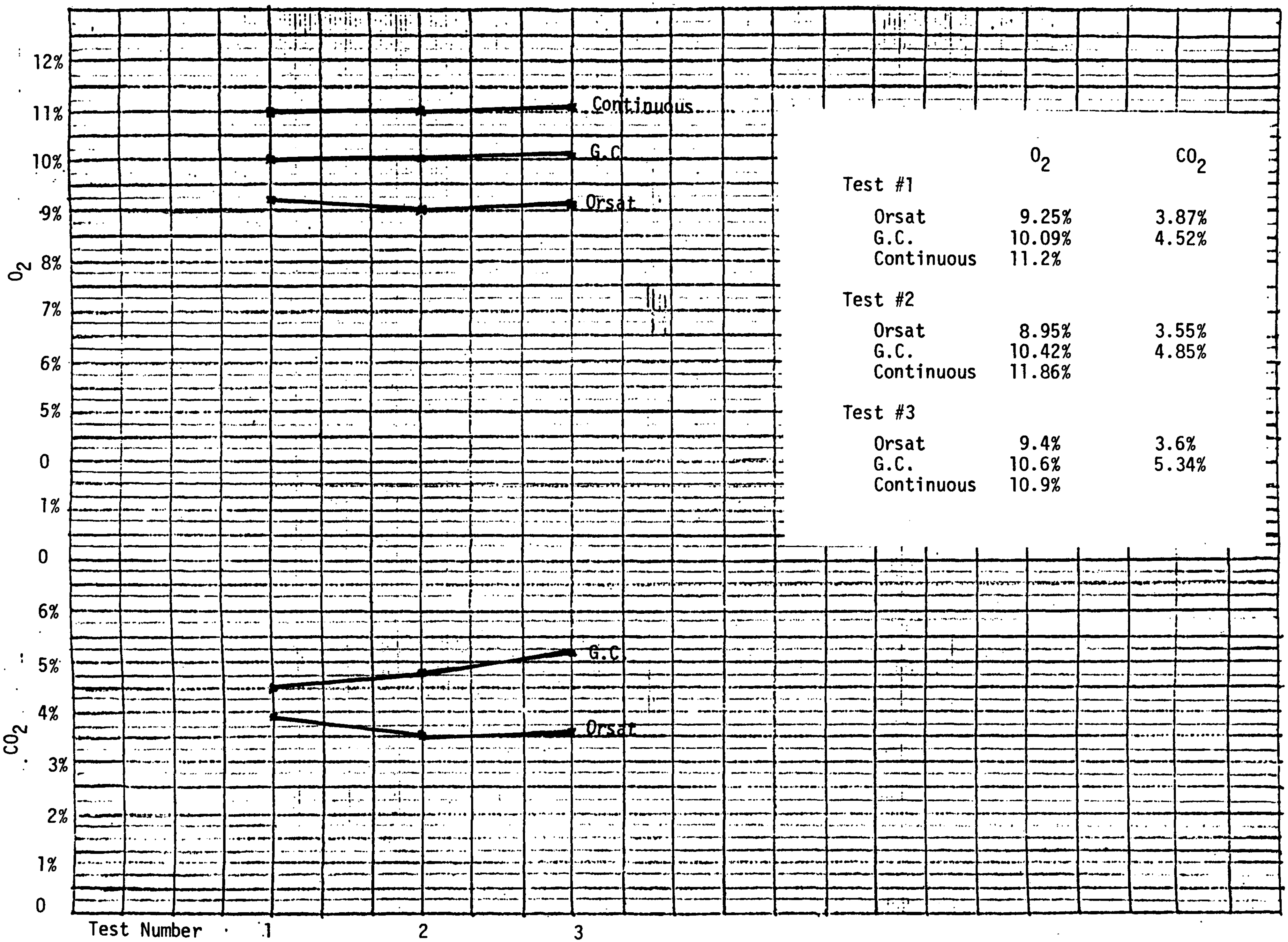
Date: 7-12-79
Type of Plant: Coke Oven
Type of Discharge: Exhaust Gas
Location of Discharge: #2 Battery Stack
Height of Point of Discharge: ≈150'
Description of Background: Clouds
Description of Sky: Cloudy
Wind Direction: Variable
Color of Plume: White
Duration of Observation: 1635-1829

Distance from Observer to Discharge Point: ≈150'
Height of Observation Point: ≈40'
Direction of Observer from Discharge Point: North
Wind Velocity: 0-5 mph
Detached Plume: No

SUMMARY OF AVERAGE OPACITY

Set Number	Start	End	Sum	Average	Set Number	Start	End	Sum	Average
1	20	20	520	21.7	21				
2	20	0	110	4.6	22				
3	0	0	0	0.0	23				
4	0	0	0	0.0	24				
5	0	0	0	0.0	25				
6	0	0	0	0.0	26				
7	0	0	0	0.0	27				
8	0	0	0	0.0	28				
9	0	0	0	0.0	29				
10	0	0	0	0.0	30				
11	0	0	0	0.0	31				
12	0	0	0	0.0	32				
13	0	0	0	0.0	33				
14	0	0	0	0.0	34				
15	0	20	335	14.0	35				
16	20	20	360	15.0	36				
17	20	30	540	22.5	37				
18	30	20	460	19.2	38				
19	20	20	475	19.8	39				
20					40				





	O_2	CO_2
Test #1		
Orsat	9.25%	3.87%
G.C.	10.09%	4.52%
Continuous	11.2%	
Test #2		
Orsat	8.95%	3.55%
G.C.	10.42%	4.85%
Continuous	11.86%	
Test #3		
Orsat	9.4%	3.6%
G.C.	10.6%	5.34%
Continuous	10.9%	

