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REGIONAL AIR POLLUTION STUDY
Point Source Emission Inventory

by

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ABSTRACT

Emissions data from stationary point sources in the St. Louis Interstate Air Quality Control Region (AQCR) have been gathered during the calendar year of 1975. Data for "criteria" pollutants will be available on an hourly basis. Emissions from large sources are based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year are based on annual data modified by a detailed operating pattern.

An emission factor verification program has been initiated. It is carried out by source testing of typical sources using standard EPA methods. Results obtained so far indicate good agreement for SO_2 values. The data obtained for NO_x and particulates originating from combusion sources tend to indicate that the existing factors are too high by variable but substantial amounts.

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1.0 SUMMARY

Emissions data from stationary point sources in the St. Louis Interstate AQCR have been gathered during the calendar year of 1975. Data for "criteria" pollutants - SO_2, NO_X, Particulates, CO and Hydrocarbons - will be available on an hourly basis. Emissions from large sources are based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year of SO_2, for example, are based on annual data modified by a detailed operating pattern.

An emission factor verification program has been initiated. It is carried out by source testing of typical sources using standard EPA methods. Results obtained so far indicate good agreement for SO_2 values. The data obtained for NO_X and particulates originating from combustion sources tend to indicate that the existing factors are too high by variable but substantial amounts.

2.0 INTRODUCTION

This is the third of a series of reports describing the operation of the Regional Air Pollution Study (RAPS) Point Source Emission Inventory. The two prior reports dealt with the methodology (EPA 450/3-74-054) and the first six months of operation of the inventory (SC553.T016FR). This report describes the data acquisition for May through December 1975, as well as the emission factor verification program carried out by stack sampling during the same period.

3.0 EMISSION DATA ACQUISITION

During the period of 1 May to 31 December 1975, the collection of hourly, measured data from all major sources of SO_2 was continued. The methodology used is described in detail in "Point Source Emission Inventory - Final Report, Task Order 16, Phase II" EPA Contract No. 68-02-1081, dated May 1975.

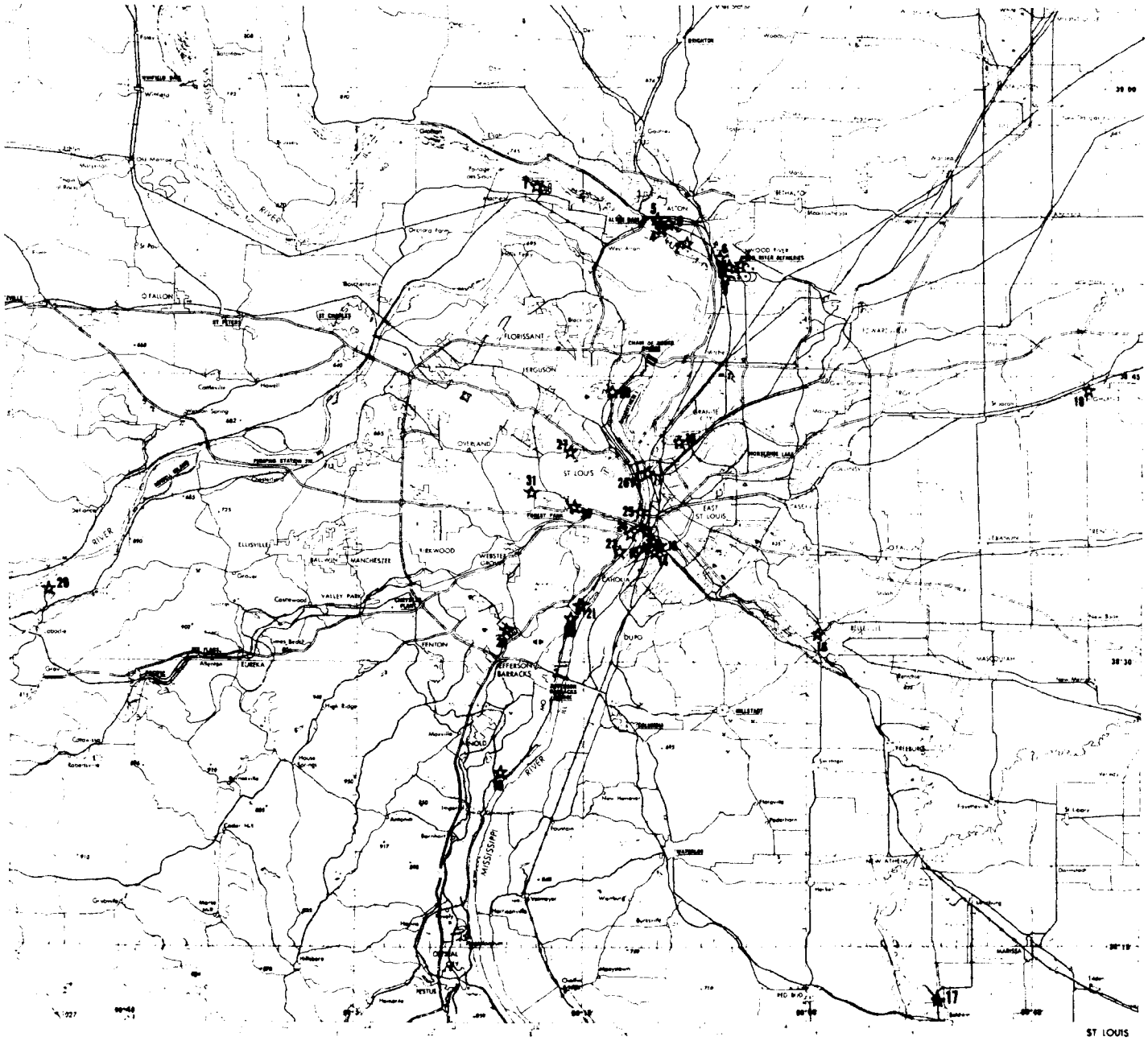
Hourly process or consumption data covering 145 points were recorded and coded on punched cards as described in the same report. The cards were verified and processed through an editing routine (also described in the named report). The information was then transferred to the Univac 1110 computer at the National Environmental Research Center at Research Triangle Park, NC. Major point sources in the St. Louis AQCR are shown in Figure 1.

The emissions from 60 smaller sources were obtained and recorded as annual data, together with the operating patterns. The pattern is capable of indicating the actual operating hours, operating days (in Julian form) and weekly patterns by days. For example, the entry

D:2-48, 50-184, 186-244, 246-365, W:1-5, H:8-17

denotes the operation of a plant which normally operates Monday through Friday (W:1-5), from 8 AM to 5 PM (H:8-17), but is closed down for New Year's (D:1), Washington's Birthday (D:49), Independence Day (D:185), and Labor Day (D:245). If an hourly output for a specific hour and day is requested, the computer will first make sure the plant was operating that day, then divide the annual number by the actual number of hours of operation for a 5 day week, 9 hours a day operation, less the number of days when the plant was shut down.

A 3 month long strike at Union Electric Company delayed the acquisition of data from all U.E. plants; however, since the resumption of normal conditions, the delayed data are forthcoming.



MAP NO.	SOURCE	APPROX. TON/YR SO_2
1	Union Electric – Sioux	115,000
2	Illinois Power – Wood River	73,000
3	Laclede Steel	375
4	Alton Box Board	13,000
5	Owens Illinois Glass	300
6	Amoco Oil Refinery	12,000
7	Shell Oil Refinery	30,000
8	Antin Co.	2,500
9	Clark Oil Refinery	5,000
10	Granite City Steel	2,000
11	Union Electric – Venice	25,000
12	AMAX Zinc	1,500
13	Edwin Cooper	800
14	Monsanto – WG Krummrich	12,000
15	Union Electric – Cahokia	10,000
16	Stag Brewery	900
17	Illinois Power – Baldwin	200,000
18	Highland Electric	1,400
19	Union Electric – Meramec	50,000
20	N.L. Industries	9,000
21	Great Lakes Carbon	700
22	Alpha Cement	500
23	Anheuser Busch	2,500
24	Monsanto – J F Queeny	2,000
25	Union Electric – Ashley	4,800
26	PVO Int.	1,500
27	General Motors	1,500
28	Missouri Portland	900
29	Union Electric – Labadie	200,000
30	Washington Univ. – Euclid Sta.	550
31	Washington Univ. – Campus	350

RAPS
Major Point Source Emissions

FIGURE 1

Arrangements are being made with all companies furnishing data to continue the data collection through 1976. It appears that most, if not all, companies will again cooperate in this effort.

Once the necessary output programs become fully operational, it will be possible to obtain emissions for criteria pollutants emanating from stationary sources for any one-hour period in the St. Louis AQCR for the calendar year of 1975. The information for hydrocarbon emissions will be refined and supplemented under a separate task order next year.

A typical printout, showing hourly data for Particulates, SO_2, NO_X, Hydrocarbons (HC) and CO, is shown in Figure 2. The printout gives name and address of the source, its classification, location in UTM coordinates, stack parameters, fuel analysis and method of calculation, in addition to the emission values.

R A P S S T . L O U I S E M I S S I O N I N V E N T O R Y

****
* POINT SOURCE LISTING *
****

03: UNION ELECTRIC CO
HIGHWAY M LABADIE 63055
5200: MISSING STATE OR CITY CODE
1680: FRANKLIN CO
26: MISSOURI

STACK ID: 01
POINT ID: 01
SIC: 4911
AQCR: 070
OWNERSHIP: UTILTY

SCC(1-01-002-01):EXTCOMB BOILER - ELECTRIC GENERATN- BITUMINOUS COAL - >100MMBTU PULVWET

UTM GRID COORDINATES
****
UTM ZONE: 15
HORIZONTAL: 688.37 KM
VERTICAL: 4270.23 KM

STACK PARAMETERS
****
STACK HEIGHT: 700 FT
STACK DIAMETER: 20.5 FT
GAS TEMPERATURE: 285 F
GAS FLOW RATE: 1600000 CFM
BOILER CAPACITY:5387 MBTU/HR

EMISSION FACTORS
****
PART: AP-42
SOX: AP-42
NOX: AP-42
HC: AP-42
CO: AP-42

FUEL CONTENT
****
SULFUR: 3.05 %
ASH: 10.11 %
HEAT: 21.99 MBTU/STON

CONTROL EQUIPMENT
****

PRIMARY CONTROLS	*SECONDARY CONTROLS*	*EFFICIENCIES*
PART: ELECTROSTATIC PRECIPITATOR-HIGH EFFICIENCY	PART: NO EQUIPMENT	98.0 %
SOX: NO EQUIPMENT	SOX: NO EQUIPMENT	.0 %
NOX: NO EQUIPMENT	NOX: NO EQUIPMENT	.0 %
HC: NO EQUIPMENT	HC: NO EQUIPMENT	.0 %
CO: NO EQUIPMENT	CO: NO EQUIPMENT	.0 %

* * * * EMISSIONS IN LBS * * * *

DATE	HOUR	PART	SOX	NOX	HC	CO
10/ 1/74	0	497.92	21954.44	5682.77	56.83	189.43
10/ 1/74	1	505.42	22284.94	5768.32	57.68	192.28
10/ 1/74	2	540.76	23843.00	6171.61	61.72	205.72
10/ 1/74	3	478.65	21104.60	5462.79	54.63	182.09
10/ 1/74	4	475.44	20962.95	5426.13	54.26	180.87
10/ 1/74	5	476.51	21010.17	5438.35	54.38	181.28
10/ 1/74	6	522.55	23040.36	5963.86	59.64	198.80
10/ 1/74	8	542.90	23937.43	6196.06	61.96	206.54
10/ 1/74	9	482.93	21293.45	5511.68	55.12	183.72
10/ 1/74	10	447.60	19735.39	5108.38	51.08	170.28
10/ 1/74	11	452.95	19971.46	5169.49	51.69	172.32
10/ 1/74	12	455.09	20065.89	5193.93	51.94	173.13
10/ 1/74	13	458.30	20207.53	5230.60	52.31	174.35
10/ 1/74	14	458.30	20207.53	5230.60	52.31	174.35
10/ 1/74	15	454.02	20018.68	5181.71	51.82	172.72
10/ 1/74	16	528.98	23323.65	6037.18	60.37	201.24
10/ 1/74	17	531.12	23418.07	6061.62	60.62	202.05
10/ 1/74	18	533.26	23512.50	6086.07	60.86	202.87
10/ 1/74	19	534.33	23559.72	6098.29	60.98	203.28
10/ 1/74	20	538.62	23748.57	6147.17	61.47	204.91
10/ 1/74	21	537.54	23701.36	6134.95	61.35	204.50
10/ 1/74	22	534.33	23559.72	6098.29	60.98	203.28
10/ 1/74	23	493.64	21765.59	5633.89	56.34	187.80

FIGURE 2 - POINT SOURCE LISTING

4.0 EMISSION FACTOR VERIFICATION STUDIES

4.1 INTRODUCTION

Emission estimates are based on consumption or production figures from which emissions are calculated using an emission factor. Emission factors are averaged numbers relating emissions to consumption or process data. In some cases, the relationship is direct and relatively uncomplicated. For example, for every ton of bituminous coal burned, a total of 38$\underline{S}$ pounds of sulfur dioxide is produced, where $\underline{S}$ indicates the sulfur content of the fuel, on a weight percent basis. Thus, if a plant burns 100 tons of 3% sulfur coal per hour, it emits

$$100 \times 38 \times 3 = 11{,}400$$

11,400 lbs of SO_2 per hour. Since in this particular case the sulfur is contained in the fuel and is converted virtually completely to SO_2, the numbers resulting from the use of the emission factor are quite accurate and reliable.

If, on the other hand, we wish to determine the amount of oxides of nitrogen produced by the same operation, a somewhat different situation ensues. The emission factor for a boiler burning bituminous coal, as given in the EPA publication AP-42 "Compilation of Air Pollution Emission Factors", varies with both boiler type and size, from 6 to 55 lbs. of NO_x per ton of coal. This is because the factors affecting NO_x production include flame and furnace temperature, residence time of the combustion gases, rate of cooling, amount of excess air, as well as the amount of nitrogenous compounds in the fuel. Thus, the emission factor of 18, which is applicable to a pulverized coal boiler of this size, is an averaged value. Actual values may depart significantly from the numbers obtained by such a factor.

In order to improve the accuracy of the emission inventory gathered at St. Louis, a number of representative sources were sampled and their stack effluents analyzed. An attempt was made to encompass a wide variety of the larger point sources: large and medium sized power plants burning coal, fuel oil and gas; industrial boilers of different types and sizes; and industrial

operations, such as catalyst recovery units in a petroleum refinery, known or suspected of being major sources of pollution.

The program is an ongoing one; during 1975, the following sources were sampled:

Illinois Power's Wood River Power Plant

- Boiler No. 1, operated on gas
- Boiler No. 1, operated on fuel oil
- Boiler No. 4, operated on coal

Highland Power Plant, Highland, Illinois

- Boiler No. 3, operated on coal

Stag Brewery, Belleville, Illinois

- Boiler No. 1, operated on coal

General Motors Power Plant, St. Louis

- Boiler No. 2, operated on coal

Amoco Refinery, Hartford, Illinois

- Boiler No. 6, operated on oil and gas
- Catalyst Regeneration Unit

Complete stack sampling reports are attached as Appendix II.

4.2 DISCUSSION: METHODS AND RESULTS

In general, the test methods specified in the Appendix of Part 60, CFR Title 40, "Standards of Performance for New Stationary Sources" were used. The methods include:

Method 1 - Sample and Velocity Traverses
2 - Determination of Stack Gas Velocity
3 - Gas Analysis for CO_2, Excess Air and Dry Molecular Weight
4 - Determination of Moisture in Stack Gases
5 - Determination of Particulate Emissions
6 - Determination of SO_2 Emissions
7 - Determination of Nitrogen Oxide Emissions

The only deviation from these methods was the use of a higher probe and oven temperature in Method 5. A temperature of 325^{O} was used instead of 250^{O}F to avoid any problems with condensation of sulfuric acid.

Serious problems were encountered with stack gas velocity measurements using Method 2. Using mass balance methods as a check, it became apparent that the values obtained with an S-type pitot tube, used in accordance with Method 2, were too high by varying, but substantial amounts. Reproducibility was adequate, and repeated calibration of the pitot tube indicated that correct readings were obtained. A careful check of the literature indicated that high readings had been observed by other investigators. Burton (1) indicated that values of 104 to 150% of the rated value can be obtained. Grove (2) presented data indicating that a) significant errors are always positive and b) they can be very large. The most common source of errors is due to cyclonic flow, unfortunately a fairly common occurrence in power plant stacks, where "double entry" stacks (two boilers feeding one stack) are frequently used.

TABLE 1

COMPARISON OF MEASURED* and CALCULATED** FLOWS

Location	Flow, SCFH		% Δ
	Measured	Calculated	
Wood River #1	10,086,750	8,237,263	+22.5
Wood River #4	17,981,280	13,089,200	+37.4
Highland Power	1,386,070	910,920	+52.2
Stag Brewery	1,394,990	782,900	+78.2
Monsanto	1,687,655	1,563,000	+ 8.0
General Motors	1,598,005	1,434,847	+11.4
Amoco	2,543,040	-	-

* Using S-type Pitot tube, EPA Method 2
** Based on stoichiometry and excess air.

(1) Burton, C.S., Quantitation of Stack Gas Flow, Jnl., APCA 22, pp. 631-635 (1972).

(2) Grove, D.J. and Smith, W.S., Pitot Tube Errors due to Misalignment and Non-streamlined Flow, Stack Sampling News, 1974.

One way of ascertaining the correctness of the data is by comparing the mass flow of SO_2 calculated from fuel consumption and sulfur analysis of the fuel, on one hand, with the value obtained from stack gas flow and analysis, on the other. The former is calculated according to Eq. 1

$$W_{SO_2} = W_c \times 38 \times S \quad , \qquad (1)$$

where

W_{SO_2} - weight of SO_2 produced, lbs/hr

W_c - weight of coal consumed, Tons/hr

S - % sulfur in coal, dry basis

This value should be equal to one obtained from EQ. 2

$$W_{SO_2} = C_{SO_2} \times Q_S \quad , \qquad (2)$$

where

C_{SO_2} - Concentration of SO_2 in stack gas, lbs./SCF

Q_S - Stack gas flow rate, SCF/hr

For example, the flow rate for Boiler #4 at Wood River was calculated thusly:

Composition of Coal		Boiler #4 Lb-mols/100 lbs Coal		Oxygen Required For Combustion, mols
C	61.43%	5.12	(1)	5.12
H_2	4.38	(2.19)	(2)	(1.09)
S	3.21	0.10	(3)	0.10
O_2	9.67	0.30		-.30
N_2	1.11	0.04	(4)	-
H_2O (moisture)	11.82	(0.66)	(2)	-
Ash	8.55			
Chlorides	0.02			
	100.19			6.01 mols oxygen
			Average Excess Air: 40%	2.40
			Total	8.41
			Corresponding Nitrogen	31.77

Assumed reactions:

(1) $C + O_2 \rightarrow CO_2$

(2) Excluded from calculation for dry flue gas

(3) $S + O_2 \rightarrow SO_2$

(4) Oxidation reaction uncertain

Dry flue gases per 100 lbs coal, lb-mols:

CO_2	5.12	
SO_2	0.10	lb-mol x 386 = SCF
O_2	2.40	
N_2	0.04	
Air Nitrogen	31.77	
Total	39.43	= 15,220 SCF/100#
@ 43 tons coal/hour		= 13,089,200 SCF#

A comparison of results is shown in Table 2. As can be seen from Table 2, the values obtained using flow rates based on mass balance show a much better agreement with values obtained from emission factors, than those based on pitot measurements.

TABLE 2

COMPARISON OF SO_2 EMISSIONS BASED ON

CALCULATED AND MEASURED FLOWRATES

Location	W_{SO_2} - Weight of SO_2 Produced, Based on		
	Emission Factor	Calc. Gas Flow	Measured Gas Flow
Wood River #1 (oil)	153 lbs/hr	178 lbs/hr	217 lbs/hr
Wood River #4	5245	5104	7035
Highland Power	414	433	658
Stag Brewery	75	82	125
General Motors	479	472	546
Amoco (boiler)	309	-	320
(catalytic cracker)	708	-	354

For this reason, calculated flow rates were used whenever there was an indication of non-linear flow in the stack, as indicated by the fact that turning the pitot tube 90^0 on axis did not give a zero reading on the manometer.

Using the most reliable available results, experimental emission factors were calculated for SO_2, NO_X and particulates for the sources tested so far. These emission factors are compared with "standard" emission factors, taken from AP-42, in Table 3. Calculations are shown in Appendix I.

TABLE 3

COMPARISON OF "STANDARD" AND EXPERIMENTAL EMISSION FACTORS

Location	Standard Emission Factors					Experimental Emission Factors				
	SO_2*	NO_x	Part**	CO	HC	SO_2*	NO_x	Part**	CO	HC
Wood River #1 (gas fired)(1)	-	600	10	17	1	-	105	-	2.8	-
#1 (oil fired)(2)	144S	105	8	3	2	168S	16	1.0	.4	.17
#4 (coal fired)(3)	38S	18	17A	1	0.3	37S	1.4	10.0A		.02
Highland Power (coal fired)(3)	38S	15	5A	2	1	40S	4.1	.4A		
Stag Brewery (coal fired)(3)	38S	15	5A	2	1	41S	7.2	1.9A	.3	.14
General Motor (coal fired)(3)	38S	15	13A	2	1	37S	10.8	23.6	.7	.03
Amoco(2) Boiler #6	160S	69	20	1	.3	-	-	-	-	-
Cat. Cracker Recovery(4)	493	71	242	-	220	246	153	360	-	.48

*S - percentage sulfur in fuel

**A - percentage ash in fuel; emissions before control equipment

(1) - lbs per 10^6 cu. ft.

(2) - lbs. per 10^3 gal. Both process gas and fuel oil were burned simultaneously.

(3) - lbs. per ton of coal

(4) - lbs. 10^3 bbl fresh feed.
Unit equipped with electric precipitator and CO boiler -

Even though relatively few source tests have been run so far, certain conclusions can be drawn from the results obtained:

1. Determinations of stack gas volumes according to EPA Method 2 is uncertain. Incorrect results are obtained in a high number of cases, since the basic assumption of laminar flow, parallel to the walls of the stack does not pertain in many cases.

2. Engineering calculations of mass flow, based on ultimate analysis of the fuel and determinations of the excess air in the stack gases, give reasonably accurate results. This is borne out by sulfur balance calculations. For example, the average experimental emission factors for SO_2 for coal burning installations comes out to 38.75S compared with 38S suggested in AP-42.

3. The emission factors shown in Table 3 are applicable to the specific installations for which they were obtained. However, definite patterns appear to exist, which seem to have more general validity:

   a) Emission factors for NO_x for combustion sources appear to be too high by a variable, but substantial margin. The experimentally obtained factors range from a low of 7.7% to 72% of the applicable AP-42 factors.

   b) Experimental emission factors for particulates similarly vary from 8 to 58% of the applicable AP-42 factors for installations which do not have precipitators. In the presence of the latter, their assumed efficiency becomes an overriding factor.

   c) Hydrocarbon and CO emissions, which are rather insignificant for combustion sources, likewise run less than suggested by AP-42 factors.

5.0 CONCLUSIONS

The RAPS Point Source Emission Inventory has produced an extensive and accurate data base with an hourly resolution for the base year of 1975, with a temporal resolution of 1 hour for the important point sources in the AQCR-70.

The emission factor verification program, though somewhat limited in scope, indicates that good accuracy can be expected from the SO_2 inventory. Estimates for oxides of nitrogen and particulates appear to be on the high side and may have to be adjusted by changes in the emission factors.

The continuation of the program for another year will do much in improving the definition of the data obtained so far.

APPENDIX I
EMISSION FACTOR CALCULATIONS

EMISSION FACTOR CALCULATIONS

WOOD RIVER #1 - GAS FIRED

Burn Rate: 580×10^3 SCF/hr Sulfur: - Ash: - Flow Rate: 8,237,280 SCFH

NO_X expected $.580 \times 600 = 348$ lbs/hr

found: 7.4×10^6 lbs/SCF (average)

$7.4 \times 10^6 \times 8{,}237{,}280 = 60.9$ lbs.

Experimental EMFAC: $600 \times \frac{60.9}{348} = 105$

CO expected: $.580 \times 17 = 9.9$ lbs/hr

found: 2.5 ppm

$2.5 \times 10^6 \times 8{,}237{,}280 \times 28.3 \times \frac{28}{22.4} \times 2.205 \times 10^3 = 1.6$ lb/hr

Experimental EMFAC: $17 \times \frac{1.6}{9.9} = 2.76$

WOOD RIVER #1 - OIL FIRED

Burn Rate: 3.66×10^3 gal/hr Sulfur: .29% Ash: - Flow Rate: 8,237,263 SCFH

SO_2 expected: $3.66 \times 144 \times .29 = 152.8$ lbs/hr

found: 178.0 lbs/hr

Experimental EMFAC: $144 \times \frac{178}{152.8} = 167.7$

NO_X expected: $3.66 \times 105 = 384.3$ lbs/hr

found: $7.1 \times 10^6 \times 8{,}237{,}263 = 58.5$ lbs/hr

Experimental EMFAC: $105 \times \frac{58.5}{384.3} = 16.0$

EMISSION FACTOR CALCULATIONS

CO expected: $3.66 \times 3 = 11.0$ lbs/hr

found: $2.5 \times 10^{-6} \times 8{,}237{,}263 \times \frac{28.3}{22.4} \times \frac{28}{454} = .635 = 1.6$ lbs/hr

Experimental EMFAC: $3 \times \frac{1.6}{11.0} = .44$

PARTICULATE expected: $3.66 \times 8 = 29.3$ lbs/hr

found: $4.55 \times 10^{7} \times 8{,}237{,}263 = 3.7$ lbs/hr

Experimental EMFAC: $8 \times \frac{3.7}{29.3} = 1.0$

HC expected: $3.66 \times 2 = 7.3$ lbs/hr

found: 1.7 ppm

$1.7 \times 10^{-6} \times 8{,}237{,}263 \times \frac{28.3}{22.4} \times \frac{16}{454} = .635$ lbs/hr

Experimental EMFAC: $2 \times \frac{.635}{7.3} = .17$

WOOD RIVER #4 - COAL FIRED

Burn Rate: 43 T/hr Sulfur: 3.21% Ash: 10.95% Flow Rate: 13,089,200 SCFH

SO_2 expected: 5245 lbs/hr

found: 5104 lbs/hr

Experimental EMFAC: $38 \times \frac{5104}{5245} = 36.97$

NO_X expected: $18 \times 43 = 774$ lbs/hr

found: 4.46×10^{6} lb/SCF

$4.46 \times 10^{6} \times 13{,}089{,}200 = 58.37$ lbs/hr

Experimental EMFAC: $18 \times \frac{58.4}{774} = 1.36$

EMISSION FACTOR CALCULATIONS

Particulates: expected: $43 \times 17 \times 10.95 = 8004$ lbs/hr

Less: Precipitator at 99.5% off = 7964

40 lbs/hr

found: 23.45 lbs/hr

Experimental EMFAC: $17 \times \frac{23.5}{40} = 9.96$

HC expected: $43 \times .3 = 12.9$ lbs/hr

found: 1.3 ppm

$1.3 \times 10^6 \times 13{,}089{,}200 \times \frac{28.3}{22.4} \times \frac{16}{454} = .76$ lbs/hr

Experimental EMFAC: $.3 \times \frac{.76}{12.9} = 0.018$

HIGHLAND POWER COMPANY

Burn Rate: 6702 lbs/hr 3.25% Sulfur 10.98% Ash Flow Rate: 910,920

SO_2: expected: 414 lbs/hr

found: 433 lbs/hr

Experimental EMFAC: $38 \times \frac{433}{414} = 39.7$

NO_X: expected: $\frac{6702}{2000} \times 15 = 50.26$ lbs/hr

found: $1.5 \times 10^5 \times 910{,}920 = 13.66$ lbs/hr

Experimental EMFAC: $15 \times \frac{13.7}{50.3} = 4.1$

Particulates: expected $\frac{6702}{2000} \times 5 \times 1.95 = 183.5$ lbs/hr

found: $1.76 \times 10^5 \times 910{,}920 = 16$ lbs/hr

Experimental EMFAC: $5 \times \frac{16}{183.5} = 0.44$

EMISSION FACTOR CALCULATIONS

STAG BREWERY

Burn Rate: 3604 lbs/hour Sulfur: 3.25% Ash 10.98% Flow Rate: 782900 SCFM

SO_2 expected: 74.9 81.4 lbs/hr
founded: 79.0 91.1 lbs/hr

Experimental EMFAC: $38 \times \frac{79}{749} = 40.1$ $38 \times \frac{91.1}{81.4} = 42.5$

NO_X expected: $\frac{3604}{2000} \times 15 = 27.0$ lbs/hr
found: 1.65×10^5 lbs/SCF
$1.65 \times 10^5 \times 782{,}900 = 12.9$ lbs/hr

Experimental EMFAC: $15 \times \frac{12.9}{27} = 7.16$

Particulates expected: $\frac{3604}{2000} \times 5 \times 10.98 = 98.9$ lbs/hr
found: 37 lbs/hr

Experimental EMFAC: $5 \times \frac{37}{98.9} = 1.87$

Hydrocarbons: expected: $\frac{3604}{2000} \times 1 = 1.8$ lbs/hr
found: 7 ppm
$782{,}900 \times 7 \times 10^6 \times \frac{28.3}{22.4} \times \frac{16}{454} = .24$ lbs/hr

Experimental EMFAC: $1 \times \frac{.24}{1.8} = .14$

CO expected: $1.802 \times 2 = 3.6$ lbs/hr
found: 8.9 ppm = .54 lbs/hr

Experimental EMFAC: $2 \times \frac{.54}{3.6} = .30$

EMISSION FACTOR CALCULATIONS

GENERAL MOTORS

SO_2 expected: 479 lbs/hr

found: 472 lbs/hr

Experimental EMFAC: $38 \times \frac{472}{479} = 37.4$

NO_X expected: $\frac{7491}{2000} \times 15 = 56.2$ lbs/hr

found: $2.81 \times 10^5 \times 1{,}434{,}847 = 40.3$ lbs/hr

Experimental EMFAC: $15 \times \frac{40.3}{56.2} = 10.8$

Particulates expected: $\frac{7491}{2000} \times 13 \times 10.9 = 531$ lbs/hr

less: Precipitation at 98% $\frac{520}{11}$ lbs/hr

found: $1.396 \times 10^5 \times 1{,}434{,}847 = 20.0$ lbs/hr

Experimental EMFAC: $13 \times \frac{20}{11} = 23.6$

CO expected: $\frac{7491}{2000} \times 2 = 7.5$ lbs/hr

found: $1{,}434{,}847 \times 25 \times 10^6 \times \frac{28.3}{22.4} \times \frac{28}{454} = 2.8$ lbs/hr

Experimental EMFAC: $2 \times \frac{2.8}{7.5} = .74$

HC expected: $\frac{7491}{2000} \times 1 = 3.8$ lbs/hr

found: $1{,}434{,}847 \times 1.8 \times 10^6 \times \frac{28.3}{22.4} \times \frac{16}{454} = .11$ lbs/hr

Experimental EMFAC: $1 \times \frac{.11}{3.8} = .03$

EMISSION FACTOR CALCULATIONS

AMOCO - BOILER #6

Burn Rate: 64,063 SCF/W Refinery Gas 308 gal/hr Fuel Oil Sulfur 3.5%
Flow Rate: 21,453,040 1.4%

SO_2 expected: $64.063 \times 3.5 \times 1.069^{*} = 239.7$ *Spec. Emission Factor
$.308 \times 1.4 \times 160 = \frac{68.9}{308.6}$

found: $1.26 \times 10^{4} \times 2{,}543{,}040 = 320.2$ lbs/hr

AMOCO - CATALYTIC CRACKER RECOVERY

Feed Rate: 34,485 bbl/day fresh feed Flow Rate: 5,160,271

SO_2 expected: $34.485 \times 493 \times \frac{1}{24} =$ 708 lbs/hr

found: $5{,}160{,}271 \times 6.853 \times 10^{5} = 353.6$ lbs/hr

Experimental EMFAC: $493 \times \frac{354}{708} = 246.3$

NO_x expected: $34.485 \times 71 \times \frac{1}{24} = 102.0$ lbs/hr

found: $4.26 \times 10^{5} \times 5{,}160{,}271 = 219.8$ lbs/hr

Experimental EMFAC: $71 \times \frac{220}{102} = 153$

Particulates expected: $34{,}485 \times 242 \times \frac{1}{24} = 347.7$ lbs/hr

less precipitator at 94% $\frac{327.9}{19.8}$

found: 29.5 lbs/hr

Experimental EMFAC: $242 \times \frac{29.5}{19.8} = 360$

HC expected: $34.485 \times 220 \times \frac{1}{24} = 316.1$ lbs/hr

found: $5{,}160{,}271 \times 3 \times \frac{28.3}{22.4} \times \frac{16}{454} = .69$ lbs/hr

Experimental EMFAC: $220 \times \frac{.69}{316.1} = .48$

APPENDIX II

SOURCE TEST REPORTS

SOURCE TEST REPORT

ILLINOIS POWER COMPANY

WOOD RIVER PLANT

ALTON, ILLINOIS

BOILERS NO. 1 AND 4

JUNE, 1975

Tested by: Rockwell International

R.W. Griscom
O.C. Klein
F.E. Littman
W.G. Norris
R.G. Ducker

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TABLES

FIGURES

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boilers No. 1 and 4 at the Wood River Plant of the Illinois Power Company.

The stack testing included the following pollutants: SO_2, particulates, NO_x, H_2SO_4, and hydrocarbons. Orsat analysis for CO_2, CO, and O_2 were also performed. Detailed results are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the emissions were well within limits, with the exception of SO_2 emissions from the coal fired boiler No. 4.

We acknowledge and appreciate the excellent cooperation we obtained from both local and home office representatives of Illinois Power Co.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Illinois Power Co.-Wood River Plant in Alton, Illinois. Testing was performed on boiler No. 1 during natural gas and oil firings and on boiler No. 4 during coal firing. The test on boiler No. 1 was during the week of 16 June 1975 and the test on boiler No. 4 was during the week of 23 June.

Boiler No. 1 is a gas and/or oil fired, 450,000 pounds per hour steam generating unit. There are no stack emission controls on boiler No. 1. Boiler No. 4 is a pulverized coal fired, 713,000 pounds per hour steam generating unit. There are mechanical and electrostatic precipitators on boiler No. 4.

Both units were sampled for total particulates, nitrogen oxides, hydrocarbons, sulfur dioxide, sulfuric acid mist, carbon dioxide and oxygen. Boiler No. 4 was also sampled for particle size distribution.

3.0 PROCESS DESCRIPTION

Boiler No. 1 was built by Combustion Engineering and installed in 1949. It was originally operated as a pulverized coal fired unit but was converted to gas and/or oil fired. The unit is rated at 450,000 lbs per hour steam at 1325 psi and 1010^{o}F. Boiler No. 1 is a forced draft unit and it has no stack emission controls. This boiler is illustrated in Figure 1. Boilers 1, 2 and 3 are similar units and are served by a common stack. The stack is of brick construction, 250 ft tall and 15.5 ft inside diameter at the top.

Boiler No. 4 was built by Combustion Engineering and installed in 1954. It is a pulverized, coal-fired steam generating unit. The unit is rated at 713,510 lbs per hour at 1500 psi and 1005^{o}F. The boiler is an induced draft type and it is equipped with centrifugal and electrostatic precipitators, rated at 99.5% collection efficiency. This boiler is illustrated in Figure 2.

Boiler No. 4 is served by a brick stack, 250 ft tall and, 17 ft inside diameter at the top.

There is a Monsanto CATOX, sulfur dioxide scrubber installed on unit No. 4 adjacent to the electrostatic precipitator. This unit is currently not in operation and should have no effect on this source test.

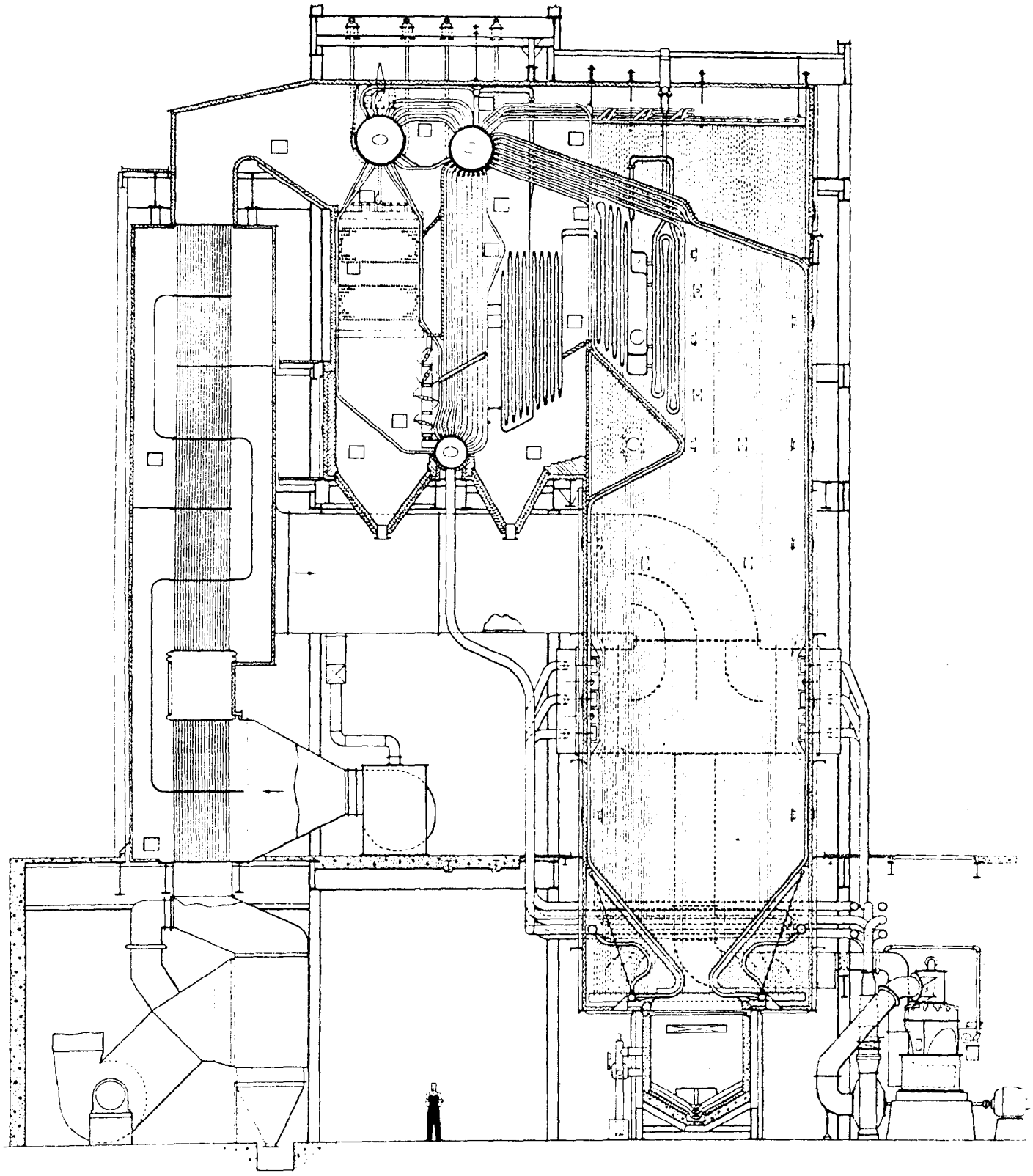

FIGURE 1 - BOILER NO. 1

C-E STEAM GENERATING UNIT

MAX. CONT. CAP. – 450,000 LB PER HR AT 1325 PSI AND 1010 F TOTAL TEMP.

WOOD RIVER POWER STATION

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Illinois Power Company, Wood River, Ill.

DESIGNED AND BUILT BY COMBUSTION ENGINEERING - SUPERHEATER, INC.

SARGENT & LUNDY, Consulting Engineers

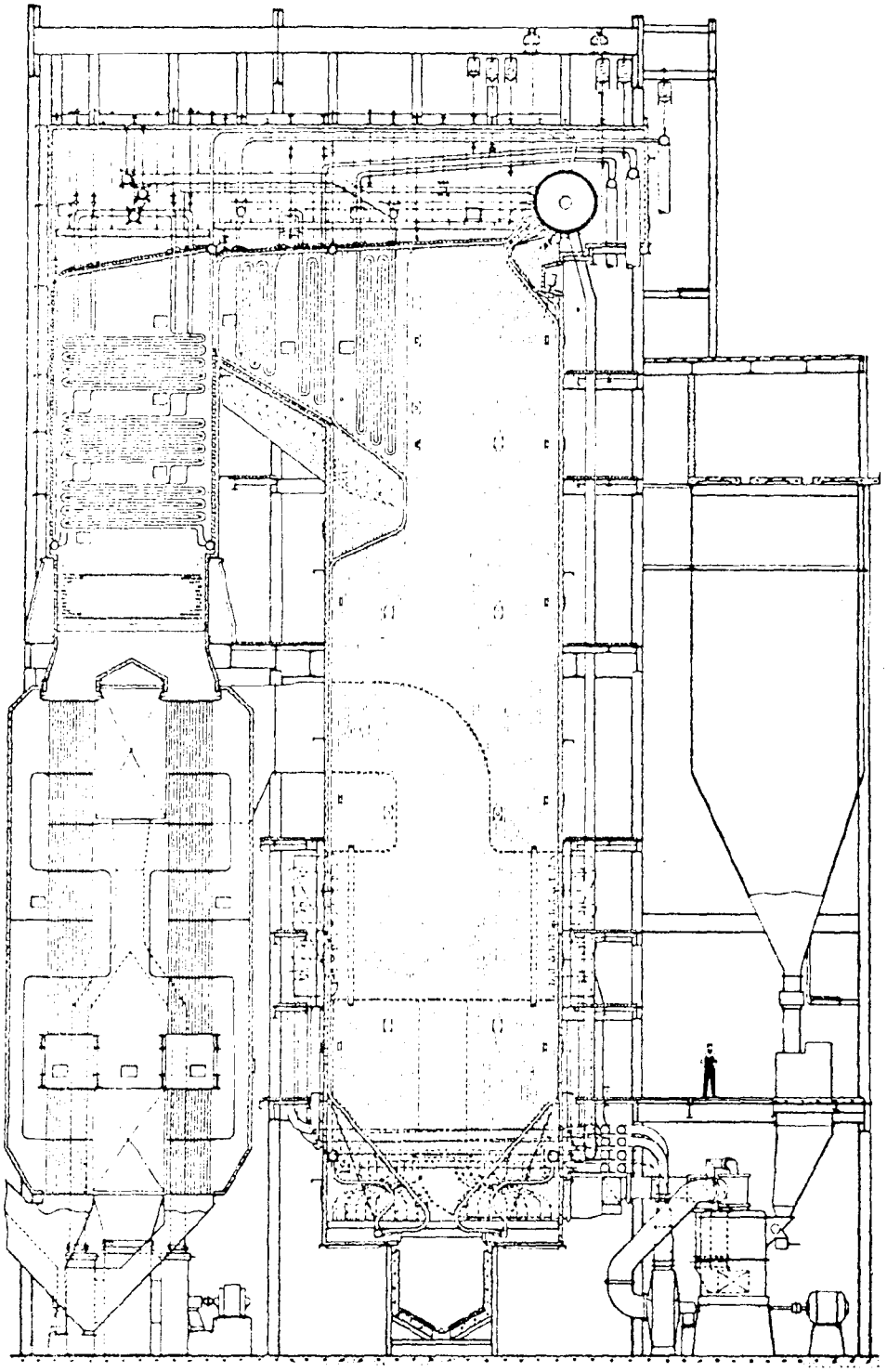


FIGURE 2 - BOILER NO. 4

C-E REHEAT STEAM GENERATOR

CAPACITY — 713,510 LB PER HR AT 1500 PSI AND 1005 F TOTAL TEMP. REHEAT TO 1005 F

WOOD RIVER POWER STATION

Illinois Power Company, Wood River, Ill.

Designed and Built by COMBUSTION ENGINEERING - SUPERHEATER, INC.

SARGENT & LUNDY, Consulting Engineers

4.0 SOURCE TEST DESCRIPTION

Boiler No. 1 was tested in the duct work, just ahead of where the duct combines with flow from Boiler No. 2 (see Figure 3 below).