FIGURE 2-1. COMPARATIVE RESULTS OF GAS ANALYSIS

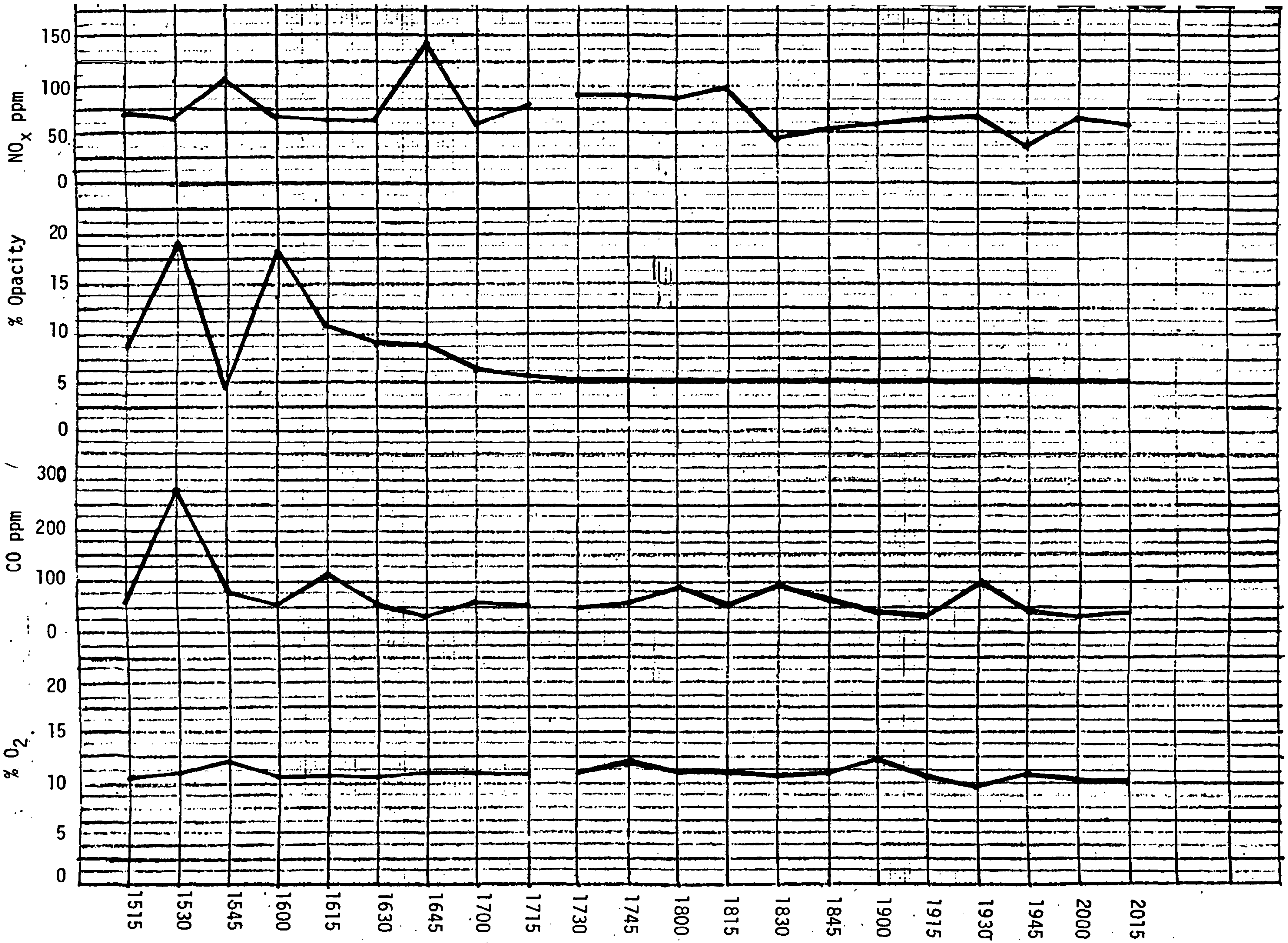


FIGURE 2-2. TEST #1 RELATIONSHIP OF CO, NO_x CONENTRATIONS, % OPACITY AND % OXYGEN

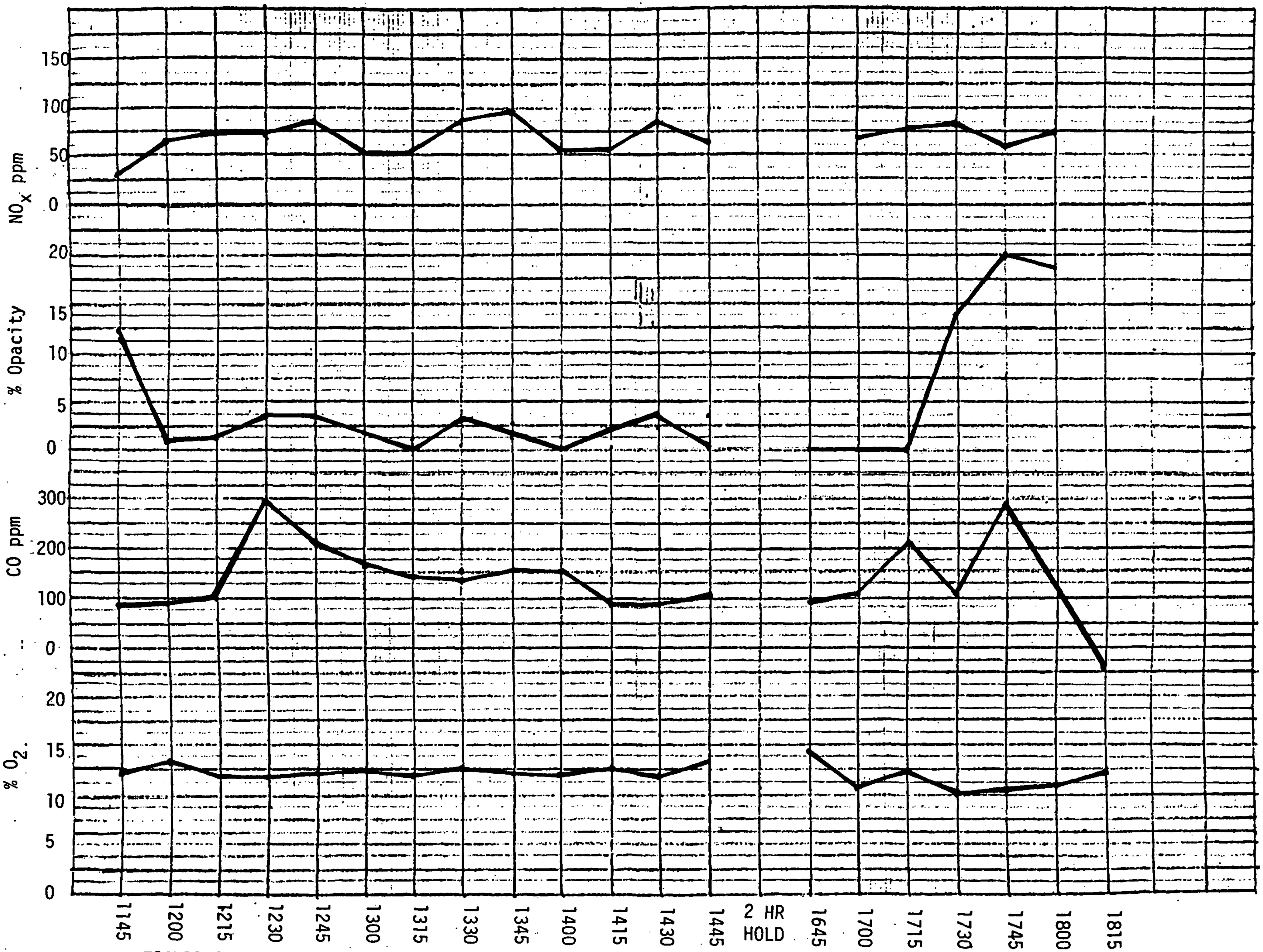


FIGURE 2-3. TEST #2 RELATIONSHIP OF CO, NO_x CONCENTRATIONS, % OPACITY AND % OXYGEN

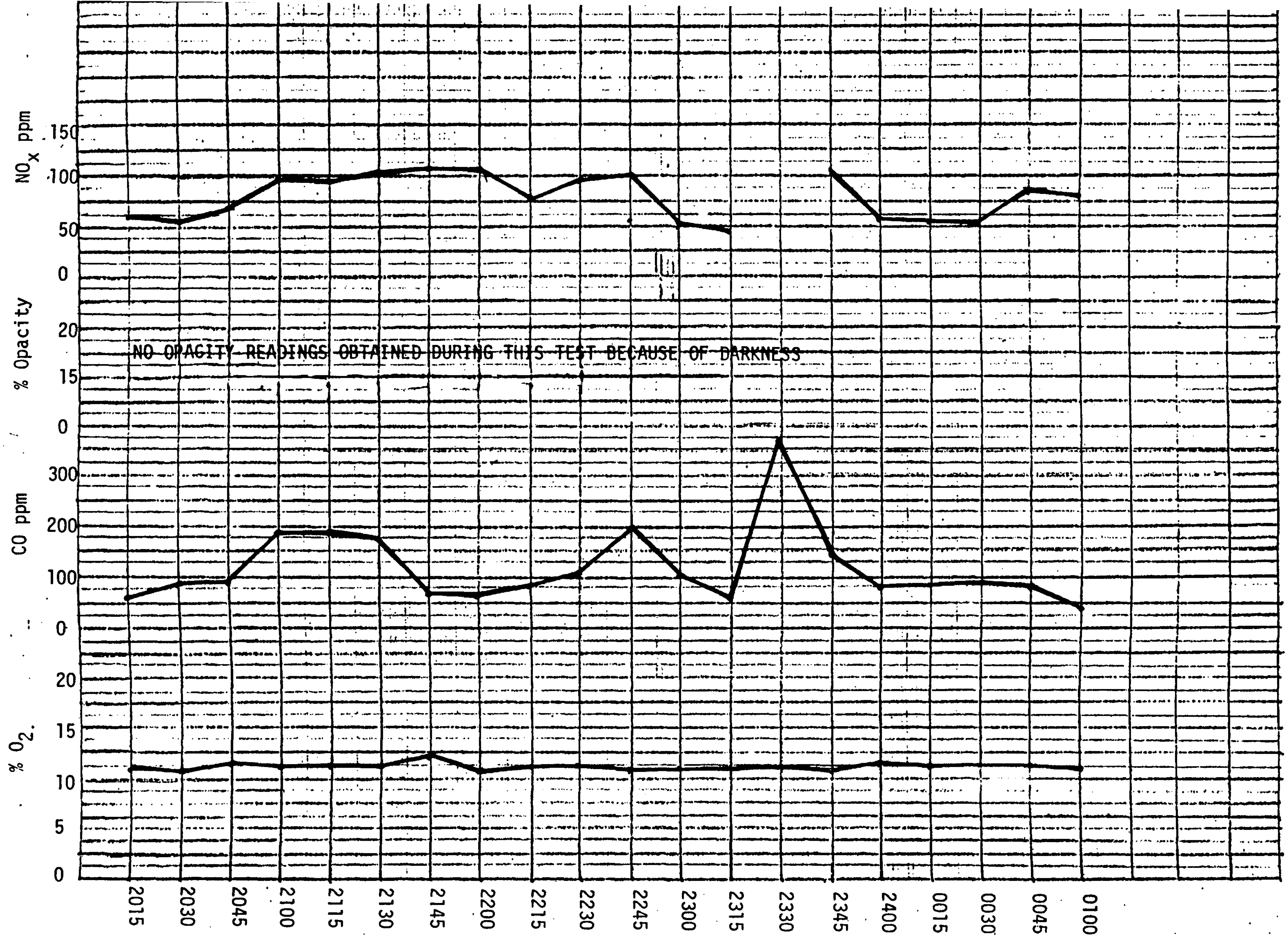


FIGURE 2-4. TEST #3 RELATIONSHIP OF CO, NO_x CONCENTRATIONS, % OPACITY AND % OXYGEN

3. PROCESS DESCRIPTION

There are twelve coke oven batteries (No. 1 through No. 12) at Bethlehem Steel's Sparrows Point, Maryland integrated steel plant. Presently, there are 10 batteries operating with two batteries (Nos. 7 and 8) permanently shutdown. Future plans include the construction of a new 6-m battery and discontinuing operations of some existing batteries after the new battery is on-line.

Only two of the coke oven battery stacks (No. 2 and No. 12) had appropriate sampling ports and platforms for stack sampling. Of these, only Battery No. 2 was fired with coke oven gas (COG). Therefore, the battery stack serving Battery No. 2 at Sparrows Point, Maryland was selected to carry out emission tests of a coke oven facility where mobile gunning is employed.

Battery No. 2 is a 60-oven Koppers gun-flue battery, fired with undesulfurized coke oven gas from the by-product plant. No. 2 Battery began operations in 1961 and has not been rehabilitated since start-up. Additional plant design and operational data are presented in Table 3-1. Maintenance techniques used on Battery No. 2 are mobile-gunning and hand-held gun slurry patching.

The mobile gunning device is a 200 gallon refractory slurry spraying system with a 50 foot water-cooled spraying boom mounted on a 50,000 GVW truck. It is used to spray the oven roofs and the top portion of the oven walls. The mobile-gun spray patching was started on Battery No. 2 in July 1978 and stopped in early September 1978. During this 2 to 3 month period, all ovens except for Ovens No. 245 and No. 228, had the entire upper region of the oven above the coke line sprayed at least once with the mobile-gunner.

During February and March of 1979, the mobile gun sprayer was used to patch 14 additional ovens (Nos. 201, 202, 206, 208, 211, 221, 246, 248, 249, 256, 258, 259, 264 and 266) on Battery No. 2. On May 3, 1979, use of the mobile gunner was restarted on Battery No. 2. The dates when each oven was sprayed since that time are shown in Table 3-2.

In addition to oven spraying with the mobile gun truck, hand-held slurry spraying guns were used to patch the end flues and door jambs of the ovens. This procedure has been employed frequently for a long time. For example, in the first half of 1979 each oven (door jambs and end flues) in No. 2 Battery has been patched at least four times. The actual hand-held gun patching occurred after an oven was pushed and before the door-machines replaced the doors on the oven. This maintenance technique takes 10 to 15 minutes for each door.

During each test day, process operating data was obtained at approximately 1-hour intervals. The time that each oven was pushed and charged was recorded whenever possible. Bethlehem Steel performed daily coke oven fuel gas and coal analysis. The daily average fuel gas and coal analysis results during the testing period are reported in Table 3-3. Copies of circular charts recording the daily process data were obtained along with the flue inspection sheets and the wall temperature logs. All process operating logs and charts obtained during the tests are presented in Appendix E.

3.1 PROCESS DESCRIPTION

The process description that follows was supplied by

Midwest Research Institute
425 Volker Boulevard
Kansas City, Missouri 64110

Table 3-1. PLANT DESIGN AND OPERATION RECORD

Date 7/9/79

Plant Name Bethlehem Steel
Plant Location Sparrows Pt., MD
Battery No. 2
Name of Plant Contact George Thomas (Heater Foreman)

Type of Ovens and Designer Koppers-Gunflue
Date Built 1960 - started 1961
Date of Last Rehabilitation None
Type of Last Rehabilitation N/A

Number of Ovens Total 60 In Service 60
Size of Ovens Height 10 ft, Width 19.75in, Length 37 ft

Type of coke produced Met. Coke
Normal coking time (hr) 20.25
Coal charged per oven (tons) 13.8
Reversal period (min) 30

Nozzle decarbonization method Carbon Caps
Is flue gas recirculated? No

Type of fuel gas Coke Oven Gas Heating value 490-500 Btu/scf
Is fuel gas desulfurized? No
Note use of stage charging, preheated coal, etc. Stage charging w/ single stand pipe loading
Stack height and top diameter 250 ft 16 ft 6½ in. ID bottom 11 ft 0 in. ID at top
Test location (stack or waste heat canal) Stack (provide sketch)

Control method used Mobile Gunning

Fuel gas analysis Component	Vol.%
CO_2	
Ill.	
O_2	
CO	
H_2	
CH_4	
N_2	
H_2S	

Coal analysis Component	Vol.%
Ash	
S	
H_2O	
VM	

Table 3-2. MOBILE GUN SPRAYING LOG FOR BATTERY NO. 2

SLUR TRUCK #6260

#2 BATTERY

OVEN	BEGAN SLURRING 5/3/79	
01	6/22/79	
11	5/10/79	6/22/79
21	5/10/79	
31	5/11/79	6/8/79
41	5/11/79	6/7/79
51	5/4/79	6/13/79
61	5/4/79	6/13/79
X		
02	5/8/79	
12	5/8/79	
22		
32		
42		
52	6/11/79	
62	6/11/79	
X		
03	6/22/79	
13	6/22/79	
23	5/11/79	6/14/79
33	5/11/79	6/7/79
43	6/14/79	
53	6/8/79	
63		
04	5/8/79	6/11/79
14	5/8/79	6/11/79
24	5/9/79	6/18/79
34	5/9/79	6/18/79
44	5/3/79	
54	5/3/79	6/19/79
64	6/19/79	
05		
15		
25		
35		

OVEN		
45	6/8/79	
55	7/2/79	
65	7/2/79	
06	5/9/79	
16	5/9/79	
26	5/3/79	6/18/79
36	6/18/79	
46	6/12/79	
56	6/12/79	6/19/79
66	6/6/79	6/19/79
07	5/14/79	
17	6/25/79	
27	7/2/79	
37	7/3/79	
47	7/2/79	
57	7/3/79	
[redacted]		
08	6/12/79	6/21/79
18	6/12/79	6/21/79
28	5/10/79	6/13/79
38	5/4/79	6/13/79
48	5/4/79	
58	5/10/79	
[redacted]		
09	6/25/79	
19	6/25/79	
29		
39		
49		
59		
[redacted]		

REMARKS: TRUCK OUT OF SERVICE - 5/7/79 - OPERATIONAL - All UNITS. 5/14/79

Table 3-3. DAILY AVERAGE FUEL GAS ANALYSIS AND COAL ANALYSIS

Fuel Gas Component (vol. %)	7/10/79	7/11/79	7/12/79
CO_2	2.5	2.5	2.1
Ill.	2.7	2.7	2.6
O_2	0.4	0.2	0.3
CO	5.4	6.6	6.5
H_2	56.3	56.8	56.0
CH_4	26.9	26.7	27.0
N_2	5.8	4.5	5.5
H_2S $\left(\frac{\text{grains}}{\text{100 scf}}\right)$	310	298	293
Coal Component (wt. %)			
Ash	6.7	6.7	6.9
S	1.04	1.03	1.00
H_2O	7.2	6.6	6.4
VM	31.5	32.3	32.0
Bulk Density (lb/ft^3)	46.8	46.7	46.6