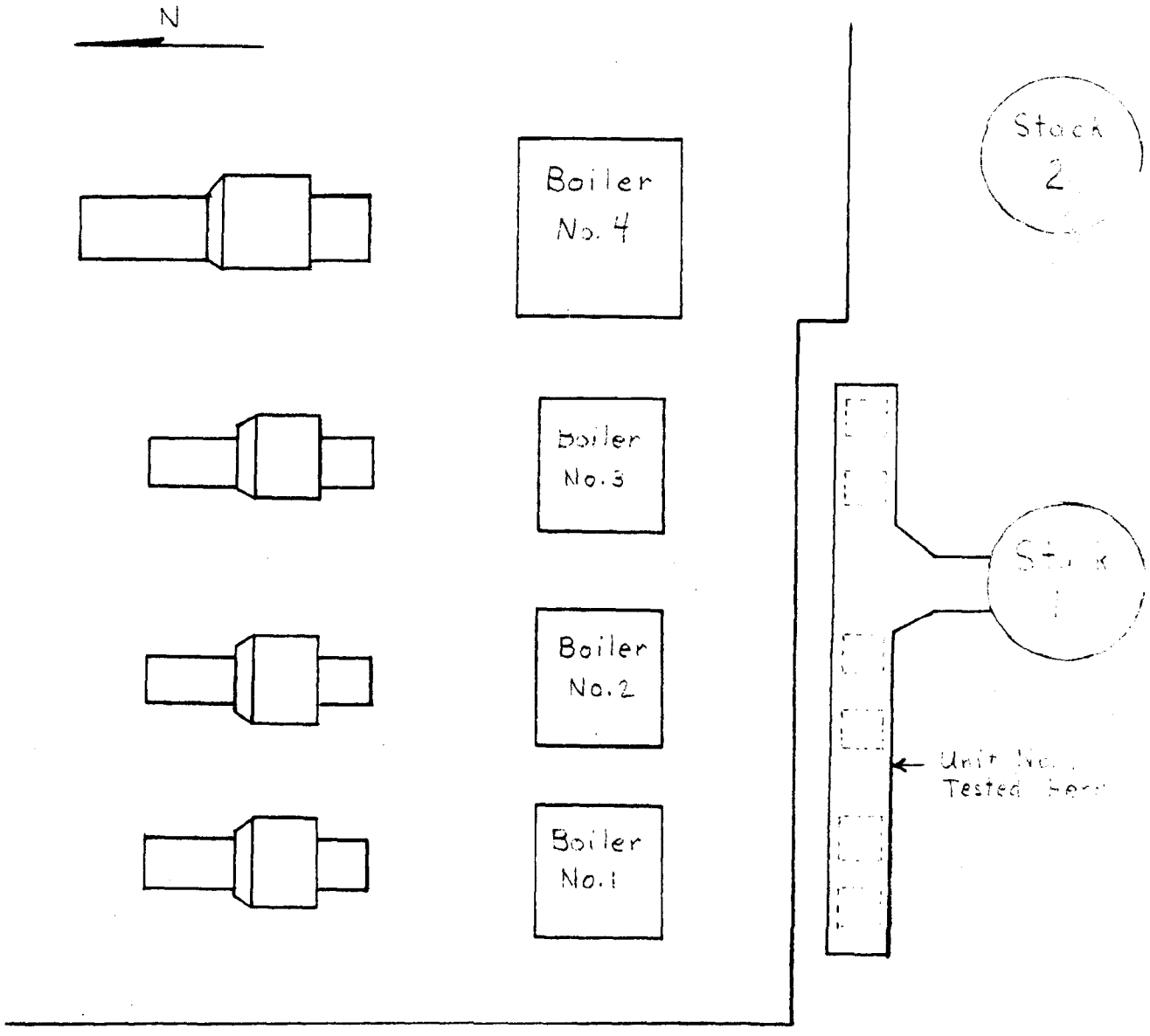


FIGURE 3 - WOOD RIVER PLANT, PLOT PLAN

At this sampling point the duct is 7'1" x 11'6 5/8" inside dimensions. To obtain forty-two sampling points, eight, 3 inch sampling ports were welded in place, approximately 17 1/2 inches apart vertically and six points were sampled at each port. This sampling point is only 1-2 duct diameters from the nearest induced draft fan outlet and is therefore not an ideal spot for sampling, but it is the best available location for testing this boiler without going to the large expense of constructing a sampling platform on the stack.

As it turned out, the bottom sampling port was at the same level as the build-up of particulates in the duct. The inside duct dimensions are then revised for this point to 7'1" x 10'8 5/8".

Figures 4 and 5 illustrate the sampling location and arrangement for this test.

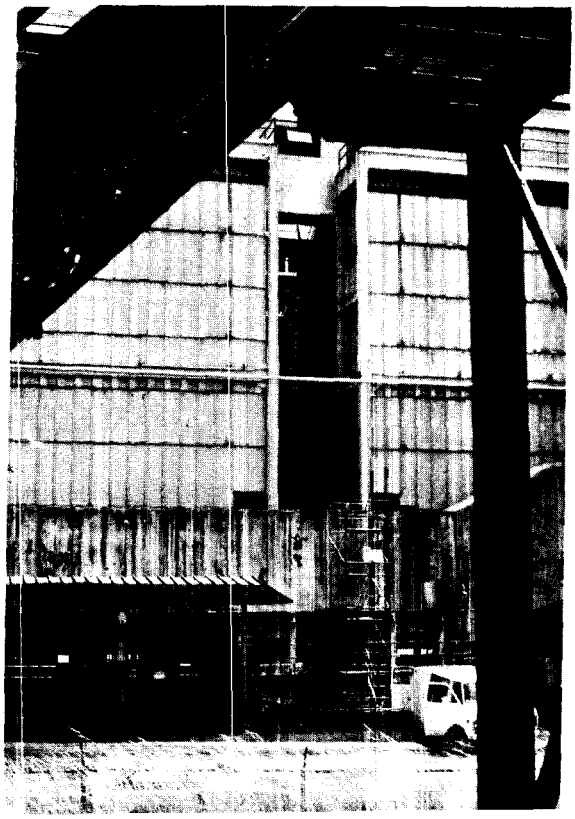


FIGURE 4

FIGURE 5

The test on boiler No. 4 was performed on a platform on the stack at roof top level, approximately 140 feet above ground level. This platform was installed for the testing of this unit in conjunction with the evaluation of the CATOX scrubbing system. There is a ramp connecting this platform to the roof of the power plant building.

At this level there are four 6 inch ports installed at 90 degrees around the stack. At each of these points on the platform, there are extensions to the platform to allow for a good working area and for set-up and supporting sampling equipment. An adapter was made to give us a 3 inch coupling to attach to for our supporting monorail.

At this location the stack diameter is 24.75 feet and it is approximately four diameters from the inlet to the stack. A full traverse of the stack was performed with eighteen sampling points on the traverse.

Figures 6 and 7 illustrate the sampling location and set-up for this test.

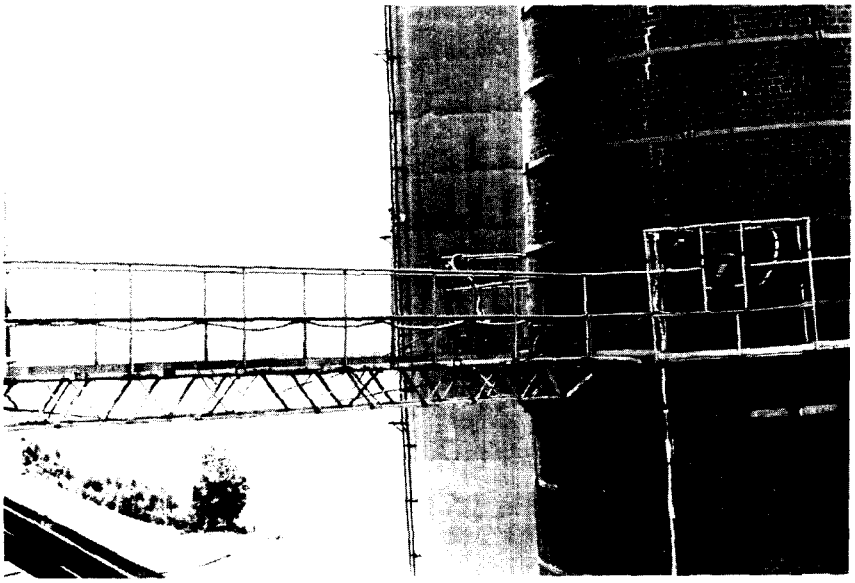


FIGURE 6

FIGURE 7

5.0 PROCESS OPERATION

Boiler No. 1 was tested 17 June to 20 June. On 17 and 18 June, the boiler was fired with natural gas only and on 19 June and 20 June the boiler was fired with distillate oil only. During testing periods on all four days the boiler was under constant load of 420,000 lbs per hour steam. There was only one short fluctuation for approximately 30 minutes on 19 June when some oil burners malfunctioned. Only one time was there any excessive emissions from stack No. 1 and this was due to an unbalanced fuel/air ratio in getting boiler No. 1 up to full load prior to our testing.

Boiler No. 4 was tested from 24 June to 27 June. During this entire sampling period the load on this boiler was maintained almost constant, with a generator output of 100 MW. There were no noticeable excessive emissions during this period. Ashes are blown from the boiler at approximately 10:30 AM and 3:00 PM. There was no visible change in emissions during these periods, although the actual amount of particulates apparently increased as shown by our particle size testing before and during this time period.

6.0 DISCUSSION

The EPA standard method 2, Volumetric Flow Rate Determination, has come under question as a result of this testing. On boiler No. 1 the flow rate as determined by method 2 is 168,113 SCFM compared to a flow rate determined stoichiometrically from the fuel rate and fuel composition of 137,288 SCFM. At the sampling point for boiler No. 1, method 2 was not applied precisely since only 42 points were used instead of perhaps 48 or 50 due to the bottom port being blocked, but by observing the values that were obtained it is unlikely that more sampling points would bring these two flow rates into agreement.

On boiler No. 4 the average flow rate determined by method 2 is 299,688 SCFM compared to an average flow rate of 218,497 SCFM determined stoichiometrically. At the sampling point for boiler No. 4 only one complete traverse was made per test instead of two on perpendicular diameters as described in method 2. Despite this, the values obtained corresponded with values obtained by other testers of this unit, so it is felt that this test is a valid measurement using method 2.

The flow rate determined stoichiometrically compares very well with the expected flow as seen by a comparison of sulfur dioxide emissions using both flow rates. Using the published emission factor of 38 S, which allows for a 95% conversion of sulfur in the coal to sulfur dioxide emission, the emissions should be 5245 lb/hr. With the flow rate using method 2 the emissions would be 6689 to 7318 lb/hr, which is definitely too great. With the stoichiometric flow rate the emissions would be 4877 to 5335 lb/hr, which is a reasonable result. For this reason the emissions determined using the stoichiometric flow rate are reasoned to be the correct results. For comparison the emissions are expressed using both flow rates.

On boiler No. 4 the coal scales were not functioning during the test period. The fuel firing rate of 43 tons per hour was determined by comparing the operating conditions with similar conditions on record as part of the ongoing emission inventory.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

7.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350^{O}F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 8.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train were determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

7.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacu-

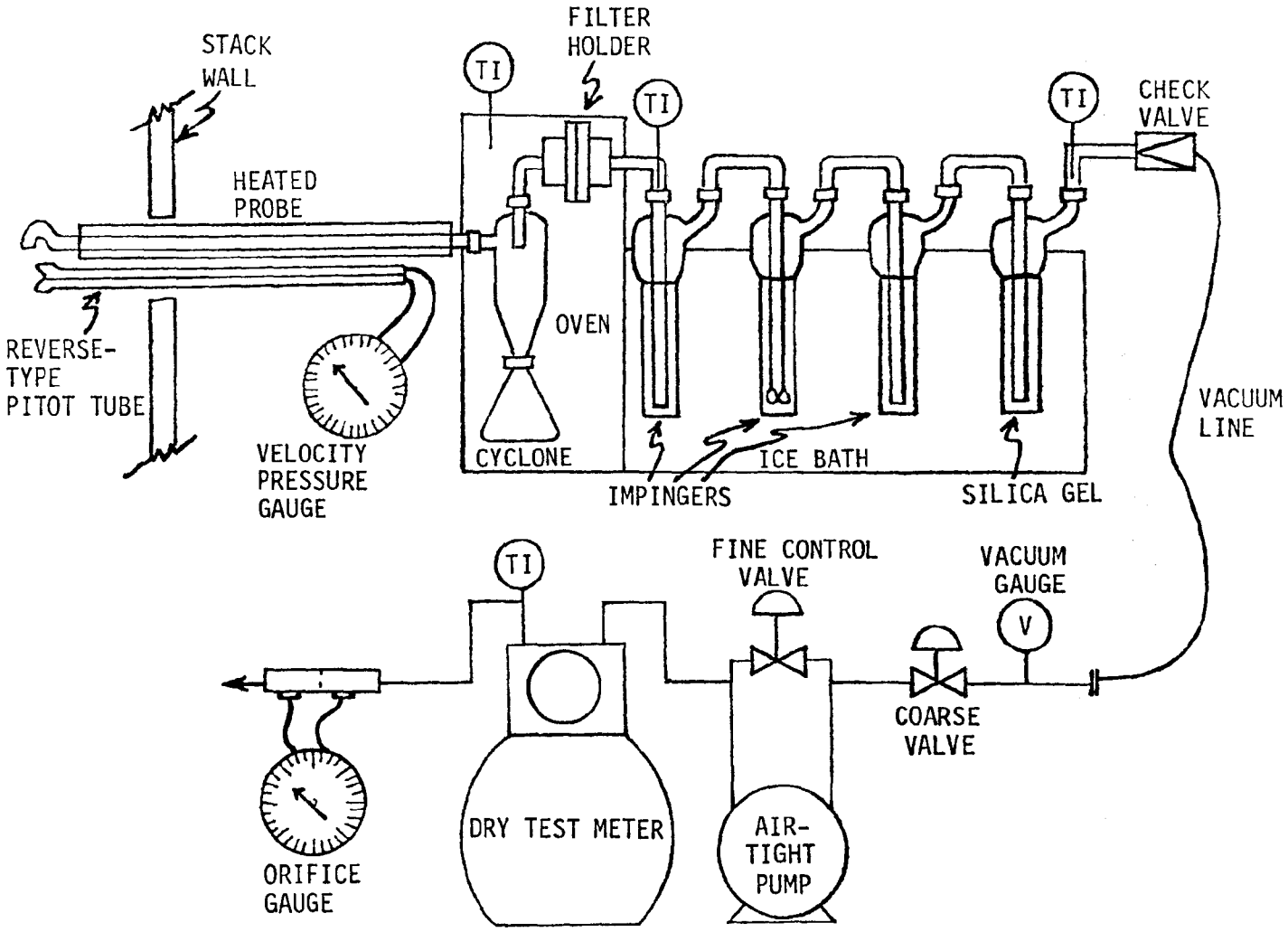


FIGURE 8

PARTICULATE SAMPLING TRAIN

ated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

7.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The "Shell Method"* was chosen for this determination due to uncertainties which exist about the validity of the results using method 8. A gas sample is drawn from the stack using a heated probe and passed through a water cooled, coil condenser maintained below the dew point of sulfuric acid at 140^{o}-194^{o}F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This set-up is shown in Figure 9.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

* Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases", Combustion, Jan. 1965.

Goksøyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases", J. Inst. Fuel, No. 35, 177, (1962).

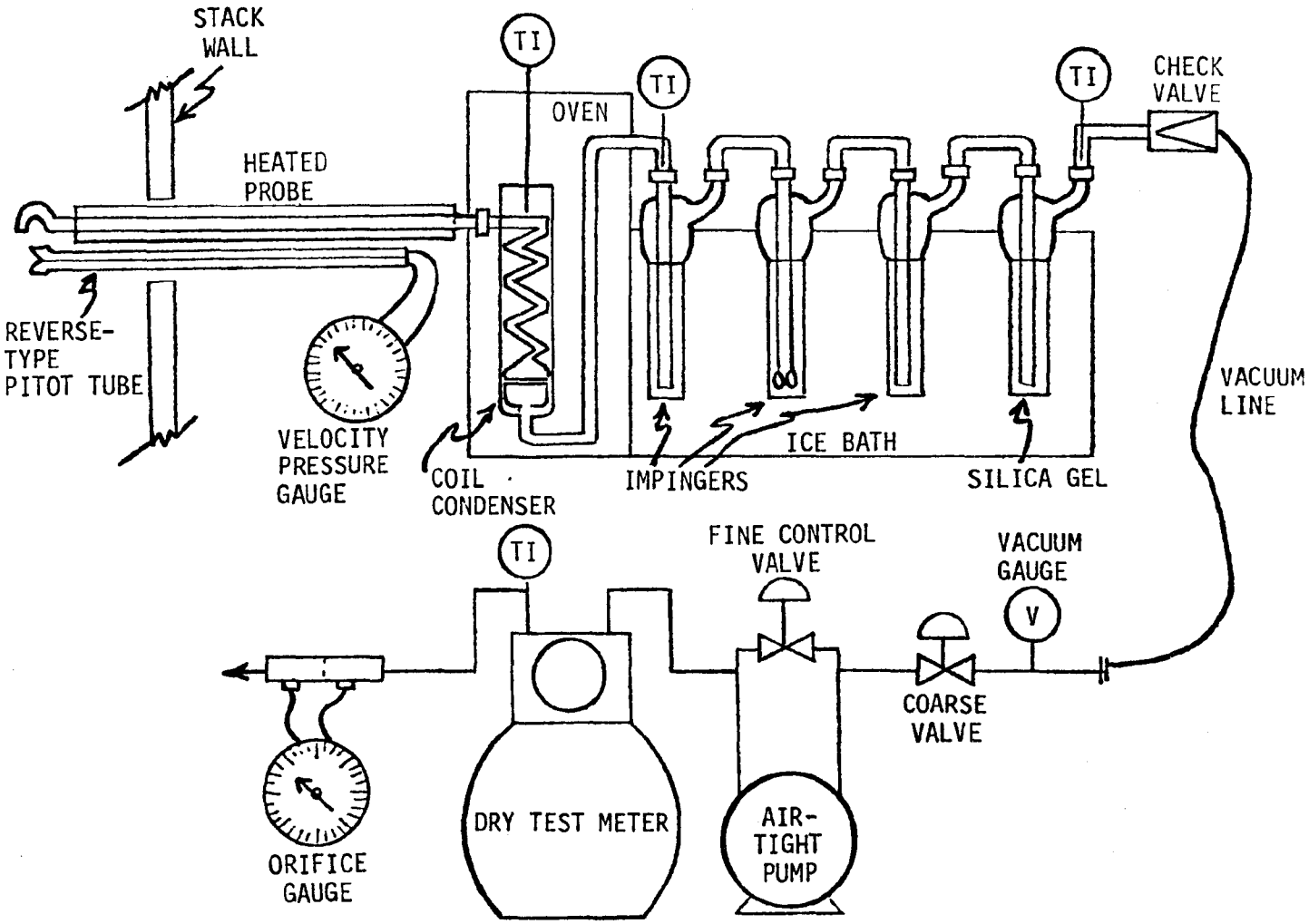


FIGURE 9

SULFURIC ACID MIST SAMPLING TRAIN

7.4 PARTICLE SIZE

An Andersen, fractionating, inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed either in the stack at the end of the sampling probe or in the oven after the heated sample probe. A sample of stack gas is drawn isokinetically through the sampler (see Figure 10). The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density.

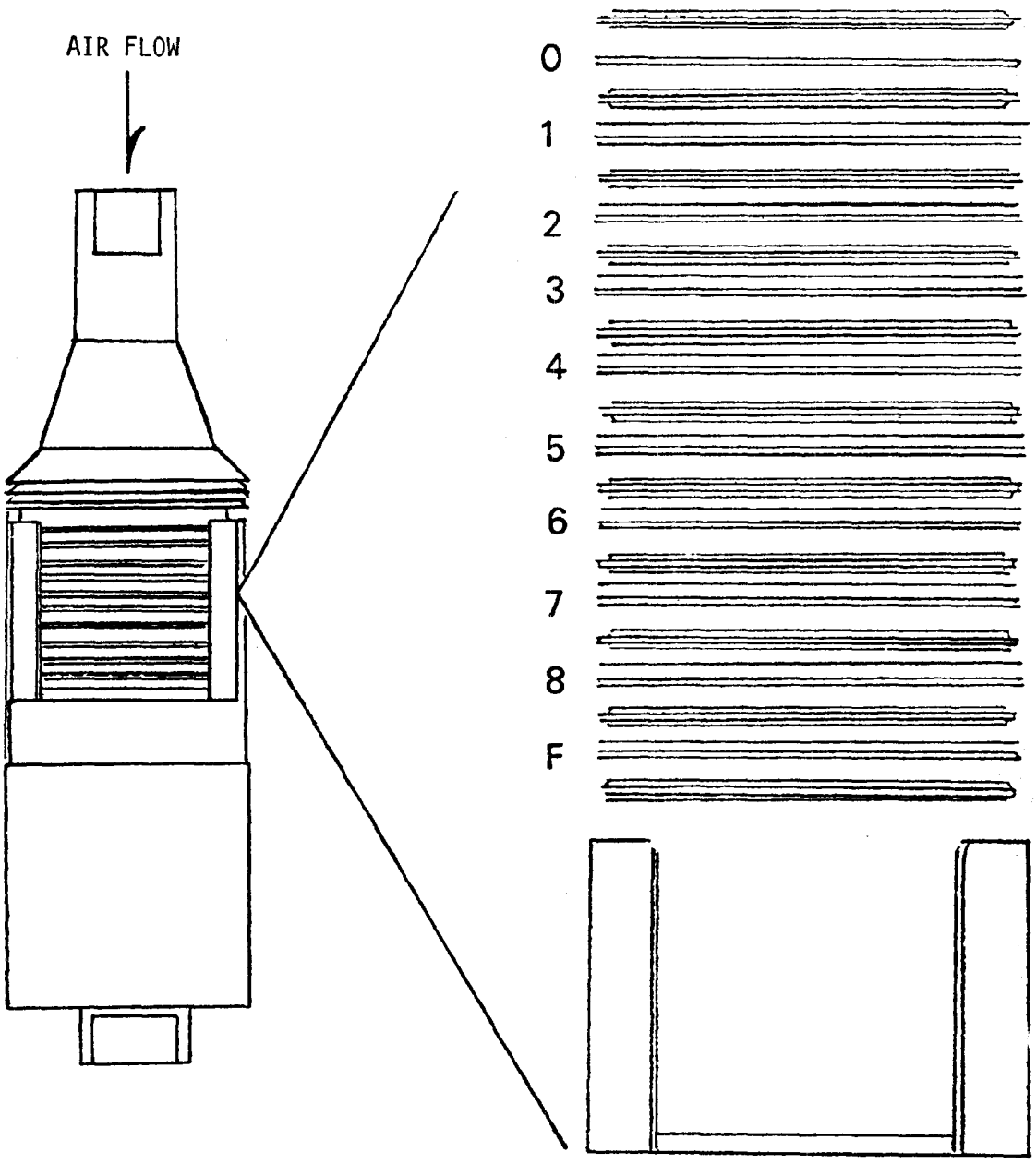


FIGURE 10

ANDERSEN STACK SAMPLER

8.0 RESULTS

The results obtained from these tests are summarized in Table 1 and 2. As discussed previously, the main flow of pollutant is based on calculated, rather than measured, flow rates. The actual calculations and field data are attached as Appendixes A and B. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used (except as indicated). It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 3.

TABLE 1
Boiler No. 1
SUMMARY OF RESULTS

Date	6/18	6/19	6/20		
Stack Flow Rate - SCFM * dry		137,288			
% Water Vapor - % Vol.		10.1			
% CO_2 - Vol % dry		10.3			
% O_2 - Vol % dry		8.9			
% Excess air @ sampling point		70.7			
SO_2 Emissions - lbs/10^6 Btu			0.35		
NO_x Emissions - lbs/10^6 Btu	0.08	0.12	0.10		
H_2SO_4 Mist - lbs/10^6 Btu			0.01		
Particulates Probe, Cyclone, & Filter Catch lbs./hr.		3.7			
lbs/10^6 Btu		0.007			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling		79.8			

*70^0 F, 29.92" Hg
Calculated flow, dry

TABLE 2
Boiler No. 4
SUMMARY OF RESULTS

Date	6/25	6/26	6/27		
Stack Flow Rate - SCFM * dry	218497	218,497	218,497		
% Water Vapor - % Vol.	8.25	8.16			
% CO_2 - Vol % dry	16.4	14.7	15.3		
% O_2 - Vol % dry	6.4	5.6	5.5		
% Excess air @ sampling point	45.3	35.9	35.3		
SO_2 Emissions - lbs/10^6 Btu		5.77	5.27		
NO_x Emissions - lbs/10^6 Btu	0.65	0.62			
H_2SO_4 Mist - lbs/10^6 Btu		0.05	0.05		
Particulates Probe, Cyclone, & Filter Catch lbs./hr.	29.8	17.1			
lbs/10^6 Btu	0.03	0.02			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	96.8	93.4			

*70^0 F, 29.92" Hg
Calculated Flow, dry

TABLE 3

COMPARISON OF RESULTS

Pollutant	Fuel	Standard lbs/10^6 Btu	Found lbs/10^6Btu	Comment
SO_2	Gas	-----	--------	Boiler 1
	Oil (Dist)	0.3	0.35	Boiler 1
	Coal	1.8	5.52	Boiler 4
NO_x	Gas	0.3	0.08	Boiler 1
	Oil(Dist)	0.3	0.11	Boiler 1
	Coal	0.9	0.64	Boiler 4
Particulates	Gas	0.1		Boiler 1
	Oil	0.1	0.007	Boiler 1
	Coal	0.1	0.02	Boiler 4

Minor Constituents are summarized in Table 4.

TABLE 4

MINOR CONSTITUENTS

	Boiler No. 1	Boiler No. 4
H_2SO_4 (mist)	0.01 lbs/10^6 Btu	0.05 lbs/10^6 Btu
CO	2.5 ppm (Avg)	
Hydrocarbon	1.7 ppm (Avg)	1.3 (Avg)

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Table 5 and Figure 11. The high percentage of particles less than 0.4 microns in diameter is probably spurious. Microscopic examination indicates the presence of large ammonium sulfate particles, which apparently were formed by subsequent reactions of ammonia with sulfuric acid. The latter, present in vapor form at stack temperature, was apparently retained by the glass fiber filter.

TABLE 5
PARTICLE SIZE DETERMINATION

Test: Run 1 Boiler #4 Date: 6/27

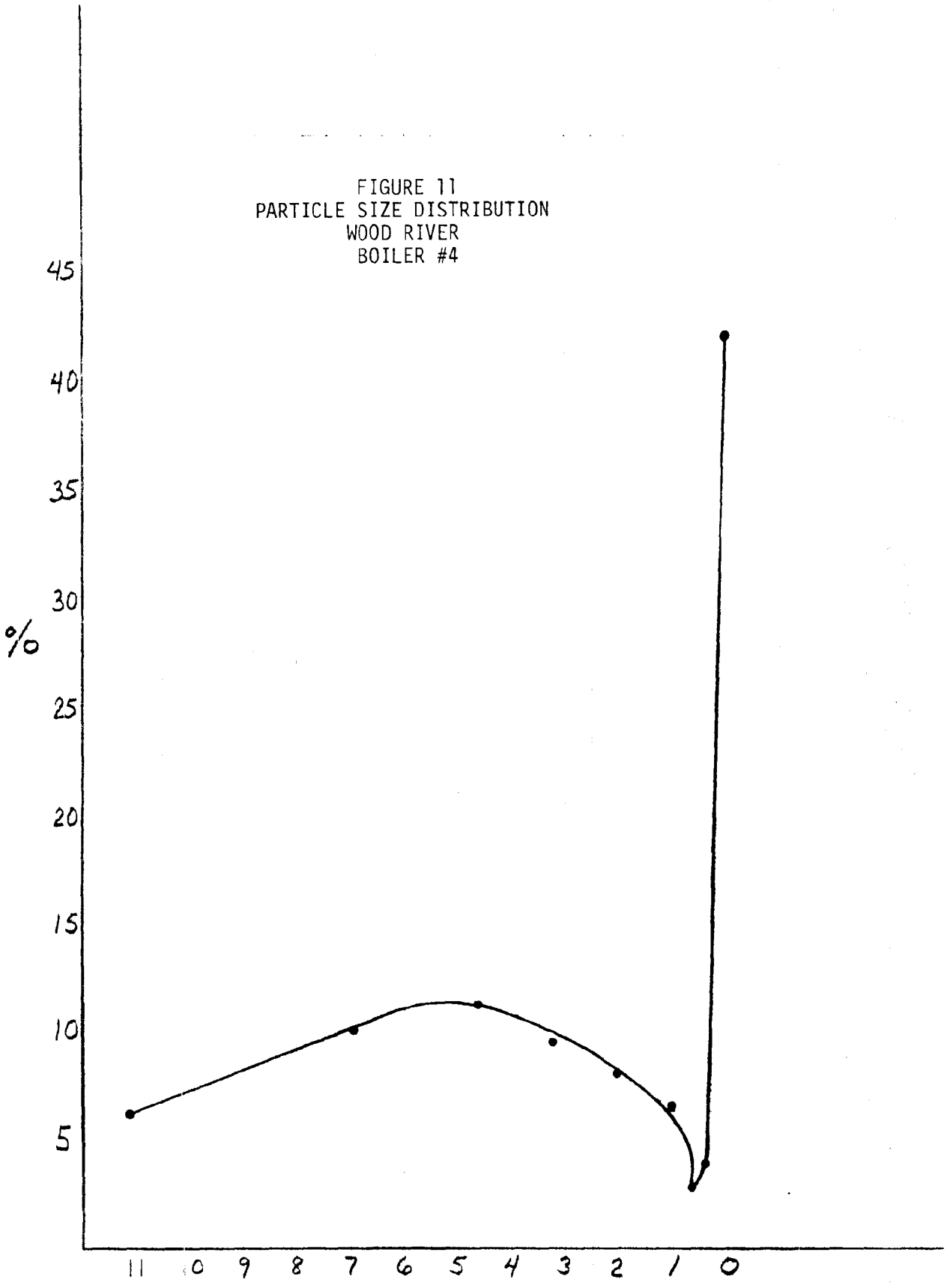
Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.4725	20.4746	2.1			6.2	100.0	11.1 # above
2	21.4719	21.4753	3.4			10.0	93.8	6.95
3	21.6035	21.6073	3.8			11.2	83.8	4.65
4	22.5153	22.5185	3.2			9.4	72.6	3.25
5	11.7385	11.7412	2.7			8.0	63.2	2.05
6	11.4893	11.4915	2.2			6.5	55.2	1.05
7	11.7409	11.7418	0.9			2.7	48.7	0.64
8 *	21.4087	21.4100	1.3			3.8	46.0	0.43
Back Up Filter				14.3		42.2	42.2	<0.43
		Total	19.6	14.3	33.9			

Test: Run 2 Boiler #4 Date: 6/27

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.1922	20.1955	3.3			7.7	100.0	11.1 # above
2	21.3713	21.3758	4.5			10.6	92.3	6.95
3	21.6884	21.6920	3.6			8.5	81.7	4.65
4	22.3725	22.3768	4.3			10.1	73.2	3.25
5	11.6966	11.7003	3.7			8.7	63.1	2.05
6	11.6809	11.6836	2.7			6.3	54.4	1.05
7	11.6868	11.6892	2.4			5.6	48.1	0.64
8 *	20.9214	20.9219	0.5			1.2	42.5	0.43
Back Up Filter				17.6		41.3	41.3	<0.43
			25.0	17.6	42.6			

* Weighed after test, cleaned, tared

FIGURE 11
PARTICLE SIZE DISTRIBUTION
WOOD RIVER
BOILER #4



APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{o} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{o} R or 70^{o} F

Tm = Meter temperature, 530^{o} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{lc}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times V_{lc}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{lc} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{o}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\% O_2 \times \frac{32}{100}\right) + \left(\% N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \% M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P \text{ avg.}}{Ps \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{\text{ft.}}{\text{sec.}} \left(\frac{\text{lb.}}{\text{lb. Mols - oR}}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^oR

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s \; A\left(\frac{Tstd}{Ts} \; \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667 \left[(0.00267) \quad V_{lc} \quad + \quad \frac{V_{mc}}{T_m} \left(P_B \quad + \frac{\Delta H}{13.6} \right) \right] T_s}{\Theta \; V_s \; P_s \; A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$$0.00267 = \frac{\rho_{H2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454 \text{ gm.}}$$

Θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \quad X \quad 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$$

C_s = particulate emission, lb/scf

$2.205 \text{ X } 10^{-6}$ = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \text{ X } Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: IP - Wood River. #1 Blr Date: 6/19

Material collected (mg) =

Filter Catch = 14.2
Dry Catch =
Acetone Wash = 1.5

TOTAL = 15.7

Gas Volume $V_{m_{std}} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$

$0.0334\frac{(77.715)}{1.021}\left(29.86 + \frac{0.784}{13.6}\right) = 76.059$ SCF

Volume of water vapor Vw = 0.0474 x Vlc

0.0474 (181.1 ml) = 8.584 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(8.584)}{(76.059)+(8.584)} = 10.1\ \%$

Molecular Weight of dry stack gas

MW $MW_D = \%\ CO2 \times 0.44 + \%02 \times 0.32 + \%N2 \times 0.28$

(10.3 x 0.44) + (8.9 x 0.32) + (80.8 x 0.28) = 30.0

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 10.1}{100} \times 30.0\right] + \left[\frac{10.1}{100} \times 18\right] = 28.79$

PARTICULATE SAMPLING CALCULATIONS

Test: IP - Wood River - #1 Blr. Date: 6/19

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{743 \times 0.717}{29.9 \times 28.79}\right] 1/2 =$ 57.84 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(10.1)}{100}\right](57.84)(75.59)\frac{530}{(743)}\frac{(29.9)}{29.92} =$ 10,086,753 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6} \frac{(15.7)}{(76.059)} =$ 4.55×10^{-7} lb/scf

$C_E = C_s \times Qs = (4.55 \times 10^{-7})(10,086,753) =$ 4.59 lb/hr

$C_H = C_E \div H = \frac{(4.59)}{(512.4)} =$ 8.96×10^{-3} lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)(181.1) + \frac{76.117}{530}\left(29.86 + \frac{0.784}{13.6}\right)\right](743)}{(126)(57.84)(29.9)(3.406 \times 10^{-3})} =$ 79.8%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$\frac{100\ (8.9)}{(0.266 \times 80.8) - (8.9)} =$ 70.7%

PARTICULATE SAMPLING CALCULATIONS

Test: IP Wood River #4 Date: 6/25

Material collected (mg) =

Filter Catch = 65.1
Dry Catch =
Acetone Wash = 41.8

TOTAL = 106.9

Gas Volume $V_{m_{std}} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$

$0.0334\left(\frac{106.635}{1.021}\right)\left(29.63 + \frac{1.46}{13.6}\right) = 103.734$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474\ (196.9\text{ml}) = 9.333$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(9.333)}{(103.734) + (9.333)} = 8.25\ \%$

Molecular Weight of dry stack gas

MW $MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(16.4 \times 0.44) + (6.4 \times 0.32) + (77.2 \times 0.28) = 30.89$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.25}{100} \times 30.89\right] + \left[\frac{8.25}{100} \times 18\right] = 29.83$

PARTICULATE SAMPLING CALCULATIONS

Test: IP - Wood River - #4 Blr Date: 6/25

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{756.9 \times 0.058}{29.66 \times 29.83}\right] 1/2 =$ 16.37 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(8.25)}{100}\right](16.37)(480.9)\ \frac{530}{(756.9)}\ \frac{(29.66)}{29.92} =$ 18,049,238 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{Mn}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(106.9)}{(103.734)} =$ 2.27×10^{-6} lb/scf

$C_E = C_s \times Qs = (2.27 \times 10^{-6})\ (18,049,238) =$ 41.01 lb/hr

$C_H = C_E \div H = \frac{(41.01)}{(925.0)} =$ 0.044 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \dfrac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ Ps\ An}$

$1.667 \dfrac{\left[(0.00267)\ (196.9) + \frac{104.442}{530}\left(29.63 + \frac{1.46}{13.6}\right)\right](756.9)}{(126)\ (16.37)\ (29.66)\ (1.36 \times 10^{-3})} =$ 96.84%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$\frac{100\ (6.4)}{(0.266 \times 77.2) - (6.4)} =$ 45.3%

PARTICULATE SAMPLING CALCULATIONS

Test: IP Wood River #4 Date: 6/26

Material collected (mg) =

Filter Catch = 37.2
Dry Catch =
Acetone Wash = 21.5

TOTAL = 58.7

Gas Volume $V_{m_{std}} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\triangle H}{13.6}\right)$

$0.0334\left(\frac{102.058}{1.021}\right)\left(29.62 + \frac{1.43}{13.6}\right) = 99.241$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474\ (186.1 ml) = 8.821$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(8.821)}{(99.241) + (8.821)} = 8.16$ %

Molecular Weight of dry stack gas

MW $MW_D = \%CO2 \times 0.44 + \%02 \times 0.32 + \%N2 \times 0.28$

$(14.7 \times 0.44) + (5.6 \times 0.32) + (79.7 \times 0.28) = 30.58$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.16}{100} \times 30.58\right] + \left[\frac{8.16}{100} \times 18\right] = 29.55$

PARTICULATE SAMPLING CALCULATIONS

Test: IP-Wood River - #4 Blr Date: 6/26

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{763.6 \times 0.057}{29.65 \times 29.55}\right]^{1/2} =$ 16.38 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(8.16)}{100}\right](16.38)\ (480.9)\ \frac{530}{(763.6)}\ \frac{(29.65)}{29.92} =$ 17,913,319 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(58.7)}{(99.241)} =$ 1.304×10^{-6} lb/scf

$C_E = C_s \times Qs = (1.304 \times 10^{-6})\ (17,913,319) =$ 23.36 lb/hr

$C_H = C_E \div H = \frac{(23.36)}{(925)} =$ 0.025 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \dfrac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ Ps\ A_n}$

$1.667 \dfrac{\left[(0.00267)\ (186.1) + \frac{99.959}{530}\left(29.62 + \frac{1.43}{13.6}\right)\right](763.6)}{(126)\ (16.38)\ (29.65)\ (1.36 \times 10^{-3})} =$ 93.35%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$$\frac{100\ (5.6)}{(0.266 \times 79.7) - (5.6)} =$$ 35.4%

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1

Oil Composition		mols/100#		mols O_2 required
S	0.29%	÷ 32	x 1	= 0.009
C	86.4	÷ 12	x 1	= 7.200
H_2	12.7	÷ 2 = 6.35	x 0.5	= 3.175
N_2	0.2	÷ 28 = 0.007		
O_2	0.2	÷ 32	x -1	= -0.006
Ash	trace			
Btu	140,000 Btu/gal			
			Theoretical O_2	= 10.378
Excess air = 70.7%			excess O_2	= 7.337
			O_2 Total	= 17.715
$N_2 = 3.76 \times O_2$				= 66.608

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 7.200 + 0.009 + 0.007 + 7.337 + 66.608 = 81.161

Flue Gas = $58.54 \times 386.7 \frac{ft^3}{mol}$ = 31385 scf/100#

@61gpm = $61 \times 7.171 \frac{\#}{gal} \times \frac{1}{100\#} \times 22637.4$ = 137,288 SCFM

= 8,237,263 SCFH

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #4

Composition of Coal		Lb-mols/100 lbs Coal		Oxygen Required for Combustion, mols
C	61.43%	5.12	(1)	5.12
H_2	4.38	(2.19)	(2)	(1.09)
S	3.21	0.10	(3)	0.10
O_2	9.67	0.30		-.30
N_2	1.11	0.04	(4)	-
H_2O (moisture)	11.82	(0.66)	(2)	-
Ash	8.55	-		
Chlorides	0.02	-		
	100.19			6.01 Moles oxygen

Average Excess Air: 40% 2.40

Total 8.41

Corresponding Nitrogen 31.77

Assumed reactions:

(1) $C + O_2 \rightarrow CO_2$

(2) Excluded from calculation for dry flue gas

(3) $S + O_2 \rightarrow SO_2$

(4) Oxidation reaction uncertain

Dry flue gases per 100 lbs coal, lb-mols:

CO_2	5.12
SO_2	0.10
O_2	2.40
N_2	0.04
Air (Nitrogen)	31.77
Total	39.43

lb-mol x 386 = SCF

= 15,220 SCF/100#

@ 43 tons coal/hour = 13,089,200 SCF#

NO_x EMISSION DATA

Date 6/17 & 6/18 Gas Final

Run No.	1	2	3	4	1	2	3	4
Time	-	-	-	-	1130	1200	1400	1430
µg NO_2	blank	252	276	285	155	182	142	155
T_i- Initial Flask Temp, ^oF	90	90	90	90	90	90	90	90
T_f- Final Flask Temp, ^oF	90	90	90	90	90	90	90	90
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2047	2038	2039	2028
P_i- Initial Flask Pres, "Hg	3.0	—	—	—	—	—	—	—
P_f- Final Flask Pres, "Hg	29.7	—	—	—	—	—	—	—
lb/scf NO_2 $\times 10^{-6}$	-	8.4	9.8	10.1	5.5	6.3	5.0	5.5
lb/10^6Btu NO_2	-	0.12	0.14	0.14	0.08	0.09	0.07	0.08

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 6/19 Oil Fired

Run No.	1	2	3	4	5	6	7	8
Time	1200	1230	1300	1330	1400	1500	1530	1600
µg NO_2	220	212	196	224	227	214	223	220
T_i- Initial Flask Temp, °F	90	—	—	—	—	—	—	—
T_f- Final Flask Temp, °F	90	—	—	—	—	—	—	—
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	3.0	—	—	—	—	—	—	—
P_f- Final Flask Pres, "Hg	29.7	—	—	—	—	—	—	—
lb/scf NO_2 $\times 10^{-6}$	7.7	7.5	6.9	8.0	8.1	7.5	7.8	7.7
lb/10^6Btu NO_2	0.12	0.12	0.11	0.13	0.13	0.12	0.13	0.12

$$Vsc = \left(17.71 \frac{^{o}R}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 6/20 Oil Fired

Run No.	1	2	3	4				
Time	1335	1350	1330	1355				
µg NO_2	173	173	162	173				
T_i- Initial Flask Temp, ^oF	90	—	—	—				
T_f- Final Flask Temp, ^oF	90	—	—	—				
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028				
P_i- Initial Flask Pres, "Hg	3.0	—	—	—				
P_f- Final Flask Pres, "Hg	29.8	—	—	—				
lb/scf NO_2 $\times 10^{-6}$	6.1	6.2	5.7	6.0				
lb/10^6Btu NO_2	0.10	0.10	0.09	0.10				

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\text{µg/ml}} \left(\frac{\text{µg } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	6/20		6/20	6/20		
Run No.	1		2	1+2		
V_{mc}-Meter Volume, Ft^3	7.513		7.079	14.592		
Vmstd-Meter Volume, Std. Cond.	7.336		6.912	14.248		
P_B-Barometric Pressure, "Hg	29.84		29.84			
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1			
V_t-Vol. of Titrant, ml.	0.4		0.4	43.5		
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil	nil		
Vsoln-Vol. of Solution, ml.	100		100	500		
V_a-Vol. of Aliquot, Titrated, ml.	10		10	50		
lb/scf H_2SO_4 $\times 10^{-7}$	5.89		6.25			
lb/10^6 Btu H_2SO_4	0.01		0.01			
lb-scf SO_2 $\times 10^{-5}$				2.15		
lb/10^6 Btu SO_2				0.35		

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

Hydrocarbon Results

Test: IP-Wood River #1 Date: 6/18 Time: 1120

Carbon Monoxide:	1.29	ppm
Methane:	1.81	ppm
Total Hydrocarbons, as CH_4:	1.37	ppm

Test: Wood River #1 Date: 6/18 Time: 1420

Carbon Monoxide:	4.33	ppm
Methane:	0.85	ppm
Total Hydrocarbons, as CH_4:	1.90	ppm

Test: Wood River #1 Date: 6/19 Time: 1200

Carbon Monoxide:	0.272	ppm
Methane:	0.604	ppm
Total Hydrocarbons, as CH_4:	1.539	ppm

Test: Wood River #1 Date: 6/19 Time:

Carbon Monoxide:	0.373	ppm
Methane:	0.634	ppm
Total Hydrocarbons, as CH_4:	1.112	ppm

NO_x EMISSION DATA

Date 6/25

Run No.	1	2	3	4	5	6	9	10
Time	1220	1310	1420	1425	1610	1640	1710	1715
µg NO_2	1290	1500	1160	1320	1180	1220	1220	1420
T_i- Initial Flask Temp, ^oF	90	—	—	—	—	—	—	—
T_f- Final Flask Temp, ^oF	90	—	—	—	—	—	—	—
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	3.0	—	—	—	—	—	—	—
P_f- Final Flask Pres, "Hg	29.6	—	—	—	—	—	—	—
lb/scf NO_2 $\times 10^{-5}$	4.5	5.3	4.1	4.7	4.2	4.3	4.3	5.0
lb/10^6Btu NO_2	0.64	0.75	0.58	0.67	0.60	0.61	0.61	0.71

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 6/26

Run No.	1	2	3	4	5	6	9	10
Time	1200	1230	1330	1335	1415	1445	1515	1520
µg NO_2	1250	1370	940	1210	1150	1250	1320	1450
T_i- Initial Flask Temp, ^oF	90	—	—	—	—	—	—	
T_f- Final Flask Temp, ^oF	90	—	—	—	—	—	—	
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	3.0	—	—	—	—	—	—	
P_f- Final Flask Pres, "Hg	29.6	—	—	—	—	—	—	
lb/scf NO_2 $\times 10^{-5}$	4.4	4.8	3.3	4.3	4.1	4.4	4.6	5.1
lb/10^6Btu NO_2	0.62	0.68	0.47	0.61	0.58	0.62	0.65	0.72

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	6/26	6/26		6/27	6/27	6/27
Run No.	1	1		1	2	1+2
V_{mc}-Meter Volume, Ft^3	7.695	7.695		7.452	7.301	
Vmstd-Meter Volume, Std. Cond.	7.537	7.537		7.206	7.060	14.266
P_B-Barometric Pressure, "Hg	29.62			29.55	29.55	
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1			0.1		
V_t-Vol. of Titrant, ml.	5.9	17.4		5.9	5.6	30.1
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil		nil	nil	nil
Vsoln-Vol. of Solution, ml.	100	250		100	100	250
V_a-Vol. of Aliquot, Titrated, ml.	25	1.0		25	25	1.0
lb/scf H_2SO_4 $\times 10^{-6}$	3.4			3.5	3.4	
lb/10^6 Btu H_2SO_4	0.05			0.05	0.05	
lb-scf SO_2 $\times 10^{-4}$		4.07				3.72
lb/10^6 Btu SO_2		5.77				5.27

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \ (\underline{N}) \ \left(\frac{V_{soln}}{Va}\right) = lb/scf}{V_{mstd}}$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \ (\underline{N}) \ \left(\frac{V_{soln}}{Va}\right) = lb/scf}{V_{mstd}}$$

HYDROCARBON ANALYSIS

TEST: IP Wood River #4 DATE: 6/26 TIME: 1400

COMPOUND	CONCENTRATION (ppm)
Ethane	0.074
Propane	0.043
1 - Butene	0.015
n - Butane	0.018
iso - Pentane	0.018
cis, 2 - Pentene	0.016
1 - Hexene	0.046
n - Hexane	0.117
3,3 dimethyl, 1 - Pentene	0.029
2,4 dimethyl Pentane + Benzene	0.068
1 - Heptene	0.040
n - Heptane	0.016
Toluene	0.065
Ethyl Benzene	0.113
meta-, para-, xylene	0.394
orthoxylene	0.087
C_3's	0.043
C_4's	0.052
C_5's	0.143
C_6's	0.308
C_7's	0.185
C_8's	0.622

APPENDIX B
FIELD DATA

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number		6/17	6/18	6/19	6/20*
Net Unit Load - MW			43		
Boiler Heat Rate - BTU/KW hr.			13,893		
Boiler Heat Input - 10^6 BTU/hr.		592.3	597.4	512.4	512.4
Emission Level - lb./10^6 BTU					
	Particulates				
	SO_2				
	NO_x				
Fuel Heating Value - BTU/lb.		1030 Btu/CF	1030 Btu/CF	19520	
Fuel Burning Rate During Test - lb./hr.		575 10^3CF/hr	580 10^3CF/hr	61 GPM	
Fuel Ash Content - %					
Additive Rate - lb/hr.					