4. SAMPLING LOCATIONS AND LOCATION OF TRAVERSE POINTS

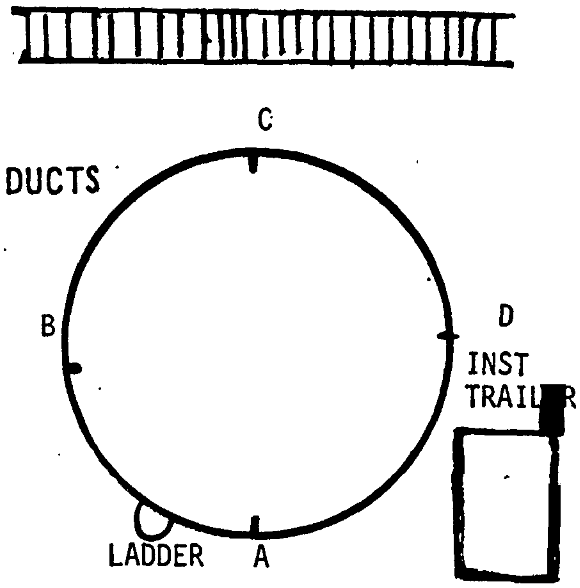
The sample locations were at the eighty (80') foot level of Battery Stack No. 2. Access to the testing platform was gained by way of a caged ladder. Equipment was transported to the testing platform by means of a pulley and davit. Cummunications were established by citizen band radio between the testing location and the mobile laboratory. Figure 4-1 is a generalized schematic of Battery Stack No. 2.

Table 4-1 lists the traverse point location as calculated and utilized in the field. The normal procedure of two perpendicular traverses was modified in order to facilitate easier sampling. Therefore, eight (8) points at four (4) locations were utilized rather than sixteen (16) points at two (2) locations. These traverse points at all four ports were used for preliminary velocity traverse, the particulate, and the benzo-α-pyrene sampling. Port D was used for the continuous monitoring. Port A was used for the Method 7 sampling.

TRW / ENVIRONMENTAL ENGINEERING DIVISION

Table 4-1.

TRAVERSE POINT LOCATION FOR CIRCULAR DUCTS



SCHEMATIC OF SAMPLING LOCATION

PLANT Bethelem Steel - Sparrows Point
DATE 7/10/79
SAMPLING LOCATION Battery Stack #2
INSIDE OF FAR WALL TO OUTSIDE OF NIPPLE, (DISTANCE A) 16.83'
INSIDE OF NEAR WALL TO OUTSIDE OF NIPPLE, (DISTANCE B) 2.83'
STACK I.D., (DISTANCE A - DISTANCE B) 14.00'
NEAREST UPSTREAM DISTURBANCE >2 I.D.
NEAREST DOWNSTREAM DISTURBANCE ~ 6.4 I.D.
CALCULATOR JONGLEUX

TRAVERSE POINT NUMBER	FRACTION OF STACK I.D.	STACK I.D.	PRODUCT OF COLUMNS 2 AND 3 (TO NEAREST 1/8 INCH)	DISTANCE B	TRAVERSE POINT LOCATION FROM OUTSIDE OF NIPPLE (SUM OF COLUMNS 4 & 5)
1	1.6	14 ft.	.224' ft	34"	36.7"
2	4.9	14 ft.	.686 ft.	34"	42.2"
3	8.5	14 ft.	1.19 ft.	34"	48.3"
4	12.5	14 ft.	1.75	34"	55.0"
5	16.9	14 ft.	2.366	34"	62.4"
6	22.0	14 ft.	3.08 ft.	34"	71.0"
7	28.3	14 ft.	3.962 ft.	34"	81.5"
8	37.5	14 ft.	5.25 ft.	34"	107.0"
9	62.5	14 ft.	8.75 ft.	34"	--
10	71.7	14 ft.	10.038 ft.	34"	--
11	78.0	14 ft.	10.92 ft.	34"	--
12	83.1	14 ft.	11.634 ft.	34	--
13	87.5	14 ft.	12.25 ft.	34"	--
14	91.5	14 ft.	12.81 ft.	34"	--
15	95.1	14 ft.	13.314 ft.	34"	--
16	98.4	14 ft.	13.776 ft.	34"	--

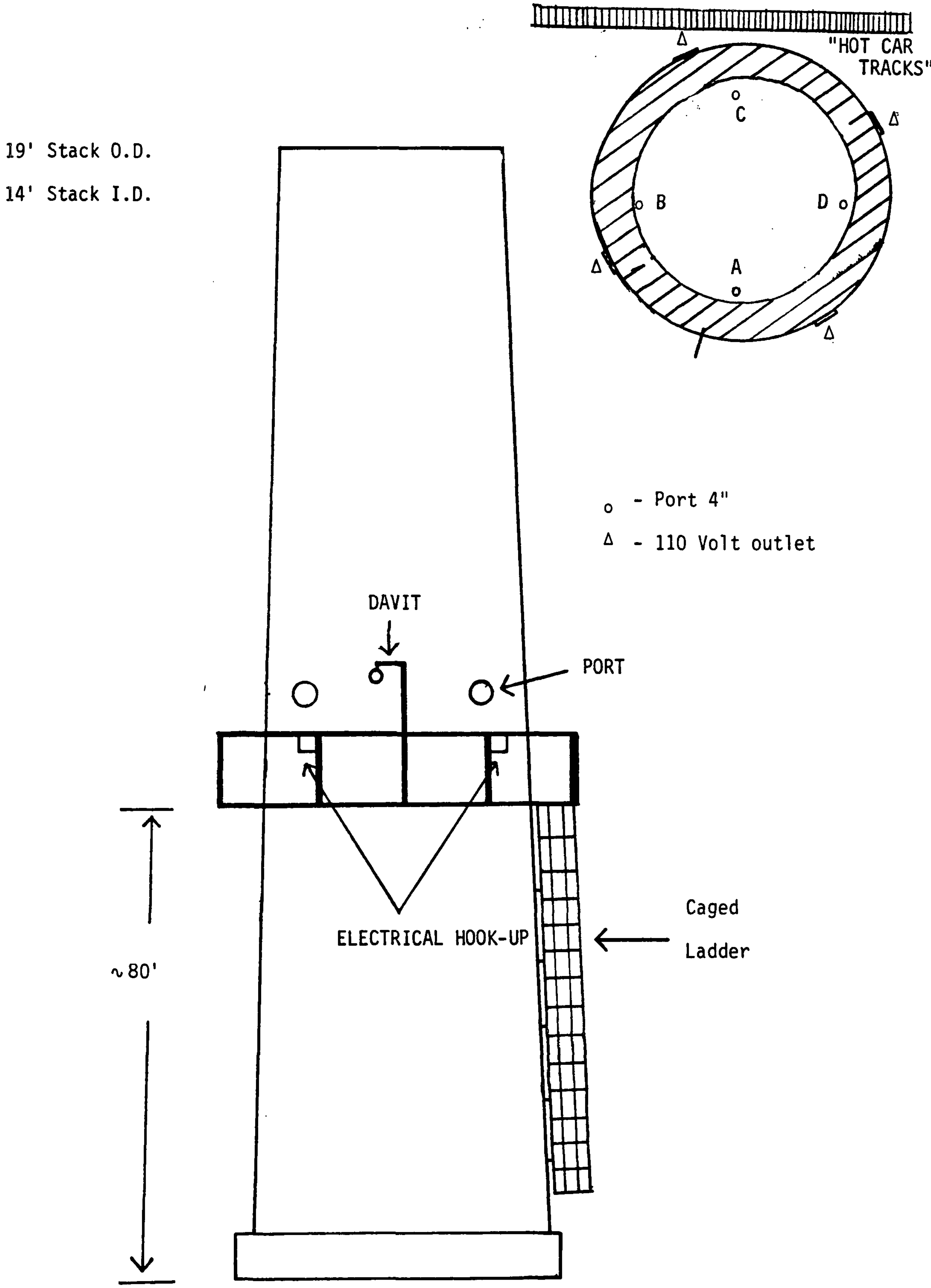


FIGURE 4-1. SCHEMATIC OF BATTERY STACK #2.