*Assumed same as 6/19

ORSAT FIELD DATA

Location ILL. POWER - BOILER 1 Comments:

Date _____

Time _____

Operator _____

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6-17	1.8 %	9.2 %	0.0 %
6-18	7.2 %	8.4 %	0.0 %

6.18 Mw dry = .072 (44) + .084 (32) + .844 (28)

3.2 2.7 23.6 = 29.5 Mw(dry)

@ 16.5 % H_2O

Mw wet .165 (18) . 835 (.072)(44) + .835(.084)(32) + .835(.844) 28

2.97 2.65 2.24 19.73 = 27.

Mw

ORSAT FIELD DATA

Location ILL. POWER CO. ALTON, ILL. Comments:

Date _____ No. 1 BOILER

Time _____

Operator _____

TEAM
LITTMAN
GRISCOM
KLEIN

DATE	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6-19-75	1120 hrs.	8.6	17.6 / 9.0	17.6
	1600 hrs.	12.0	20.8 / 8.8	20.8
6-20-75	1130 hrs.	15.0	23.2 / 8.2	23.2
	1300 hrs.	11.4 *	16.4 / 5.0	16.4
	avg. 6/19	10.3	8.9	0.0

* Sampled at economizer--plant sample point on 4th floor of boiler house

6-19 Mw dry = .103 (44) + .089 (32) + .808 (28) = 30.0
4.53 2.85 22.62

Mw wet = .899 (30) + .101 (18) = 26.97 + 1.82 = 28.79

6-20 Mw dry = .15 (44) + .082 (32) + .768 (28) = 30.72
6.6 2.62 21.50

Plant IP Wood River

Run No. 1

Location #1 Boiler

Date 6-18

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

5 Filter

Ambient Temp °F 85-90

Bar. Press. "Hg _____

Assumed Moisture % 15

Heater Box Setting °F (4)

Probe Tip Dia., In. 1/4 in

Probe Length 10 ft.

Probe Heater Setting 7

Avg. ΔP ____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-6	12:08	126.445	0.45	0.6	0.6	185	80	5.5	315	130		290
1-5	12:11	128.150	0.75	1.0	1.0	220	70	8.5	310	150		290
1-4	12:14	130.34	0.9	1.2	1.2	230	65	11.0	305	175		290
1-3	12:17	132.90	0.9	1.2	1.2	230	65	11.0	310	180		290
1-2	12:20	135.14	0.75	1.0	1.0	245	65	9.5	315	180		290
1-1	12:23	137	0.15	.2	.2	250	70		325	175		285
	12:26											
2-1	1:58	138.9	.35	0.5	0.5	210	90	4.5	370	135		290
2-2	2:01	140.3	0.9	1.3	1.3	280	70	12.5	360	170		290
2-3	2:04	142.	1.1	1.5	1.5	280	70		350	170		290
2-4	2:07	145.2	1.2	1.65	1.5	280	75	15	340	175		290
2-5	2:10	147.8	1.1	1.5	1.5	285	80	15	335	180		300
2-6	2:13	150.45	0.9	1.3	1.3	280	85	12.5	335	180		300
	2:16	152.920										

Run No. 1

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H_2O Δ P	Orifice Δ H In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	2:58	152.92	.3	0.4	.4	110	100	4	315			290
3-2	3:01	154.4	.9	1.2	1.2	235	85	11.5	325	150		290
3-3	3:04	156.6	1.1	1.5	1.5	255	85	15	325	170		295
3-4	3:07	159.1	1.1	1.5	1.5	255	95	15	320	175		300
3-5	3:10	161.6	1.1	1.5	1.5	260	100	15	320	180		300
3-6	3:13	164.4	0.9	1.2	1.2	260	105	12	320	180		300
off	3:16	166.920										

Comments Filter No. 5

Plant IP WOOD RIVER

Run No. 2

Location #1 B/r

Date 6-19

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 90°F

Bar. Press. "Hg 29.86

Assumed Moisture % 16%

Heater Box Setting °F 325 @ 4

Probe Tip Dia., In. 1/4 in

Probe Length 10 ft.

Probe Heater Setting 4 280°300°

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	11:18	167.100	.6	.85	.85	185	70	16.5	320	245	0.5	280
1-2	11:21		7/8	1.2	1.0	210	65	17.5	330	300		285
1-3	11:24	171.05	9/8	1.5	0.9	230	65	17.5	340	315		285
1-4	11:27	173.13	9/8	1.5	0.9							
1-5	11:30	175.30	8/8	1.4	0.9	250	68	17.5	350	315		285
1-6	11:33	177.40	.5	.7	.7	260	70	13.5	355	315		280
	11:36	179.255										
2-1	12:35	181.430	0.4	0.55	.55	225	75	9	340	205		270
2-2	12:38	183.000	1.00	1.3	.95	255	70	17.5	350	290		270
2-3	12:41	185.10	10/8	1.7	.95	265	70	17.5	355	305		270
2-4	12:44	187.20	11/8	1.8	.95	270	70	17.5	355	300		270
2-5	12:47	189.3	10/8	1.7	.95	275	75	17.5	355	295		260
2-6	12:50	191.4	0.75	1.05	.95	280	75	17	360	300		260
	12:53	193.360										

Meter Out 105°F

Comments: Particulates 0.0429 + .0015 = .0579

Run # 2

	Point	Clock Time	Dry Gas Meter, CF	Pitot In. H_2O Δ P	Orifice Δ H In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
					Desired	Actual	Inlet	Outlet					
upset about 1 hr for 10 min. ½ of oil burners off	3-1	1:40	193.360	.25	.34	.34	220	80	5.5	355	240		270
	3-2	1:43	194.6	1.0	1.4	1.0	255	70	17.5	360	295		270
	3-3	1:46	196.6	9/8	1.6	1.0	270	65	17.5	355	315		280
meter 110°	3-4	1:49	198.6	9/8	1.6	1.0	275	65	17.5	360	325		280
	3-5	1:52	200.75	9/8	1.6	1.0	285	70	17.5	365	330		260
	3-6	1:55	202.7	.95	1.3	1.0	290	70	17.5	365	320		250
	off	1:58	204.845										
	4-1	2:58	204.845	0.2	.28	.3	205	80	5.5	325	220		280
	4-2	3:01	206.0	0.8	1.1	1.0	240	65	17	330	270		285
	4-3	3:04	207.65	0.8	1.1	1.0	255	65	17	335	280		290
	4-4	3:07	209.8	0.8	1.1	1.0	265	65	17	340	290		290
	4-5	3:10	211.9	0.95	1.3	1.0	270	65	17	345	305		290
	4-6	3:13	214.0	0.85	1.2	1.0	265	70	17	350	305		290
	off	3:16	216.062										
meter 115°	5-1	3:54	216.062	0.1	0.14	0.15	195	90	3.5	340	220		290
	5-2	3:57	216.98	0.6	0.8	0.8	250	80	14.5	345	275		295
	5-3	4:00	218.85	0.5	.68	0.7	270	75	13	350	315		300
	5-4	4:03	220.7	.65	0.9	0.9	275	75	16	350	330		295
	5-5	4:06	222.75	.8	1.1	0.9	280	80	17	355	330		295
	5-6	4:09	224.8	.8	1.1	0.9	285	80		365	320		295
	off	4:12	226.840										

Comments

Run #1

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
6-1	4:55	226.840	0.15	0.2	0.2	195	90	4.5	345	215		295
6-2	4:58	227.85	0.6	0.8	0.8	255	80	13.5	350	280		300
6-3	5:01	229.7	.45	.65	.65							
6-4	5:04	231.45	0.6	.8	0.8	275	75	14.5	355	290		295
6-5	5:07	233.45	0.7	1.0	.95							
6-6	5:10	235.5	0.6	0.8	0.8	280	75	14	355	280		295
off	5:13	237.455										
meter 105°F 7-1	5:49	237.455	0.15	0.2	0.2			4.5				
7-2	5:52	238.48	0.4	0.55	0.55	255	85	10	345	285		300
7-3	5:55	240.1	0.4	0.55	0.55							
7-4	5:58	241.78	0.5	0.67	0.67	275	80	12	360	340		295
7-5	6:01	243.55	0.55	0.7	0.7							
7-6	6:04	245.35	0.35	0.5	0.5	285	85	10	365	320		295
off	6:07	246.990										
8-1												
8-2	Bottom Hole Full of Deposits											
8-3												
8-4												
8-5												
8-6												
off												

Comments $V_s = 85.48(.86)(.717)\ 1/2\left[\frac{743}{29.9(28.81)}\right]^{1/2}$

$= 73.5(.847)(.929) = 57.84$ fps

PARTICULATE CLEANUP SHEET

Date: 6/19/75 Plant: IP - Wood River

Run Number: 2 Location Of Sample Port: #1 Boiler Duct

Operator: _____ Barometric Pressure: 29.86 in. Hg.

Sample Box No. _____ Ambient Temperature 90 °F

Impinger H_2O Silica Gel

Volume After Sampling 361 ml Weight After 373.2 g

Impinger Prefilled With 200 ml Weight Before 353.1 g

Volume Collected 161 ml Moisture Weight 20.1 g Moisture Total 181.1 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0015 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
4			

Filter Particulate Weight 0.0142 g

Total Particulate Weight 0.0157 g

% Moisture By Volume $V_{m_{std}} = 0.0334 \left(\frac{77.715}{1.031}\right)\left(29.86 + \frac{0.784}{13.6}\right) = 76.059$ cu. ft.

$V_{w_{std}} = 0.0474\,(181.1) = 8.584$ cu ft.

$\%M = \frac{8.584}{76.059 + 8.584} = .101 \Rightarrow 10.1\%$ moisture

OXIDES OF NITROGEN FIELD DATA

Date 6/17 & 6/18

Plant IP-WOOD RIVER - BLR #1

Sample Collected By O. Klein

Run No. _____

Power Stat Setting _____

Field Data	6/17				6/18			
Clock Time	blank	-	-	-	1130	1200	1400	1430
Flask number	1	2	3	4	1	2	3	4
Volume of flask less correction (ml)	2047	2038	2039	2028	2047	2038	2039	2028
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Flask temperature, ^{o}F	90	90	90	90	90	90	90	90

OXIDES OF NITROGEN FIELD DATA

Date 6/19

Plant IP - Wood River - Blr. #1

Sample Collected By O. Klein

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	1200	1230	1300	1330	1400	1500	1530	1600
Flask number	1	2	3	4	5	6	7	8
Volume of flask less correction (ml)	2047	2038	2039	2028	2025	2052	2052	2056
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.-
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Flask temperature, °F	90	90	90	90	90	90	90	90

OXIDES OF NITROGEN FIELD DATA

Date 6/20

Plant IP - Wood River - Blr #1

Sample Collected By O. Klein

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	1325	1350	1330	1355				
Flask number	1	2	3	4				
Volume of flask less correction (ml)	2047	2038	2039	2028				
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0				
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7				
Flask temperature, ^{o}F	90	90	90	90				

GAS SAMPLING FIELD DATA

Material Sampled For Sulfuric Mist & SO_2

Date 6-20-75

Plant Wood River Location #1 Boiler

Bar. Pressure 29.84 "Hg Comments:

Ambient Temp 90° °F

Run No 1

Power Stat Setting Probe-4 @ 315°F

Filter Used: Yes _____ No X Shell method

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
12:02	253.747	0.7	0.1 in H_2O	290°F	310°F	65°C		
12:07	254.000	0.7	0.1		315°F	73°C	145°F	85°F
12:12	256.27	0.7	0.1		310°F	73°C	135°F	85°F
12:17	257.55	0.7	0.1		305°F		130°F	82°F
12:22	258.82	0.7	0.1		315°F	73°C	125°F	82°F
12:27	260.10	0.7	0.1 (1 in Vac.)		315°F		125°F	82°F
12:32	261.360	0.7	off		315°F	72°C	120°F	85°F

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For Sulfuric Mist & SO_2

Date 6-20

Plant Wood River Location #1 Blr.

Bar. Pressure 29.84 "Hg Comments:

Ambient Temp 90 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

SO 2 Impingers not changed

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
1:07	261.260	0.7	0.1		355°F	76°C	70°F	95°F
1:12	262.475	0.7	0.1		345°F		70°F	90°F
1:17	263.68	0.7	0.1 (1 in Vac)		335°F	80°C	55°F	90°F
1:22	264.875	0.7	0.1		325°F	78°C	45°F	90°F
1:27	266.02	0.7	0.1		325°F	78°C	35°F	88°F
1:32	267.18	0.7	0.1		325°F	77°C	35°F	90°F
1:37	268.339		off					

Comments:

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number		6/25	6/26	6/27	
Net Unit Load - MW		100	100	100	
Boiler Heat Rate - BTU/KW hr.					
Boiler Heat Input - 10^6 BTU/hr.		925.0	925.0	925.0	
Emission Level - lb./10^6 BTU					
	Particulates				
	SO_2				
	NO_x				
Fuel Heating Valve - BTU/lb.		10756	10756	10756	
Fuel Burning Rate During Test - lb./hr.		86000	86000	86000	
Fuel Ash Content - %					
Additive Rate - lb/hr.					

ORSAT FIELD DATA

Location ILL POWER CO. ALTON, ILL. Comments:

Date _____ No. 4 BOILER

Time _____ TEAM

Operator _____ GRISCOM
KLEIN
NORRIS

DATE	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6-25-75	1340 hrs.	16.4	22.8/6.4	22.8
6-26-75	1245 hrs.	13.2	19.0/5.8	19.0
	1535 hrs.	16.2	21.6/5.4	21.6
6-27-75	1030 hrs.	15.3	20.8/5.5	20.8

6.25. $MW_D = .164(44) + .064(32) + .772(28) = 30.89$

$MW_{wet} = .9175(30.89) + .0825(18) = 28.34 + 1.49 = 29.83$

6.26 $MW_D = .147(44) + .056(32) + .797(28) = 30.58$

$6.47 \quad 1.79 \quad 22.32$

$MW_{wet} = .9184(30.58) + .0816(18) = 28.08 \quad 1.47 \quad 29.55$

6.27 $MW_D = .153(44) + .055(32) + .792(28) = 30.67$

$6.73 \quad 1.76 \quad 22.18$

Plant Wood River

Run No. 1

Location #4 Stack

Date 6-25-75

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.022

C Factor 0.55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

#3 filter

Static press. 0.4 in H_2O

Ambient Temp °F 85

Bar. Press. "Hg 29.63

Assumed Moisture % 8

Heater Box Setting °F @ 4 320°F

Probe Tip Dia., In. 1/2

Probe Length 10 ft.

Probe Heater Setting

Avg. ΔP .05 Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1	7 min	269.350	0.020	0.5	0.5	225	60	2.5	330	270		170
2		273.0	0.05	1.25	1.25	240	60	6.0	335	330		260
3		279.0	0.055	1.4	1.4	270	65	6.0	350	335		310
4		285.1	0.055	1.4	1.4	275	65	6.0	345	295		320
5		291.0	0.06	1.5	1.5							
6		297.4	0.065	1.6	1.6	270	65		315	255		320
7		304.0	0.065	1.6	1.6	270	65	6.5	305	235		320
8		310.0	0.06	1.5	1.5	265	65	6.5	300	230		320
9		316.0	0.06	1.5	1.5	265	65	6.5	312	240		320
	≈2:45	321.965										

0.055 use ΔP of actual variation .04-0.09 avg. = 0.055

probe & oven setting up to 7 strong breeze

Run #1

Point	Clock Time	Dry Gas Meter CF	Pitot In. H_2O Δ P	Orifice Δ H In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
18	4:35	321.965	0.04	1.0	1.0	245	65	4.0	360	265		210
17		326.8	0.06	1.5	1.5	280	63	7.0	370	305		290
16		333	0.07	1.75	1.75	295	70	8.0	380	335		310
15		339.4	0.07	1.75	1.75	290	70	8.0	355	325		320
14		345.7	0.07	1.75	1.75	285	72		345	315		320
13		352	0.06	1.5	1.5	275	75	7.0	360	310		320
12		358	0.06	1.5	1.5	285	80	7.0	355(3)	320(7)		320
11		364	0.07	1.75	1.75	275	75	8.0	350	305(7)		320
10		370	0.06	1.5	1.5	275	70	7.0	350	285(7)		
		375.985										

oven off
Δp's 0.03...
0.08 ca

met

Comments

PARTICULATE CLEANUP SHEET

Date: 6/25 Plant: IP Wood River

Run Number: 1 Location Of Sample Port: #4 Boiler Stack

Operator: _____ Barometric Pressure: 29.63

Sample Box No. _____ Ambient Temperature 85

Impinger H_2O Silica Gel

Volume After Sampling 368.5 ml Weight After 516.5 g

Impinger Prefilled With 200 ml Weight Before 488.1 g

Volume Collected 168.5 ml Moisture Weight 28.4 g Moisture Total 196.7 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0416 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
3				Filter Particulate Weight 0.0651 g
				Total Particulate Weight 0.1067 g

% Moisture By Volume

Plant Wood River

Run No. 2

Location Blr #4

Date 6-26

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.022

C Factor .55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

#2 Filter
Static press. 0.4 in H2O

Ambient Temp °F 90°F

Bar. Press. "Hg 29.62

Assumed Moisture % 8%

Heater Box Setting °F 4

Probe Tip Dia., In. 1/2

Probe Length 10 ft

Probe Heater Setting

Avg. ΔP 0.06 Avg. ΔH 1.5

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
18	11:45	375.985	0.03	0.75	0.75	230	65	4	330	240		175
17		380	0.05	1.25	1.25	245	63	6	320	290		260
16		385.8	0.07	1.75	1.75	265	65	9	330	325		320
15		392	0.07	1.75	1.75	280	69	9	340(5)	330 (6)		320
14		398	0.07	1.75	1.75	290	69	9	345	320		320
13		405.7	0.07	1.75	1.75	295	69	9	350	320		320
12		411	0.05	1.25	1.25	295	70	6	350(4)	315(5.5)		320
11		416.5	0.05	1.25	1.25	285	70	6	335	320		320
10		422	0.05	1.25	1.25	290	74	6	355	330		320
	12:48	427.050										

Run #2

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H_2O Δ P	Orifice Δ H In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
Δp varies 0.03-0.1												
9		427.050	0.06	1.5	1.5	185	75	8.5	315 (7)	170		320
8		433	0.06	1.5	1.5	260	71	8.5	340	315 (7)		325
7		438.7	0.06	1.5	1.5	280	70	8.5	380 (4)	355 (5)		320
6		445.5	0.06	1.5	1.5	281	71	8.5	360	335		320
5		451.5	0.06	1.5	1.5	265	75	9.0	360	255 (7)		320
4		456.0	0.08	1.5	1.5	250	70	9.0	305 (5)	285 (6)		320
3		462.0	0.06	1.5	1.5	255	80	9.0	360	320		320
2		468.0	0.06	1.5	1.5	260	85	9.0	345	305		320
1		473.5	0.04	1.0	1.0	255	85	7.0	325	310		225
		478.043										

Comments There may be a short leak at joint at end of probe

Unable to get a good seal when box is far out ∴ nozzle not vertical

PARTICULATE CLEANUP SHEET

Date: 6/26 Plant: IP Wood River

Run Number: #2 Location Of Sample Port: #4 Boiler Stack

Operator: _____ Barometric Pressure: 29.62

Sample Box No. _____ Ambient Temperature 90

Impinger H_2O Silica Gel

Volume After Sampling 358 ml Weight After 528.1 g

Impinger Prefilled With 200 ml Weight Before 500.0 g

Volume Collected 158 ml Moisture Weight 28.1 g Moisture Total 186.1 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0215 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
2	_____	_____	_____	Filter Particulate Weight 0.0372 g
_____	_____	_____	_____	
_____	_____	_____	_____	Total Particulate Weight 0.0587 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 6/25

Plant IP Wood River - Boiler No. 4

Sample Collected By O. Klein

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	1220	1310	1420	1425	1610	1640	1710	1725
Flask number	1	2	3	4	5	6	9	10
Volume of flask less correction (ml)	2047	2038	2034	2028	2025	2052	2054	2051
Pressure before sampling in. Hg.	3.0	---						
Pressure after sampling, in. Hg.	29.6	---						
Flask temperature, °F	90	---						

OXIDES OF NITROGEN FIELD DATA

Date 6/26

Plant IP-Wood River - Boiler No. 4

Sample Collected By O. Klein

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	1200	1230	1330	1335	1415	1445	1515	1520
Flask number	1	2	3	4	5	6	9	10
Volume of flask less correction (ml)	2047	2038	2039	2028	2025	2052	2054	2057
Pressure before sampling in. Hg.	3.0	—						
Pressure after sampling, in. Hg.	29.6	—						
Flask temperature, ^{o}F	90							

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 6-26

Plant Wood River Location #4 B/r

Bar. Pressure 29.62 "Hg Comments:

Ambient Temp 90 °F

Run No 1 Traverse Point #5

Power Stat Setting _____

Filter Used: Yes _____ No ___ Shell Method

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O Δ P	Orifice in H_2O Δ H	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
~ 4 PM 0	478.045	0.05	0.1	325				
5	479.5	0.05	0.1	325	280	83	170	80
10	481	0.05	0.1	325	285	82.5	150	82
15	482	0.05	0.1	325	305	81	135	83
20	483.2	0.05	0.1	325	318(55)	79	130	83
25	484.4	0.05	0.1	325	300	77.5	120	85
30	485.740							

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 6.27

Plant Wood River Location #4

Bar. Pressure 29.547 "Hg Comments:

Ambient Temp 85 °F

Run No 1 Traverse Point #5

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
10:55 0	485.748	0.055	0.1	320	280	73		
5	486.5	0.055	0.1	320	295	78	155	70
10	488	0.055	0.1	320	315(7)	78	135	72
15	489.5	0.055	0.1	320	300(6)	78	130	72
20	490.8	0.055	0.1	320	300	77	125	72
25	492	0.055	0.1	320	310	76	125	72
30	493.200							

Comments:

1. Moisture condenses by the impinger inlet Thermometer from ambient cooling
2. Probe setting has to be at 7 to keep temp up ~~unusual~~ for the glass probe

GAS SAMPLING FIELD DATA

Material Sampled For SO2 & SO3

Date 6-27

Plant Wood River Location #4

Bar. Pressure 29.55 "Hg Comments:

Ambient Temp 85 °F

Run No 2 Traverse Point #5

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil °C	Impinger In	Impinger Out
11:50 0	493.200	0.055	0.1	325	318(7)	74°C	160°F	85°F
5	494.4	0.055	0.1	325	320	83.5°C	170°F	80°F
10	495.7	0.055	0.1	325	320	84°C	142°F	78°F
15								
20	498.1	0.055	0.1	325	328	81°C	132°F	78°F
25	499.3	0.055	0.1	330	330(7)	80°C	130°F	80°F
30	500.501							

Comments:

Anderson-Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Wood River

Run No. 1

Location #4

Date 6-27

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor _____

Ambient Temp °F 90

Bar. Press. "Hg _____

Assumed Moisture % 8

Heater Box Setting °F _____

Probe Tip Dia., In. _____

Probe Length _____

Probe Heater Setting _____

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
5	1:05	500.501	0.055	1.4	1.4	115	75	6	165			325 assume
	1:15		assumed	1.4	1.4	180	70	6	285			
	1:25			1.4	1.4	195	70	6	300			
	1:35			1.4	1.4	200	70	6	270			
	1:45	530.18		1.4	1.4	210	70	6	275			
	1:55	538.35		1.4	1.4	215	72	6	275			
	2:05	545.850	off									

Anderson - Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Wood River

Run No. #2

Location B/r #4

Date 6-27

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.0??

C Factor _____

Ambient Temp °F 90

Bar. Press. "Hg _____

Assumed Moisture % 7

Heater Box Setting °F _____

Probe Tip Dia., In. _____

Probe Length _____

Probe Heater Setting _____

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
5	2:18	545.850	0.055	1.4	1.4	210	80		305			assume 325°
	2:28	553.45	assumed	1.4	1.4	235	79		300			
	2:38	562		1.4	1.4	235	82		300			
	2:48	-		1.4	1.4	-	-		-			
	2:58	576		1.4	1.4	240	90		305			
	3:08	584		1.4	1.4	255	90		325			
	3:18	591.671										

meter 130

SOURCE TEST REPORT

HIGHLAND POWER & LIGHT

HIGHLAND, ILLINOIS

BOILER NO. 3

JULY, 1975

Tested by: Rockwell International

R.W. Griscom

O.C. Klein

F.E. Littman

TABLE OF CONTENTS

TABLES

FIGURES

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler No. 3 at the Highland Power and Light Co. in Highland, Illinois.

The stack testing included the following pollutants: SO_2, particulates, NO_x, and H_2SO_4. Orsat analysis for CO_2, CO, and O_2 were also performed. Detailed results are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the particulate emissions are within limits while the SO_2 emissions are not.

We acknowledge and appreciate the excellent cooperation we obtained from the officials of the power company and the City of Highland.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Highland Power and Light Co. in Highland, Illinois. Testing was performed on boiler No. 3 during the week of 14 July 1975.

Boiler No. 3 is a coal fired, 75,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, and oxygen.

3.0 PROCESS DESCRIPTION

Boiler No. 3 was built by Union Iron Works and installed in 1959. It is equipped with a traveling grate stoker which is gravity fed. The economizer has not been used for 10 years. The boiler was originally rated at 75,000 pounds per hour steam, however, present operating capacity is approximately 60,000 pounds per hour. Steam pressure is maintained at approximately 610 psi. Boiler No. 3 is an induced draft unit and has no stack emission controls. The stack is of steel construction, 90 feet tall and 5 feet inside diameter.

4.0 SOURCE TEST DESCRIPTION

Boiler No. 3 was tested in the stack, approximately 35 feet above the ground. The City of Highland provided the use of a "cherry picker" for the period of testing. The testing arrangement is illustrated in Figure 1, 2 and 3.

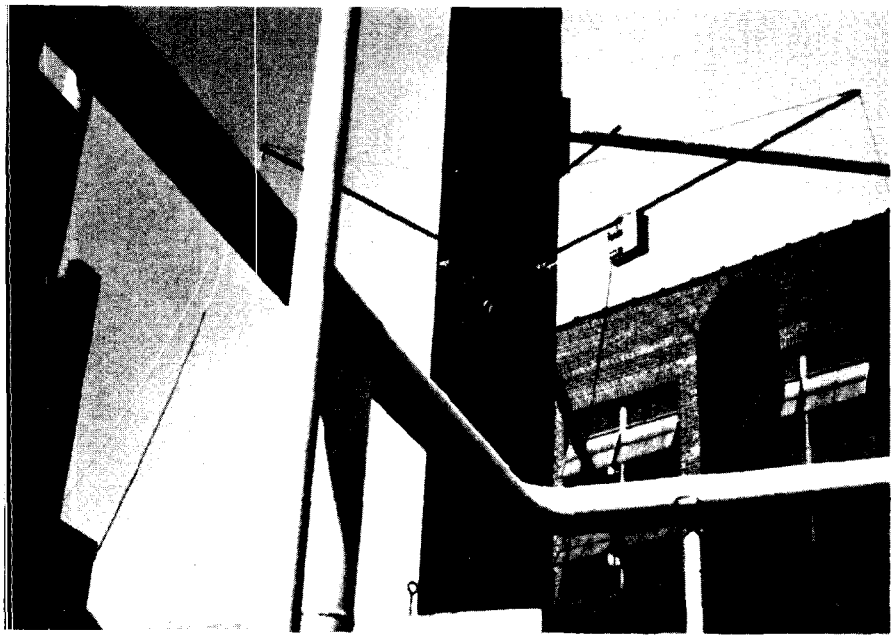


FIGURE 1

POSITIONING OF UNI-STRUTS TO CARRY THE EPA EQUIPMENT

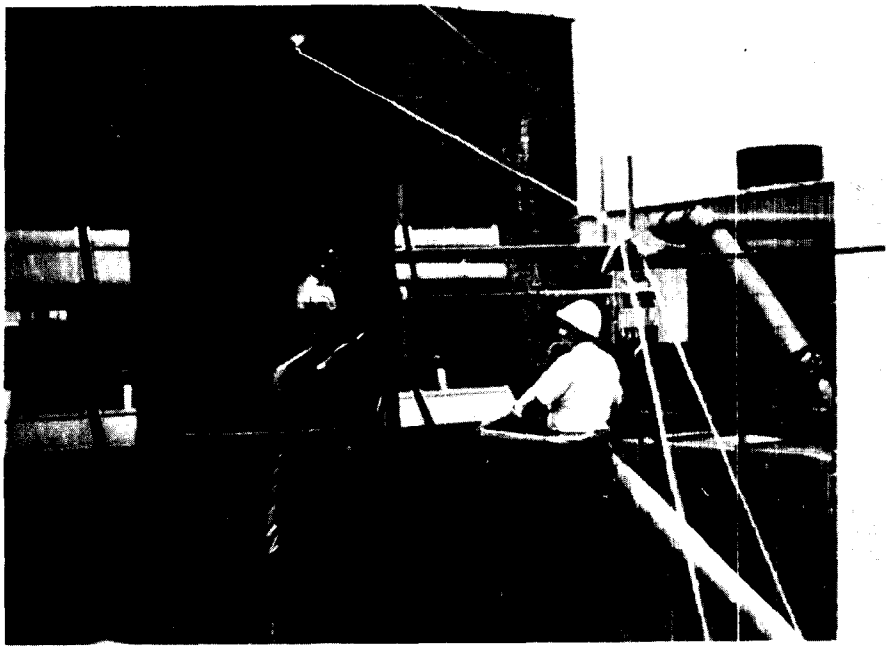


FIGURE 2

ANALYSIS AND PROBE ADJUSTMENT BY OPERATOR IN CHERRY PICKER BUCKET

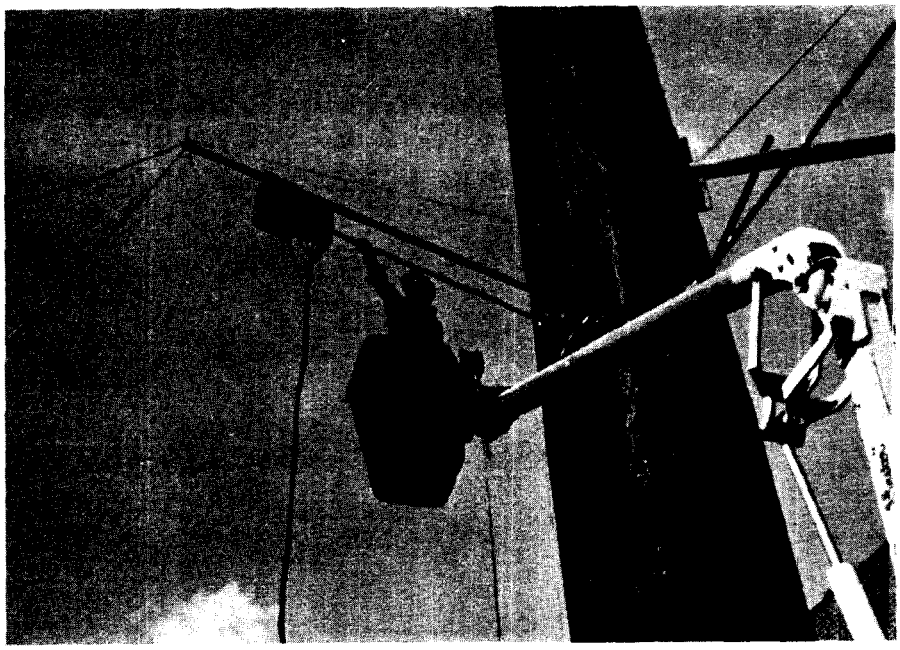


FIGURE 3

DETAIL SHOWING UNI-STRUTS AT 90 DEGREE PLACEMENT ON STACK.
OPERATOR ADJUSTS PITOT POSITION.

The No. 3 stack is 5.0 feet inside diameter and approximately 90 feet tall. This sampling point is approximately 5 diameters from the flue gas inlet. In accordance with the EPA Standard Method 1, fourteen sampling points were chosen on each of two perpendicular diameters. Two, 3 inch couplings were installed on the stack for use as sampling ports.

5.0 PROCESS OPERATION

Boiler No. 3 was tested 14 July to 16 July. During this testing period, the load on the boiler remained fairly constant since this boiler drives a turbine which provides the baseline electrical generation for the plant. Generator output was generally between 4000 and 4300 KW. There was no visible change in emissions during testing. Ashes were pulled almost every hour. During these periods visible emissions didn't change, but the flow rate in the stack increased.

6.0 DISCUSSION

A problem exists about the use of EPA Standard Method 2, Volumetric Flow Rate Determination. On boiler No. 3 the flow rate determined by method 2 is 23101.2 SCFM compared to a flow rate determined stoichiometrically from the fuel rate and fuel composition of 15182 SCFM. At this sampling point this should have been a good check of method 2, since it was a reasonable distance downstream, 5 diameters, and two complete, perpendicular traverses were made.

The flow rate determined stoichiometrically compares very well with the expected flow as seen by a comparison of sulfur dioxide emissions using both flow rates. Using the published emission factor of 38S, which allows for a 95% conversion of sulfur in the coal to sulfur dioxide emission, the emissions would be 413.87 lb/hr. With the flow rate using method 2 the emissions would be 658.4 lb/hr, which is definitely too great. With the stoichiometric flow rate the emissions would be 432.6 lb/hr, which is a reasonable result. For this reason the emission determined using the stoichiometric flow rate are reasoned to be the correct results.

To determine the amount of coal consumed, the generator output and a ratio of kw to pounds of coal were used to calculate coal consumption. The ratio used was based on operating records for the previous month. Using the current ratio of 1.6, the average fuel consumption for 15 July was 6702.4 lb/hr.

During testing for particle size, the first run was with the Andersen impactor in the stack while the other two were run with the impactor in the oven. For this test, a problem existed which forced the use of an unheated probe. With the impactor in the stack this is no problem, however with the impactor in the oven there was probably some condensation in the probe which increases the weight of particulates.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

7.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350^{O}F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 4.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

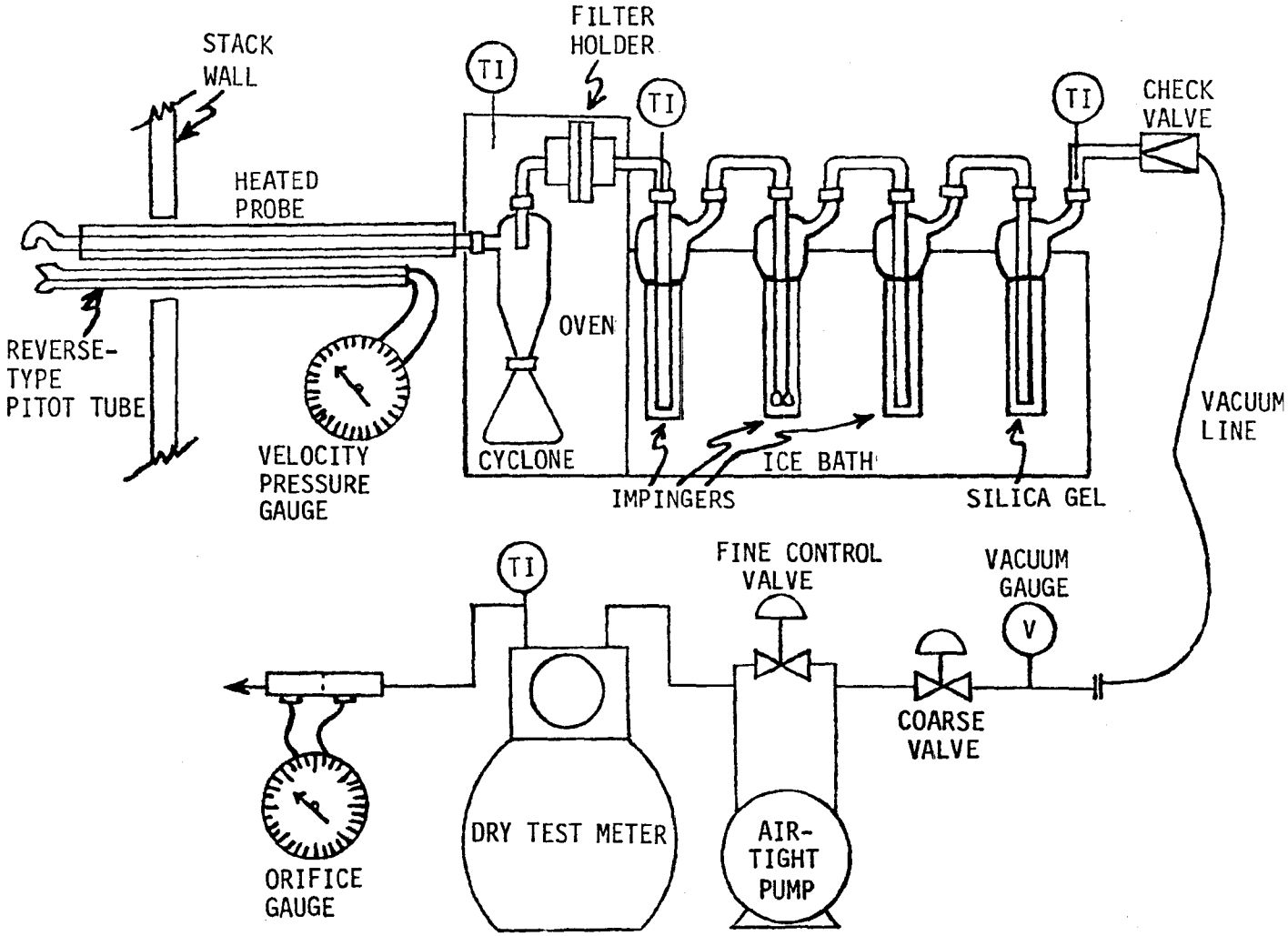


FIGURE 4

PARTICULATE SAMPLING TRAIN

7.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

7.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The "Shell Method"* was chosen for this determination due to uncertainties which exist about the validity of the results using method 8. A gas sample is drawn from the stack using a heated probe and passed through a water-cooled, coil condenser maintained below the dew point of sulfuric acid at 140^{o}-194^{o}F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 5.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

*Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point In Flue Gases", Combustion, Jan. 1965.

Goksøyr, H. and K. Ross "The Determination of Sulfur Trioxide in Flue Gases", J. Inst. Fuel, No. 35, 177, (1962)

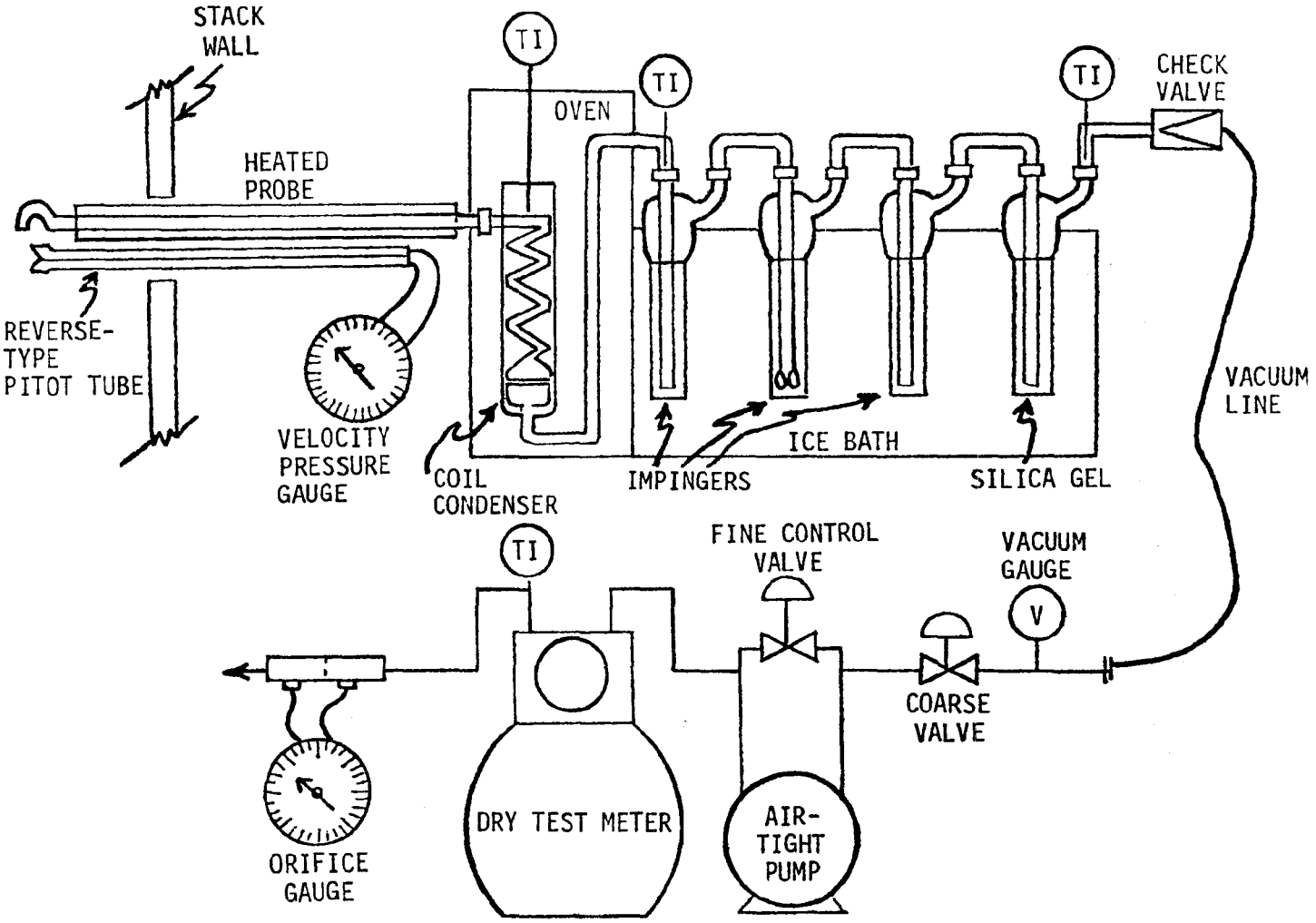


FIGURE 5

SULFURIC ACID MIST SAMPLING TRAIN

7.4 PARTICLE SIZE

An Andersen, fractionating, inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed either in the stack at the end of the sampling probe or in the oven after the heated sample probe (see Figure 6). A sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density.

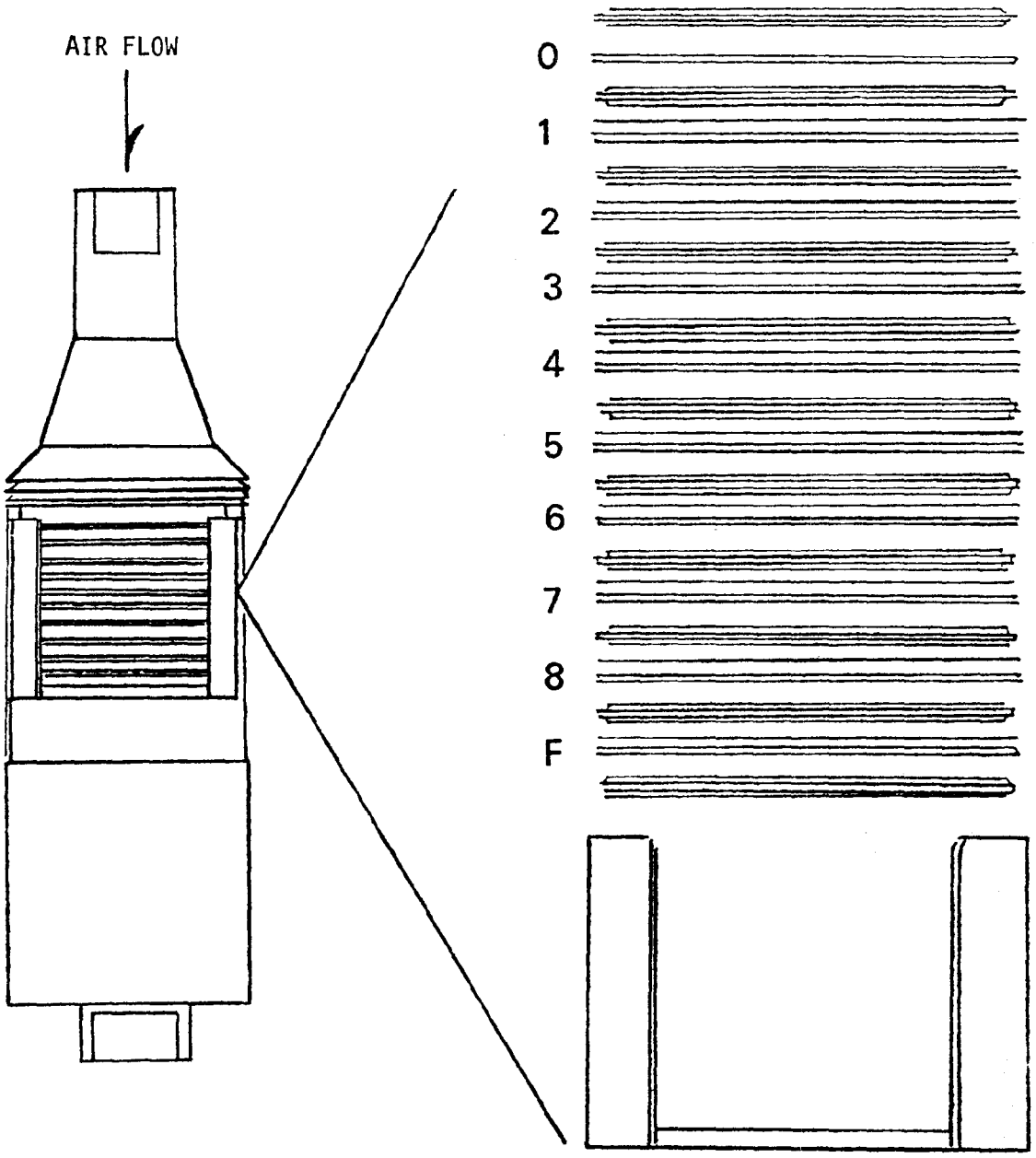


FIGURE 6

ANDERSEN STACK SAMPLER

8.0 RESULTS

The results obtained from this test are summarized in Table 1. As discussed previously, the main flow of pollutant is based on calculated, rather than measured flow rates. The actual calculations and field data are attached as Appendixes A and B. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used (except as indicated). It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 2.

TABLE 1

Boiler 3 - Highland Power
SUMMARY OF RESULTS

Date	7/15/75	7/16/75			
Stack Flow Rate - SCFM * dry	15182	16962			
% Water Vapor - % Vol.	8.798	8.55			
% CO_2 - Vol % dry	14.0	11.8			
% O_2 - Vol % dry	4.3	5.2			
% Excess air @ sampling point	24.7	30.8			
SO_2 Emissions - lbs/10^6 Btu	5.9				
NO_x Emissions - lbs/10^6 Btu	0.17	0.24			
H_2SO_4 Mist - lbs/10^6 Btu	0.04				
Particulates Probe, Cyclone, & Filter Catch lbs./hr.	16.08				
lbs/10^6 Btu	0.22				
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	92.67				

*70° F, 29.92" Hg
Calculated, dry

TABLE 2

COMPARISON OF RESULTS

Pollutant	Standard lbs/10^6BTU	Found lbs/10^6BTU
SO_2	1.8	5.9
NO_x	no standard for sources < $250x10^6$BTU/hr	0.19
Particulates	0.23	0.22

The only minor constituent measured during this test was sulfuric acid mist which was determined to be 0.04 lbs/10^6 BTU.

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Tables 3 and 4 and Figure 7. The high percentage of particles less than 0.5 microns in diameter is probably spurious. Microscopic examination indicates the presence of large ammonium sulfate particles, which apparently were performed by subsequent reactions of ammonia with sulfuric acid. The latter, present in vapor form at stack temperature, was apparently retained by the glass fiber filter. The results for the first few plates on runs 2 and 3 are misleading since the cyclone was ahead of the Andersen impactor and it fairly effectively removes the larger particles.

Some of the photomicrographs are included for illustration. Figure 8 is of the total particulate filter from the run on 15 July. It shows bits of unburned to partially burned coal and sulfate needles. Figure 9 is from stage 5 of the impactor and shows small carbonaceous particles and sulfates, which are the white, shiny areas. Figure 10 is from stage 6 of the impactor and shows less carbonaceous particles and much more sulfate particles. The sulfate particles are definitely recrystallized on the filter since they follow filter fibers and are much larger than the impactor plate holes would allow.

TABLE 3

PARTICLE SIZE DETERMINATION

Test: No. 1 HIGHLAND POWER Date: July 16, 1975

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.4711	20.4745	3.4			5.6	100.0	13.12 & ABOVE
2	21.4703	21.4755	5.2			8.7	94.4	8.96
3	21.6021	21.6108	8.7			14.5	85.7	6.02
4	22.5136	22.5178	4.2			7.0	71.2	4.61
5	11.7377	11.7412	3.5			5.8	64.2	2.64
6	11.4886	11.4904	1.8			3.0	58.4	1.34
7	11.7399	11.7418	1.9			3.1	55.4	0.83
8	21.4084	21.4150	6.6			11.0	52.3	0.55
Back Up Filter				24.8		41.3	41.3	<0.55
		Total	35.3	24.8	60.1	100.0		

Test: No. 2 Date: July 16, 1975

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.1914	20.1918	0.4			1.8	100.0	12.64 & ABOVE
2	21.3706	21.3707	0.1			0.4	98.2	7.96
3	21.6880	21.6884	0.4			1.8	97.8	5.27
4	22.3718	22.3721	0.3			1.3	96.0	3.86
5	11.6965	11.6972	0.7			3.1	94.7	2.34
6	11.6807	11.6813	0.6			2.6	91.6	1.17
7	11.6864	11.6876	1.2			5.3	89.0	0.71
8	20.9210	20.9251	4.1			18.1	83.7	0.48
Back Up Filter				14.8		65.6	65.6	<0.48
		Total	7.8	14.8	22.6	100.0		

TABLE 4

PARTICLE SIZE DETERMINATION

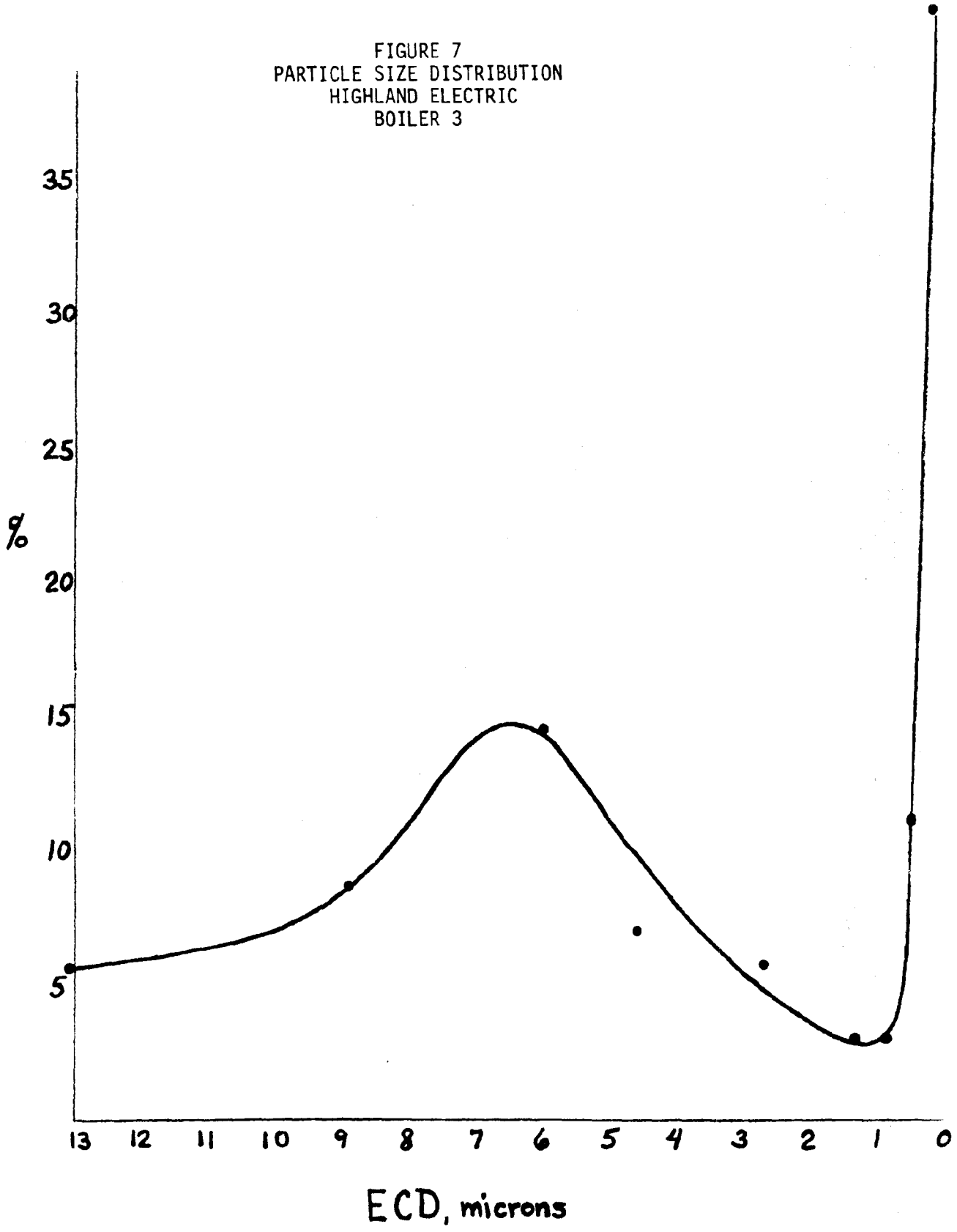
Test: No.3 Highland Power Date: July 16, 1975

Plate	Tare(g)	Final(g)	Net(mg)	Plate ~~Filter~~ Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1436	0.1442	0.6	1.1	1.7	4.8	100.0	12.87 & ABOVE
2	0.1496	0.1498	0.2	1.4	1.6	4.5	95.2	8.07
3	0.1452	0.1457	0.5	0.8	1.3	3.6	90.7	5.85
4	0.1476	0.1482	0.6	1.1	1.7	4.8	87.1	3.98
5	0.1480	0.1490	1.0	0.8	1.8	5.0	82.3	2.34
6	0.1502	0.1512	1.0	0.9	1.9	5.3	77.3	1.18
7	0.1497	0.1525	2.3	1.0	3.3	9.2	72.0	0.75
8	0.1470	0.1538	6.8	0.7	7.5	21.0	62.8	0.49
Back Up Filter	0.2110	0.2232	12.2	2.7	14.9	41.8	41.8	<0.49
		Total	25.2	10.5	35.7	100.0		

Test: Date:

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1				0.6		2.4	100.0	12.87 & ABOVE
2				0.2		0.8	97.6	8.07
3				0.5		2.0	96.8	5.85
4				0.6		2.4	94.8	3.98
5				1.0		4.0	92.4	2.34
6				1.0		4.0	88.4	1.18
7				2.3		9.1	84.4	0.75
8				6.8		27.0	75.3	0.49
Back Up Filter				12.2		48.3	48.3	<0.49
		Total		25.2		100.0		

FIGURE 7
PARTICLE SIZE DISTRIBUTION
HIGHLAND ELECTRIC
BOILER 3



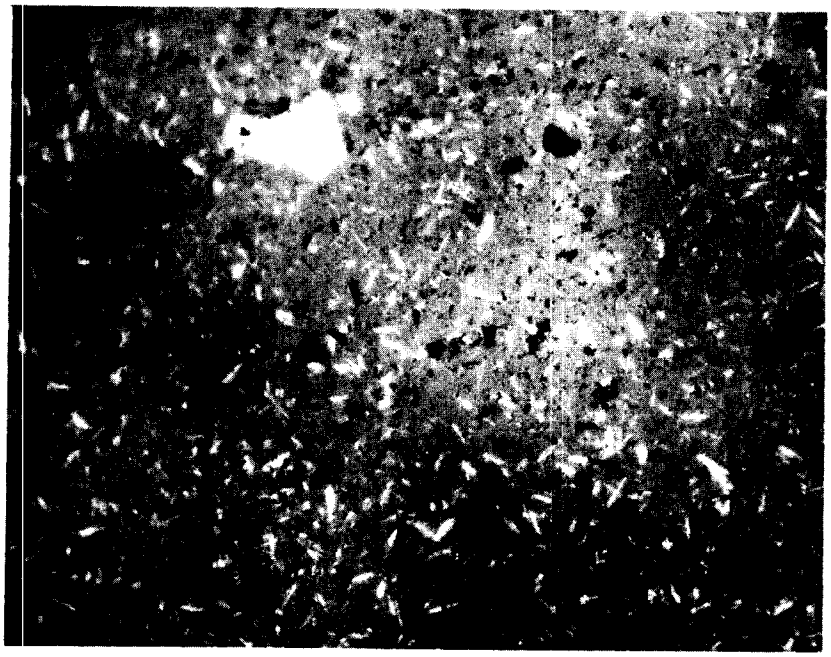


FIGURE 8

TOTAL PARTICULATE FILTER

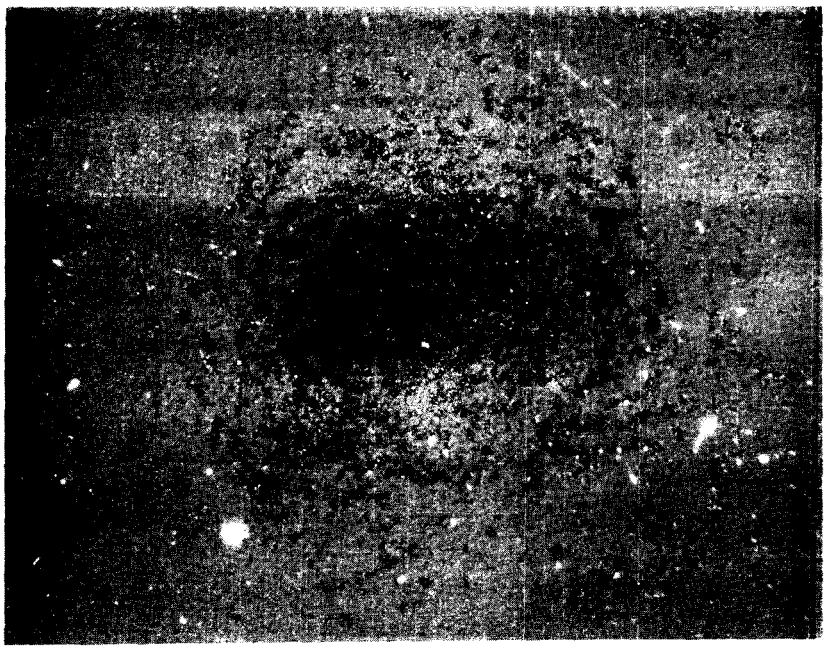


FIGURE 9

SMALL CARBONACEOUS PARTICLES AND SULFATES FROM STAGE 5 OF ANDERSEN IMPACTOR. WHITE SHINY PARTICLES ARE SULFATES.

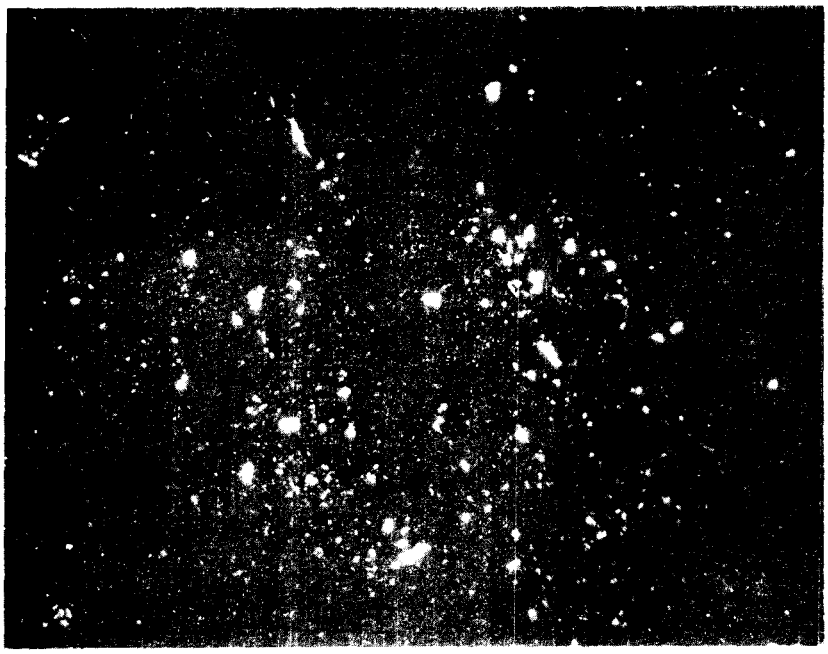


FIGURE 10

CARBONACEOUS PARTICLES AND SULFATES FROM STAGE 6 OF ANDERSEN IMPACTOR. NOTE INCREASE IN AMOUNT OF SULFATE FROM STAGE 5 TO STAGE 6.

Figure 11 is the backup filter for the impactor and it shows mostly sulfates with some very fine carbonaceous particles. Figure 12 is of material collected in the cyclone. There are a large variety of particle sizes, although somewhat misleading due to agglomeration of particles, and there is the presence of fused and partially fused glassy material and minerals.

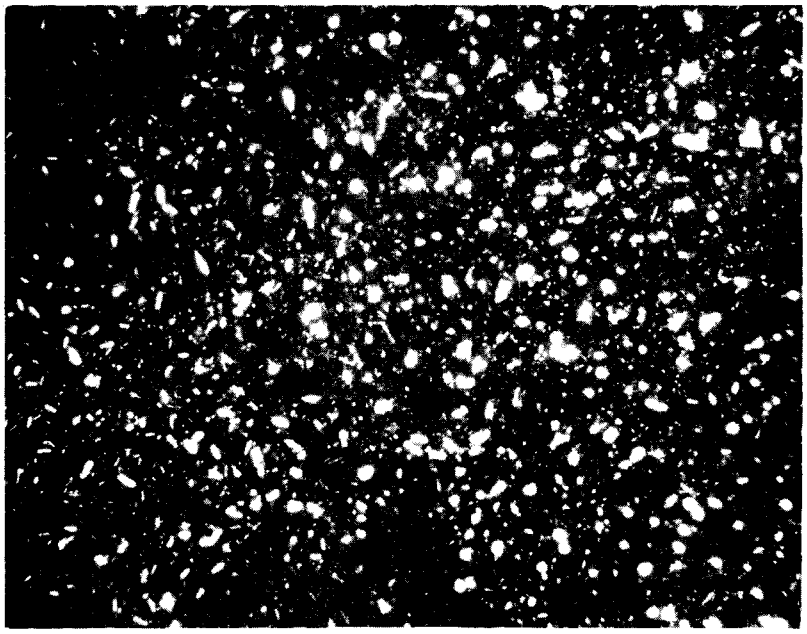


FIGURE 11
ANDERSEN IMPACTOR BACK-UP FILTER SHOWING VERY FINE CARBONACEOUS MATERIAL AND A GREAT NUMBER OF SULFATE CRYSTALS.

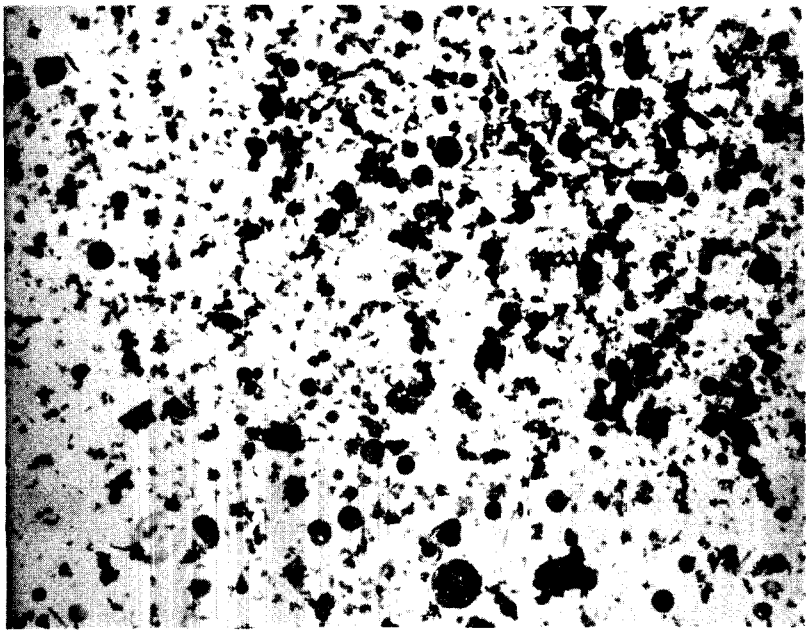


FIGURE 12
CYCLONE COLLECT. NOTE AGGLOMERATION AND PARTICULARLY THE SPHERES OF FUSED GLASSY PARTICLES.

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{o} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{o} R or 70^{o} F

Tm = Meter temperature, 530^{o} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{lc}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times V_{lc}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{lc} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{o}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%\ O_2 \times \frac{32}{100}\right) + \left(\%\ N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \%\ M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P\ avg.}{Ps \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb.\ Mols - {}^oR}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^oR

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s\ A\left(\frac{Tstd}{Ts}\ \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = 1.667 \frac{\left[(0.00267) \quad V_{lc} \quad + \quad \frac{V_{mc}}{T_m} \left(P_B \quad + \frac{\Delta H}{13.6} \right) \right] T_s}{\Theta \; V_s \; P_s \; A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454 \text{ gm.}}$$

Θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \quad X \quad 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$$

C_s = particulate emission, lb/scf

$2.205 \; X \; 10^{-6}$ = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \; X \; Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: # 1 Date: 7/15/75

Material collected (mg) =

Filter Catch = 0.2338
Dry Catch = 0.6037
Acetone Wash = 0.0992
0.9367
TOTAL = 936.7 mg

Gas Volume $V_{m_{std}} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334\frac{(118.006)}{1.021}\left(30.20 + \frac{1.60}{13.6}\right) = 117.036$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474\ (238.2\ ml) = 11.291$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(11.291)}{(117.056) + (11.291)} = 8.798\ \%$

Molecular Weight of dry stack gas

MW $MW_D = \%\ CO2 \times 0.44 + \%02 \times 0.32 + \%N2 \times 0.28$

$(14.0 \times 0.44) + (4.3 \times 0.32) + (81.7 \times 0.28) = 30.412$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.198}{100} \times 30.412\right] + \left[\frac{8.198}{100} \times 18\right] = 29.3196$

PARTICULATE SAMPLING CALCULATIONS

Test: Highland - #3 Boiler Date: 7/15/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times MW_w}\right] 1/2$

$85.48 \times (0.85) \left[\frac{985 \times 0.267}{30.20 \times 29.320}\right] 1/2 =$ 34.598 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(8.798)}{100}\right](39.598)\ (19.63)\ \frac{530}{(985)}\ \frac{(30.2)}{29.92} =$ 1,386,071 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(936.7)}{(117.036)} =$ 1.7647×10^{-5} lb/scf

$C_E = C_s \times Qs = (1.765 \times 10^{-5})\ (1,386,071) =$ 24.46 lb/hr

$C_H = C_E \div H = \frac{(24.46)}{(72.76)} =$ 0.336 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \dfrac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ Ps\ A_n}$

$1.667 \dfrac{\left[(0.00267)\ (238.2) + \frac{115.579}{530}\left(30.2 + \frac{1.6}{13.6}\right)\right](985)}{(140)\ (34.598)\ (30.2)\ (7.67 \times 10^{-4})} =$ 92.67%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$\frac{100\ (4.3)}{(0.266 \times 81.7) - (4.3)} =$ 24.7 %

STOICHIOMETRIC
FLOWRATE CALCULATION

Boiler #3

	Coal Composition		mols/100#		mols O_2 required
7/15/75	S	3.25%	÷ 32	x 1	= 0.102
	H_2O	12.89	÷ 18 = 0.716		
	Ash	10.98			
	Btu	10856 Btu/lb			
5/27/67	C	61.63%	÷ 12	x1	= 5.136
	H_2	4.37	÷ 2 = 2.185	x 0.5	= 1.093
	N_2	0.77	÷ 28 = 0.028		
	O_2	8.86	÷ 32	x -1	= -0.277
			Theoretical O_2		6.054
	Excess air = 24.7%		excess O_2		= 1.495
					7.549
	$N_2 = 3.76 \times O_2$				= 28.384

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 5.136 + 0.102 + 0.028 + 1.495 + 28.384 = 35.145 mols

Flue Gas = $35.145 \times 386.7 \frac{ft3}{mol}$ = 13590.6 SCF/100#

@ 6702.4 lb coal/hr = $6702.4 \times \frac{1}{100} \times 13590.6$ = 910,896 SCFH
= 15,182 SCFM

Sulfur Check - SO_2 emissions

by emission factor 6702.4 ÷ 2000 x 38 x 3.25 = 413.9 #/hr SO_2

using calculated flow

$$910{,}896 \times 4.75 \times 10^{-4} \frac{lb}{SCF} = 432.6 \text{ \#/hr } SO_2$$

NO_x EMISSION DATA

Date 7/15/75

Run No.	1	2	3	4	5	6	7	8
Time	0915	1005	1053	1110	1300	1340	1400	1400
µg NO_2	492	428	408	326	428	183	326	346
T_i- Initial Flask Temp, ^oF	90	—	—	—	—	—	—	—
T_f- Final Flask Temp, ^oF	120	—	—	—	—	—	—	—
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2054	2057
P_i- Initial Flask Pres, "Hg	2.55	—	—	—	—	—	—	—
P_f- Final Flask Pres, "Hg	30.2	—	—	—	—	—	—	—
lb/scf NO_2 $\times 10^{-5}$	1.771	1.548	1.475	1.185	1.558	0.657	1.170	1.246
lb/10^6Btu NO_2	0.22	0.19	0.18	0.15	0.20	0.08	0.15	0.16

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\text{µg/ml}} \left(\frac{\text{µg } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 7/16/75

Run No.	1	2	3	4				
Time	0945	1320	1350	1350				
µg NO_2	552	472	552	472				
T_i- Initial Flask Temp, ^oF	90	—	—	—				
T_f- Final Flask Temp, ^oF	120	—	—	—				
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028				
P_i- Initial Flask Pres, "Hg	2.55	—	—	—				
P_f- Final Flask Pres, "Hg	30.2	—	—	—				
lb/scf NO_2 $\times 10^{-5}$	1.987	1.707	1.996	1.715				
lb/10^6Btu NO_2	0.26	0.22	0.26	0.23				

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\text{µg/ml}} \left(\frac{\text{µg } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	7/15	7/15	7/15			
Run No.	1	2	1+2			
V_{mc}-Meter Volume, Ft^3	6.237	5.751	11.988			
Vmstd-Meter Volume, Std. Cond.	6.163	5.683	11.846			
P_B-Barometric Pressure, "Hg	30.2	30.2				
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1	0.1				
V_t-Vol. of Titrant, ml.	1.8	1.8	31.92			
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil	nil			
Vsoln-Vol. of Solution, ml.	250	250	250			
V_a-Vol. of Aliquot, Titrated, ml.	25	25	1.0			
lb/scf H_2SO_4 $\times 10^{-6}$	3.15	3.42				
lb/10^6 Btu H_2SO_4	0.04	0.04				
lb-scf SO_2 $\times 10^{-4}$			4.75			
lb/10^6 Btu SO_2			5.9			

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = \text{lb/scf}$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = \text{lb/scf}$$

APPENDIX B

FIELD DATA

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number		7/15/75	7/16/76		
Net Unit Load - ~~MW~~ KW		4188.9	4457.1		
Boiler Heat Rate - BTU/KW hr.					
Boiler Heat Input - 10^6 BTU/hr.		72.76	77.4		
Emission Level - lb./10^6 BTU					
	Particulates				
	SO_2				
	VO_x				
Fuel Heating Valve - BTU/lb.		10856	10856		
Fuel Burning Rate During Test - lb./hr.		6702.4	7131.4		
Fuel Ash Content - %		10.98	10.98		
Additive Rate - lb/hr.					

7/15

time	KW
9	4600
10	4400
11	4200
12	4200
1	4200
2	4000
3	4000
4	4000
5	4100
	4188.9

7/16

time	KW
9	5000
10	4200
11	4200
12	4300
1	4300
2	4600
3	4600
	4457.1

Fuel Consumption Basis: 1.6 lb Coal / 1 KW

Calculated Flow Rates: 7/15 910,896 SCFH

7/16 1,017,736 SCFH

ORSAT FIELD DATA

Location Highland, Ill. Comments:

Date 7-15-75

Time

Operator Klein

	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
7-15-75	0845 hrs	14.0/14.0	18.2/4.2	18.2/0.0
	1235 hrs.	14.0/14.0	18.4/4.4	18.4/0.0
7-15-75	1005 hrs.	11.4/11.4	16.0/4.6	16.0/0.0
	1330 hrs.	12.2/12.2	18.0/5.8	18.0/0.0

Plant HIGHLAND POWER CO.

Run No. 1

Location #3 BOILER STACK

Date 7/15/75

Operator GIBISCOM/KLEIN

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor 0.55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.2

Assumed Moisture % 8

Heater Box Setting °F 310°

Probe Tip Dia., In. 3/8

Probe Length 5FT. GLASS

Probe Heater Setting 310°

Avg. ΔP .18 Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:06	746.091	0.02	0.12	0.13	200	75	1.0	310	245	0.22	195
2	11	747.50	.08	.47	.47	225	70	3.0	305	310		505
3	16	749.95	.12	.74	.74	245	70	4.3	320	322		550
4	21	753.1	.12	.74	.74	265	70	4.3	340	310		560
5	26	756.1	.20	1.20	1.20	280	72	7.0	335	325		510
6	31	759.9	.12	.74	.74	285	73	4.3	325	320		565
7	36	763.0	.12	.74	.74	285	75	4.3	320	320		560
8	41	766.5	.35	2.20	2.20	285	76	12.0	335	340		560
9	46	770.8	.37	2.3	2.25	310	77		360	360		560
10	51	775.8	.40	2.5	2.25	315	82		370	340		560
11	56	780.9	.40	2.5	2.25	320	83	13.0	365	330		560
12	01	785.8	.35	2.2	2.20	320	84	13.0	360	335		560
13	06	790.9	.34	2.1	2.10	320	85		350	330		560
14	11	795.4	.35	2.2	2.20	320	87	13.0	335	320		560
OFF	11:16	800.853										

Plant HIGHLAND Power Co.

Run No. 1

Location #3 Boiler Stack

Date 7/15/75

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ _____

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F _____

Bar. Press. "Hg _____

Assumed Moisture % _____

Heater Box Setting °F _____

Probe Tip Dia., In. _____

Probe Length _____

Probe Heater Setting _____

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-1	12:44	800.858	0.20	1.2	1.2	200	80	8.0	315	280		280
2	49	804.6	.24	1.4	1.4	252	68	8.5	320	315		510
3	54	808.8	.24	1.4	1.4	275	70	8.5	325	325		550
4	59	813.0	.24	1.4	1.4	280	75	8.5	345	330		550
5	04	817.1	.26	1.52	1.5½	290	75		350	335		
6	09	821.5	.30	1.8	1.8							
7	14	826.3	.34	2.0	2.0	290	78	12.5	340	325		550
8	19	831.1	.34	2.0	2.0	290	79		340	330		550
9	24	836.1	.30*	2.0	2.0							
10	29	840.8	.29	2.3	2.1	295	75		355	355		550
11	34	845.5	.35	2.1	2.1	320	75	13.5	355	348		550
12	39	850.3	.34	2.0	2.0	310	78		360	360		545
13	44	855.0	.34	2.0	2.0	315	78	13.5	365	365		540
2-14	49	859.6	.30	1.8	1.8	315	80	12.0	360	325		530
2-15	1:54	864.152										

PARTICULATE CLEANUP SHEET

Date: 7/15/75 Plant: HIGHLAND POWER CO.

Run Number: 1 Location Of Sample Port: 30' ABOVE GND. IN STACK

Operator: _____ Barometric Pressure: 30.20 IN. Hg

Sample Box No. _____ Ambient Temperature 90° F

Impinger H_2O Silica Gel

Volume After Sampling 401 ml Weight After 537.2 g

Impinger Prefilled With 200 ml Weight Before 500.0 g 300 TARE

Volume Collected 201 ml Moisture Weight 37.2 g Moisture Total 238.2 g

---

Dry Probe and Cyclone Catch: Container No.: _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.7029 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
11				Filter Particulate Weight 0.2338 g
				Total Particulate Weight 0.9367 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 7-15-75

Plant Highgate Electric Boiler #3

Sample Collected By Klein

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	9:15	10:06	10:51	11:18	1:00	1:40	2:00	2:[illegible]
Flask number	1	2	3	4	5	6	9	10
Volume of flask less correction (ml)	2047	2038	2039	2028	2025	2052	2054	2037
Pressure before sampling ~~in.~~ cm Hg.	6.5	6.5	6.0	5.8	6.3	6.2	6.5	6.3
Pressure after sampling, in. Hg (atm)	30.20	30.20	30.20	30.20	30.20	30.20	30.20	30.[illegible]
Flask temperature, °F	90	90	90	90	90	90	90	90

OXIDES OF NITROGEN FIELD DATA

Date 7/16/75

Plant HIGHLAND ELECTRIC

Sample Collected By _____

Run No. _____

Power Stat Setting _____

Field Data

Clock Time	0945	1320	1350	1350				
Flask number	1	2	3	4				
Volume of flask less correction (ml)	2047	2038	2039	2028				
Pressure before sampling ~~in.~~ CM Hg.	6.5	6.5	6.5	6.5				
Pressure after sampling, in. Hg.	30.2	30.2	30.2	30.2				
Flask temperature, °F	90	90	90	90				

GAS SAMPLING FIELD DATA

Material Sampled For H_2SO_4 & SO_2

Date 7-15-75

Plant Highland Electric Co. Location Boiler #3

Bar. Pressure 30.2 "Hg Comments:

Ambient Temp 95 °F

Run No 1 Point 2-7

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom / Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O Δ H	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
3:35	864.102	0.30	0.1	570	290	70 °C	140 °F	90 °F
3:40	865.1	0.32	0.1	560	305		150 °F	85 °F
3:45	866.3	0.34	0.1	560	310	74 °C	135 °F	85 °F
3:50	867.3	0.34	0.1	550	320	71 °C	135 °F	88 °F
3:60	869.5	0.30	0.1	550	315		125 °F	90 °F
4:05	870.339							

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For H_2SO_4 & SO_2

Date 7-15-75

Plant Highland Location Stack 3

Bar. Pressure 30.2 "Hg Comments:

Ambient Temp 95 °F

Run No 2 Point 2-7

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom / Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
4:18	870.339	0.30	0.1	550	320°F	53°C	130°F	95°F
4:23	871.3	0.30	0.1	550	320°F		155°F	90°F
4:28	872.5	0.34	0.1	550	330°F	82°C	185°F	92°F
4:33	873.35	0.38	0.1	560	335°F		185°F	92°F
4:38	874.25	0.38	0.1	560	340°F	80°C	150°F	130°F
4:43	875.20	0.36	0.1	560	340°F		140°F	135°F
4:48	876.090					75°C		

Comments:

Anderson Particle Size Test

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Highland

Run No. 1

Location Boiler #3 Stack

Date 7-16-75

Operator Griscom/Klein

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor 0.52

backup filter #6

Ambient Temp °F 80

Bar. Press. "Hg 30.20

Assumed Moisture % 10

Heater Box Setting °F _____

Probe Tip Dia., In. 3/8

Probe Length 5 ft. steel

Probe Heater Setting _____

Avg. ΔP 0.32 Avg. ΔH 1.7

Point	Clock 20 min.	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-9	10:25	876.093	0.32		1.4	230	68	16.5	320			545
	:30	880.1		1.7	1.2	235	65		325			
	:35	883.8			1.1	255	70		335			
	:40	887.3			1.05	265	74	17.0	340			
off	10:45	890.962			1.05							

Anderson sampler in stack in center probe used.

Anderson Particle Size Test

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Highland Electric
Run No. 2
Location Boiler #3 Stack
Date 7-16-75
Operator Griscom / Klein
Sample Box No. _____
Meter Box No. _____
Meter ΔH@ 1.022
C Factor .56

Backup Filter #5

Ambient Temp °F 90
Bar. Press. "Hg 30.2
Assumed Moisture % 8
Heater Box Setting °F 340 @ 6
Probe Tip Dia., In. 3/8
Probe Length 5 ft. steel
Probe Heater Setting _____
Avg. ΔP 0.2 Avg. ΔH 1.2

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
			assume	Desired	Actual	Inlet	Outlet					assume
2-12	1252	891.270	0.20	1.3					340			550
	1253	892.?			1.3				340			
	1255	894.0			1.3				340			
	1257	895.4			1.3				335			
	1259	897.1			1.3				335			
	1301	898.7			1.3				335			
	1303	900.1			1.3				335			
		900.21										

Anderson Sampler in over traction plane. Use unheated probe

Andersen Particle Size Test

PARTICULATE FIELD DATA

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant *Highland Electric*

Run No. *3*

Location *Boiler #3 Stack*

Date *7-16-75*

Operator *Griscom/Klein*

Sample Box No. ______

Meter Box No. ______

Meter Δ H@ ______

C Factor ______

Backup Filter #4

Ambient Temp °F *90*

Bar. Press. "Hg *30.2*

Assumed Moisture % *8*

Heater Box Setting °F ______

Probe Tip Dia., In. *3/8*

Probe Length *5 ft. steel*

Probe Heater Setting ______

Avg. Δ P ______ Avg. Δ H ______

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
			assume	Desired	Actual	Inlet	Outlet					*assume*
2-12	*0*	*900.210*	*0.2*	*1.3*					*280*			*560*
	2	*902.8*			*1.3*		*70*		*320*			
	4	*903.3*			*1.3*				*325*			
	6	*905.9*			*1.3*				*325*			
	8	*906.4*			*1.3*		*70*		*330*			
	10 min	*907.9[illegible]*										

PARTICULATE CLEANUP SHEET

Date: 7/16/75 Plant: HIGHLAND ELECTRIC

Run Number: Andersen 1,2,3 Location Of Sample Port: #3 Boiler Stack

Operator: _____ Barometric Pressure: _____

Sample Box No. _____ Ambient Temperature _____

Impinger H_2O Silica Gel

Volume After Sampling 252 ml Weight After 509.5 g

Impinger Prefilled With 200 ml Weight Before 500.0 g

Volume Collected 52 ml Moisture Weight 9.5 g Moisture Total 61.5 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 261.5 mg

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Filter Particulate Weight 118.4 mg

Total Particulate Weight 379.9 mg

~~% Moisture By Volume~~ Particulate Concentration

$V_{m\,std} = (14.869 + 8.994 + 7.75) \times 0.0334 \div 1.021 \times \left(30.2 + \frac{1.3}{13.6}\right) = 31.178$

$C_s = 2.205 \times 10^{-6} \left(\frac{379.9}{31.178}\right) = 2.69 \times 10^{-5}$ lb/scf

% Moisture $0.0474 \times 61.5 = 2.915$

$100 \times \frac{2.915}{(21.178 + 2.915)} = 8.55\%$

PRELIMINARY

SOURCE TEST REPORT

CARLING BREWING CO. - STAG BREWERY

BELLEVILLE, ILLINOIS

BOILER NO. 1

4 NOVEMBER 1975

TESTED BY: Rockwell International

R.W. Griscom

O.C. Klein

F.E. Littman

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TABLES

FIGURES

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report summarizes the results obtained on boiler No. 1 at the Stag Brewery in Belleville, Illinois. Some work remains on the combustion efficiency of the unit to better clarify some of the obtained results. A final report will be issued at that point.

The stack testing included the following pollutants: SO_2, particulates, NO_x, H_2SO_4, and hydrocarbons. Orsat analysis for CO_2, CO, and O_2 were also performed. Results of these tests are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the particulate emissions and the SO_2 emissions are just slightly above the limits.

We acknowledge and appreciate the excellent cooperation we obtained from the officials of the Stag Brewery.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Stag Brewery in Belleville, Illinois. Testing was performed on boiler No. 1 on 11, 12 and 13 August and 15, 16 and 20 October 1975.

Boiler No. 1 is a coal fired, 50,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen and hydrocarbons.