5. SAMPLING AND ANALYTICAL PROCEDURES

PARTICULATE SAMPLING

Flue gas particulate concentrations were measured at the outlet of the battery stack. The sampling procedure used was EPA Method 5 as outlined in the Federal Register (40 CFR, Part 60, Appendix A). The only deviation from Method 5 was in the analysis and is discussed under Sulfate Analysis and Ether Chloroform extraction. The prescribed Method 5 analysis was performed prior to the Sulfate analysis and Ether chloroform extraction. A diagram of the Sampling train is shown in Figure 5-1.

The particulate and BαP trains were run simultaneously. A process upset occured midpoint of Test No. 2 which resulted in a 2-hour hold before testing could be resumed. The particulate train sampled four minutes at thirty-two points during Test No. 1. The time sampled at each point was increased to five minutes for the next two tests to assure that adequate volumes would be sampled.

SULFATE ANALYSIS OF PARTICULATE SAMPLES

After analysis of the particulate samples, a 25ml portion of the H_2O collection was removed for sulfate analysis. Analysis was performed by titrating with 0.0100 N Barium perchlorate. The filter was soaked in 80% Isopropyl alcohol and titrated for sulfate analysis.

ETHER CHLOROFORM EXTRACTION

Ether and chloroform extraction was performed on the H_2O portion of the particulate samples for condensibles. This was performed on the H_2O collection minus the 25ml portion used for sulfate analysis. The remaining portion of the H_2O samples was evaporated and the residue weighed and included in the particulate emissions.

BαP SAMPLING

The BαP train and the particulate train were run simultaneously. A process upset occurred midpoint of Test No. 2 which resulted in a 2-hour hold before testing could be resumed. The BαP train sampled four minutes at thirty-two points during Test No. 1. The time sampled at each point was increased to five minutes for the next two tests to assure that adequate volumes would be sampled.

Testing was conducted to determine concentrations of BαP at the outlet of the battery stack. The sampling procedure used consisted of an EPA Method 5 train, modified in the following manner (see Figure 5-2). A Battelle trap was used as an adsorbent sampler and was inserted between the heated filter and first impinger. A thermostatically controlled water bath was used to control the temperature of the adsorbent sampler at 127°F. The Battelle trap was shielded from visible and ultraviolet light during sampling by wrapping with aluminum foil. The adsorbent sampler was capped after sampling and remained covered until analysis was performed (see Figure 5-3). Methylene Chloride was used for rinsing the probe, filter holder, and connecting glass-ware up to the Battelle trap. Acetone was used for rinsing the remainder of the train.

The adsorbent sampler consists of a length of 8mm pyrex tubing wound for approximately eight coils. The adsorbent is retained by an extra coarse Pyrex frit and a spring loaded glass wool plug. The adsorbent section has dimensions equal to a 15mm radius and 70mm in length. Analysis was performed by extracting the BαP from the XAD-2 resin using Cyclohexane. The samples were refrigerated until analysis was performed. Final analysis was performed by measuring the wavelength of the extracted BαP.

Since the adsorbent trap is located in the train prior to the impingers and is cooled to 127°F, some condensation occurs in the trap prior to the impingers. Impingers and silica gel moisture catches do not reflect the total moisture in the stack gas. For this reason, moisture content values from Method 5 runs were used for BαP calculations.

ANALYSIS PROCEDURE FOR BαP

A fluorescence spectrophotometry analysis was used to determine concentrations of BαP. The equipment used for this analysis was the Aminco Model SPF125 Spectrofluorometer with a 7mm lightpath cell. This instrument accurately measures concentrations of BαP as low as 0.001 ppm. The wavelength settings were 378 nm excitation and 403 nm emission with respective slit width openings of 1mm and 5mm. All the samples were in a liquid state, so the only preparations involved with examining each sample was diluting in Cyclohexane any sample which was darkly colored, contained abundant suspended material, or was extremely viscous. This was necessary because any particles or opacity will affect the absorbence. This instrument (the Spectrofluorometer) becomes extremely substance specific at very narrow slit widths, as were used in this analysis.

Filtered particulates and solid samples required an eight hour extraction period in Cyclohexane before analysis could be performed. A Cyclohexane blank was run and taken into account on all extracted and diluted samples in the final calculations.

The quality control procedures taken for this analysis included preparation of a series of BαP standards, exclusion from light, and spiking. A set of standards were prepared for each range (high, medium, and low concentrations) by serial dilutions. Each set was analyzed for linearity by continual measurement throughout the days testing. Since BαP is light sensitive, standards and sample aliquots were discarded after analysis and the samples were kept in closed, dark containers. Lastly, a spiking procedure was used to determine recovery efficiencies on solid and filtered samples, and on samples with very low BαP concentrations. A spiking procedure was followed to assure accurate detection near the limits of the instrument.

No major problems were encountered with the fluorescence spectrophotometric procedure for BαP analysis. This method is preferred over the thin layer chromatographic (TLC) method for low level BαP analysis, as the TLC method had only about 0.01 the sensitivity of direct liquid measurement. The benzo-α-pyrene method was tailored to these samples.

The method originally chosen was intended to be a thin layer chromatography separation with measurement by scanning in situ with a scanning attachment for the fluorescence spectrophotometer. This method lacks the sensitivity required for the analyses. The samples were to be preconcentrated using Kuderna-Danish concentrators with a nitrogen stream flowing over them. It was found, reviewing the literature, that no compound expected to be present in these samples had similar excitation/ emission spectrum to benzo-α-pyrene. Previous analyses by GC/MS on similar samples were the basis of the compounds to be considered as interferences. In addition, a general compendium of polyorganic materials and other organics showed no similar spectrum.[1] It was, therefore, decided to go to a direct in situ method as previously described.

Analysis for BαP was also conducted in the water impingers, but no significant concentrations were found.

[1] Fluorescence and Phosphorescence Data Compendium, Donald L. Helman, American Instrument Co., 1977.

SAMPLING FOR NITROGEN OXIDES

Oxides of Nitrogen (NO_x) were sampled according to EPA Method 7 and by continuous monitoring. One sample flask (CK-15-M7-2B) was opened inadvertently by the sampler, and low concentrations are suspected for that flask. Method 7 uses a grab sample of the flue gas which is collected in an evacuated 2-liter flask containing 25 ml. of a dilute Sulfuric acid-Hydrogen peroxide absorbing solution. Four NO_x samples were taken during each test run. A diagram of the sampling train is shown in Figure 5-4.

ANALYSIS

Nitrogen oxides, except nitrous oxide, were measured colorimetrically using the phenoldisulfonic acid (PDS) procedure which is the Federal Register Method.

GAS SAMPLING AND ANALYSIS

Two grab bag samples were taken for each test. The samples were analyzed for CO_2, O_2, N_2, and CO. Two methods were employed for determining gas composition. Samples of each bag were analyzed on a Gas Chromatograph (GC) using the thermal conductivity principle, and then the bag samples were analyzed using an Orsat analyzer. The GC concentrations were slightly higher than the Orsat concentrations. The Orsat analyzer was suspected of having weak chemicals which would result in the lower concentrations. This would be substantiated by the greater than normal number of passes required before complete absorption occurred. The Orsat analyzer was used, in addition to the GC, for the purpose of maintaining program continuity. The bag sample analysis was used for determining molecular weight and for providing supportive data for the continuous monitors.

CONTINUOUS MONITORS

Continuous monitors were run throughout each test to measure O_2, CO, and NO_x. A stainless steel probe was inserted into the centroid of the stack for removal of flue gas for the continuous monitors (see Figure 5-5). The probe was followed by an ice bath moisture trap for removal of moisture. A pump followed the ice bath moisture trap and supplied flue gas to a mobile laboratory located adjacent to the Battery stack. A second ice bath moisture trap was located inside of the mobile laboratory and was followed by a filter for removal of particulate. Each continuous monitor was equipped with a flow meter to control flows to the desired operating range of the equipment (see Figure 5-6). The electrical output of the continuous monitors was connected to recorders and recordings were made of emission levels throughout each test.