3.0 PROCESS DESCRIPTION

Boiler No. 1 was built by Henry Vogt Boiler Co. and was installed in 1939. It is equipped with a gravity fed, traveling grate stoker. Steam pressure is maintained at approximately 125 psi. The firing rate of the boiler is directly controlled by the steam requirements of the brewery. As a result, there is a considerable fluctuation in the steam load throughout the day. Boiler No. 1 is a natural draft unit and has no stack emission controls. The stack is of brick construction and is 225 feet tall and 8 feet inside diameter.

4.0 SOURCE TEST DESCRIPTION

Boiler No. 1 was tested in the ductwork between the boilers and the stack. This is a common duct for both boilers 1 and 2, however, boiler No. 2 was not in operation at the time of testing. The sampling location is illustrated in Figure 1.

The duct at this point is 52.5 inches wide by 102 inches deep. The cross-section of the duct at this point is not rectangular since fly ash is deposited at the bottom and sloped to one side. Sample points were chosen accordingly to avoid sticking the probe into this fly ash. In accordance with the EPA Standard Method 1, thirty-five sampling points were chosen, seven at each of five sampling ports. Five, 4-inch pipe nipples were installed on the duct for use as sampling ports.

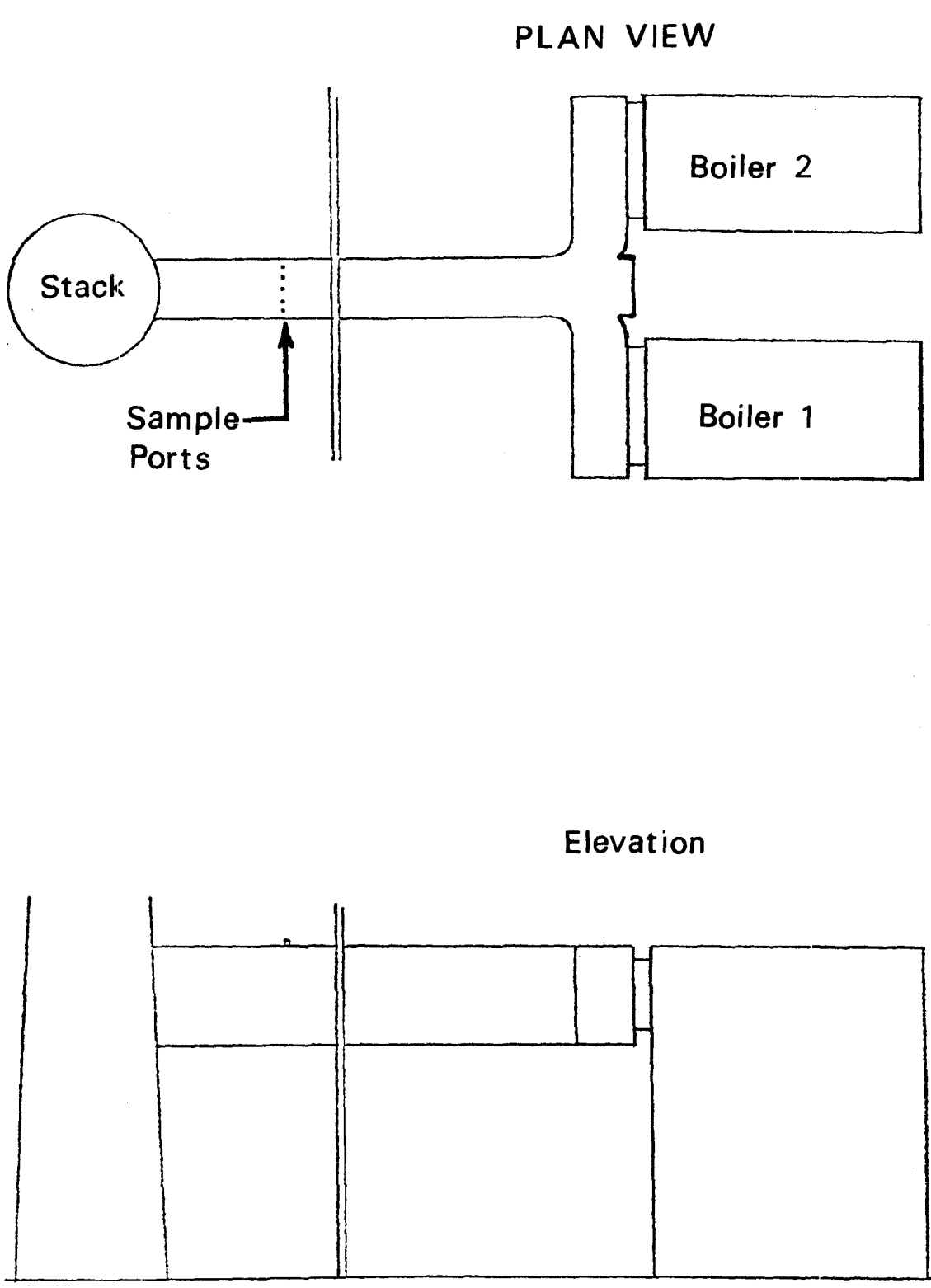

FIGURE 1

SAMPLING LOCATION FOR BOILER NO. 1

5.0 PROCESS OPERATION

As mentioned previously, the firing rate on this boiler is determined by the steam requirements of the plant operation. As a consequence, load fluctuations of up to 100% occurred. During testing on 16 October, the boiler load was reduced considerably since no brewing operations were taking place that day. The load that day remained very constant. Ashes are pulled approximately once an hour. At those times the flow rate in the ductwork increased.

During testing in August, high sulfur coal was being burned; in October low sulfur coal, (1% S), was used.

6.0 DISCUSSION

Flow determinations were made in accordance with EPA Standard Method 2, using an S-Type Pitot Tube. This method gives correct results as long as the pitot tube is positioned normally to the flow of gases. This is no problem as long as the flow of gases is laminor and parallel to the walls of the ducts. However, if the flow is turbulent or vortex-type, the readings obtained are incorrect, with a positive bias (too high). The existence of a turbulent condition can be ascertained by turning the pitot tube 90^{0} on its axis. A zero reading should then result. If no zero reading is obtained, the results are open to question.

In the duct being tested, the existence of turbulence was evident by the fact that a zero reading could not be obtained except on 16 October when the boiler was operated under reduced load. Actually, the flow rate on that day was not much lower than under full load conditions, but the gases consisted of a large excess of air and little combustion products. As a result, the flue gas temperature was lower.

Under conditions when satisfactory flow measurements cannot be obtained, a stoichiometric calculation of flow rates can be made, based on fuel consumption, fuel composition, combustion rate and excess air. As a check on the correctness of the assumption, the mass flow of SO_2 can be calculated based on gas flow and SO_2 concentration on one hand, and fuel consumption and sulfur analysis on the other. The conversion of sulfur in coal to SO_2 is straightforward and occurs with 95% efficiency.

To determine the amount of coal consumed, the steam output and a boiler efficiency were used to calculate coal consumption. The boiler efficiency was determined by comparing steam output to coal usage on thirteen high production day shifts. By this method an efficiency of 82.5% was determined.

Table 1 shows the comparison of the results obtained by the two methods.

TABLE 1
COMPARISON OF FLOW RATE DETERMINATIONS

DATE	FLOW RATE, SCFH Measured	Calculated	SO_2 (lbs/hr) BASED ON AP-42*	Calculated Flow	Measured Flow
8/12	1,394,989	782,909			
10/20		736,170	74.9	81.4	
10/20		776,420	79.0	91.1	

* Compilation of air pollutant.
Emission Factors, EPA Publ. No. AP-42

A small problem still remains in that these SO_2 emissions are still higher than predicted by emission factors. There is evidence to believe that the combustion efficiency of this boiler is very poor. If this is the case, then some amount of coal goes unburned. The stoichiometric flow rate determination is based upon complete combustion of the coal and, therefore, the actual flow rate would be less if combustion is not complete and the SO_2 emissions would be closer to the predicted results. This assumption will be evaluated shortly with a coal and ash analysis. Following this test, a final report on this installation will be completed.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods. The following EPA methods were utilized during testing:

Method 1: Sample and Velocity Traverse
Method 2: Volumetric Flow Rate Determination
Method 3: Gas Analysis by Orsat Method
Method 4: Stack Gas Moisture Determination
Method 5: Determination of Particulate Emissions
Method 7: Determination of Nitrogen Oxide Emissions

In addition, a modified method 8 using the "Shell Method for Sulfuric Mist" was used for sulfuric mist and sulfur dioxide. Particle size determinations were made using an Andersen fractionating, inertial impactor. Hydrocarbon grab samples were taken.

8.0 RESULTS

The results obtained from this test are summarized in Table 2. As previously discussed, the pollutant emissions are based on calculated, rather than measured, flow rates. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used. It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 3.

Since the measured flow rate is higher than the calculated flow rate, the testing for particulates was apparently conducted at greater than isokinetic conditions and the results are then higher than they should be. For this reason, it would appear that for the testing on 12 August, this boiler is very nearly within compliance.

The results of a sample taken on 6 August for hydrocarbon was:

Carbon Monoxide:	8.93 ppm
Methane:	0.33 ppm
Total Hydrocarbons, as CH_4:	6.97 ppm

The results of another sample for hydrocarbons taken on 11 August are given in Table 6. The total amounts to 7.14 ppm.

TABLE 2

SUMMARY OF RESULTS

Date	8/11	8/12	10/15	10/16	10/20
Stack Flow Rate - SCFM * dry	13048	13048	13604	12359	12605
% Water Vapor - % Vol.		9.02		4.7	
% CO_2 - Vol % dry		10.5	9.3	5.6	11.55
% O_2 - Vol % dry		10.4	10.8	14.8	8.7
% Excess air @ sampling point		97.7	103.3	232.2	69.5
SO_2 Emissions - lbs/10^6 Btu			2.4		2.35
NO_X Emissions - lbs/10^6 Btu	0.36	0.31			
H_2SO_4 Mist - lbs/10^6 Btu					0.031
Particulates Probe, Cyclone, & Filter Catch lbs./hr.		37.03		7.46	
lbs/10^6 Btu		0.95		0.37	
Total Catch lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling					

*70^o F, 29.92" Hg

TABLE 3

COMPARISON OF RESULTS

POLLUTANT	ILLINOIS STATE STANDARDS lbs/10^6 BTU	FOUND lbs/10^6 BTU
SO^2	1.8	2.4, 2.3, 2.4
NO_X	No standard for sources <250 X 10^6 BTU/hr	0.36, 0.31
Particulates 8/12 10/16	0.28	0.95 0.37

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Tables 4 and 5.

TABLE 4

PARTICLE SIZE DETERMINATION

TEST: STAG - ANDERSEN #1 DATE: 8/13

PLATE	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	13.7			18.6	18.6	12.28 & Above
2	10.6			14.3	32.9	7.72
3	6.4			8.7	41.6	5.15
4	4.9			6.6	48.2	3.63
5	2.6			3.5	51.7	2.23
6	3.1			4.2	55.9	1.15
7	1.5			2.0	57.9	0.70
8	10.9			14.8	72.7	0.47
BACK UP FILTER	20.2			27.3	100.0	<0.47
TOTAL	73.9			100.0		

TEST: STAG - ANDERSEN #2 DATE: 8/13

PLATE	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	9.4			14.6	14.6	12.28 & Above
2	6.4			9.9	24.5	7.72
3	5.2			8.1	32.6	5.15
4	4.3			6.7	39.3	3.63
5	3.0			4.6	43.9	2.23
6	2.6			4.0	47.9	1.15
7	3.0			4.6	52.5	0.70
8	6.8			10.5	63.0	0.47
BACK UP FILTER	23.9			37.0	100.0	<0.47
TOTAL	64.6			100.0		

TABLE 5

PARTICLE SIZE DETERMINATION

TEST: STAG - ANDERSEN #3 DATE: 8/13

PLATE	NET(mg) PLATE	NET(mg) FILTER	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	3.3	16.1	19.4	25.2	25.2	12.28 & Above
2	2.5	5.0	7.5	9.7	34.9	7.72
3	2.1	4.3	6.4	8.3	43.2	5.15
4	1.8	2.3	4.1	5.3	48.5	3.63
5	1.2	2.0	3.2	4.2	52.7	2.22
6	1.5	1.4	1.9	2.5	55.2	1.12
7	1.7	6.1	7.8	10.1	65.3	0.69
8	2.0	7.2	9.2	11.9	77.2	0.46
BACK UP FILTER		17.6	17.6	22.8	100.0	<0.46
TOTAL	16.1	62.0	77.1	100.0		

TEST: STAG - ANDERSEN #3 DATE: 8/13

PLATE	TARE(g)	FINAL(g)	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM%	ECD (MICRONS)
1				16.1		26.0	26.0	12.28 & Above
2				5.0		8.1	34.1	7.72
3				4.3		6.9	41.0	5.15
4		FILTERS ONLY		2.3		3.7	44.7	3.63
5				2.0		3.2	47.9	2.22
6				1.4		2.3	50.2	1.12
7				6.1		9.8	60.0	0.69
8				7.2		11.6	71.6	0.46
BACK UP FILTER				17.6		28.4	100.0	<0.46
TOTAL				62.0		100.0		

TABLE 6

HYDROCARBON ANALYSIS

TEST: STAG #1 DATE: 8/11/75 TIME:

COMPOUND	CONCENTRATION(ppb)
Ethane	76.6
Propane	57.3
Isobutane	46.5
1-Butene	29.2
n-Butane	28.2
Isopentane	4.9
1-Pentene	2.5
n-Pentane	5.4
2-methyl Pentane	3.4
2-Methyl, 1-Pentene	2.8
1-Hexene	38.3
n-Hexane	115.1
3,3-dimethyl, 1-Pentene	22.9
2,4-dimethyl Pentane & Benzene	34.4
1 methylcyclopentene & 2M C3 Hexene	10.4
Cyclohexane	4.9
2-methyl Hexane	1.8
3-methyl Hexane	2.9
1-Heptene	8.6
n-Heptane	12.2
Toluene	49.9
2,2,5-trimethyl Hexane	3.4
1-Octene	6.8
n-Octane	3.6
Ethylbenzene	37.3
meta, para Xylene	72.2
Orthoxylene	18.9
n-Nonane	6.3
N-Propylbenzene	4.7
1,3,4 Trimethyl Benzene	3.5

APPENDIX A

PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{o} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{o} R or 70^{o} F

Tm = Meter temperature, 530^{o} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{lc}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times V_{lc}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{lc} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{o}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%\ O_2 \times \frac{32}{100}\right) + \left(\%\ N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_w = \left(\frac{100 - \%\ M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P\ avg.}{Ps \times MW_w}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb.\ Mols - {}^oR}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^oR

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s\ A\left(\frac{Tstd}{Ts} \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667\left[(0.00267)\quad V_{lc} \quad + \quad \frac{V_{mc}}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\Theta\ V_s\ P_s\ A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454\ gm.}$$

Θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \quad X \quad 10^{-6}\left(\frac{M_n}{Vm_{std}}\right)$$

C_s = particulate emission, lb/scf

$2.205\ X\ 10^{-6}$ = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S\ X\ Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 Date: 8/12/75

Material collected (mg)

Filter Catch = 163.2
Dry Catch =
Acetone Wash = 1509.0

TOTAL = 1672.2

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{81.037}{1.01}\right)\left(29.30 + \frac{1.4}{13.6}\right) = 78.795$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474 (163 \text{ ml}) = 7.726$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(7.726)}{(78.795) + (7.726)} = 8.93\ \%$

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.5 \times 0.44) + (10.4 \times 0.32) + (79.1 \times 0.28) = 30.20$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.93}{100} \times 30.2\right] + \left[\frac{8.93}{100} \times 18\right] = 29.11$

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 Date: 8/12/25

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{997.7 \times 0.078}{29.37 \times 29.11}\right] 1/2 =$ 22,183 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(8.93)}{100}\right](22,183)\ (36.82)\ \frac{530}{(997.7)}\ \frac{(29.\ )}{29.92} =$ 1,396,369 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(1672.2)}{(78.795)} =$ 4.68×10^{-5} lb/scf

$C_E = C_s \times Qs = (4.68 \times 10^{-5})\ (1,396,369) =$ 65.35 lb/hr

$C_H = C_E \div H = \frac{(65.35)}{(54.12)} =$ 1.67 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)\ (163) + \frac{71.37}{530}\left(29.3 + \frac{1.4}{13.6}\right)\right](997.7)}{(102)\ (22,183)\ (29.37)\ (1.36 \times 10^{-3})} = 88.98\%$

Excess Air at Sample Point

$$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

$\frac{100\ (10.4)}{(0.266 \times 79.1) - (10.4)} =$ 91.7%

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1 8/12/75

	Coal Composition Peabody-River King		Mols/100#		Mols O_2 required
	S	3.25%	÷ 32	x 1	= 0.102
7/15/75	H_2O	12.89	÷ 18 = 0.716		
	Ash	10.98			
	Btu	10856 Btu/lb			
	C	6163	÷ 12	x 1	= 5.136
	H_2	4.37	÷ 2 = 2.185	x .5	= 1.093
	N_2	0.77	÷ 28 = 0.028		
5/27/67	O_2	8.86	÷ 32	x -1	= -0.277
				Theoretical O_2	6.054
	@ 97.7 % Excess air				= 5.915
					11.969
	$N_2 = 3.76 \times O_2$				= 45.003
					56.972

Mols Flue Gas = 5.136 + 0.102 + 5.915 + 45.003 + 0.028 = 56.184 mols

$$56.184 \times 386.7 \frac{ft^3}{mol} = 21726.4 \text{ SCF/100\# coal @ } 70^oF, 1 atm.$$

8/12/75 31.775×10^3 #/hr steam @ 82.5% boiler eff.

1193.8 Btu/# 125 psig; sat. steam

178.1 Btu/# 210°F water

1015.7 But/#

$$\frac{31.775 \times 10^3 \times 1015.7}{.825} = 3.91198 \times 10^7 \text{ Btu/hr input}$$

$3.91198 \times 10^7 \div 10856 = 3603.5$ #/hr coal

$3603.5 \times \frac{1}{100} \times 21726.4 = 782909.1$ SCFH, dry

NO_x EMISSION DATA

Date 8/11/75

Run No.	1	2	3	4	5	6		
Time	1200	1210	1415	1420	1425	1430		
µg NO_2	532	552	472	512	388	388		
T_i- Initial Flask Temp, ^oR	90	—	—	—	—	—		
T_f- Final Flask Temp, ^oR	120	—	—	—	—	—		
V_{fc}- Flask Volume, ml.	2047	2038	2037	2028	2025	2052		
P_i- Initial Flask Pres, "Hg	2.66	—	—	—	—	—		
P_f- Final Flask Pres, "Hg	29.26	—	—	—	—	—		
lb/scf NO_2 $\times 10^{-5}$	1.99	2.08	1.78	1.94	1.47	1.45		
lb/10^6Btu NO_2	0.40	0.42	0.36	0.39	0.29	0.29		

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 8/12/75

Run No.	1	2	3	4	5	6	9	10
Time	1215	1220	1520	1525	1530	1535	1550	1555
µg NO_2	408	428	-	388	346	346	444	490
T_i- Initial Flask Temp, ^oR	90	—	—	—	—	—	—	—
T_f- Final Flask Temp, ^oR	120	—	—	—	—	—	—	—
V_{fc}- Flask Volume, ml.	2072	2063		2053	2050	2077	2079	2082
P_i- Initial Flask Pres, "Hg	2.66	—	—	—	—	—	—	—
P_f- Final Flask Pres, "Hg	29.30	—	—	—	—	—	—	—
lb/scf NO_2 $\times 10^{-5}$	1.53	1.61		1.47	1.31	1.29	1.66	1.83
lb/10^6Btu NO_2	0.31	0.32		0.29	0.26	0.26	0.33	0.37

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

PARTICULATE SAMPLING CALCULATIONS

Andersen Runs 1, 2, 3

Test: Stag - Boiler #1 Date: 8/13/75

Material collected (mg)

Filter Catch	=	242.8
Dry Catch	=	
Acetone Wash	=	49.6
TOTAL	=	292.4

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{24.897}{1.01}\right)\left(24.3 + \frac{1.4}{13.6}\right) = 24.208$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474 \ (61.0 \text{ ml}) = 2.891$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(2.891)}{(24.208) + (2.891)} = 10.67\ \%$

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(11.2 \times 0.44) + (9.2 \times 0.32) + (79.6 \times 0.28) = 30.16$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 10.67}{100} \times 30.16\right] + \left[\frac{10.67}{100} \times 18\right] = 28.86$

PARTICULATE SAMPLING CALCULATIONS

Test: Boiler #1 - Andersons 1, 2, 3 Date: 8/13/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{1025.7 \times 0.08}{29.37 \times 28.86}\right] 1/2 =$ 22.877 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(10.67)}{100}\right](22.877)\ (36.82)\ \frac{530}{(1025.7)}\ \frac{(29.37)}{29.92} =$ 1,373,980 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{Mn}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(292.4)}{(24.208)} =$ 2.66×10^{-5} lb/scf

$C_E = C_s \times Qs = (2.66 \times 10^{-5})\ (1,373,980) =$ 36.59 lb/hr

$C_H = C_E \div H = \frac{(36.59)}{(45.416)} =$ 0.806 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \dfrac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ Ps\ A_n}$

$1.667 \dfrac{\left[(0.00267)\ (61.0\ ) + \frac{24.38}{530}\left(29.3 + \frac{1.4}{13.6}\right)\right](1025.7)}{(30)\ (22.877)\ (29.37)\ (1.36 \times 10^{-3})} =$ 94.56%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$\frac{100\ (9.2\ )}{(0.266 \times 79.6) - (9.2\ )} =$ 76.84%

Hydrocarbon Results

Test: Stag - #1 Boiler Date: 8/6 Time:

Carbon Monoxide: 8.93 ppm

Methane: 0.33 ppm

Total Hydrocarbons, as CH_4: 6.97 ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

APPENDIX B

FIELD DATA

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	8/11 - 8/13			
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb	10856			
Fuel Sulfur Content - %	3.25			
Fuel Ash Content - %	10.98			
Fuel Moisture Content %	12.89			

8/11 NO_x

31.775×10^3 lb/hr steam
39.12×10^6 Btu/hr
3603.5 lb/hr coal
782909 SCFH

8/13 Andersen 1, 2, 3

36.889×10^3 lb/hr steam
45.416×10^6 Btu/hr
4183.5 lb/hr coal
811669 SCFH

8/12 NO_x & Part.

31.775×10^3 lb/hr steam
39.12×10^6 Btu/hr
3603.5 lb/hr coal
782909 SCFH

ORSAT FIELD DATA

Location Stag Brewery Comments:

Date 8-12-75

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
* 1115	10.6	24.2 / 13.6	24.2
1240	12.0	20.6 / 8.6	20.6
1535	9.0	21.2 / 12.2	21.2
avg.	10.5	10.4	0.0

* There is reason to believe that this number is not valid and has been eliminated from the average.

ORSAT FIELD DATA

Location Stag Brewery Comments:

Date 8-13-75

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
1045	11.6	20.8/9.2	20.8
1300	10.8	20.0/9.2	20.0
avg.	11.2	9.2	0.0

Plant Stag Brewery

Run No. 2

Location Power House Stack

Date 8-12-75

Operator Griscom/Klein

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.026

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 90

Bar. Press. "Hg 29.30

Assumed Moisture % 10.5

Heater Box Setting °F 4.5

Probe Tip Dia., In. 1/2 inch

Probe Length 10 ft

Probe Heater Setting 7

Avg. ΔP 0.08 Avg. ΔH 1.4

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg. H2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:30	1070.655	0.06	1.05	1.05	160	80	8.0	310	90	0.9	590
1-2	:33	1072.	0.06	1.05	1.05	190	70		320	160		590
1-3	:36	1075.0	0.06	1.05	1.05	215	70	7.5	330	170		560
1-4	39	1077.1	0.06	1.05	1.05	230	72		335			560
1-5	42	1079.2	0.06	1.05	1.05	245	75		345			540
1-6	45	1081.4	0.08	1.4	1.4	255	75		350			530
1-7	48	1083.7	0.09	1.6	1.6	265	74	11.0	355			530
off	10:51	1086.255										
2-1	11:30	1086.255	0.07	1.2	1.2	200	85	8.5	340	95		505
2-2	:33	1088.5	0.07	1.2	1.2	250	71		345	160		560
2-3	36	1090.8	0.08	1.4	1.4	260	73	10.0	350	180		580
2-4	39	1093.1	0.09	1.6	1.6	265	77	11.3	355	185		580
2-5	42	1095.7	0.10	1.75	1.75							
2-6	45	1098.3	0.11	1.9	1.9	285	80	14.0	365	200		590
2-7	48	1101.0	0.10	1.75	1.75	290	80		375	210		570
off	11:51	1103.890										

10:15 - 10:35 Blowing ashes

Run # 2

Point	Clock Time	Dry Gas Meter CF	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	12:30	1103.890	0.07	1.2	1.2	200	80	8.5	305	100		450
3-2	33	1106.1	0.07	1.2	1.2	230	72		320	150		460
3-3	36	1108.4	0.07	1.2	1.2	240	75		325	170		540
3-4	39	1110.6	0.08	1.4	1.4	250	75		335			550
3-5	42	1113.0	0.08	1.4	1.4	260	75		340	185		560
3-6	45	1115.6	0.09	1.6	1.6	265	75		345			570
3-7	48	1118.0	0.10	1.75	1.75	270	77	13.0	345	190		580
off	12:51	1120.615										
4-1	2:25	1120.615	0.05	0.9	0.9	190	85	7.0	335	70		570
4-2	28	1122.6	0.06	1.05	1.05	200	75		320			550
4-3	31	1124.7	0.07	1.2	1.2	250	75	9.0	310			530
4-4	34	1127.1	0.08	1.4	1.4	250	75	10.5	310			550
4-5	37	1129.5	0.08	1.4	1.4	250	76		310			540
4-6	40	1132.3	0.09	1.6	1.6	255	78		320			560
4-7	43	1134.5	0.09	1.6	1.6	255	80		320			570
off	46											
5-1	3:16	1137.0	0.08	1.4	1.4	210	80	10.5	340			400
5-2	19	1139.8	0.07	1.2	1.2	240	70		345			430
5-3	22	1141.8	0.08	1.4	1.4	250	72		335			500
5-4	25	1144.3	0.08	1.4	1.4	250	72		330			510
5-5	28	1146.8	0.08	1.4	1.4	250	75		330	90		520
5-6	31	1149.2	0.09	1.6	1.6	255	75		330			540
off	34	Last point eliminated due to fly ash build up in duct										
		1151.692	2.65									17745
			0.078 avg.									Avg. = 537.7

meter: 120 °

Comments 12:45 - 1:00 Blowing ashes
Probe has shorted again 4 & 5 traverse with heat off
2:30 - 2:45 Blowing ashes

PARTICULATE CLEANUP SHEET

Date: 8/12/7[illegible] Plant: Stag Brewery

Run Number: 2 Location Of Sample Port: #1 Boiler Duct

Operator: Grimm / Klein Barometric Pressure: 29.30

Sample Box No. _____ Ambient Temperature 90

Impinger H_2O Silica Gel

Volume After Sampling 341 ml Weight After 322.[illegible] g

Impinger Prefilled With 200 ml Weight Before 300.0 g

Volume Collected 141 ml Moisture Weight 22.0 g Moisture Total 163.[illegible] g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 1.5090 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
8				Filter Particulate Weight 0.1632 g
				Total Particulate Weight 1.6722 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 8/11/75

Plant Stag - Boiler #1

Sample Collected By Klein

Field Data

Clock Time	1200	1210	1415	1420	1425	1430		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2047	2038	2039	2028	2025	2052		
Pressure before sampling in. Hg.	2.66	—	—	—	—	—		
Pressure after sampling, in. Hg.	29.26	—	—	—	—	—		
Flask temperature, ^{o}F	120	—	—	—	—	—		

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 8/12/75

Plant Stag - Blr. #1

Sample Collected By Klein

Field Data

Clock Time	1215	1220	1520	1525	1530	1535	1550	1555
Flask number	1	2	3	4	5	6	9	10
Volume of flask (ml)*	2047	2038	-	2028	2025	2052	2054	2057
Pressure before sampling in. Hg.	2.66	—	—	—	—	—	—	
Pressure after sampling, in. Hg.	29.30	—	—	—	—	—	—	
Flask temperature, ^{o}F	120	—	—	—	—	—	—	

* Flask + valve - 25 ml. for absorbing solution

Andersen Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Stag Brewery
Run No. Andersen #1
Location #1 Boiler Stack
Date 8/13/75
Operator Griscom / Klein
Sample Box No. _____
Meter Box No. _____
Meter ΔH@ 1.026
C Factor _____

Andersen in Oven, plates only

Ambient Temp °F 90
Bar. Press. "Hg 29.30
Assumed Moisture % 10.5
Heater Box Setting °F _____
Probe Tip Dia., In. 1/2"
Probe Length 5 ft. glass
Probe Heater Setting _____
Avg. ΔP 0.08 Avg. ΔH 1.4

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O Desired	Orifice ΔH in H_2O Actual	Impinger °F Temp. Inlet	Impinger °F Temp. Outlet	Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
3-3	10:50	1160.155	0.08	1.4	1.4	150	85	12.5	305	280		580
	:52	1161.8	0.08	1.4	1.4	175	70		315	315		580
	:54	-	0.08	1.4	1.4							
	:56	1165.0	0.08	1.4	1.4	220	70		335	330		590
	:58	1166.7	0.08	1.4	1.4	240	74		345	330		540
off	11:00	1168.382	0.08									535
		8.227 ft³										

10:55 - Pulling Ashes

Andersen Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Stag Brewery
Run No. Andersen #2
Location #1 Boiler Stack
Date 8/13/75
Operator Griscom / Klein
Sample Box No. _____ Andersen in oven, plates only
Meter Box No. _____
Meter ΔH@ 1.026
C Factor _____

Ambient Temp °F 90
Bar. Press. "Hg 29.30
Assumed Moisture % 10.5
Heater Box Setting °F _____
Probe Tip Dia., In. 1/2
Probe Length 5 ft glass
Probe Heater Setting _____
Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
3-3	11:48	1168.382	0.08	1.4	1.4	145	80	11.5	300	290		540
	:50	1170.1	0.08	1.4	1.4	180	68		320	310		550
	:52	1171.7	0.08	1.4	1.4	200	65		330	320		550
	:54	1173.2	0.08	1.4	1.4	215	68		340	330		550
	:56	1174.9	0.08	1.4	1.4	235	70		350	340		560
off	11:58	1176.610	0.08									
		8.228	~~13~~									

Andersen Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Stag Brewery
Run No. Andersen #3
Location #1 Boiler Stack
Date 8/13/75
Operator Griscom/Klein
Sample Box No. _____
Meter Box No. _____
Meter ΔH@ 1.026
C Factor _____

Andersen in oven, plates with filters

Ambient Temp °F 90
Bar. Press. "Hg 29.30
Assumed Moisture % 10.5
Heater Box Setting °F _____
Probe Tip Dia., In. 1/2
Probe Length 5 ft. glass
Probe Heater Setting _____
Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
3-3	1:05	1176.610	0.08	1.4	1.4	170	73	12.0	315	335		580
	:07	1178.3	0.08	1.4	1.4	195	63		330	355		590
	:09	1180.0	0.08	1.4	1.4	205	60		335	360		590
	:11	1181.7	0.08	1.4	1.4	220	62	13.5	335	370		590
	:13	1183.3	0.08	1.4	1.4	235	65		335	360		560
off	1:15	1185.052	0.08									
		8.442 ft³										

1:13 - Pulling Ashes

PARTICULATE CLEANUP SHEET

Date: 8/13/75 Plant: Stag Brewery

Run Number: Andersen 1,2,3 Location Of Sample Port: #1 Boiler Duct

Operator: Griscom / Klein Barometric Pressure: 29.30

Sample Box No. _____ Ambient Temperature 90°

Impinger H_2O Silica Gel

Volume After Sampling 250.5 ml Weight After 310.5 g

Impinger Prefilled With 200 ml Weight Before [illegible] g

Volume Collected 50.5 ml Moisture Weight 10.5 g Moisture Total 61.0 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 49.6 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
Andersen	Plates & Filters			Filter Particulate Weight 242.8 g
				Total Particulate Weight 292.4 g

% Moisture By Volume

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 Date: 10/16/75

Material collected (mg)

Filter Catch =
Dry Catch =
Acetone Wash =

TOTAL =

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{55.44}{1.01}\right)\left(29.61 + \frac{0.516}{13.6}\right) = 54.355$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474 \ (56 \text{ ml}) = 2.654$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(2.654)}{(54.355) + (2.654)} = 4.66\ \%$

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(5.6 \times 0.44) + (14.8 \times 0.32) + (79.6 \times 0.28) = 29.488$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 4.66}{100} \times 29.488\right] + \left[\frac{4.66}{100} \times 18\right] = 28.953$

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 Date: 10/16/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{942.2 \times 0.026}{29.50 \times 28,953}\right] 1/2 =$ 14.60 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{P_s}{Pstd}\right)$

$3600 \left[1 - \frac{(4.66)}{100}\right](14.60)\ (35.0)\ \frac{530}{(942.2)}\ \frac{(29.50)}{29.92} =$ 972,729 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(297.9)}{(54.355)} =$ 1.006×10^{-5} lb/scf

$C_E = C_s \times Qs = (1.006 \times 10^{-5})\ (972,729) =$ 9.78 lb/hr

$C_H = C_E \div H = \frac{(9.78)}{(18,258)} =$ 0.54 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)\ (56) + \frac{55.44}{530}\left(29.61 + \frac{0.516}{13.6}\right)\right](942.2)}{(105)\ (14.6)\ (29.5)\ (1.36 \times 10^{-3})} =$ 83.0%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$$\frac{100\ (14.8)}{(0.266 \times 79.6) - (14.8)} =$$ 232.2%

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1 10/15/75

Coal Composition		mols/100#		mols O_2 required
C	65.00%	÷ 12	x 1	= 5.417
S	1.04	÷ 32	x 1	= 0.033
H_2	4.50	÷ 2 = 2.25	x 0.5	= 1.125
N_2	1.0	÷ 28 = 0.036		
O_2	7.94	÷ 32 = 0.248	x-1	= -0.248
Ash	8.34			
Moist	12.18	÷ 18 = 0.677		
Btu	10.390 Btu/lb			
		Theoretical O_2		= 6.327 mols
Excess air = 103.3%		excess O_2		= 6.536
		Total O_2		= 12.863
$N_2 = 3.76 \times O_2$				= 48.364

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 5.417 + 0.033 + 0.036 + 6.536 + 48.364 = 60.386 mols

Flue Gas = $60.386 \times 386.7 \frac{ft^3}{mol}$ = 23,351.3 SCF/100#

@ 29.5×10^3 lb/hr steam = $\frac{29.5 \times 10^3 \times 1015.7}{0.825}$ = 36.319×10^6 BTU/hr

$36.319 \times 10^6 \div 10390$ = 3495.6 lb/hr coal

$3495.6 \times \frac{1}{100} \times 23,351.3$ = 816267 SCFH
= 13604 SCFM

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	10/15		10/20	10/20	10/20	10/20
Run No.	1		1	1	2	2
V_{mc}-Meter Volume, Ft^3	16.583		12.965		12.794	
Vmstd-Meter Volume, Std. Cond.	16.171		12.653		12.486	
P_B-Barometric Pressure, "Hg	29.48		29.51		29.51	
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1		0.1	
V_t-Vol. of Titrant, ml.	9.92		3.6	8.67	4.2	9.08
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil	nil	nil	nil
Vsoln-Vol. of Solution, ml.	250		100	250	100	250
V_a-Vol. of Aliquot, Titrated, ml.	1.0		20	1.0	20	1.0
lb/scf H_2SO_4 $\times 10^{-6}$			1.536		1.816	
lb/10^6 Btu H_2SO_4			0.029		0.034	
lb-scf SO_2 $\times 10^{-4}$	1.081			1.207		1.281
lb/10^6 Btu SO_2	2.4			2.3		2.4

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right)(V_t - V_{tb})(\underline{N})\left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right)(V_t - V_{tb})(\underline{N})\left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	10/15	10/16	10/20 -1	10/20 -2
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr	29.5	14.83	32.0	33.75
Boiler Heat Input 10^6 Btu/hr	36.3	20.1	39.4	41.55
Fuel Burning Rate - lb/hr	3495.6	1933	3791.8	39.991
Fuel Heating Value - BTU/lb	10390	10390	10390	10390
Fuel Sulfur Content - %	1.04	1.04	1.04	1.04
Fuel Ash Content - %	8.34	8.34	8.34	8.34
Fuel Moisture Content %	12.18	12.18	12.18	12.18

Calculated Flow Rates :

10/15 816,267 SCFH

10/16 741,556 SCFH

10/20-1 736,170 SCFH

10/20-2 776,420 SCFH

ORSAT FIELD DATA

Location Stag - Boiler #1 Comments:

Date 10/15 & 10/16 & 10/20

Time

Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
10/15 1310	9.2	11.0	0.0
1350	9.4	10.6	0.0
10/16 1340	5.6	14.8	0.0
1130	5.8	9.0	0.0
10/20 1120	11.5	8.9	0.0
1135	11.6	8.5	0.0

Plant Stag

Run No. 1

Location Blr #1

Date 10/16

Operator Griscom, Klein

Meter ΔH@ _____

C Factor _____

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Trouble with probe thermister, invalid readings
No beer brewed today

Ambient Temp °F 70°

Bar. Press "Hg 29.61

Assumed Moisture % 8

Probe Tip Dia., In. 1/2

Probe Length 10 ft

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:45	1705.760	0.02	0.4	0.4				325	125	-0.9	480
1-2	:48	1707.2	0.02	0.4	0.4	195	59	3.0	310	170		480
1-3	:51	1708.8	0.02	0.4	0.4	190	59		305	185		485
1-4	:54	1710.0	0.02	0.4	0.4	190	58		305	195		490
1-5	:57	1711.5	0.03	0.57	0.57	195	59		305	195		480
1-6	11:00	1713.2	0.04	0.77	0.77	205	58		310	200		490
1-7	:03	1715.3	0.045	0.85	0.85	230	59	6.0	320	230		485
off	11:06	1716.965										
2-1	11:45	1716.965	0.025	0.50	0.50	170	58	4.5	335	145		485
2-2	:48	1718.6	0.025	0.5	0.5	210	52		340	210		485
2-3	:51	1720.1	0.025	0.5	0.5	215	51		335	225		485
2-4	:54	1721.7	0.03	0.57	0.57	210	52	4.5	332	225		485
2-5	:57	1723.2	0.04	0.76	0.76	210	52		330	210		505
2-6	12:00	1725.2	0.04	0.76	0.76	235	52		330	225		500
2-7	103	1727.1	0.045	0.85	0.85	230	53		330	230		500
off	12:06	1729.080										

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger ^oF Temp.		Pump Vacuum In. Hg. Gauge	Box Temp ^oF	Probe Temp ^oF	Stack Press. In. Hg.	Stack Temp. ^oF
				Desired	Actual	Inlet	Outlet					
3-1	12:48	1729.080	0.02	0.4	0.4	150	58	3.5	320	120		470
-2	:51	1730.5	0.02	0.4	0.4	205	54		320	200		470
-3	:54	1731.9	0.02	0.4	0.4	215	54		320	230		470
-4	:57	1733.3	0.02	0.4	0.4	215	54		320	225		475
-5	1:00	1734.8	0.025	0.5	0.5	225	54	4.0	325	240		480
-6	:03	1736.4	0.025	0.5	0.5	220	55		330	230		480
-7	:06	1737.9	0.025	0.5	0.5	225	55		335	220		475
off	1:09	1739.550										
4-1	1:45	1739.550	0.02	0.4	0.4	140	62	3.5	340	130		485
-2	:48	1740.9	0.02	0.4	0.4	215	57		340	195		480
-3	:51	1742.4	0.02	0.4	0.4	215	57		340	205		480
-4	:54	1743.8	0.025	0.5	0.5	215	57		335	205		490
-5	:57	1745.5	0.025	0.5	0.5	235	58		335	225		490
-6	2:00	1747.1	0.025	0.5	0.5	245	60		340	250		480
-7	:03	1748.7	0.04	0.77	0.77	240	60	5.5	340	255		480
off	2:06	1750.620										
5-1	2:47	1750.620	0.02	0.4	0.4	170	65	4.0	340	150		480
-2	:50	1752.5	0.02	0.4	0.4	225	60		335	210		490
-3	:53					220	60		335	215		485
-4	:56	1754	0.02	0.4	0.4							
-5	:59	1755	0.02	0.4	0.4	240	61		335	240		470
-6	3:02	1757.8	0.03	0.57	0.57	240	63		340	250		470
-7	:05	1759.7	0.02	0.57	0.57	250	65		340	250		460
off	3:08	1761.200										

COMMENTS: 55.44 CF 0.026 0.516 482.2°

PARTICULATE CLEANUP SHEET

Date: 10/16 Plant: Stag

Run Number: 1 Location Of Sample Port: Boiler #1

Operator: Griscom, Klein Barometric Pressure: 29.61

Sample Box No. _____ Ambient Temperature 70 °F

Impinger H_2O Silica Gel

Volume After Sampling 241 ml Weight After 515.0 g

Impinger Prefilled With 200 ml Weight Before 500.0 g

Volume Collected 41 ml Moisture Weight 15 g Moisture Total 56 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.1605 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
12				Filter Particulate Weight 0.0874 g
				Total Particulate Weight 0.2479 g

% Moisture By Volume

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 10/15/75

Plant Stag. Location Boiler #1

Bar. Pressure 29.48 "Hg Comments: 29.48 in. Hg. - ground
29.445 in. Hg. - stack

Ambient Temp 75 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	~~Coil~~ Oven	Impinger In	Impinger Out
12:55	1689.162	0.03	0.1	540	235	158	105	70
1:05	1692	0.04	0.1	550	278	183	135	61
1:15	1694.8	0.04	0.1	565	275	180	130	63
1:25	1697.75	0.05	0.1	565	275	170	124	63
1:35	1700.65	0.04	0.1	550	278	178	130	65
1:45	1703.15	0.02	0.1	540	278	170	126	66
155	1705.745							

Comments: 30,000 lbs coal charged on 7-3 shift
avg. 29.5×10^3 lb/hr steam

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 10/20/75

Plant Stag Location Boiler #1

Bar. Pressure _____ "Hg Comments: 29.505 in. Hg. ground
29.465 in. Hg. stack

Ambient Temp 75 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
11:10	1783.420	0.07	0.1	590	275	144	135	80
11:20	1785.6	0.05	0.1	575	325		160	70
11:30	1788.0	0.06	0.1	550	295		155	70
11:40	1790.1	0.05	0.1	570	310	168	148	69
11:50	1792.3	0.06	0.1	550	285		132	69
12:00	1794.4	0.055	0.1	530	275	166	124	68
12:10	1796.385					171		
	12,965 CF							

Comments: 1. Could not get a zero reading on the pitot - apparently too much turbulence.

2. ΔP dropped off from 0.07 to 0.05 right after the operator stopped pulling ashes.

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 10/20

Plant Stag Location #1 Boiler

Bar. Pressure 29.51 "Hg Comments

Ambient Temp 75 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
12:35	1796.386	0.02	0.1	505	275	150	110	69
12:45	1798.4	0.04	0.1	570	275	155	135	65
12:55	1800.7	0.035	0.1	580	290		130	65
1:05	1803.1	0.035	0.1	550	290		125	65
1:15	1805.2	0.04	0.1	590	295		120	68
1:25	1807.3	0.03	0.1	560	305	155	120	69
1:35	1809.180							

Comments: 12.794 CF

SOURCE TEST REPORT
GENERAL MOTORS ASSEMBLY DIVISION
ST. LOUIS, MISSOURI

BOILER NO. 2

TESTED BY: ROCKWELL INTERNATIONAL
R.W. Griscom
O.C. Klein
F.E. Littman

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TABLES

FIGURES

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler no. 2 at the General Motors Assembly Plant in St. Louis, Missouri.

The stack testing included the following pollutants: SO_2 (sulfur dioxide), particulates, NO_x (nitrogen oxides), H_2SO_4 (sulfuric acid mist) and hydrocarbons. Orsat analysis for CO_2 (carbon monoxide), and O_2 (oxygen) were also performed. Results of these tests are included in this report. Although these tests were not conducted to ascertain compliance with St. Louis standards, it is of interest that the particulate emissions are within the limits. The SO_2 emissions standards are not applicable for this time of the year, nor for an individual boiler in an installation.