The continuous monitors were conditioned prior to field testing to verify the accuracy of the instruments. Calibration gases certified as traceable to National Bureau of Standards (NBS) were applied to analyzers to determine analyzer response, drift, linearity, and traceability of calibration gases. The instruments were operated in the field prior to testing and data was obtained to determine the arithmetic mean value and 95% confidence interval of the equipment. The calibration error determination for these instruments can be found in Appendix D.

Oxides of Nitrogen were sampled by EPA Method 7 and by continuous monitoring. Problems occurred with the continuous monitor used for monitoring NO_x periodically. The continuous monitor used operates on internal pumps. Extreme heat at the sampling location resulted in lost voltage which rendered the pumps inoperative. After brief cooling periods, the pumps were reset and continuous monitoring was resumed. This should not affect the results of the data obtained, since the instrument responded to the correct calibration values at the end of each test.

Continuous monitors were run to monitor O_2 and CO in addition to NO_x. Comparative results for the O_2 and CO continuous monitoring were obtained by the GC and Orsat analysis. The averages of the concentrations obtained by the CO continuous monitor are high in comparison with the bag sample analysis. The higher concentrations are the result of peaks of CO that occurred during monitoring on a continuous basis. This is shown in Figure 2-1.

OPACITY

Visible determination of Opacity was performed for the duration of tests No. 1 and No. 2. Test No. 3 was performed at night and no visible determination could be obtained. The observations were performed in accordance with EPA Method 9 by a qualified visible emission person.