We acknowledge and appreciate the excellent cooperation we obtained from the engineering department and the power plant personnel at General Motors.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the General Motors Assembly Plant in St. Louis, Missouri. Testing was performed on boiler no. 2 on 8,9 and 10 September 1975.

Boiler no. 2 is a coal-fired, 80,000 pounds per hour steam generating unit. The unit is equipped with a cyclone, mechanical precipitator. This boiler was sampled for total particulates, particle size, NO_x, SO_2, H_2SO_4 CO_2 and O_2.

3.0 PROCESS DESCRIPTION

Boiler no. 2 was built by Union Iron Works and was installed in November 1952. It is equipped with a gravity fed spreader stoker. Steam pressure is maintained at approximately 165 psi. The firing rate is controlled to match the demands of the assembly plant. At shift changes the load drops off 20-25% for an hour or two. The capacity of this boiler is rated at 80,000 pounds of steam per hour.

This boiler is equipped with a Western Precipitation Multi-cyclone mechanical precipitator rated at 98% efficiency. Boiler no. 2 is an induced draft unit and uses a common stack with boilers 1, 3, and 4. The stack is of brick construction and is 225 feet tall and 13 feet inside diameter at the top.

This boiler and no. 4 boiler are equipped with caustic scrubbers for removing SO_2. These scrubbing units are in operation from October through March for compliance with the local St. Louis standards.

4.0 PROCESS OPERATION

Boiler no. 2 was tested 8 September to 10 September. During the testing period the boiler load remained fairly constant. Because of shift change, the load started to decrease between 2 and 2:30 PM. Testing was generally completed prior to 2 PM. Ashes were pulled on the boiler at approximately 11:30 AM and 1:30 PM each day.

5.0 SOURCE TEST DESCRIPTION

Boiler no. 2 was tested in the ductwork between the boiler and the stack and ahead of the takeoff for the SO_2 scrubber. The sampling location and testing arrangement are illustrated in Figures 1, 2, and 3.

The duct at this point is 49 inches wide by 5 feet high. This location was between four and five diameters from the last bend in the duct. In accordance with EPA Standard Method 1, thirty-two sampling points were chosen, eight at each of four sampling ports. General Motors already had four, 3-inch pipe couplings installed for use as sampling ports.

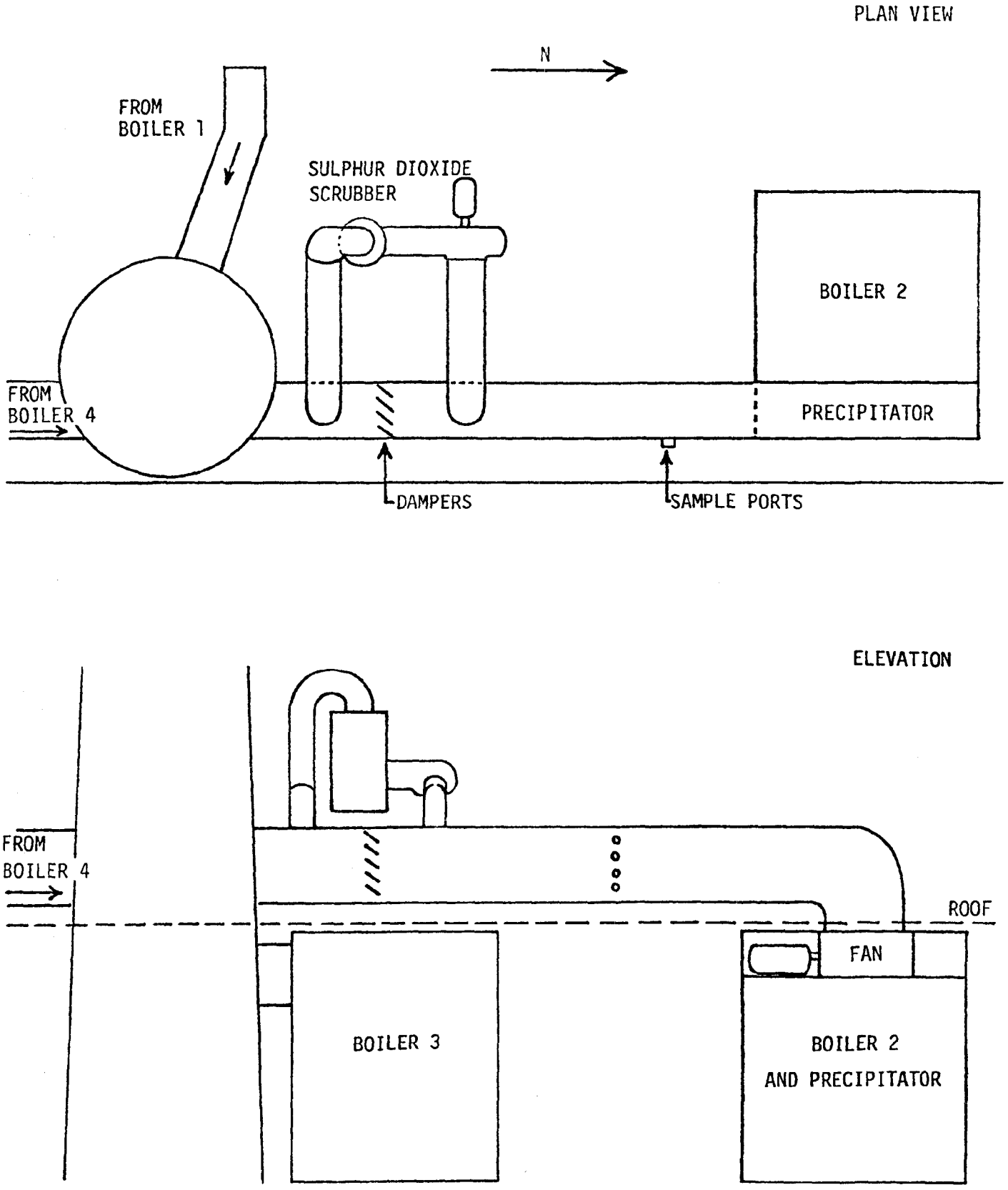

FIGURE 1 SAMPLING LOCATION FOR BOILER 2

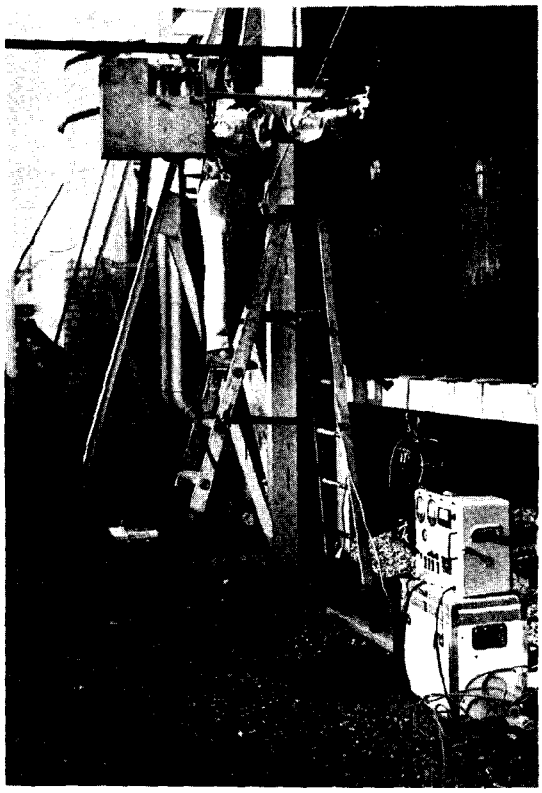

FIGURE 2

OPERATOR POSITIONING SAMPLING UNIT AT TEST LOCATION

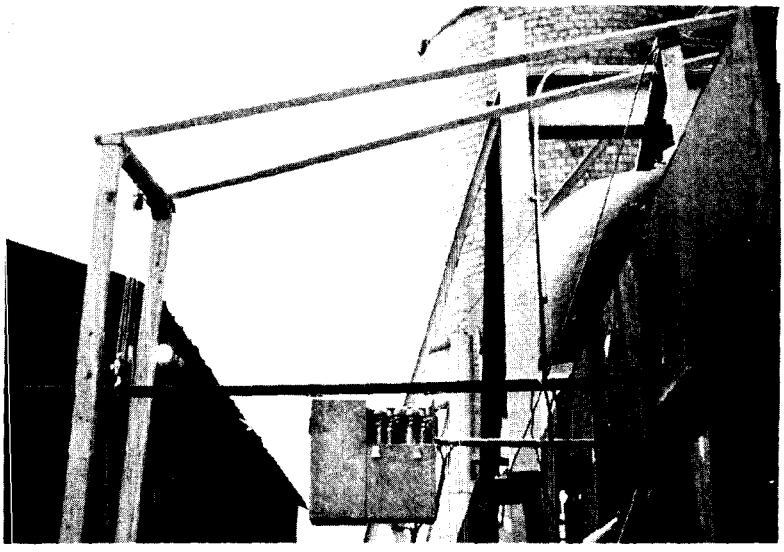

FIGURE 3

SUPPORTING STRUCTURE FOR SAMPLING EQUIPMENT

6.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of CO_2, oxygen, CO, and nitrogen by difference were measured with a standard Orsat apparatus. This method is shown in Figure 4. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

5.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350^{o} ^{o}F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 5.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

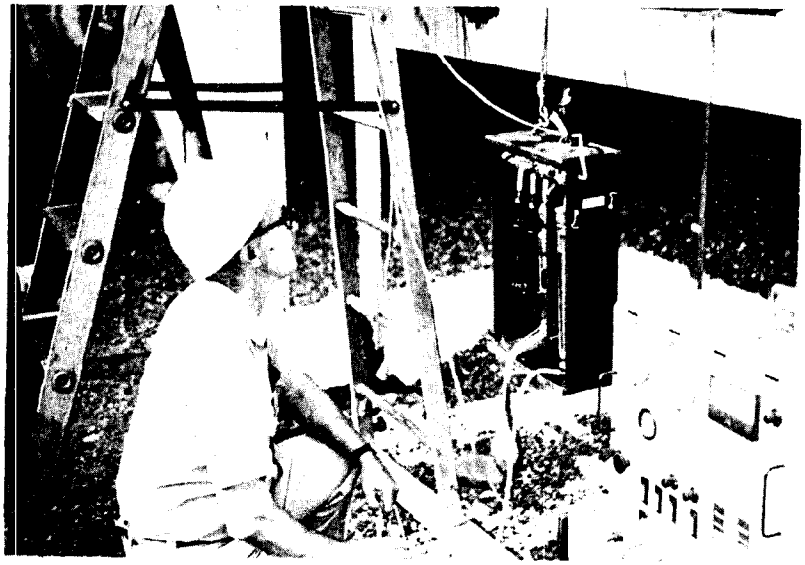

FIGURE 4

OPERATOR DETERMINING STACK GAS COMPOSITION

WITH ORSAT APPARATUS

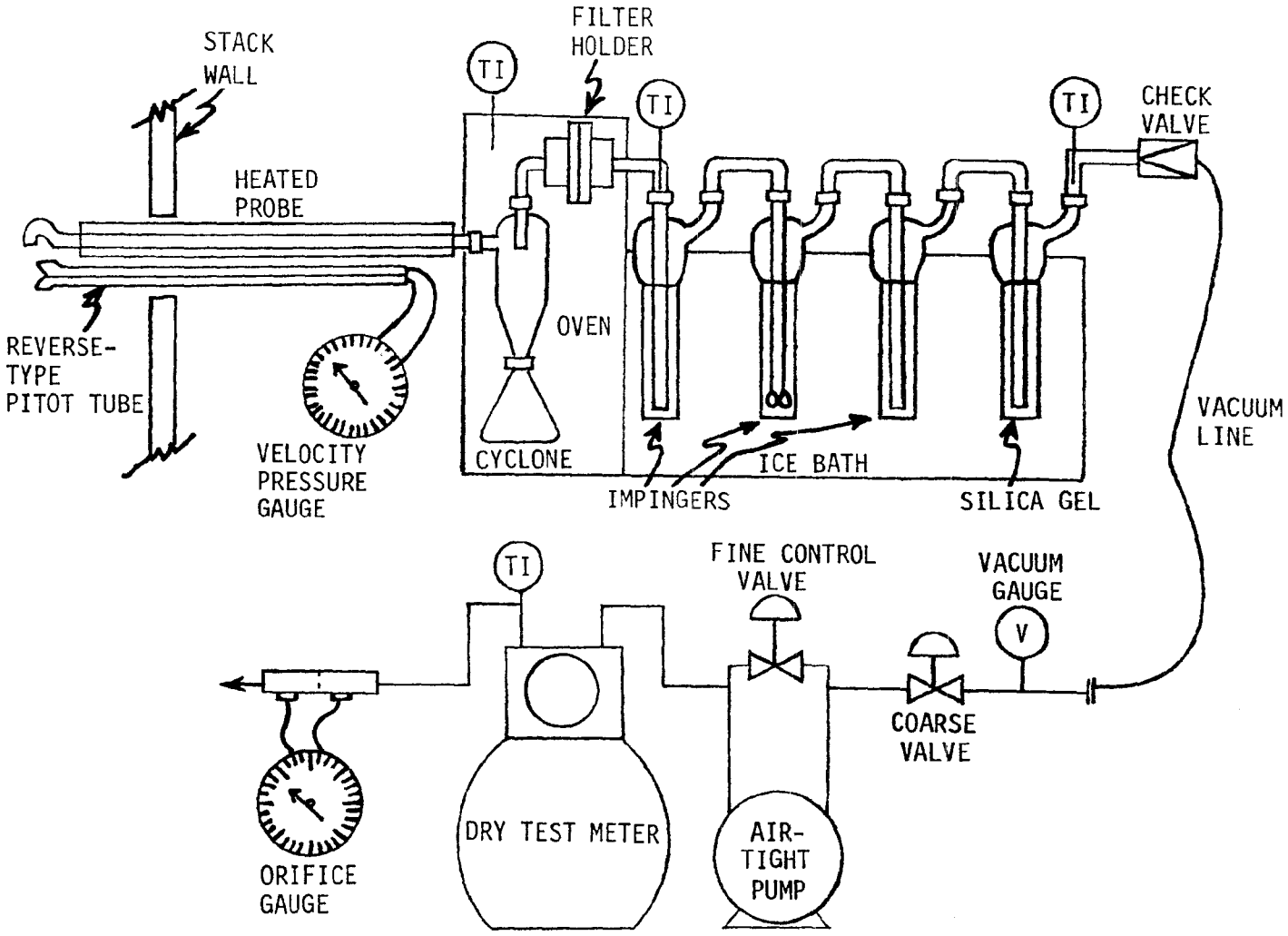

FIGURE 5

PARTICULATE SAMPLING TRAIN

6.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically. The field procedure is shown in Figures 6 and 7.

6.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The Shell method was chosen for this determination due to uncertainties which exist about the validity of the results using method 8.* A gas sample is drawn from the stack using a heated probe and passed through a water-cooled, coil condenser maintained below the dew point of sulfuric acid at 140^{o}-194^{o}F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 8.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide in the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

*Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases," Combustion, Jan.1965.

Goksoyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases," J. Inst. Fuel, No. 35, 177, (1962)

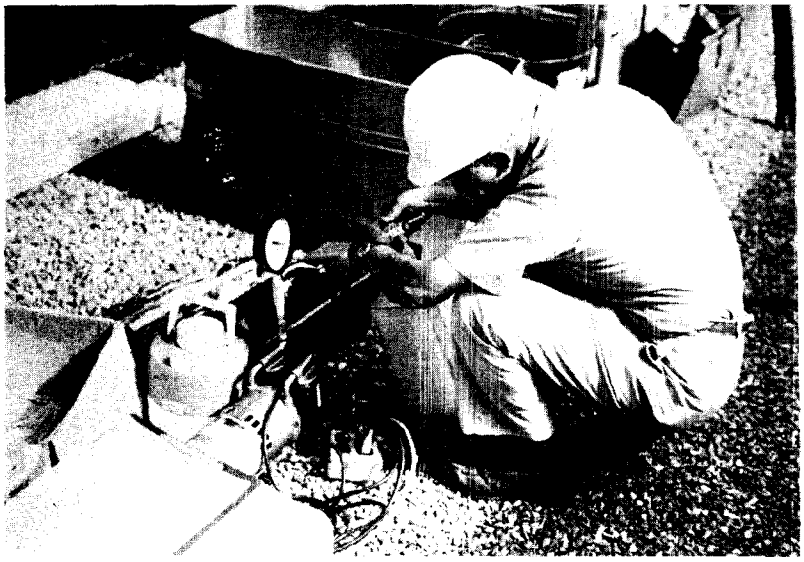

FIGURE 6

OPERATOR EVACUATING FLASK FOR NITROGEN OXIDES TESTING

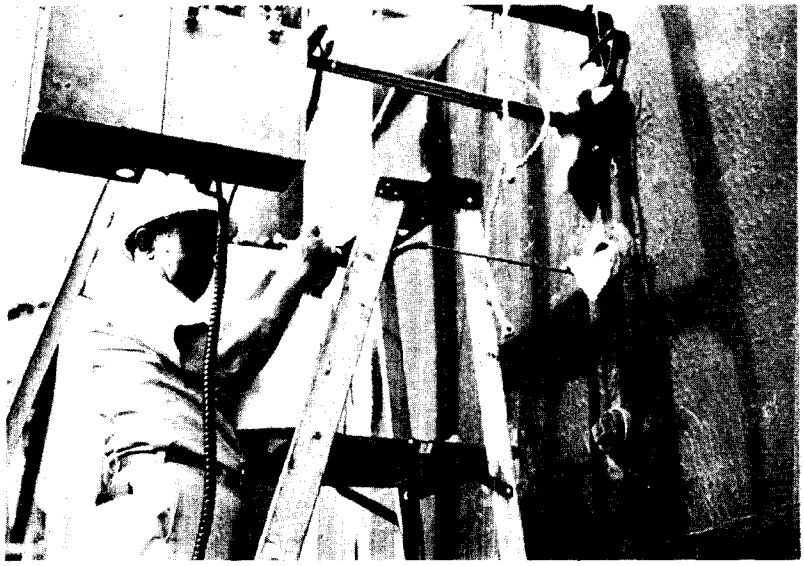

FIGURE 7

OPERATOR FILLING EVACUATED FLASK WITH STACK GAS SAMPLE

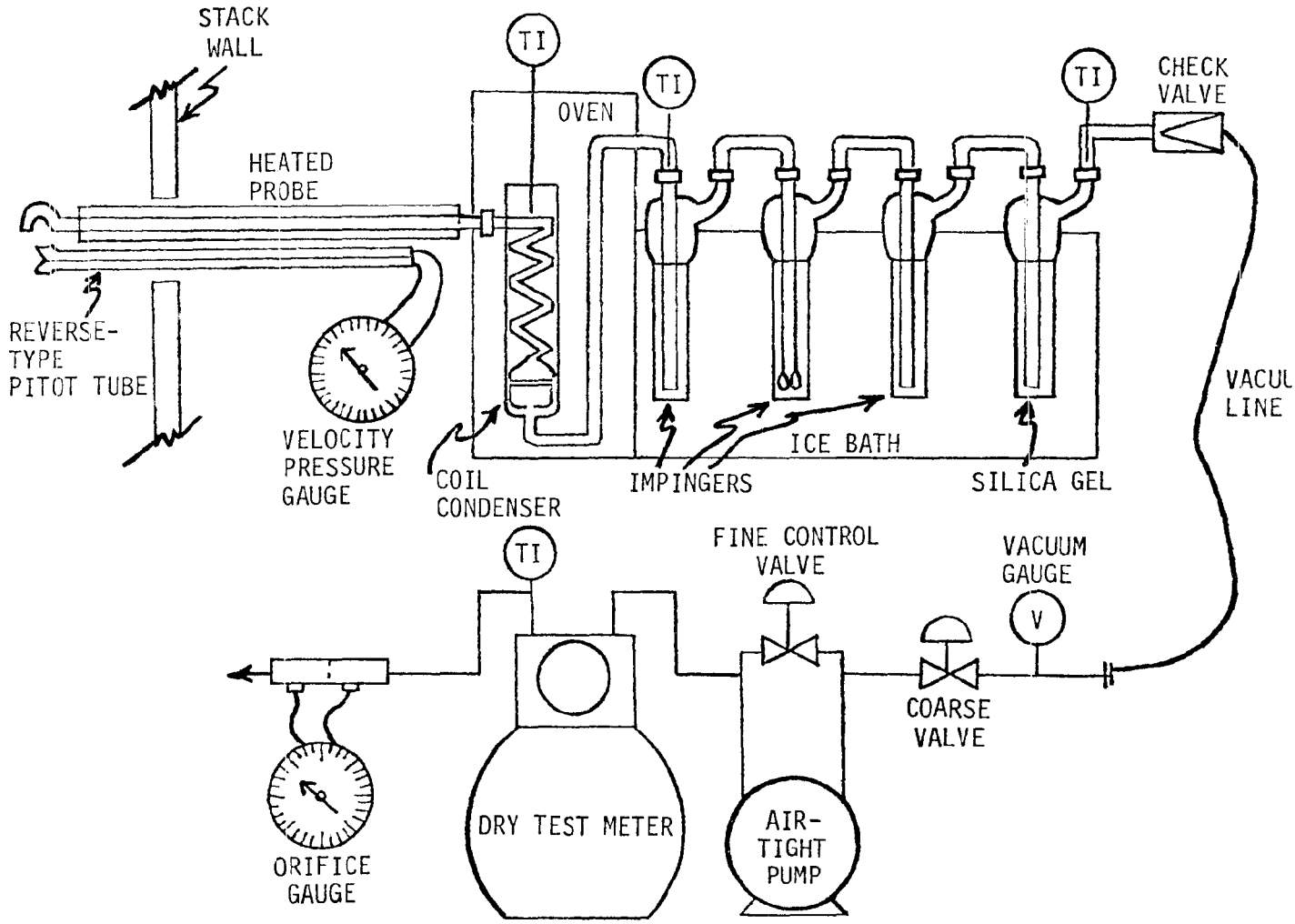

FIGURE 8

SULFURIC ACID MIST SAMPLING TRAIN

6.4 PARTICLE SIZE

An Andersen fractionating inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed in the oven after the heated sampling probe and a sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density. The sampling arrangement is shown in Figure 9. The sampling head assembly is shown in Figure 10.

6.5 HYDROCARBONS

Gas samples were withdrawn from the stack using a vacuum pump to fill Tedlar bags. The composition of the hydrocarbons was determined by gas chromatograph.

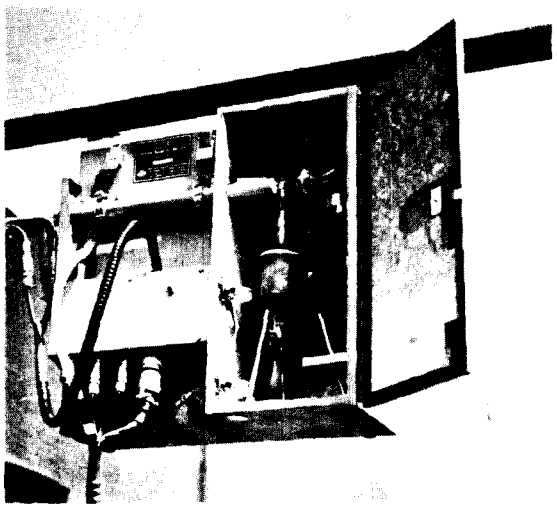

FIGURE 9

SAMPLING UNIT WITH ANDERSEN SAMPLER IN OVEN

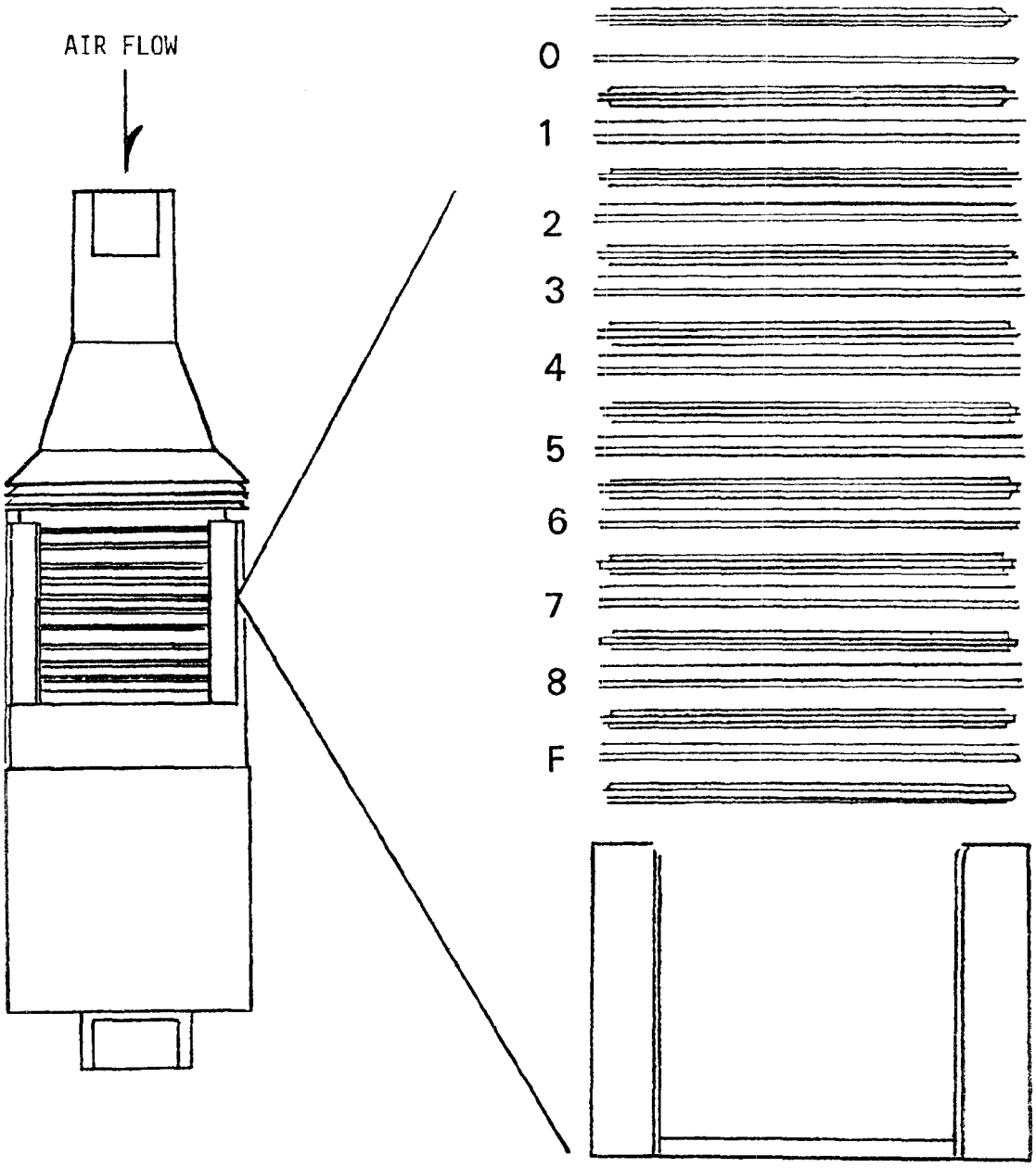

FIGURE 10

ANDERSEN STACK SAMPLER

7.0 RESULTS

The results obtained from this test are summarized in Table 1. As explained in the following discussion, the pollutant emissions are based on calculated, rather than measured, flow rates. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used. Due to the seasonal nature of the local SO_2 regulations the only applicable standard is for particulates. It is of interest to note that this boiler is within the standard: 0.28 lb/10^6 Btu compared to the standard of 0.40 lb/10^6 Btu.

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Table 2 and Figure 11.

The results of two samples taken on 8 September for hydrocarbons were:

Carbon Monoxide:	26.80 and 23.04 ppm
Methane:	0.23 and 0.25 ppm
Total Hydrocarbons, as CH_4:	1.31 and 2.30 ppm

The major components of several hydrocarbon samples taken on 8 and 9 September are given in Table 3.

TABLE 1

SUMMARY OF RESULTS

Date	9/8	9/9	9/10		
Stack Flow Rate - SCFM * dry	27,041	26,633	26,633		
% Water Vapor - % Vol.	8.34	7.38			
% CO_2 - Vol % dry	11.16	10.65			
% O_2 - Vol % dry	8.37	9.25			
% Excess air @ sampling point	64.2	76.72			
SO_2 Emissions - lbs/10^6 Btu		5.81	6.14		
NO_x Emissions - lbs/10^6 Btu	0.49	0.48			
H_2SO_4 Mist - lbs/10^6 Btu		0.19	0.16		
Particulates Probe, Cyclone, & Filter Catch lbs./hr.	20.41	20.03			
lbs/10^6 Btu	0.25	0.24			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	119.3	110.8			

*70^o F, 29.92" Hg

TABLE 2

PARTICLE SIZE DISTRIBUTION

Test: GM-Ardersen #1 Date: 9/10
Oven Temperature = 300°F

Plate	Filter Net (mg)	% Of Total	ECD (Microns)
1	1.1	1.43	16.8
2	1.7	2.21	10.7
3	3.5	4.55	7.1
4	4.7	6.10	4.9
5	4.6	5.97	3.1
6	4.6	5.97	1.6
7	3.5	4.55	0.99
8	5.3	6.88	0.66
Backup Filter	48.0	62.34	<0.66
Total	77.0	100.00	

Test: GM-Andersen #2 Date: 9/11
Oven Temperature = 370.9°F

Plate	Filter Net (mg)	% Of Total	ECD (Microns)
1	1.2	2.39	17.3
2	1.4	2.78	10.9
3	3.3	6.56	7.3
4	5.3	10.54	5.0
5	4.8	9.54	3.2
6	4.5	8.95	1.7
7	3.2	6.36	1.0
8	3.8	7.55	0.68
Backup Filter	22.8	45.33	<0.68
Total	50.3	100.00	

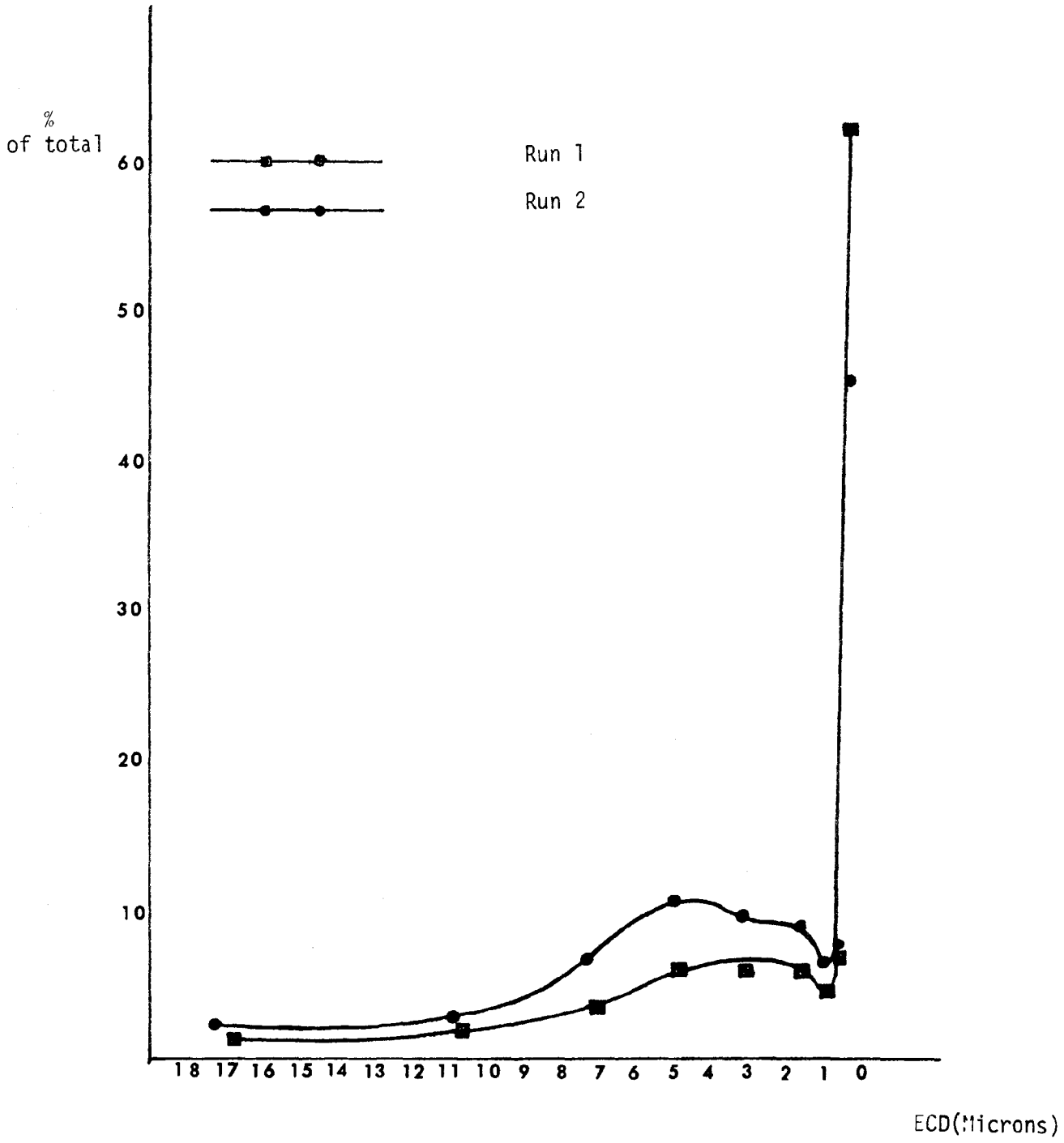

FIGURE 11
PARTICLE SIZE DISTRIBUTION
GENERAL MOTORS
BOILER 2

TABLE 3
HYDROCARBON ANALYSIS
(Concentrations in ppb as Carbon)

Compound	9/8	9/8	9/9	9/9
Ethane-Ethylene	51.7	70.7	48.0	70.3
Acetylene	15.8	29.7	33.7	25.1
Propylene	3.1	7.1		1.7
Propane	29.3	20.2	22.1	33.7
Isobutane	20.3		14.8	25.6
1-Butene & Isobutylene		52.1		29.9
Butane	62.4	72.0	16.9	21.5
Pentane	2.1	9.1	7.4	22.3
Isopentane	6.7	9.2	4.3	21.5
Hexane	52.1	31.7	136.7	95.2
Benzene & 2,4-Dimethyl Pentane	66.3	53.5	14.6	18.7
1-Methylcyclopentane & 2M-C3-Hexane	21.2	37.9		
Toluene	143.4	62.6	76.5	115.3
Ethyl Benzene	58.7	65.2	83.1	100.1
Meta, Para-Xylene	130.3	141.8	182.6	180.4
Ortho-Xylene	29.3	30.4	38.4	40.9

8.0 DISCUSSION

Flow determinations were made in accordance with EPA Standard Method 2, using an S-type pitot tube. This method gives correct results as long as the pitot tube is positioned normally to the flow of gases. This is no problem as long as the flow of gases is laminar and parallel to the walls of the duct. However, if the flow is turbulent or vortex-type, the readings obtained are incorrect, with a positive bias (too high). The existence of a turbulent condition can be ascertained by turning the pitot tube 90^{o} on its axis. A zero reading should then result. If no zero reading is obtained, the results are open to question.

In the duct being tested, the existence of turbulence was evident by the fact that a zero reading was not obtained with a 90^{o} rotation of the probe.

Under conditions when satisfactory flow measurements cannot be obtained, a stoichiometric calculation of flow rates can be made, based on fuel consumption, fuel composition, combustion rate and excess air. As a check on the correctness of the assumption, the mass flow of SO_2 can be calculated based on gas flow and SO_2 concentration on one hand, and fuel consumption and sulfur analysis on the other. The conversion of sulfur in coal to SO_2 is straightforward and occurs with 95% efficiency.

To determine the amount of coal consumed and Btu input, coal scale readings were checked against the actual steam production. This ratio was also compared with a ratio determined by power plant supervision over several previous months. On 10 September the coal scale readings averaged 7314 lbs/hour and the steam flow averaged 66,910 pounds of steam per hour. This gives a ratio of 9.15 pounds of steam per pound of coal. The ratio used by plant supervision is 9.3. Since these two ratios are so close, the ratio of 9.3 determined by plant supervision was the one used for all determinations of coal consumption during the test.

Table 4 shows the comparison of the results obtained by the two methods.

TABLE 4

COMPARISON OF FLOW RATE DETERMINATIONS

Date	FLOW RATE, SCFH		SO_2 (lbs/hr) Based On		
	Measured	Calculated	AP-42*	Calculated Flow	Avg. Measured Flow
9/8	1,622,490	1,403,921			
9/9	1,598,005	1,434,847	478.5	472.0	545.9
9/10		1,396,329	480.0	501.3	578.1

* Compilation of Air Pollutant Emission Factors, EPA Publ. No. AP-42

STOICHIOMETRIC
FLOWRATE CALCULATIONS
BOILER #2

Coal Composition

Moisture 7.71%

Ash	10.895					
S	3.465	÷ 32	= 0.108	x 1	=	0.108
C	62.0	÷ 12	= 5.167	x 1	=	5.167
H_2	5.0	÷ 2	= 2.500	x 5	=	1.25
N_2	1.0	÷ 28	= 0.036			
O_2	9.9	÷ 32	= 0.309	x-1	=	-0.309
						6.216
@ 70.46% Excess Air						4.380
						10.596
$N_2 = 3.76 \times O_2$					=	39.840

Mols Flue Gas = $CO_2 + SO_2 + N_2 + EA + N_2$ =
5.167 + 0.108 + 0.036 + 4.38 + 39.84 = 49.53 mols/100#

On 9/9 7268.8 lb/hr coal during SO_2 test 49.53 x 386.7 x 72.688 =
1,392,211.5 SCFH

On 9/9 7491.4 lb/hr coal during particulate test 49.53 x 386.7 x 74.914 =
1,434,846.6 SCFH

9/8 7329.9 lb/hr 1,403,921.1 SCFH

9/9 1,434,846.6 SCFH Part.
1,392,211.5 SCFH SO_2

9/10 1,396,329.4 SCFH SO_2
1,363,385.8 SCFH Andersen

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{o} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{o} R or 70^{o} F

Tm = Meter temperature, 530^{o} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{lc}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times V_{lc}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{lc} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{o}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%\ O_2 \times \frac{32}{100}\right) + \left(\%\ N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_w = \left(\frac{100 - \%\ M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P\ avg.}{Ps \times MW_w}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb.\ Mols - {}^oR}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^oR

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s\ A\left(\frac{Tstd}{Ts} \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667 \left[(0.00267) \quad V_{lc} + \frac{V_{mc}}{T_m} \left(P_B + \frac{\Delta H}{13.6} \right) \right] T_s}{\Theta \, V_s \, P_s \, A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454 \text{ gm.}}$$

Θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \quad X \quad 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$$

C_s = particulate emission, lb/scf

$2.205 \text{ X } 10^{-6}$ = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \text{ X } Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 1 Date: 9/8/75

Material collected (mg)

Filter Catch	=	145.1
Dry Catch	=	
Acetone Wash	=	149.4
TOTAL	=	294.5

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{44.74}{1.01}\right)\left(30.16 + \frac{0.46}{13.6}\right) =$ 44.672 SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (85.8 ml) = 4.067 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(4.067)}{(44.672) + (4.067)} =$ 8.34 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

(11.16 X 0.44) + (8.37 X 0.32) + (80.47 X 0.28) = 30.12

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.34}{100} \times 30.12\right] + \left[\frac{8.34}{100} \times 18\right] =$ 29.125

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 1 Date: 9/8/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.85) \left[\frac{883.7 \times 0.299}{30.13 \times 29.125}\right] 1/2 =$ 39.869 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(8.34)}{100}\right](39.869)\ (20.42)\ \frac{530}{(883.7)}\ \frac{(30.13)}{29.92} =$ 1,622,489.7 SCFH *

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(294.5)}{(44.672)} =$ 1.454×10^{-5} lb/scf

$C_E = C_s \times Qs = (1.454 \times 10^{-5})\ (1,403,921) =$ 20.41 lb/hr

$C_H = C_E \div H = \frac{(20.41)}{(82.0)} =$ 0.25 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667 \left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right] Ts}{\theta\ Vs\ Ps\ A_n}$

$\frac{1.667 \left[(0.00267)\ (85.8) + \frac{44.297}{530}\left(30.16 + \frac{0.46}{13.6}\right)\right](883.7)}{(96)\ (34.50)\ (30.13)\ (3.407 \times 10^{-4})} =$ 119.3%

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (8.37)}{(0.266 \times 80.47) - (8.37)} =$ 64.2 %

* Stoichiometric $Q_s = 1,403,921.1$ SCFH

$V_s = \frac{1,403,921}{1,622,490} \times 39.869 = 34.50$ fps

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 2 Date: 9/9/75

Material collected (mg)

Filter Catch = 130.3
Dry Catch =
Acetone Wash = 138.8

TOTAL = 269.1

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{42.61}{1.01}\right)\left(30.14 + \frac{0.40}{13.6}\right) =$ 42.511 SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (71.4 ml) = 3.385 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(3.385)}{(42.511) + (3.385)} =$ 7.38 %

Molecular Weight of dry stack gas

MW_D = %CO2 X 0.44 + %02 X 0.32 + %N2 X 0.28

(10.65 X 0.44) + (9.25 X 0.32) + (80.1 X 0.28) = 30.07

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 7.38}{100} \times 30.07\right] + \left[\frac{7.38}{100} \times 18\right] =$ 29.192

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 2 Date: 9/9/25

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.85) \left[\frac{896.4 \times 0.289}{30.11 \times 29.192}\right] 1/2 =$ 39.445 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(7.38)}{100}\right] (39.445) \quad (20.42) \quad \frac{530}{(896.4)} \quad \frac{(30.11)}{29.92} =$ 1,598,004.9 SCFH *

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6} \quad \frac{(269.1)}{(42.511)} =$ 1.396×10^{-5} lb/scf

$C_E = C_s \times Qs = (1.396 \times 10^{-5}) \quad (1,434,846) =$ 20.03 lb/hr

$C_H = C_E \div H = \frac{(20.03)}{(83.8)} =$ 0.24 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right] Ts}{\theta\ Vs\ Ps\ A_n}$

$1.667 \left[(0.00267) \quad (69.4) + \frac{42.188}{530}\left(30.14 + \frac{0.40}{13.6}\right)\right] (896.4) =$ 110.8 %

$(96) \quad (35.42) \quad (30.13) \quad (3.407 \times 10^{-4})$

Excess Air at Sample Point

$$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

$\frac{100\ (9.25)}{(0.266 \times 80.1) - (9.25)} =$ 76.7 %

* Stoichiometric $Q_s = 1,434,847$

$V_s = \frac{1,434,847}{1,598,005} \times 39.445 = 35.42$ fps

STOICIOMETRIC
FLOWRATE CALCULATIONS

Boiler #2

Coal Composition			Mols/100#		Mols O_2 required
Moisture	7.71%				
Ash	10.895				
S	3.465	÷ 32 =	0.108	x 1	= 0.108
C	62.0	÷ 12 =	5.167	x 1	= 5.167
H_2	5.0	÷ 2 =	2.500	x .5	= 1.25
N_2	1.0	÷ 28 =	0.036		
O_2	9.9	÷ 32 =	0.309	x -1	= -0.309
					6.216
@ 70.46% Excess air					4.380
					10.596
$N_2 = 3.76 \times O_2$					= 39.840

Mols Flue Gas = $CO_2 + SO_2 + N_2 + EA + N_2$ =
$5.167 + 0.108 + 0.036 + 4.38 + 39.84 = 49.53$ mols/100#

on 9/9 7268.8 lb/hr coal during SO_2 test

49.53 x 386.7 x 72.688 = 1,392,211.5 SCFH

on 9/9 7491.4 lb/hr coal during particulate test

49.53 x 386.7 x 74.914 = 1,434,846.6 SCFH

NO_x EMISSION DATA

Date 9/8/75

Run No.	1	2	3	4	5	6		
Time	1150	1200	1230	1230	1325	1330		
µg NO_2	865	865	865	815	760	760		
T_i- Initial Flask Temp, ^oF	90	90	90	90	90	90		
T_f- Final Flask Temp, ^oF	95	95	95	95	95	95		
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052		
P_i- Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5		
P_f- Final Flask Pres, "Hg	30.16	30.16	30.16	30.16	30.16	30.16		
lb/scf NO_2 $\times 10^{-5}$	2.97	2.98	2.98	2.82	2.64	2.60		
lb/10^6Btu NO_2	0.51	0.51	0.51	0.48	0.45	0.45		

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 9/9/75

Run No.	1	2	3	4	5	6	7	8
Time	0910	0912	1008	1010	1040	1042	1240	1245
µg NO_2	970	1020	710	760	760	760	760	760
T_i- Initial Flask Temp, ^oF	90	90	90	90	90	90	90	90
T_f- Final Flask Temp, ^oF	95	95	95	95	95	95	95	95
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P_f- Final Flask Pres, "Hg	30.16	30.16	30.16	30.16	30.16	30.16	30.16	30.16
lb/scf NO_2 $\times 10^{-5}$	3.33	3.52	2.45	2.63	2.64	2.60	2.60	2.60
lb/10^6Btu NO_2	0.57	0.60	0.42	0.45	0.45	0.45	0.45	0.45

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	9/9	9/9	9/9	9/10	9/10	9/10
Run No.	1	2	1 & 2	1	2	1 & 2
V_{mc}-Meter Volume, Ft^3	7.513	6.923	14.436	10.339	8.899	19.238
Vmstd-Meter Volume, Std. Cond.	7.565	6.971	14.536	10.376	8.931	19.307
P_B-Barometric Pressure, "Hg	30.14	30.14	30.14	30.04	30.04	30.04
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1	0.1	0.1	0.1	0.1	0.1
V_t-Vol. of Titrant, ml.	8.4	5.9	27.99	9.8	6.8	39.33
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil	nil	nil	nil	nil
Vsoln-Vol. of Solution, ml.	100	100	250	100	100	250
V_a-Vol. of Aliquot, Titrated, ml.	10	10	1	10	10	1
lb/scf H_2SO_4 $\times 10^{-6}$	12.00	9.14		10.20	8.22	
$lb/10^6$ Btu H_2SO_4	0.21	0.16		0.17	0.14	
lb-scf SO_2 $\times 10^{-4}$			3.39		3.59	
$lb/10^6$ Btu SO_2			5.81		6.14	

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$C_{H_2SO_4} = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

APPENDIX B
FIELD DATA

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	9/8	9/9	9/10	
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input $\times 10^6$ BTU/hr	82.0	83.8/81.3	81.6/79.6	
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb	11187			
Fuel Sulfur Content - %	3.465			
Fuel Ash Content - %	10.895			
Fuel Moisture Content %	7.71			

9/8

use 82.0×10^6 Btu/hr

9/9 for particulates & NO_x

9:00 AM	70×10^3 lb/hr steam
9:30	70
10:00	70
10:30	68
11:00	70
11:30	70
	69.67×10^3 lb/hr

$\div 9.3 = 7491.4$ lb/hr coal

$\times 11187 = 83.8 \times 10^6$ Btu/hr

9/9 for SO_2 & SO_3

11:30	70×10^3
12:00	67
12:30	70
1:00	71
1:30	69
2:00	63
2:30	63
	67.6×10^3 lb/hr

$\div 9.3 = 7268.8$ lb/hr coal

$\times 11187 = 81.3 \times 10^6$ Btu/hr input

9/10 for SO_2 & SO_3

9:00	69
9:30	67
10:00	70
10:30	68
11:00	65
	67.8×10^3 lb/hr = 7290.3 lb/hr coal = 81.6×10^6 Btu/hr

for Andersens

11:30	67
12:00	65
12:30	67
1:00	65
1:30	69
2:00	64
	66.2×10^3 = 7118.3 lb/hr coal = 79.6×10^6 Btu/hr

ORSAT FIELD DATA

Location General Motors - St. Louis Comments:

Date 9/8, 9/9, 9/10

Time

Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
9/8 1030	10.7	8.7	0
1105	11.8	8.2	0
1315	11.0	8.2	0
9/9 0900	10.5	8.9	0
0950	10.8	9.6	0
9/10 0850	10.3	9.9	0
1025	11.4	9.2	0
1315	11.2	8.8	0

Plant GMAD

Run No. 1

Location #2 Boiler

Date 9/8/75

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter Δ H@ 1.022

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.16

Assumed Moisture % 10

Heater Box Setting °F 4 (335°)

Probe Tip Dia., In. 3/8 → 1/4

Probe Length 5 ft, glass

Probe Heater Setting 5 (335°)

Avg. Δ P _____ Avg. Δ H _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O Δ P	Orifice Δ H in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:37	1219.490	0.18	1.15	1.15	160	80		310	340	-0.4	390
1-2	10:40	1222	0.21	1.4	1.4	210	69		335	340		420
1-3	11:10	1225	0.35	0.48	0.48	190	70	4.0	290	300		440
↓ Change to ¼ in nozzle 1-4	11:13	1226	0.4	0.55	0.55	220	68		315	330		440
1-5	11:16	1227.5	0.4	0.55	0.55	245	65		330	335		440
1-6	11:19	1229.4	0.32	0.44	0.44	260	66		350	370		435
1-7	11:22	1230.8	0.5	0.65	0.65	270	68		350	340		440
1-8	11:25	1232.3	0.5	0.65	0.65	275	68		350	310		440
off	11:28											
2-1	11:45	1233.8	0.25	0.35	0.35	215	80		340	315		310
2-2	11:48	1235.0	0.25	0.35	0.35	260	75		330	320		420
2-3	11:51	1236.3	0.18	0.25	0.25	245	72		335	335		430
2-4	11:54	1237.4	0.14	0.2	0.2	260	72		335	335		430
2-5	11:57	1238.4	0.14	0.2	0.2	250	72		340	345		430
2-6	12:00	1239.4	0.12	0.16	0.2	255	73		340	345		440
2 7	12:03	1240.4	0.35	0.48	0.48	260	72		345	365		440
2 8	12:06	1241.7	0.5	0.65	0.7	265	70	6.5	350	350		435
off	12:08	1243.5										

#1 RUN

Point	Clock Time	Dry Gas Meter CF	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	12:23	1243.50	0.25	0,34	0.34	195	85		335	270		360
3-2	12:26	1245	0,25	0.34	0.34	270	73		335	315		420
3-3	12:29	1246.1	0,2	0.3	0.3	270	70		335	335		420
3-4	12:32	1247.4	0,2	0.3	0.3	275	70		335	335		430
3-5	12:35	1248.5	0.16	0,2	0.2	270	70		340	340		435
3-6	12:38	1249.6	0.16	0.2	0.2							
3-7	12:41	1250.1	0.3	0.4	0.4	270	70		335	335		440
3-8	12:44	1252.0	0.55	0,75	0.75	270	69		340	340		440
off	12:47	1253.41	0,55									
4-1	1:01	1253.410	0,4	0,55	0.55	200	90		340	315		410
4-2	1:04	1255.2	0.32	0,45	0.45	270	70		335	325		430
4-3	1:07	1256.7	0,32	0.45	0.45							430
4-4	1:10	1257.9	0.28	0,4	0.4	265	70		340	345		430
4-5	1:13	1259.2	0,25	0.34	0,35	270	70		345	350		430
4-6	1:16	1260.5	0,3	0,42	0,42	275	71		350	360		430
4-7	1:19	1262	0,25	0.34	0.35							
4-8	1:22	12631	0,24	0.32	0,35	280	72		350	340		425
off	1:25	1264.230										

Comments After port 3, checked pitot against standard pitot in stack $\Delta P_s = 0.21$ $\Delta P_1 = 0.16$

$\left[\frac{\Delta P_1}{\Delta P_s}\right]^{1/2} = 0.87$

Plant GMAD

Run No. 2

Location #2 BOILER

Date 9/9/75

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.026

C Factor 0.53

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.14

Assumed Moisture % 2.5

Heater Box Setting °F _____

Probe Tip Dia., In. 1/4

Probe Length 5 ft. glass

Probe Heater Setting _____

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	9:06	1264.270	0.2	0.28	0.3	90	72	3.5	325	300	-0.4	430
1-2	9:09	1265.5	0.24	0.33	0.33	200	65		330	310		430
1-3	9:12	1266.75	0.25	0.35	0.35	215	65		335	315		430
1-4	9:15	1268.1	0.24	0.33	0.34	220	65		335	315		440
1-5	9:18	1269.4	0.24	0.33	0.34	230	64		340	315		440
1-6	9:21	1270.7	0.3	0.4	0.4	240	68		345	325		440
1-7	9:24	1272.2	0.45	0.6	0.6	240	65	6.0	345	330		440
1-8	9:27	1274	0.5	0.7	0.7	250	65		350	330		440
Off	9:30	1275.55										
2-1	9:43	1275.545	0.25	0.35	0.35	160	75		350	315		330
2-2	9:46	1276.7	0.2	0.28	0.3	250	69		355	330		430
2-3	9:49	1278	0.15	0.2	0.2	255	70		350	335		440
2-4	9:52	1279	0.1	0.15	0.15	255	70		350	325		440
2-5	9:55	1280.1	0.1	0.15	0.15	255	70		350	335		440
2-6	9:58	1281.0	0.15	0.2	0.2	255	72		345	340		440
2-7	10:01	1282.0	0.25	0.35	0.35	260	70		345	350		440
[illegible]	[illegible]	1283.6	0.65	0.9	0.9	265	67		350	350		440
[illegible]	[illegible]	1285.10										

GMAD # 2 Run

Point	Clock Time	Dry Gas Meter CF	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	10:18	1285.10	0.3	0.4	0.4	150	79		340	300		430
-2	:21	1286.6	0.2	0.3	0.3	250	68		340	320		440
-3	:24	1287.7	0.16	0.22	0.25	255	66		340	330		440
-4	:27	1288.8	0.12	0.15	0.15	250	64		340	340		440
-5	30	1289.7	0.1	0.14	0.15	250	65		340	340		440
-6	33	1290.7	0.14	0.16	0.16	250	65		340	355		440
-7	36	1291.4	0.25	0.35	0.36	250	67		345	345		440
-8	39	1292.6	0.6	0.82	0.83	260	63		345	330		440
off	:42	1294.35										
4-1	10:53	1294.355	0.4	0.55	0.55				345	350		430
-2	:56	1296.1	0.45	0.6	0.6	260	63		345	350		440
-3	:59	1297.7	0.4	0.55	0.55	270	63		350	350		445
-4	11:02	1299.4	0.3	0.42	0.42	275	65	5.0	345	330		450
-5	:05	1300.8	0.3	0.42	0.42	270	65		350	340		450
-6	:08	1302.2	0.35	0.5	0.5	275	65		345	335		450
-7	:11	1303.7	0.4	0.55	0.55	275	65		345	330		450
-8	:14	1305.3	0.5	0.7	0.7	275	65		350	330		450
off	11:17	1306.880										

Comments

PARTICULATE CLEANUP SHEET

Date: 9/8/75 Plant: GMAD

Run Number: 1 Location Of Sample Port: #2 Boiler

Operator: _____ Barometric Pressure: 30.16

Sample Box No. _____ Ambient Temperature 85

Impinger H_2O Silica Gel

Volume After Sampling 272 ml Weight After 519.0 g

Impinger Prefilled With 200 ml Weight Before 505.2 g

Volume Collected 72.0 ml Moisture Weight 13.8 g Moisture Total 85.8 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.1494 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.

Filter Particulate Weight 0.1451 g

Total Particulate Weight 0.2945 g

% Moisture By Volume

PARTICULATE CLEANUP SHEET

Date: 9/9/75 Plant: GMAD

Run Number: 2 Location Of Sample Port: #2 Boiler

Operator: _____ Barometric Pressure: 30.14

Sample Box No. _____ Ambient Temperature 85

Impinger H_2O Silica Gel

Volume After Sampling 260 ml Weight After 528.4 g

Impinger Prefilled With 200 ml Weight Before 519.0 g

Volume Collected 60 ml Moisture Weight 9.4 g Moisture Total 69.4 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.1388 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
_____	_____	_____	_____	Filter Particulate Weight 0.1303 g
_____	_____	_____	_____	
_____	_____	_____	_____	Total Particulate Weight 0.2691 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 9/8/75

Plant General Motors

Sample Collected By Klein

Field Data

Clock Time	1150	1200	1230	1230	1325	1330		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2047	2038	2039	2028	2025	2052		
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5		
Pressure after sampling, in. Hg.	30.16	30.16	30.16	30.16	30.16	30.16		
Flask temperature, ^{o}F	90	90	90	90	90	90		

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 9/9/75

Plant General Motors

Sample Collected By Klein

Field Data

Clock Time	0910	0912	1008	1010	1040	1042	1240	1245
Flask number	1	2	3	4	5	6	7	8
Volume of flask (ml)*	2047	2038	2039	2028	2025	2052	2052	2056
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pressure after sampling, in. Hg.	30.14	30.14	30.14	30.14	30.14	30.14	30.14	30.14
Flask temperature, ^{o}F	90	90	90	90	90	90	90	90

* Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/9/75

Plant GMAD Location #2 BOILER

Bar. Pressure 30.14 "Hg Comments: Point 2-6

Ambient Temp 90 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
1:00	1327.042	0.15	0.1	450	325		120	85
1:05	1328.3	0.15	0.1	450	325	160	130	75
1:10	1329.6	0.15	0.1	445	340	170	145	75
1:15	1330.9	0.15	0.1	440	350	175	140	76
1:20	1332.2	0.12	0.1	445	325	174	135	77
1:25	1333.5	0.15	0.1	440	315	170	130	80
1:30	1334.630							

Comments: 7.588 ft^3

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/9/75

Plant GMAD Location #2 BOILER

Bar. Pressure 30.14 "Hg Comments: Point 2-6

Ambient Temp 90 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
1:40	1334.630	0.15	0.1	440	300	145	110	82
1:45	1336.0	0.15	0.1	440	340	152	120	74
1:50	1337.0	0.12	0.1	440	325	164	140	74
1:55	1338.2	0.12	0.1	430	325	170	135	75
2:00	1339.3	0.12	0.1	430	320	170	130	76
2:05	1340.5	0.15	0.1	435	310	165	125	77
2:10	1341.622							

Comments: 6.992 ft^3

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/10/75

Plant GMAD Location #2 Boiler

Bar. Pressure 30.04 "Hg Comments:

Ambient Temp 80 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
9:13	1341.630	0.18	0.1	430	270	175	130	89
9:18	1342.9	0.2	0.1	430	305	170	150	79
9:28	1345.	0.2	0.1	430	300	165	125	79
9:38	1347.5	0.19	0.1	435	315		120	80
9:48	1349.8	0.2	0.1	430	330	160	118	81
9:58	1352.072							

Comments: 10.442 ft^3 Coal Counter 8:45 966511 1 count = 2a

10:05 966562

12:55 966668

2:00 966703

192 × 200 = 38400

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/10/75

Plant GMAD Location #2 BOILER

Bar. Pressure 30.04 "Hg Comments :

Ambient Temp 85 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator _____

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
10:10	1352.072	0.2	0.1	440	280	140	140	88
10:15	1353.15	0.19	0.1	440	290		160	85
10:25	1355.25	0.18	0.1	440	330	166	150	83
10:35	1357.2	0.2	0.1	440	355		130	87
10:45	1359.1	0.2	0.1	440	315	160	125	88
10:55	1361.060	0.2						

Comments: 8.988 ft^3

Plant GMAD

Run No. 1 - Andersen

Location #2 Boiler

Date 9/10/75

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter ΔH@ 1.022

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Filters in Oven

Ambient Temp °F 90

Bar. Press. "Hg 30.04

Assumed Moisture % 8.5

Heater Box Setting °F _____

Probe Tip Dia., In. 1/4

Probe Length 5 ft. glass

Probe Heater Setting _____

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-7	11:45	1361.060	0.29	0.4	0.4	190	80	5.5	300	290	-0.4	430
	11:48	1362.38	0.29	0.4	0.4	210	71		302	295		430
	11:51	1363.75	0.29	0.4	0.4	208	70		298	302		430
	11:54	1365.05	0.3	0.41	0.4	220	70		308	320		430
	11:57	1366.40	0.3	0.41	0.4	220	70		305	330		435
	12:00	1367.75	0.3	0.41	0.4	224	71		293	320		435
	12:03	1369.03	0.3	0.41	0.4	230	71	6.0	300	325		435
	12:06	1370.35	0.29	0.4	0.4	235	71		299	315		435
	12:09	1371.75	0.26	0.36	0.4	240	71		304	325		430
	12:12	1372.95	0.29	0.4	0.4	240	71		300	315		430
	12:15	1374.283										

Plant GMAD

Run No. 2 · Andersen

Location #2 BOILER

Date 9/10/75

Operator _____

Sample Box No. _____

Meter Box No. _____

Meter Δ H@ _____

C Factor _____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Filters in Oven

Ambient Temp °F 90

Bar. Press. "Hg 30.04

Assumed Moisture % 8.5

Heater Box Setting °F 7

Probe Tip Dia., In. 1/4

Probe Length 5 ft glass

Probe Heater Setting 7

Avg. Δ P _____ Avg. Δ H _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2·7	1:12	1374.283	0.29	0.4	0.4	175	90	5.5	360	310	-0.4	430
	1:15	1375.6	0.28	0.38	0.4	255	75		365	325		430
	1:18	1377.0	0.23	0.32	0.4	265	74		365	320		430
	1:21	1378.28	0.29	0.4	0.4	270	73		363	310		430
	1:24	1379.7	0.24	0.33	0.4	280	73	6.0	367	320		430
	1:27	1381.0	0.29	0.4	0.4	285	75		369	320		430
	1:30	1382.3	0.20	0.28	0.4	295	76		375	335		430
	1:33	1383.6	0.24	0.33	0.4	295	76		375	330		430
	1:36	1385.0	0.28	0.38	0.4	300	75		380	330		430
	1:39	1386.2	0.27	0.37	0.4	310	78		390	345		430
	1:42	1387.620										

PARTICULATE CLEANUP SHEET

Date: 9/10/75 Plant: GMAD

Run Number: Andersen 1 & 2 Location Of Sample Port: #2 BOILER

Operator: _____ Barometric Pressure: 30.04

Sample Box No. _____ Ambient Temperature _____

Impinger H_2O Silica Gel

Volume After Sampling 241 ml Weight After 515.4 g

Impinger Prefilled With 200 ml Weight Before 506.0 g

Volume Collected 41 ml Moisture Weight 9.4 g Moisture Total 50.4 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0406g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
Backup	_____	Filters 4	_____	Filter Particulate Weight 0.1273 g
Filters	_____	_____	_____	
Backup 8	_____	_____	_____	Total Particulate Weight 0.1679 g

% Moisture By Volume

Particle Size Determination

Test: 1 Date: 9/10/75

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1489	0.1500		1.1		1.43	1.43	16.8
2	0.1437	0.1454		1.7		2.21	3.64	10.7
3	0.1470	0.1505		3.5		4.55	8.19	7.1
4	0.1416	0.1463		4.7		6.10	14.29	4.9
5	0.1512	0.1558		4.6		5.97	20.26	3.1
6	0.1444	0.1490		4.6		5.97	26.23	1.6
7	0.1492	0.1527		3.5		4.55	30.78	0.99
8	0.1437	0.1490		5.3		6.88	37.66	0.66
Back Up Filter	0.2145	0.2625		48.0		62.34	100.0	<0.66
		Total		77.0		100.0		

Test: 2 Date: 9/10/75

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1485	0.1497		1.2		2.39	2.39	17.3
2	0.1410	0.1424		1.4		2.78	5.17	10.9
3	0.1525	0.1558		3.3		6.56	11.73	7.3
4	0.1400	0.1453		5.3		10.54	22.27	5.0
5	0.1523	0.1571		4.8		9.54	31.81	3.2
6	0.1461	0.1506		4.5		8.95	40.76	1.7
7	0.1468	0.1500		3.2		6.36	47.12	1.0
8	0.1488	0.1526		3.8		7.55	54.67	0.68
Back Up Filter	0.2132	0.2360		22.8		45.33	100.0	<0.68
		Total		50.3		100.0		

SOURCE TEST REPORT
AMOCO OIL REFINERY
WOOD RIVER, ILLINOIS
BOILER NO. 6 - POWERHOUSE
AND
CATALYTIC CRACKER REGENERATOR

TESTED BY: ROCKWELL INTERNATIONAL
R.W. Griscom
O.C. Klein
F.E. Littman

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TABLES

FIGURES

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler no. 6 in the powerhouse and the stack for the catalytic cracker regenerator at the Amoco Oil Refinery in Wood River, Illinois.

The stack testing included the following pollutants: sulfur dioxide (SO_2), particulates, nitrogen oxides (NO_x), sulfuric acid mist (H_2SO_4), and hydrocarbons. Orsat analysis is for carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2) were also performed. Results of these tests are included in this report. The tests on boiler no. 6 were not conducted to ascertain compliance with Illinois standards. Amoco Oil may choose to use the test on the catalytic cracker regenerator for demonstrating compliance since the precipitator on this unit was just recently installed. Thus, it is of interest to note that this unit is in compliance with the regulations for particulates, SO_2 and CO.

The test on the catalytic cracker regenerator was witnessed by E. Sullivan, R. Yoder, and J.C. Rhodes of Amoco and Dr. John Reed of Illinois EPA Permit Section and Mr. Fred Smith of Illinois EPA Testing Section.

We acknowledge and appreciate the excellent cooperation we obtained from the management and engineering personnel of the Amoco Oil Refinery.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Amoco Oil Refinery in Wood River, Illinois. Testing was performed on the No. 6 boiler at the powerhouse on 4, 5 and 6 November 1975 and on the Catalytic Cracker Regenerator on 12 and 17 November 1975.

Boiler No. 6 is an oil and gas fired, 200,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen and hydrocarbons.

The Catalytic Cracker Regenerator was recently equipped with an electrostatic precipitator. This stack test may be used as a compliance test on the newly installed precipitator. This unit was sampled for total particulates, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen, carbon monoxide and hydrocarbons.

3.0 PROCESS DESCRIPTION

Boiler no. 6 was built in 1954 by Babcock and Wilcox. The boiler is fired with a combination of plant oil and gas streams. Steam pressure is approximately 600 psi. This boiler "swings" with the plant, that is, it picks up upsets or changes in plant operation or demands. The capacity of this boiler is rated at 200,000 pounds of steam per hour. For environmental concerns this boiler has been derated to less than 250×10^6 Btu/hr input.

There are no stack emission controls on this boiler. Boiler no. 6 is an induced draft unit and exhausts through a masonary lined, steel stack which is 159 feet tall and 8.5 feet inside diameter.

The Catalytic Cracker Regenerator has had an electrostatic precipitator installed during 1975. This precipitator was started up at the end of October 1975. There is also a waste boiler being installed ahead of the precipitator but this was not in operation at the time of testing. The stack is of steel construction and is 171 feet tall and 8 feet inside diameter.

4.0 PROCESS OPERATION

Boiler no. 6 was tested on 4,5 and 6 November 1975. During the testing the boiler load remained fairly constant even though it was picking up any changes in plant operation. This boiler was fired on refinery gas, fuel oil, and "slop" oil during testing. Since there are no individual meters there was no way of knowing how much of each fuel was being burned. There were no visible changes in emissions during testing.

The Catalytic Cracker Regenerator was tested on 12 and 17 November 1975. Since the startup of the precipitator during late October there had been some problems with the precipitator. During testing, the conveyors that remove the collected material from the precipitator were not operating. This did not seem to interfere with testing. On 17 November, however, there was a short in one of several compartments of the precipitator and the precipitator was only kept in operation for our particulate test. The tests for sulfur dioxide, sulfuric acid mist, and nitrogen oxides were run with the precipitator by-passed. Visible emissions at this time increased significantly.

Since the waste heat boiler was still being installed during testing, water was being sprayed into the gas stream to drop the gas temperature from 1,000^{o}F to 600^{o}F to prevent damage to the precipitator. This condition raised the flue gas moisture content to approximately 29%.

5.0 SOURCE TEST DESCRIPTION

Boiler no. 6 was tested in the stack. The sampling location and testing arrangement are shown in Figures 1 and 2. Figure 2 illustrates how the sampling equipment was somewhat obstructed. In order to make a complete traverse at this sample port, a short 5 foot probe was used for the near points and a longer 10 foot probe was used for the far sample points..

The stack is 8.5 foot inside diameter. The sampling location was approximately 36 feet from the stack inlet which is perpendicular to the stack. This means that the sample ports are 4 diameters from the inlet. In accordance with EPA Standard Method 1, 36 sampling points were chosen, 18 on a traverse. A 3-inch pipe coupling, pipe nipple, and reducing flange were used to attach to an existing standard 4-inch flange on the sample ports.

The Catalytic Cracker Regenerator was tested in the stack after the precipitator. Figure 3 illustrates the regenerator to the right followed by the precipitator in the center and the stack to the left. Figure 4 shows the stack and sampling platform and the crane used to hoist the sampling equipment up to the platform. The testing arrangement is shown in Figures 5 and 6.

The stack is 8 foot inside diameter and the sampling location is approximately 80 feet from the stack inlet. In accordance with EPA Standard Method 1, since the sampling location was more than 8 diameters from the inlet, 12 sample points were chosen, 6 on a diameter. A 3-inch pipe coupling, pipe reducer, and a 4-inch flange were used to attach to the existing 4-inch flanges on the sample ports.

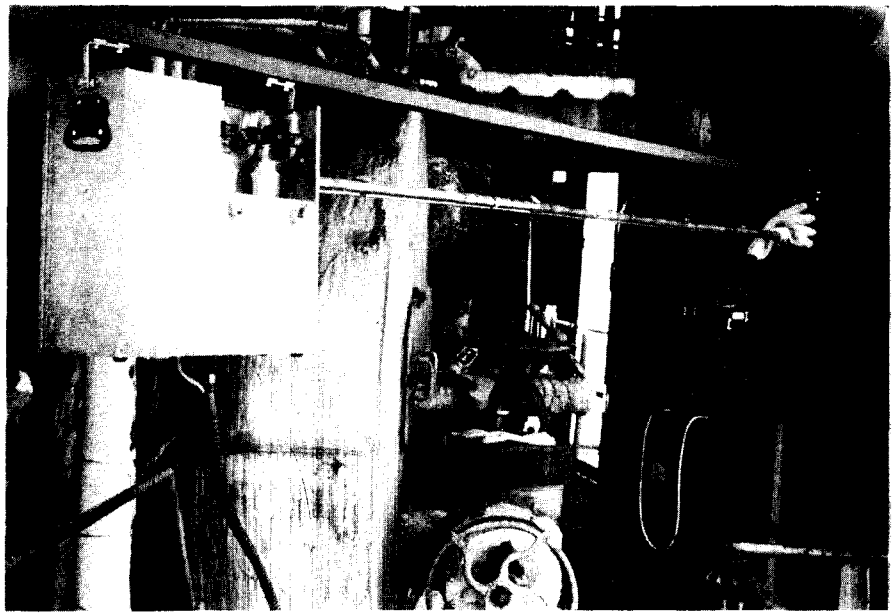


FIGURE 1

SAMPLING EQUIPMENT SET UP AT SE PORT - BOILER NO. 6

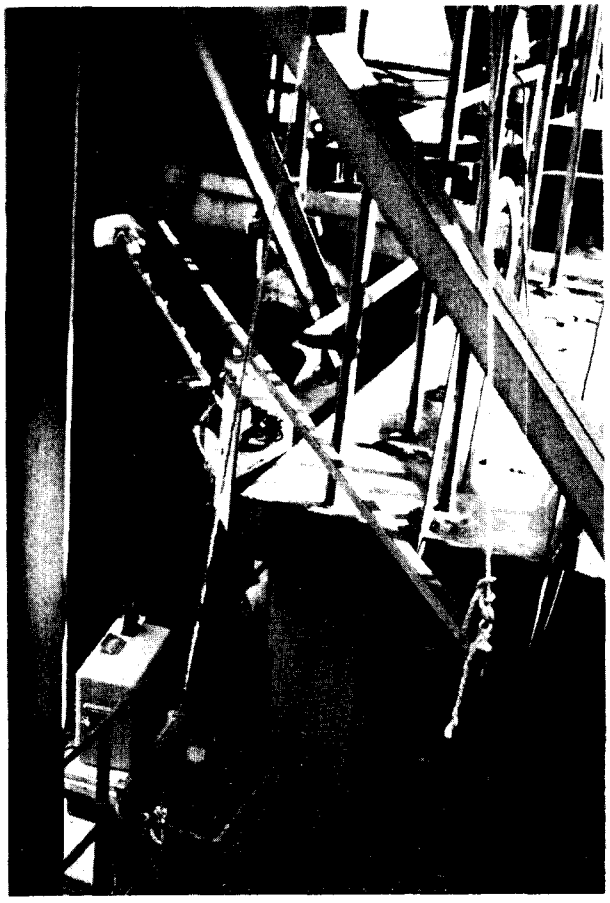


FIGURE 2

SAMPLING EQUIPMENT SET UP AT SW PORT - BOILER NO. 6

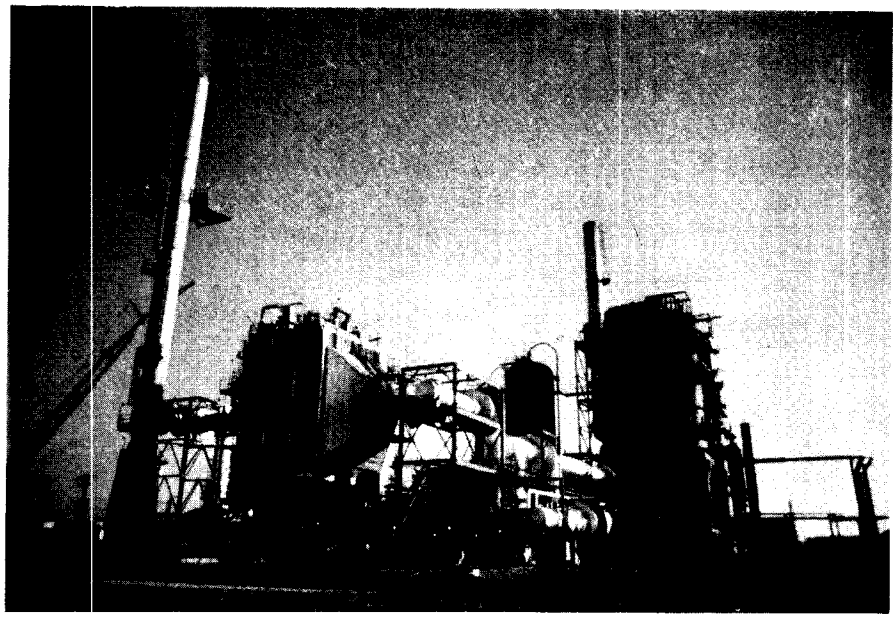


FIGURE 3

CATALYTIC CRACKER REGENERATOR, PRECIPITATOR, AND STACK

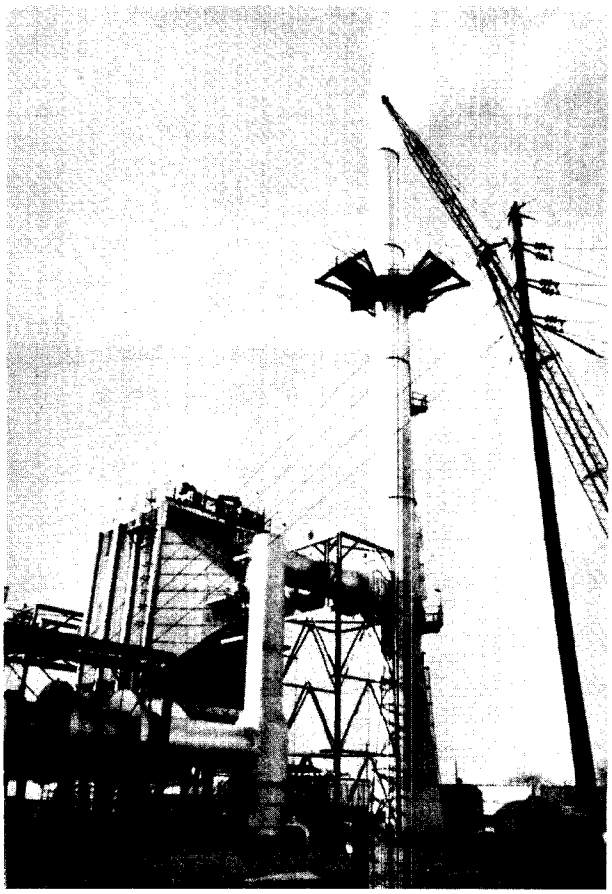


FIGURE 4

STACK, SAMPLING PLATFORM, AND CRANE FOR HOISTING

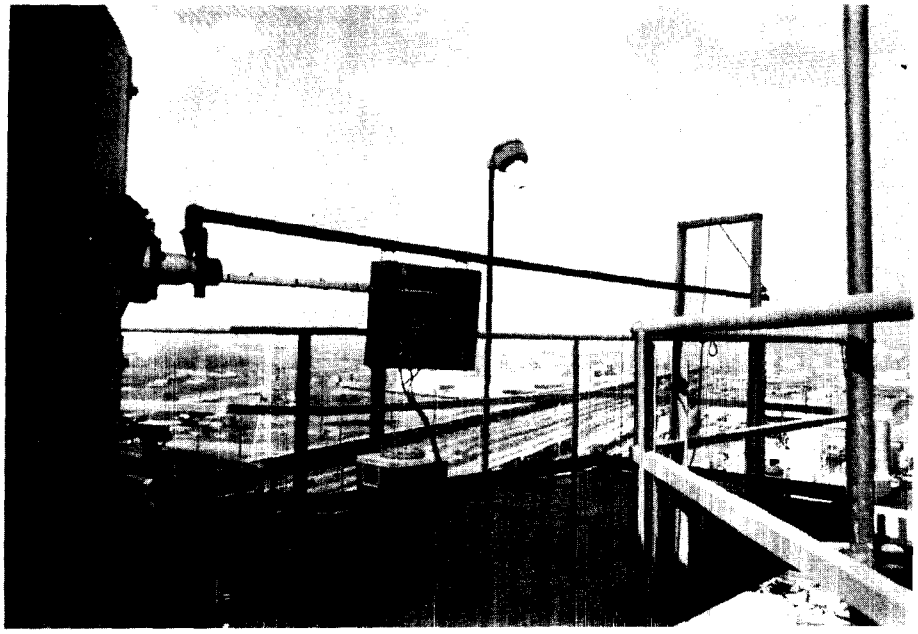


FIGURE 5

SAMPLING EQUIPMENT SUPPORT

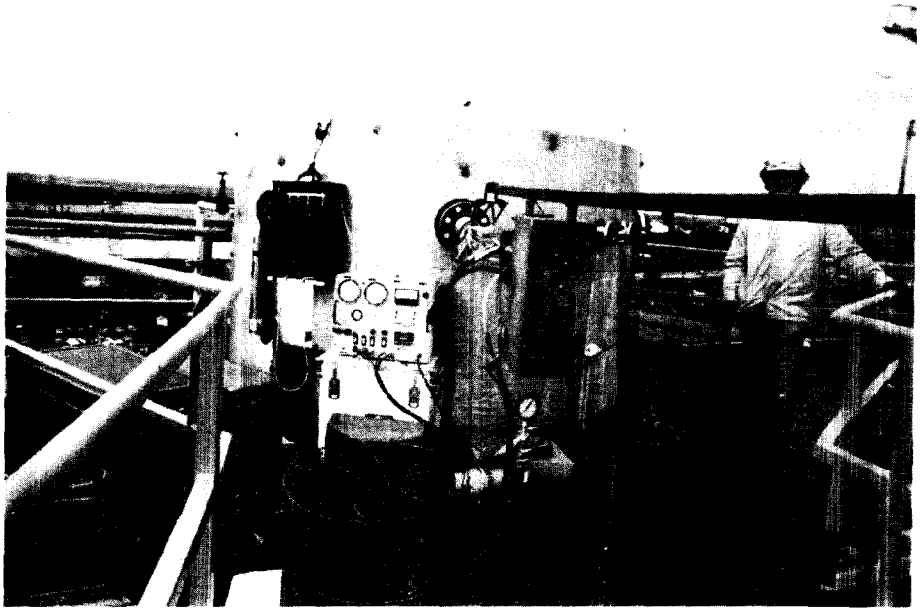


FIGURE 6

SAMPLING EQUIPMENT SET UP FOR TESTING

6.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from the increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

6.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350 ^{o}F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 7.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

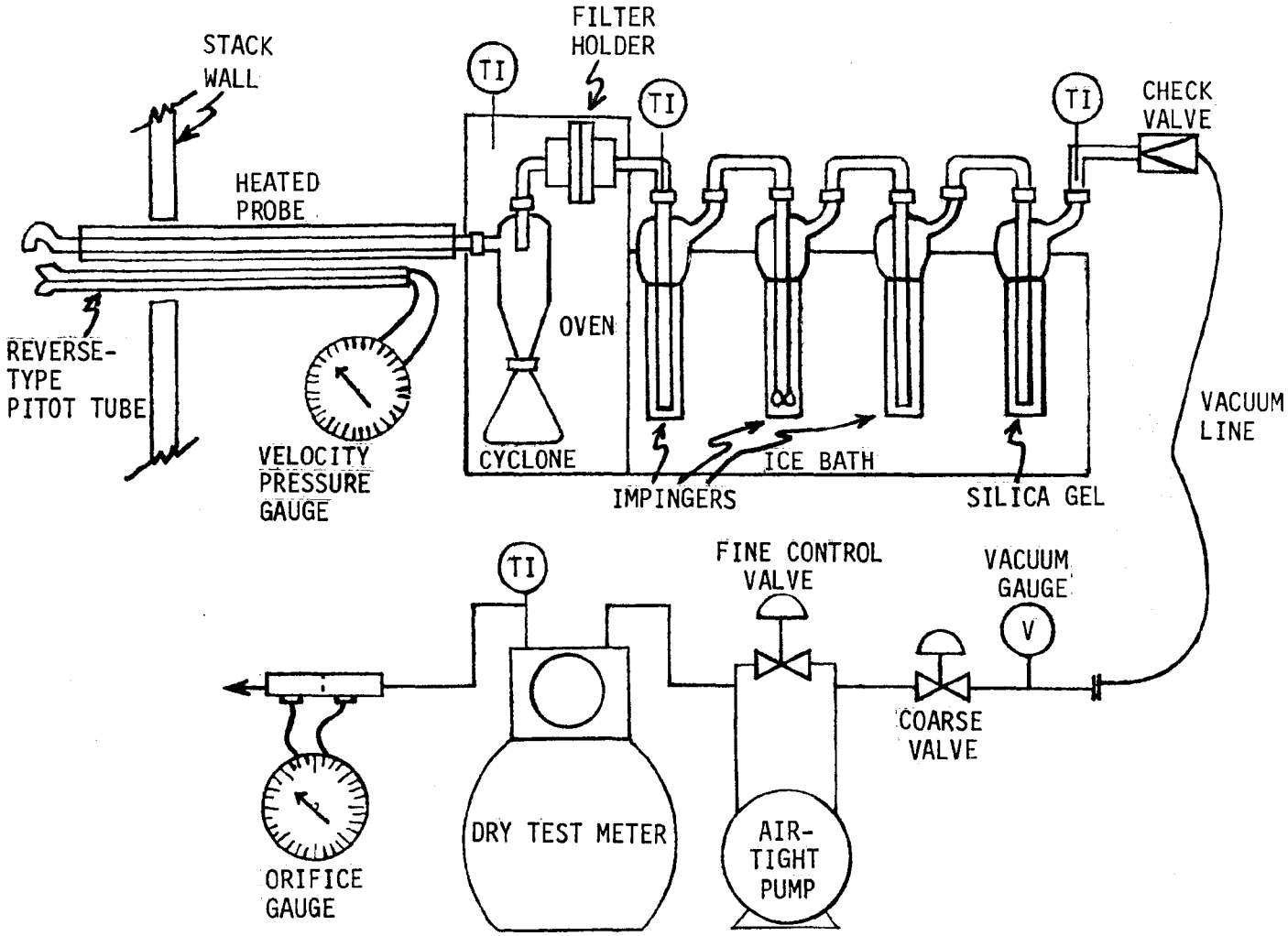


FIGURE 7

PARTICULATE SAMPLING TRAIN

6.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

6.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The Shell method was chosen for this determination due to uncertainties which exist about the validity of the results using method 8.* A gas sample is drawn from the stack using a heated probe and passed through a water-cooled coil condenser maintained below the dew point of sulfuric acid at 140^{o}-194^{o}F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 8.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

* Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases," Combustion, Jan. 1965.

Goksoyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases," J. Inst. Fuel, No. 35, 177, (1962)

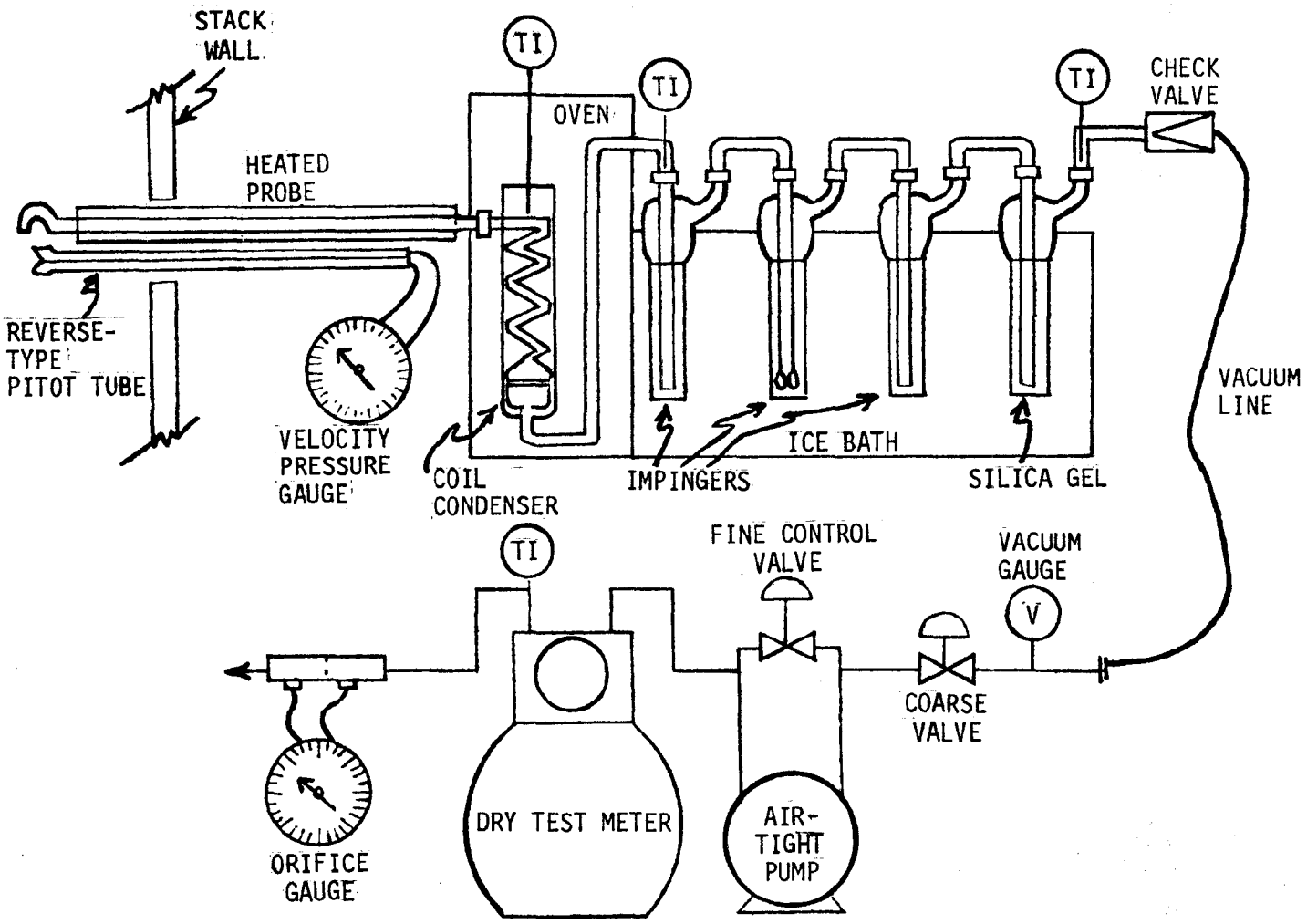


FIGURE 8

SULFURIC ACID MIST SAMPLING TRAIN

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide in the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

6.4 PARTICLE SIZE

An Anderson fractioning inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 12.0 microns. The sampling head is placed in the oven after the heated sampling probe and a sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density. The sampling head assembly is shown in Figure 9.