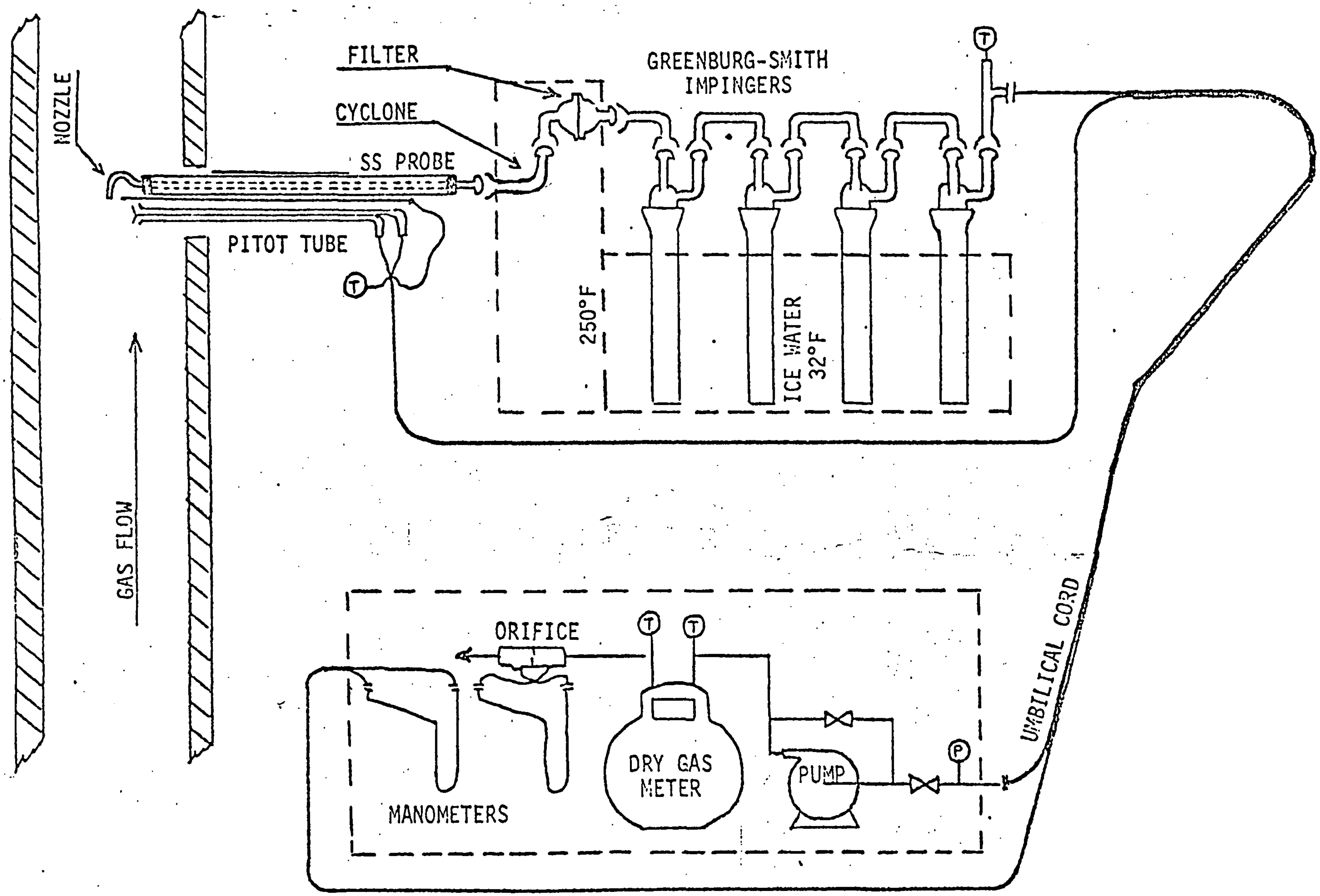


Figure 5-1 Particulate Sampling Train

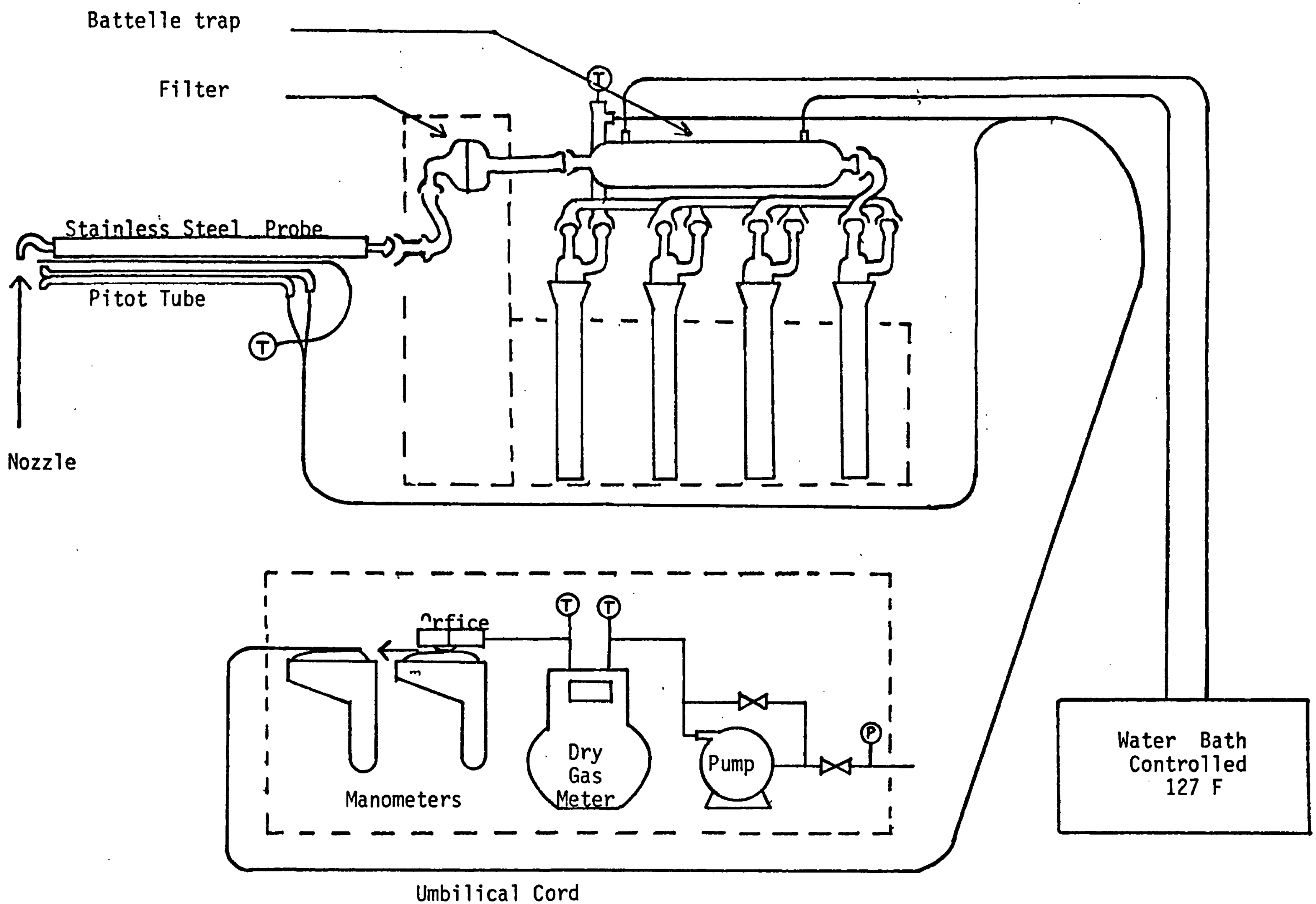


Figure 5-2 BAP Sampling Train

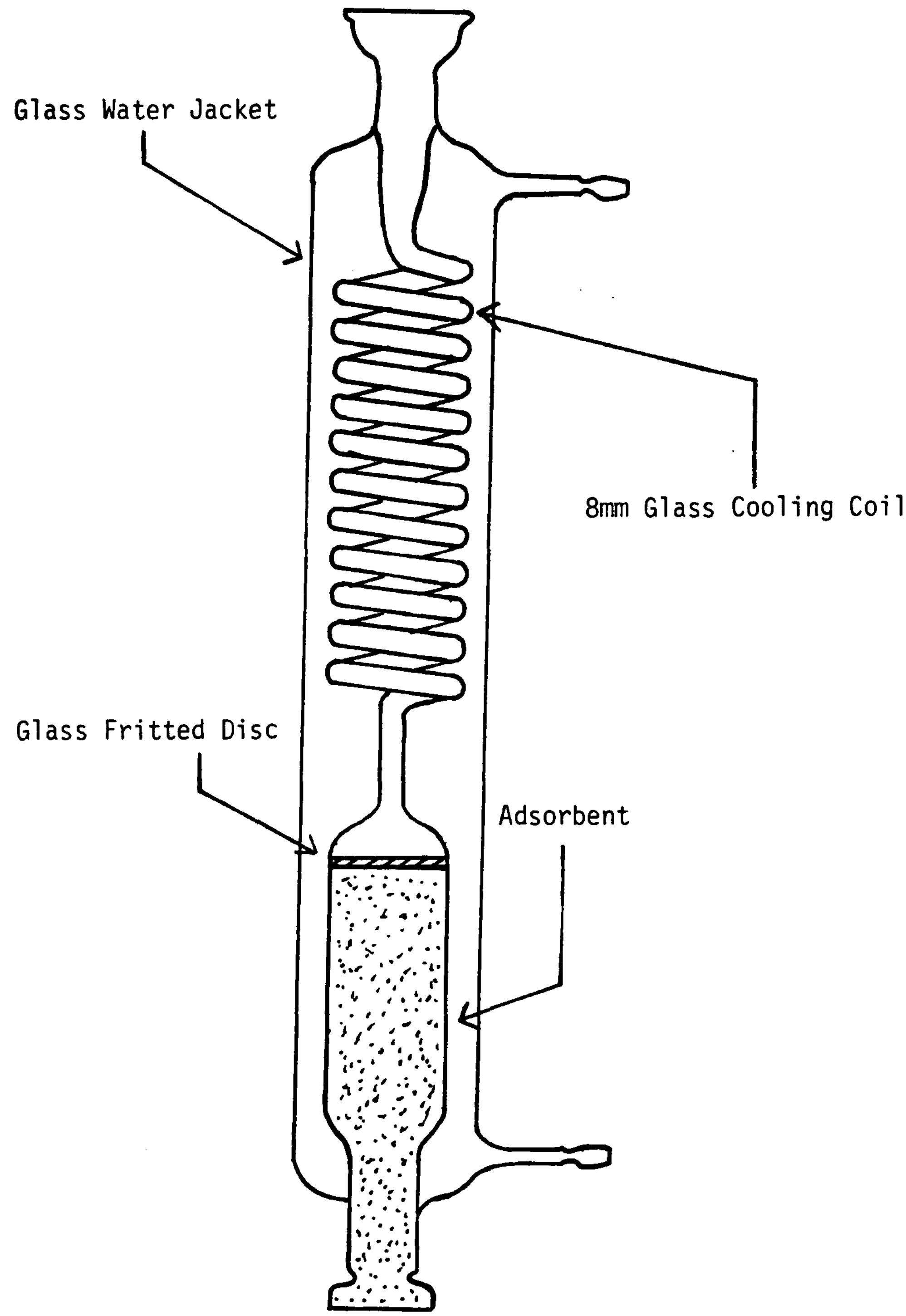


Figure 5-3 Battelle Trap

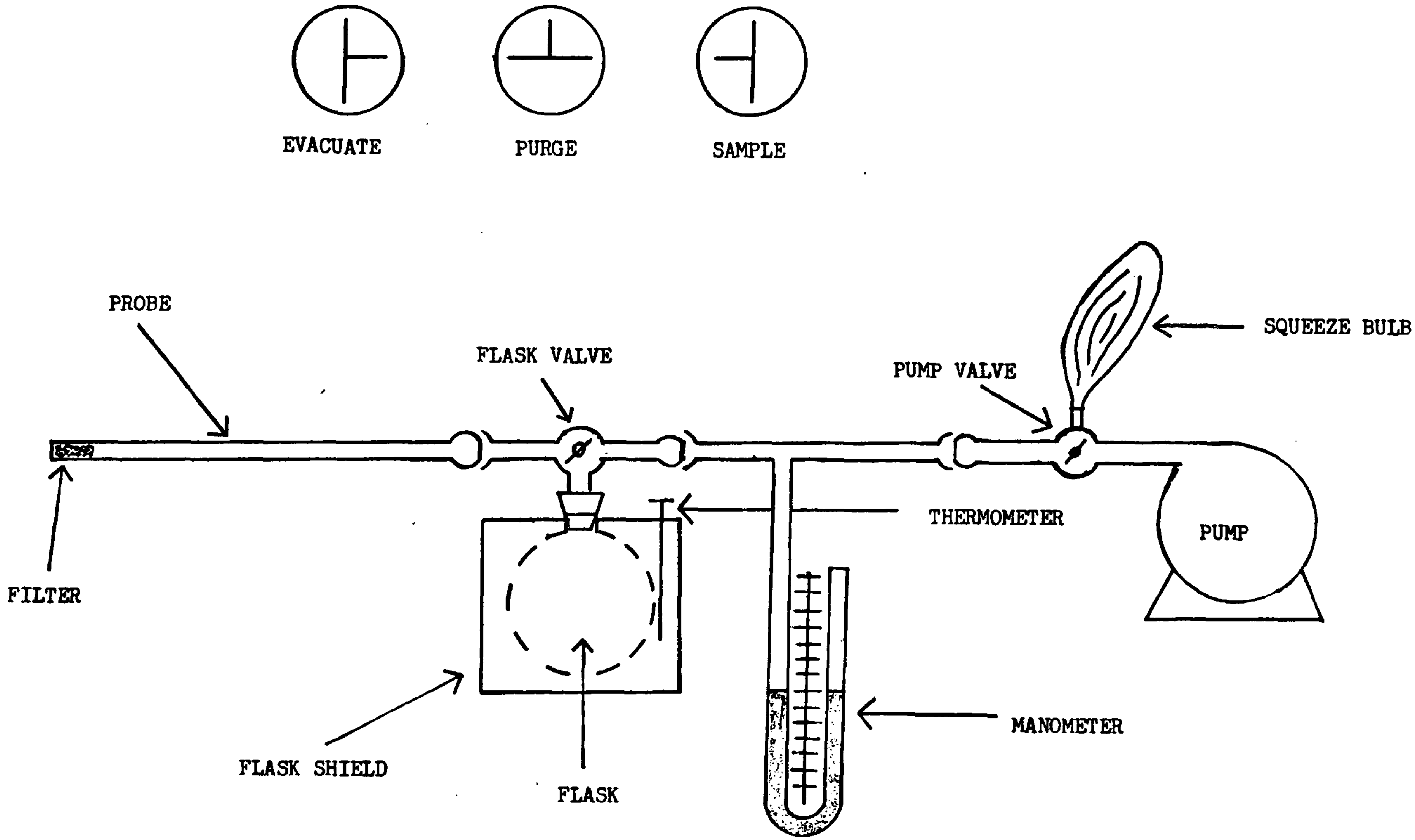


FIGURE 5-4
METHOD 7 SAMPLE TRAIN

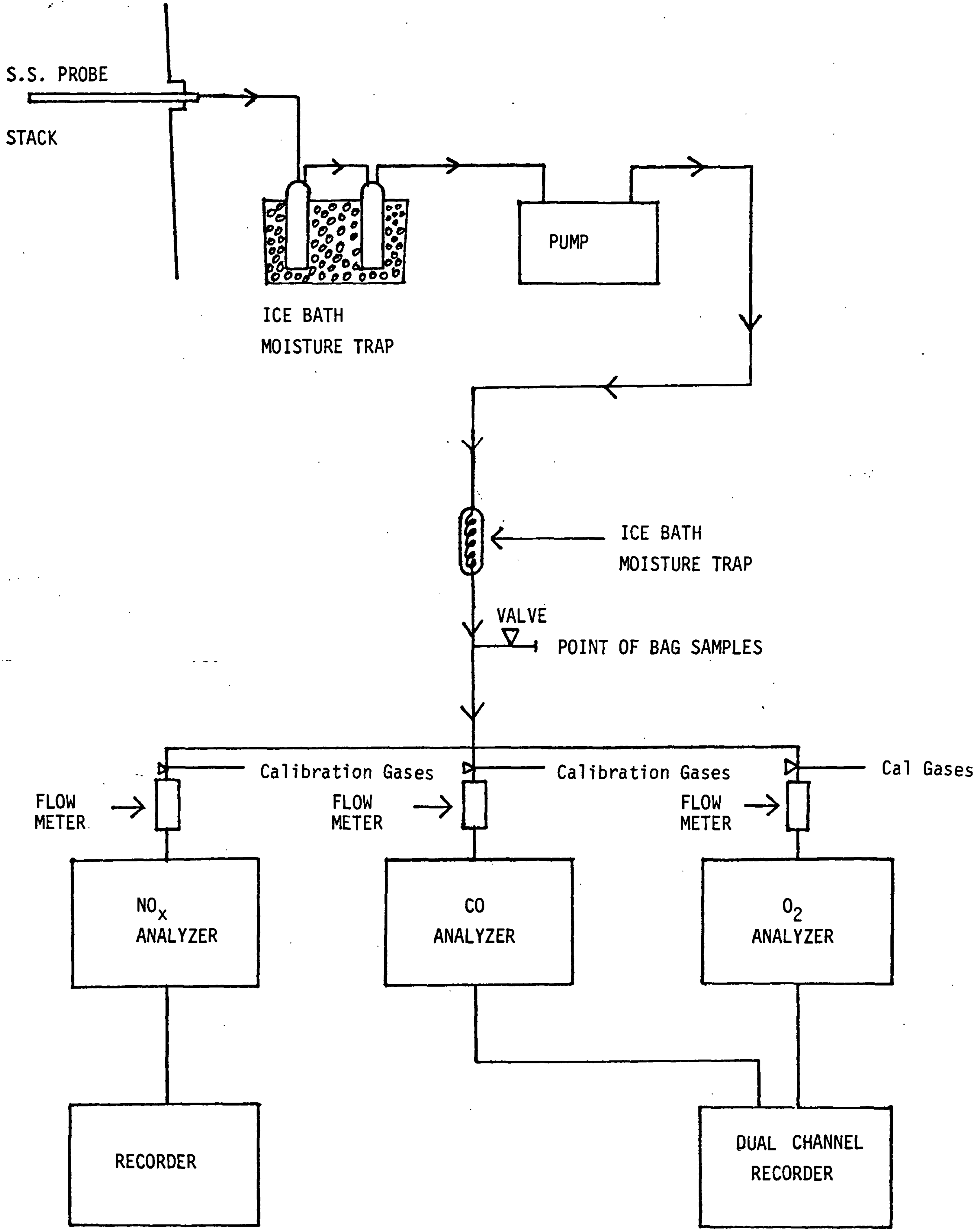


Figure 5-5 Continuous Monitor Schematic

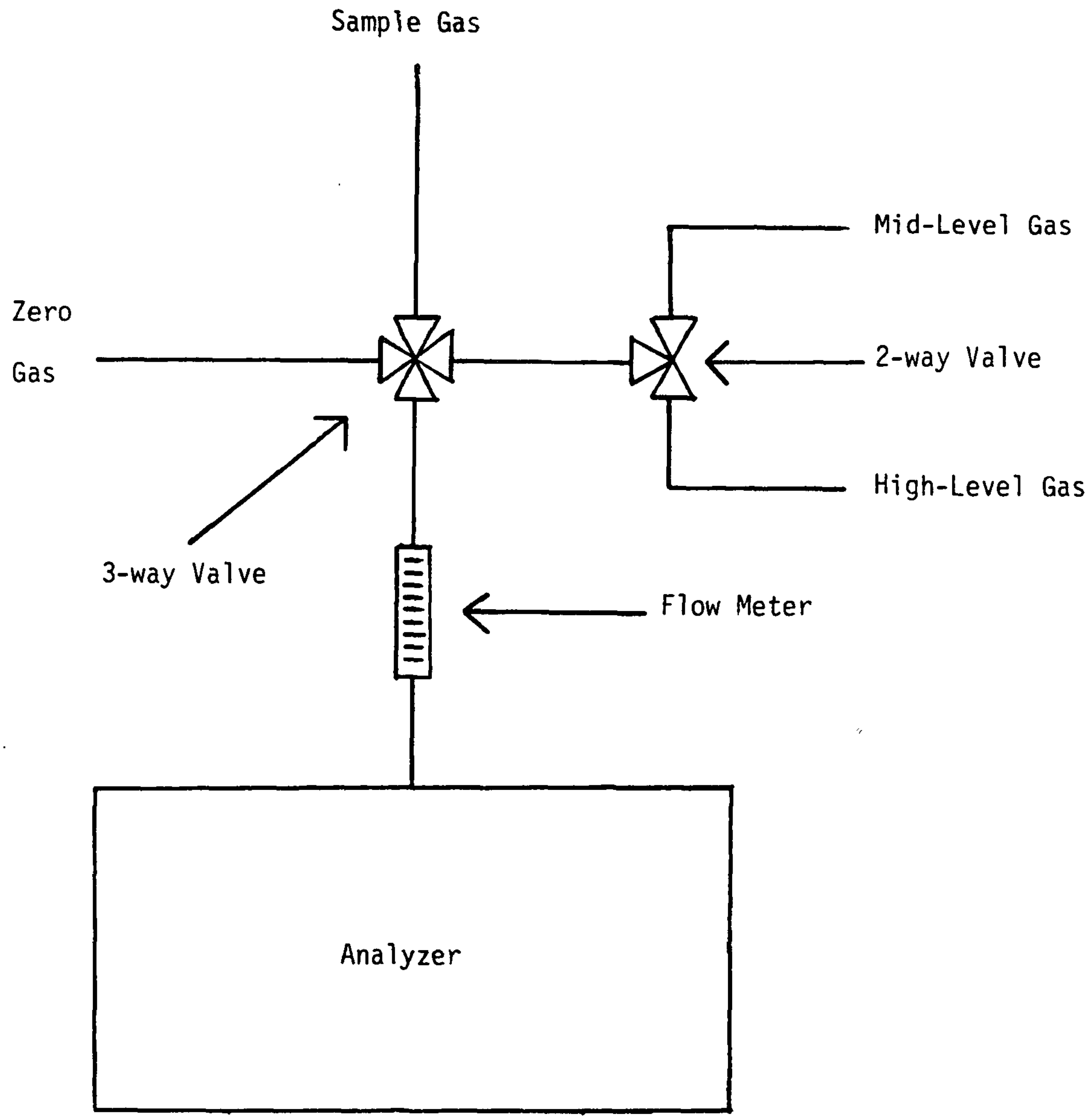


Figure 5-6
Schematic of Calibration Gas Injection
For Continuous Monitors