6.5 HYDROCARBONS

Gas samples were withdrawn from the stack using a vacuum pump to fill Tedlar bags. The composition of the hydrocarbons was determined by gas chromatograph utilizing a Beckman 6800 for CO, CH_4, and total hydrocarbons and a Perkin Elmer 900 for the complete hydrocarbon breakdown.

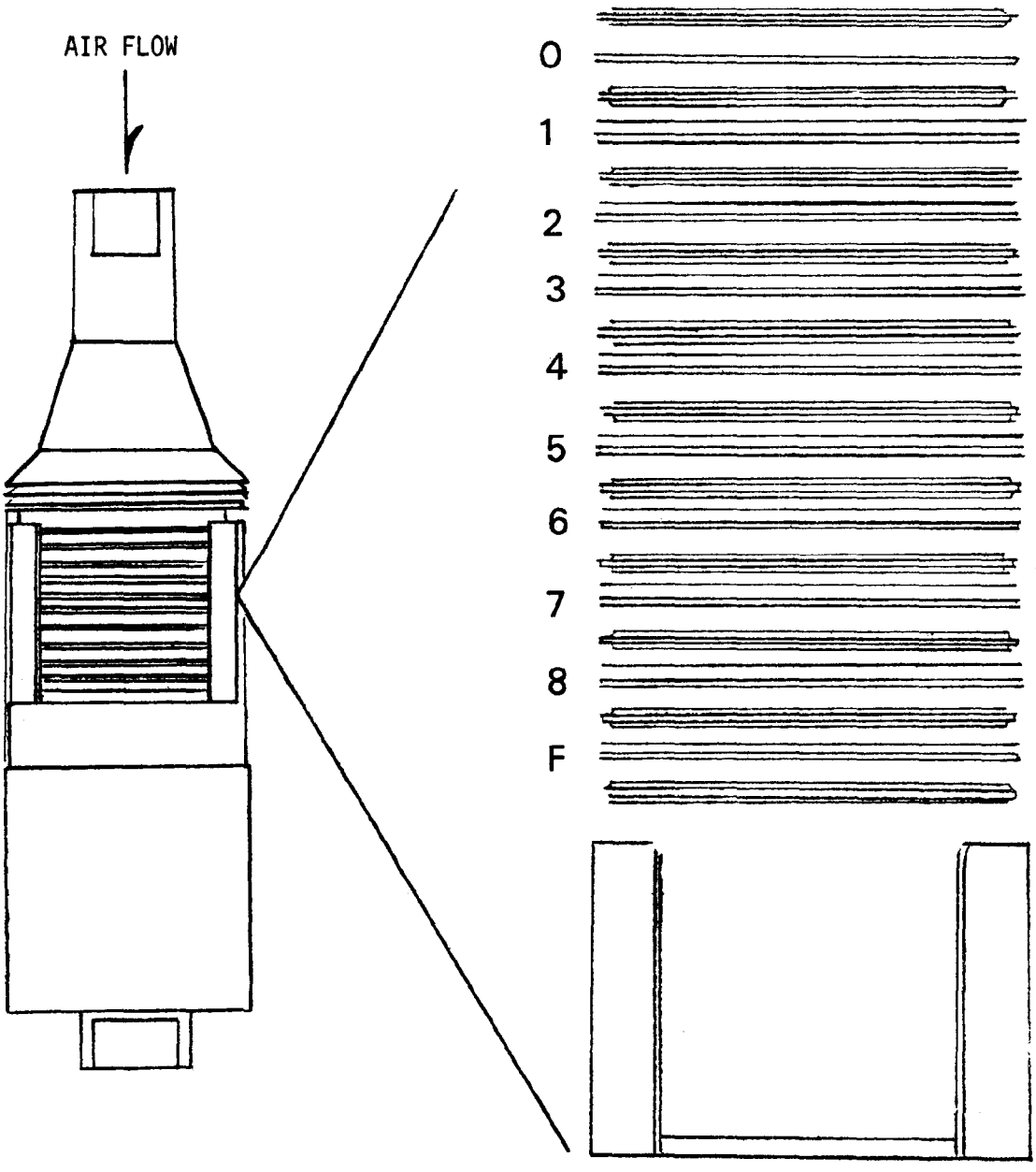


FIGURE 9

ANDERSEN STACK SAMPLER

7.0 RESULTS

Results obtained from the test on boiler no. 6 are shown in Table 1. Results obtained from the test on the Catalytic Cracker Regenerator are shown in Table 2. Although these tests were performed for research purposes, standard EPA methods were used. Since the test on the Catalytic Cracker Regenerator may be used for compliance, it is of interest to compare the results with the State of Illinois standards. A comparison is shown in Table 3.

In addition to measuring particulate loadings on boiler no. 6, a particle size analysis was made using an Andersen impactor. The results are shown in Table 4 and Figure 10.

The average results of hydrocarbon samples taken on boiler no. 6 on 4 and 5 November are:

Carbon Monoxide:	1.11 ppm
Methane:	1.07 ppm
Total Hydrocarbons, as CH_4	3.28 ppm

The major hydrocarbon components of these samples are given in Table 5.

The average results of hydrocarbon samples taken on the Catalytic Cracker Regenerator on 10 and 12 November are:

Carbon Monoxide:	28.91 ppm
Methane:	0.13 ppm

Total hydrocarbon results are not available due to a malfunction of the analyzer. A complete analysis of the major components indicates that the total hydrocarbons are approximately 2-3 ppm. The major components are given in Table 6.

TABLE 1

SUMMARY OF RESULTS - BOILER NO. 6

Date	11/4	11/5	11/6		
Stack Flow Rate - SCFM * dry	54,010	47,766	42,348		
% Water Vapor - % Vol.	13.19	12.67			
% CO_2 - Vol % dry	10.33	10.83			
% O_2 - Vol % dry	5.90	6.30			
% Excess air @ sampling point	35.6	39.6			
SO_2 Emissions - lbs/10^6 Btu			1.88		
NO_x Emissions - lbs/10^6 Btu	0.45	0.58			
H_2SO_4 Mist - lbs/10^6 Btu			0.021		
Particulates Probe, Cyclone, & Filter Catch lbs./hr.					
lbs/10^6 Btu					
Total Catch					
lbs./hr.	26.4	32.2			
lbs/10^6 Btu	0.14	0.18			
% Isokinetic Sampling	100.4	92.7			

*70° F, 29.92" Hg

TABLE 2

SUMMARY OF RESULTS - CATALYTIC CRACKER REGENERATOR

Date	11/12	11/17			
Stack Flow Rate - SCFM * dry	87,367	84,642			
% Water Vapor - % Vol.	27.98	29.9			
% CO_2 - Vol % dry	16.5	17.2			
% O_2 - Vol % dry	1.65	1.4			
% Excess air @ sampling point	8.1	6.8			
SO_2 Emissions - PPM		419			
NO_x Emissions - PPM	71.2	362.7			
H_2SO_4 Mist - PPM		3.4			
Particulates Probe, Cyclone, & Filter Catch lbs./hr.					
lbs/10^6 Btu					
Total Catch					
lbs./hr.	18.7	27.4			
lbs/10^6 Btu					
% Isokinetic Sampling	116.3	100.26			

*70^0 F, 29.92" Hg

TABLE 3

COMPARISON OF RESULTS

SOURCE	POLLUTANT	ILLINOIS STATE STANDARD	AMOUNT FOUND
Boiler No. 6	Particulates	0.1 $lb/10^6$ Btu	0.16 $lb/10^6$ Btu
	SO_2	1 $lb/10^6$ Btu	1.9 $lb/10^6$ Btu
	CO	200 ppm	1.1 ppm
Catalytic Cracker Regenerator	Particulates	80.1 lb/hr	23.1 lb/hr
	SO_2	2000 ppm	419.0 ppm
	CO	200 ppm	28.9 ppm

TABLE 4

PARTICLE SIZE DETERMINATION

TEST: AMOCO - BOILER NO. 6 DATE: 11/4

Plate	Filter Net (mg)	% Of Total	ECD (microns)
1	0.0	0.0	14.4 & above
2	0.0	0.0	9.1
3	4.0	3.57	6.1
4	4.7	4.19	4.3
5	6.9	6.16	2.6
6	9.8	8.74	1.4
7	11.7	10.44	0.84
8	15.1	13.47	0.56
Backup	59.9	53.43	<0.56
	112.1	100.00	

TEST: AMOCO - BOILER NO. 6 DATE: 11/6

Plate	Filter Net (mg)	% Of Total	ECD (microns)
1	1.7	2.75	14.2 & above
2	4.6	7.44	9.0
3	1.4	2.27	6.0
4	2.6	4.21	4.3
5	2.7	4.37	2.6
6	5.1	8.25	1.4
7	6.1	9.87	0.83
8	8.9	14.40	0.55
Backup	28.7	46.44	<0.55
	61.8	100.00	

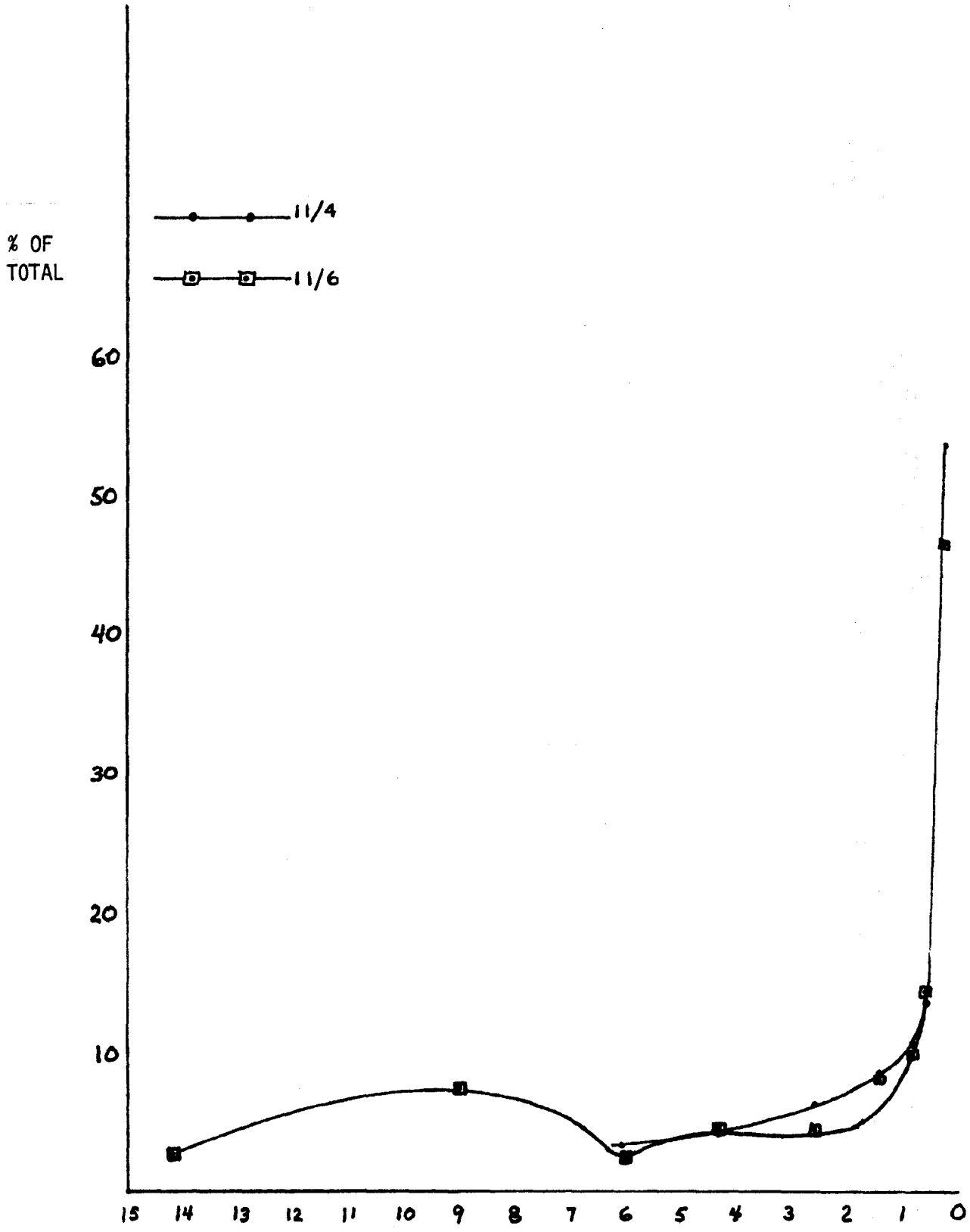


FIGURE TO

PARTICLE SIZE DISTRIBUTION-BOILER NO. 6

TABLE 5
HYDROCARBON ANALYSIS
BOILER NO. 6

COMPOUND	CONCENTRATION (ppb as C)	
	11/4	11/5
Ethane	20.7	16.8
Ethylene	36.3	27.8
n-Propane	35.5	34.3
Acetylene	35.0	32.8
n-Butane	55.7	52.2
Isopentane	11.1	7.5
n-Pentane	5.4	8.4
Hexane	29.7	33.0
Benzene + 2,4 DM-C_5		18.5
Heptane		15.1
2,5 dimethyl Hexane		10.9
Toluene	33.3	94.6
1, Octene	38.9	128.5
Octane	4.1	9.1
Ethyl Benzene	24.3	56.7
m, p-Xylene	123.2	290.3
o-Xylene	37.5	79.0
Nonane	13.2	19.1
n-Propyl Benzene	9.7	49.6
1,3,5 trimethyl Benzene	16.4	

TABLE 6

HYDROCARBON ANALYSIS

CAT CRACKER REGENERATOR

COMPOUND	CONCENTRATION (ppb as C) 11/10	11/12
Ethane		19.5
Ethylene		12.8
n-Propane		51.3
Acetylene		9.5
Isobutane		16.7
n-Butane		4.7
Propylene		3.7
Isopentane		1.4
n-Pentane		5.1
Hexane	41.3	
Benzene + 2,4 DM Pentane	38.1	
Heptane	27.6	
Toluene	46.1	
1, Octene	29.3	
Octane	4.4	
Ethyl Benzene	18.6	
m,p-Xylene	111.2	
o-Xylene	38.1	
Nonane	10.4	

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{o} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{o} R or 70^{o} F

Tm = Meter temperature, 530^{o} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{lc}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\quad \frac{lb.}{454\ gm.} = 0.0474 \times V_{lc}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{lc} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{o}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%\ O_2 \times \frac{32}{100}\right) + \left(\%\ N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \%\ M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P\ avg.}{Ps \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb.\ Mols - {}^oR}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^oR

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s\ A\left(\frac{Tstd}{Ts}\ \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667 \left[(0.00267) \quad V_{lc} \quad + \quad \frac{V_{mc}}{T_m} \left(P_B + \frac{\Delta H}{13.6} \right) \right] T_s}{\Theta \, V_s \, P_s \, A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454 \text{ gm.}}$$

Θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \quad X \quad 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$$

C_s = particulate emission, lb/scf

2.205×10^{-6} = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \times Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Blr. 6 - Run 1 Date: 11/4/75

Material collected (mg) =

Filter Catch = 217.3
Dry Catch =
Acetone Wash = 59.7

TOTAL = 277.0

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{76.078}{1.01}\right)\left(29.68 + \frac{0.9695}{13.6}\right) =$ 74.850 SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (240 ml) = 11.376 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(11.376)}{(74.85) + (11.376)} =$ 13.19 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.33 \times 0.44) + (5.9 \times 0.32) + (83.77 \times 0.28) =$ 29.889

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 13.19}{100} \times 29.889\right] + \left[\frac{13.19}{100} \times 18\right] =$ 28.321

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 6 - Run 1 Date: 11/4/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{896.5 \times 0.154}{29.64 \times 28.321}\right] 1/2 =$ 30.10 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(13.19)}{100}\right](30.1)\ (56.745)\ \frac{530}{(896)}\ \frac{(29.08)}{29.92} =$ 3,240,613 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(277)}{(74.85)} =$ 8.16×10^{-6} lb/scf

$C_E = C_s \times Qs = (8.16 \times 10^{-6})\ (3,240,613) =$ 26.44 lb/hr

$C_H = C_E \div H = \frac{(26.44)}{(185.8)} =$ 0.14 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ Ps\ A_n}$

$1.667 \frac{\left[(0.00267)\ (240) + \frac{75.325}{530}\left(29.68 + \frac{0.9695}{13.6}\right)\right](896.52)}{(108)\ (30.10)\ (29.08)\ (7.67 \times 10^{-4})} =$ 100.3%

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (5.9)}{(0.266 \times 83.77) - (5.9)} =$ 36.0%

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Blr. 6 - Run 2 Date: 11/5/75

Material collected (mg) =

Filter Catch = 290.9
Dry Catch =
Acetone Wash = 59.7

TOTAL = 350.6

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{69.735}{1.01}\right)\left(29.75 + \frac{0.8196}{13.6}\right) =$ 68.745 SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (210.4ml) = 9.973 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(9.973)}{(68.745) + (9.973)} =$ 12.67 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.83 \times 0.44) + (6.3 \times 0.32) + (82.83 \times 0.28) =$ 29.973

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 12.67}{100} \times 29.973\right] + \left[\frac{12.67}{100} \times 18\right] =$ 28.456

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 6 - Run 2 Date: 11/5/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{908.42 \times 0.1324}{29.71 \times 28.156}\right] 1/2 =$ 27.73 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{P_s}{Pstd}\right)$

$3600 \left[1 - \frac{(12.67)}{100}\right](27.73)\ (56.745)\ \frac{530}{(908)}\ \frac{(29.71)}{29.92} =$ 2,865,983 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(350.6)}{(68.745)} =$ 1.125×10^{-5} lb/scf

$C_E = C_s \times Qs = (1.125 \times 10^{-5})\ (2,865,983) =$ 32.229 lb/hr

$C_H = C_E \div H = \frac{(32.229)}{(177.0)} =$ 0.18 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right]Ts}{\theta\ Vs\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)\ (210.4) + \frac{75.325}{530}\left(29.75 + \frac{0.8196}{13.6}\right)\right](908.42)}{(124)\ (27.73)\ (29.71)\ (7.67 \times 10^{-4})} =$ 92.74%

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ C_2}$$

$$\frac{100\ (6.3)}{(0.266 \times 82.83) - (6.3)} =$$ 40.6 %

NO_x EMISSION DATA

Boiler No. 6 Date 11/4/75

Run No.	1	2	3	4	5	6	7	8
Time	1045	1055	1130	1236	1250	1510	1515	1600
µg NO_2	548	678	76	422	394	1000	1105	1045
T_i- Initial Flask Temp, ^oR	525	525	525	525	525	525	525	525
T_f- Final Flask Temp, ^oR	545	545	545	545	545	545	545	545
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P_f- Final Flask Pres, "Hg	29.65	29.65	29.65	29.65	29.65	29.65	29.65	29.65
lb/scf NO_2 $\times 10^{-5}$	1.89	2.35	0.26	1.47	1.37	3.44	3.80	3.58
lb/10^6Btu NO_2	0.33	0.41	0.05	0.26	0.24	0.60	0.67	0.63

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Boiler No. 6 Date 11/5/75

Run No.	1	2	3	4	5	6		
Time	0930	1000	1030	1200	1400	1405		
µg NO_2	965	1110	910	950	1085	1160		
T_i- Initial Flask Temp, ^oF	530	530	530	530	530	530		
T_f- Final Flask Temp, ^oF	550	550	550	550	550	550		
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052		
P_i- Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5		
P_f- Final Flask Pres, "Hg	29.75	29.75	29.75	29.75	29.75	29.75		
lb/scf NO_2 $\times 10^{-5}$	3.34	3.86	3.16	3.32	3.80	4.01		
lb/10^6Btu NO_2	0.54	0.62	0.51	0.54	0.61	0.65		

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Boiler No. 6

Date	11/6		11/6			
Run No.	1	1	2	2		
V_{mc}-Meter Volume, Ft^3	6.057		7.858			
Vmstd-Meter Volume, Std. Cond.	5.988		7.768			
P_B-Barometric Pressure, "Hg	29.59		29.59			
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1			
V_t-Vol. of Titrant, ml.	9.8	1.6	15.05	3.05		
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil			
Vsoln-Vol. of Solution, ml.	500	100	500	100		
V_a-Vol. of Aliquot, Titrated, ml.	5	25	5	25		
lb/scf H_2SO_4 $\times 10^{-6}$		1.154		1.696		
lb/10^6 Btu H_2SO_4		0.017		0.025		
lb-scf SO_2 $\times 10^{-4}$	1.154		1.366			
lb/10^6 Btu SO_2	1.72		2.04			

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{Vmstd} = lb/scf$$

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker Date: 11/12/75

Material collected (mg) =

Filter Catch = 33.0
Dry Catch =
Acetone Wash = 32.9

TOTAL = 65.9

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{42.80}{1.01}\right)\left(29.42 + \frac{0.926}{13.6}\right) =$ 41.736 SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (342 ml) = 16.211 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(16.211)}{(41.736) + (16.211)} =$ 27.976 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(16.5 \times 0.44) + (1.65 \times 0.32) + (81.85 \times 0.28) =$ 30.706

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 27.976}{100} \times 30.706\right] + \left[\frac{27.976}{100} \times 18\right] =$ 27.151

PARTICULATE SAMPLING CALCULATIONS

Test: Cat Cracker Date: 11/12/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{1012.1 \times 0.914}{29.361 \times 27.151}\right] 1/2 =$ 78.269 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(27.976)}{100}\right] (78.269) \quad (50.265) \quad \frac{530}{(1012)} \quad \frac{(29.361)}{29.92} =$ 5,241,998 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6} \quad \frac{(65.9)}{(41.736)} =$ 3.482×10^{-6} lb/scf

$C_E = C_s \times Q_s = (3.482 \times 10^{-6}) \quad (5,241,998) =$ 18.25 lb/hr

$C_H = C_F \div H = \frac{(\quad)}{(\quad)} =$ _____ lb/10^6 Btu

Isokinetic Variations $I = 1.667 \dfrac{\left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right] Ts}{\theta\ Vs\ P_s\ A_n}$

$$1.667 \frac{\left[(0.00267) \quad (342) + \frac{41.736}{530}\left(29.42 + \frac{0.926}{13.6}\right)\right] (1012.1)}{(60) \quad (78.269) \quad (29.361) \quad (3.4 \times 10^{-4})} = 116.33\%$$

Excess Air at Sample Point

$$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$$

$$\frac{100\ (1.65)}{(0.266 \times 81.85) - (1.65)} = 8.2\ \%$$

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker Date: 11/17/75

Material collected (mg) =

Filter Catch = 32.9
Dry Catch =
Acetone Wash = 51.8

TOTAL = 84.7

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{35.21}{1.01}\right)\left(29.68 + \frac{0.652}{13.6}\right) =$ 34.614 SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (311.5ml) = 14.765 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(14.765)}{(34.614) + (14.765)} =$ 29.9 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(17.7 \times 0.44) + (1.4 \times 0.32) + (81.4 \times 0.28) =$ 31.028

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 29.9}{100} \times 31.028\right] + \left[\frac{29.9}{100} \times 18\right] =$ 27.13

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker Date: 11/17/75

Stack Velocity $Vs = 85.48 \times C_p \left[\frac{Ts \times P\ avg}{P_s \times Mw_w}\right] 1/2$

$85.48 \times (0.86) \left[\frac{1039.3 \times 0.900}{29.614 \times 27.13}\right] 1/2 =$ 79.32 fps

Stack Gas Volume $Qs = 3600\left(1 - \frac{\%M}{100}\right)(Vs)(A)\left(\frac{Tstd}{Ts}\right)\left(\frac{Ps}{Pstd}\right)$

$3600 \left[1 - \frac{(29.9)}{100}\right](79.32)\ (50.265)\ \frac{530}{(1039)}\ \frac{(29.614)}{29.92} =$ 5,078,545 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(84.7)}{(34.614)} =$ 5.3956×10^{-6} lb/scf

$C_E = C_s \times Qs = (5.396 \times 10^{-6})\ (5,078,545) =$ 27.40 lb/hr

$C_H = C_E \div H = \frac{(\quad)}{(\quad)} =$ _____ lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667 \left[(0.00267)\ V_{lc} + \frac{Vm}{Tm}\left(P_B + \frac{\Delta H}{13.6}\right)\right] Ts}{\theta\ Vs\ P_s\ A_n}$

$\frac{1.667 \left[(0.00267)\ (311.5) + \frac{34.614}{530}\left(29.68 + \frac{0.652}{13.6}\right)\right](1039.3)}{(60)\ (79.32)\ (29.614)\ (3.4 \times 10^{-4})} = 100.26\%$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (1.4)}{(0.266 \times 81.4) - (1.4)} = 6.9\ \%$

APPENDIX B
FIELD DATA

NO_x EMISSION DATA

Cat. Cracker

Date 11/12 & 11/17

Run No.	1	2	3	4	5	6	7	8
	11/12		11/17					
Time	1015	1115	1210	1235	1305	1500	1530	1540
µg NO_2	242	246	1000	1200	1180	1400	1320	1220
T_i- Initial Flask Temp, ^oR	510	510	530	530	530	530	530	530
T_f- Final Flask Temp, ^oR	530	530	550	550	550	550	550	550
V_{fc}- Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2052	2056
P_i- Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P_f- Final Flask Pres, "Hg	29.42	29.42	29.61	29.61	29.61	29.61	29.61	29.61
lb/scf NO_2 $\times 10^{-5}$	0.83	0.84	3.50	4.22	4.15	4.86	4.58	4.23
lb/10^6Btu NO_2								
lb/hr NO_2	42.6	43.5	180.6	217.8	214.2	250.8	236.3	218.3

$$Vsc = \left(17.71 \frac{^oR}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Cat Cracker

Date	11/17		11/17			
Run No.	1		2			
V_{mc}-Meter Volume, Ft^3	7.386		11.955			
Vmstd-Meter Volume, Std. Cond.	7.3065		11.826			
P_B-Barometric Pressure, "Hg	29.61		29.61			
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1			
V_t-Vol. of Titrant, ml.	7.1	0.3		8.75		
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil	nil	nil		
Vsoln-Vol. of Solution, ml.	500	100		100		
V_a-Vol. of Aliquot, Titrated, ml.	5	50		50		
lb/scf H_2SO_4 $\times 10^{-6}$		0.089		1.598		
lb/10^6 Btu H_2SO_4 lb/hr		0.46		8.25		
lb-scf SO_2 $\times 10^{-5}$	6.851		6.856			
lb/10^6 Btu SO_2 lb/hr	353.5		353.8			

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) (\underline{N}) \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Boiler No. 6

Date	11/4	11/5	11/6	
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr	see	below		
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb				
Fuel Sulfur Content - %				
Fuel Ash Content - %				
Fuel Moisture Content %				

Steam loads checked over time of test

11/4

Part. 155.3×10^3 lb/hr = 185.8×10^6 Btu/hr

NO_x 154.2×10^3 lb/hr = 184.5×10^6 Btu/hr

Andersen 150.4×10^3 lb/hr = 180.0×10^6 Btu/hr

11/5

Part. 147.9×10^3 lb/hr = 177.0×10^6 Btu/hr

NO_x 148.4×10^3 lb/hr = 177.6×10^6 Btu/hr

Andersen 150.6×10^3 lb/hr = 180.2×10^6 Btu/hr

11/6

Andersen 140.6×10^3 lb/hr = 168.3×10^6 Btu/hr

SO_2 & SO_3 142.1×10^3 lb/hr = 170.1×10^6 Btu/hr

Boiler Feedwater : 290°F, 800 psi H = 259.3 Btu/#

Steam : 600 psig, superheated, 580°F H = 1276.5 Btu/#

Heat Output = 1276.5 - 259.3 = 1017.2 Btu / lb steam

Heat Input = Output ÷ 85% = 1017.2 ÷ 0.85

= 1196.7 Btu / lb. steam

ORSAT FIELD DATA

Location Amoco - Blr #6 Comments:

Date 11/4 - 11/6

Time

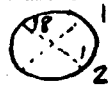
Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
11/4 1015	10.6	5.7	0.0
1030	10.4	5.8	0.0
1600	10.0	6.2	0.0
11/5 1350	11.0	6.4	0.0
1430	10.7	6.5	0.0
0910	10.8	6.0	0.0
11/6	9.2	7.0	0.0

Plant Amoco
Run No. 1
Location #6 Blr.
Date 11/4/75
Operator Griscom, Klein
Meter ΔH@ 1.026
C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.



Ambient Temp °F 65
Bar. Press "Hg 29.68
Assumed Moisture % 10
Probe Tip Dia., In. 3/8
Probe Length 10 ft
Avg. ΔP Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:40	1886.415	0.08	0.52	0.52	190	64		310	150	-0.6	200
1-2	:43	1888.3	0.11	0.70	0.70	220	57	5.0	310	200		380
1-3	:46	1890.0	0.12	0.75	0.75	230	55		312	230		430
1-4	:49	1891.8	0.14	0.9	0.9	245	57		325	245		445
1-5	:52	1894.2	0.16	1.0	1.0	250	59	7.5	330	245		440
1-6	:55	1895.9	0.16	1.0	1.0	255	60		330	250		450
1-7	:58	1898.3	0.16	1.0	1.0	265	60		335	245		450
1-8	11:01	1900.3	0.16	1.0	1.0	270	66		335	230		445
1-9	:04	1902.8	0.16	1.0	1.0	275	68		345	235		455
1-10	:07	1905	0.165	1.05	1.05	280	65	8.0	350	240		455
1-11	:10	1907	0.16	1.0	1.0	280	63		350			
1-12	:13	1909.2	0.16	1.0	1.0	285	60		345	305		450
1-13	:16	1911.5	0.16	1.0	1.0	285	60		345			450
1-14	:19	1913.5	0.18	1.15	1.15	290	60		345	250		460
1-15	:22	1916	0.18	1.15	1.15	290	61	9.0	345	255		455
1-16	:25	1918.3	0.18	1.15	1.15	295	62		345	260		460
1-17	:28	1920.8	0.19	1.2	1.2	295	62		345	350		455
1-18	:31	1923	0.19	1.2	1.2	295	63		345	300		455

Zero readings on approx. all points with pitot @ 90°
off = 1925.00. V_m = 38.585

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-9	12 27	1925.00	0.12	0.75	0.75	175	66	6.0	300	160		445
-10	:30	1927	0.15	0.95	0.95	220	54	7.3	320	210		450
-11	:33	1929.5	0.17	1.05	1.05				330	210		455
-12	:36	1931.3	0.16	1.15	1.15	245	56	8.5	300	210		455
-13	:39	1933.6	0.15	1.15	1.15	250	56		310	230		455
-14	:42	1935.8	0.2	1.25	1.25	255	57		310	225		455
-15	:45	1938.2	0.2	1.25	1.25	260	57	9.5	320	230		455
-16	:48	1940.6	0.22	1.4	1.4	260	58		330	240		460
-17	:51	1943.2	0.20	1.25	1.25	270	59		325	225		460
18	:54	1945.2	0.18	1.15	1.15	270	59		323	215		455
OFF	12:57	1947.630										
2-1	1:28	1947.63	0.0	0.5	0.5	175	68		270	320		260
-2	:31	1947.3	0.10	0.63	0.63	230	58	6.0	315	330		450
-3	:34	1951.0	0.11	0.7	0.7	240	57	6.2	330	330		450
-4	:37	1952.9	0.12	0.75	0.75	246	58	6.8	345	325		455
-5	:40	1954.1	0.12	0.75	0.75	260	60		350	325		460
6	:43	1956.6	0.12	0.75	0.75	265	60	7.0	355	325		460
-7	:46	1958.8	0.13	0.82	0.82	265	60		355	335		463
	:49	1960.6	0.14	0.9	0.9	270	62		350	335		460
OFF	:52	1962.445										
			0.151 AVG.		0.952 AVG.							441.56 AVG.
	54											431.47

873.03

436.50

COMMENTS: T 54

V_r [illegible] 0.907

[illegible] 1.027

[illegible] 0.9[illegible]

PARTICULATE CLEANUP SHEET

Date: 11/4/75 Plant: Amoco

Run Number: 1 Location Of Sample Port: #6 Air Stack

Operator: _____ Barometric Pressure: 29.68

Sample Box No. _____ Ambient Temperature 65

Impinger H_2O Silica Gel

Volume After Sampling 345 ml Weight After 545 g

Impinger Prefilled With 200 ml Weight Before 500 g

Volume Collected 195 ml Moisture Weight 45 g Moisture Total 240 g

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Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0597 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
13			

11/4

Filter Particulate Weight 0.2173 g

Total Particulate Weight 0.2770 g

% Moisture By Volume

Plant Amoco
Run No. 2
Location #6 Blr.
Date 11/5/75
Operator Griscom, Klein
Meter ΔH@ 1.026
C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS
Read and record at the start of each test point.

Ambient Temp °F 70
Bar. Press "Hg 29.75
Assumed Moisture % 12
Probe Tip Dia., In. 3/8
Probe Length 5 ft & 10 ft
Avg. ΔP 0.17 Avg. ΔH

	Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
					Desired	Actual	Inlet	Outlet					
	2-1	9:35	2003.485	0.08	0.5	0.5	120	70	4.5	300	260	-0.55	310
	2-2	9:38	2005.0	0.1	0.625	0.625	180	59		305	280		425
Short Probe	2-3	:41	2007.1	0.095	0.57	0.59	195	58	5.0	310	290		450
	2-4	:44	2008.7	0.11	0.68	0.68	210	59	5.5	325	310		460
	2-5	:47	2010.6	0.11	0.68	0.68	220	60		330	300		460
	2-6	3:50	2012.2	0.12	0.75	0.75	238	64		340	315		460
	2-7	3:53	2014.0	0.12	0.75	0.75	240	66		340	323		462
	2-8	3:56	2016.1	0.12	0.75	0.75	240	68		333	320		465
↑	off	9:59	2017.990										
↓	2-9	10:15	2017.990	0.13	0.8	0.8	150	71		310	120		465
	2-10	:18	2019.7	0.13	0.8	0.8	228	65	6.0	313	180		462
	2-11	:21	2021.7	0.13	0.8	0.8	245	60		312	200		460
Long Probe	2-12	:24	2023.7	0.14	0.86	0.86							455
	2-13	:27	2025.7	0.14	0.86	0.86	250	65	7.0	325	205		452
	2-14	:30	2027.6	0.16	1.0	1.0	255	62		333	200		450
	2-15	:33	2029.7	0.16	1.0	1.0			7.5				450
	2-16	:36	2031.9	0.16	1.0	1.0							450
	2-17	:39	2034.1	0.15	0.93	0.93							450
	2-18	:42	2036.0	0.14	0.86	0.86	250	68	7.0	315	200		450
	off	10:45	2038.150										

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger ^oF Temp.		Pump Vacuum In. Hg. Gauge	Box Temp ^oF	Probe Temp ^oF	Stack Press. In. Hg.	Stack Temp. ^oF
				Desired	Actual	Inlet	Outlet					
1-1	11:38	2038.015	0.08	0.5	0.5	150	80	4.5	280	140		365
1-2	:41	2039.6	0.10	0.62	0.62	200	66		280	205		415
1-3	:44	2041.4	0.12	0.74	0.74	210	65		286	235		445
1-4	:47	2043.3	0.12	0.74	0.74							450
1-5	:50	2045.0	0.15	0.93	0.93	235	69	7.5	315	250		455
1-6	:53	2047.3	0.14	0.86	0.86							460
1-7	:56	2049.0	0.14	0.86	0.86							460
1-8	:59	2051.2	0.14	0.86	0.86							460
1-9	12:02	2053.4	0.13	0.8	0.8	270	69		335	225		455
1-10	:05	2055.2	0.13	0.8	0.8							460
1-11	:08	2056.9	0.14	0.86	0.86							460
1-12	:11	2058.9	0.14	0.86	0.86			7.0				460
1-13	:14	2061.2	0.15	0.93	0.93							460
1-14	:17	2063.0	0.15	0.93	0.93							460
1-15	:20	2064.9	0.15	0.93	0.93							462
1-16	:23	2067.1	0.16	1.0	1.0							460
1-17	:26	2069.1	0.16	1.0	1.0							460
1-18	:29	2071.2	0.17	1.05	1.05							460
off	12:32	2073.220										
Total	124 min	69.735	0.1324		0.8196							448.4

COMMENTS:

PARTICULATE CLEANUP SHEET

Date: 11/5/75 Plant: _____

Run Number: 2 Location Of Sample Port: #6 Blr.

Operator: _____ Barometric Pressure: _____

Sample Box No. _____ Ambient Temperature _____

Impinger H_2O Silica Gel

Volume After Sampling 393 ml Weight After 517.4 g

Impinger Prefilled With 200 ml Weight Before 500.0 g

Volume Collected 193 ml Moisture Weight 17.4 g Moisture Total 210.4 g

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Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0577 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
_____	_____	_____	_____	Filter Particulate Weight 0.2909 g
_____	_____	_____	_____	
_____	_____	_____	_____	Total Particulate Weight 0.3486 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 11/7/75

Plant Amoco Powder Plant

Sample Collected By Klein

Field Data

Clock Time	10:45	10:55	11:30	12:30	12:53	15:05	15:15	16:10
Flask number	1	2	3	4	5	6	7	8
Volume of flask (ml)*	2047	2038	2039	2026	2035	2052	2052	2048
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pressure after sampling, in. Hg.	29.59	–	–	–	–	–	–	–
Flask temperature, °F	85	–	–	–	–	–	–	–

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 11/5/75

Plant Amoco - Blr #6

Sample Collected By Klein

Field Data

Clock Time	0930	1000	1030	1200	1400	1405		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2047	2038	2039	2028	2025	2052		
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5		
Pressure after sampling, in. Hg.	29.75	29.75	29.75	29.75	29.75	29.75		
Flask temperature, ^{o}F	90	90	90	90	90	90		

* Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/6/75

Plant Amoco Location #6 Boiler

Bar. Pressure 29.59 "Hg Comments:

Ambient Temp 75 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
10:40	2125.895	0.1	0.1	435	320	132	140	89
10:45	2127.3	0.1	0.1	435	305	142	180	76
10:50	2128.7	0.1	0.1	435	315	144	160	75
10:55	2130.1	0.11	0.1	438	320	145	148	75
11:00	2131.4	0.1	0.1	440	325	146	140	75
11:05	2132.013							

Comments: 6.118 ft^3
25.4 min.

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/6/75

Plant Amoco Location #6 Boiler

Bar. Pressure 29.59 "Hg Comments:

Ambient Temp 75 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
11:30	2132.013	0.1	0.1	435	295	152	175	85
11:40	2134.65	0.1	0.1	440	320	157	160	80
11:45	2136.0	0.1	0.1	440	306	158	145	80
11:50	2137.3	0.1	0.1	440	300	157	140	78
11:55	2138.7	0.1	0.1	440	300	157	135	80
12:00	2139.950							

Comments: 7.937 ft^3

Plant Amoco

Run No. Andersen #1

Location #6 Blr

Date 11/4/75

Operator Coriscam, Klein

Meter ΔH@ _____

C Factor _____

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Filter Set No. 1

Backup No. 1

Ambient Temp °F 70

Bar. Press "Hg 29.62

Assumed Moisture % 10

Probe Tip Dia., In. 3/8

Probe Length 5 ft

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-9	3:03	1962.495	0.13	0.85	0.85	205	75	9.0	360	340		460
	:13	1969.1	0.12		0.85	280	70	10.0	385	370		460
	:23	1976.0	0.13		0.85	300	70	11.0	390	360		460
	:33	1982.25	0.13		0.85	295	75	14.0	385	365		460
	:43	1988.10	0.12		0.85	310	80	16.5	380	360		460
off	:53	1994.615	0.14		0.8			18.5				

50.25 m/m 32.12 ft³

0.637 cfm.

Plant: Amoco
Run No.: Anderson #2
Location: [illegible]
Date: 11/5/[illegible]
Operator: Griscom, Klein
Meter ΔH@:
C Factor:

PARTICULATE FIELD DATA

VERY IMPORTANT FILL IN ALL BLANKS

Read and record at the start of each test point.

Filter [illegible]
Backup [illegible]

Ambient Temp. °F: 80
Bar. Press. "Hg: [illegible]
Assumed Moisture %:
Probe Tip Dia.:
Probe Length:
ΔP ... ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O Desired	Orifice ΔH in H_2O Actual	Impinger °F Temp. Inlet	Impinger °F Temp. Outlet	Pump Vacuum In. Hg Gauge	Box Temp °F	[illegible]	Stack Press In. Hg.	Stack Temp °F
A-9	1:45	2073.220	0.13	0.8	0.8	185	80	7.5	380	305		470
	1:50	2076.7	0.13	0.8	0.8	250	68		375	[illegible]		470
	1:55	2079.7	0.14	0.86	0.80	270	69	8.4	363	310		475
	2:00	2082.9	0.13	0.8	0.8	290	70		370	[illegible]		480
	:05	2086.3	0.13	0.8	0.8	300	70	8.5	375	325		480
	:10	2089	0.13	0.8	0.8	31[illegible]	70		365	[illegible]		480
	:15	2092.7	0.13	0.8	0.8	[illegible]	71		390	[illegible]		480
	:20	2095.8	0.14	0.86	0.8	330	72		[illegible]	328		480
	2:25	2098.955										

23.735

Plant Amoco
Run No. Andersen #3
Location #6 Blr.
Date 11/6/75
Operator Griscom, Klein
Meter ΔH@ 1.022
C Factor 0.495

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 72
Bar. Press "Hg 29.62
Assumed Moisture % 12
Probe Tip Dia., In. 3/8
Probe Length 5 ft
Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-8	9:15	2106.470	0.12	0.75	0.75	200	75	9.0	350	310		440
	:20	2109.7	0.11		0.75	245	62	9.2	360	320		435
	:25	2113.0	0.11		0.75	275	66	10.0	365	330		435
	:30	2116.3	0.12	0.75	0.75	295	69	10.3	380	335		435
	:35	2119.5	0.12	0.75	0.75	310	70	10.4	390	340		440
	:40	2122.6	0.12	0.75	0.75	315	72	10.7	388	325		445
	9:45	2125.895										

19.425 ÷ 30 = 0.649 cfm

372.2

Particle Size Determination

Test: Amoco - Blr. 6 Date: 11/4/75
Oven Temp. = 380°F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1536	0.1537		0.0		0.0	0.0	14.4 & above
2	0.1448	0.1448		0.0		0.0	0.0	9.12
3	0.1570	0.1610		4.0		3.57	3.57	6.12
4	0.1506	0.1553		4.7		4.19	7.76	4.32
5	0.1550	0.1619		6.9		6.16	13.92	2.64
6	0.1488	0.1586		9.8		8.74	22.66	1.368
7	0.1530	0.1647		11.7		10.44	33.10	0.84
8	0.1500	0.1651		15.1		13.47	46.57	0.56
Back Up Filter	0.2140	0.2739		59.9		53.43	100.0	<0.56
		Total		112.1		100.0		

Test: Amoco - Blr. 6 Date: 11/5/75
Oven Temp. = 372.4°F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1603	0.1609		0.6		0.54		14.4 & above
2	0.1470	0.1481		1.1		0.99		9.0
3	0.1462	0.1506		4.4		3.97		6.0
4	0.1498	0.1561		6.3		5.69		4.20
5	0.1444	0.1502		5.8		5.24		2.88
6	0.1489	0.1619		13.0		11.75		1.36
7	0.1464	0.1593		12.9		11.65		0.83
8	0.1426	0.1593		16.7		15.09		0.55
Back Up Filter	forgot filter assume = avg. first & third runs			49.9		45.08		<0.55
		Total		110.7		100.00		

Particle Size Determination

Test: Amoco - Blr. 6 Date: 11/6/75

Oven Temp. = 372.2 °F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1521	0.1538		1.7		2.75		14.23 & above
2	0.1413	0.1459		4.6		7.44		8.97
3	0.1429	0.1443		1.4		2.27		5.98
4	0.1452	0.1478		2.6		4.21		4.25
5	0.1461	0.1488		2.7		4.37		2.63
6	0.1426	0.1477		5.1		8.25		1.35
7	0.1431	0.1492		6.1		9.87		0.83
8	0.1461	0.1550		8.9		14.40		0.55
Back Up Filter	0.2121	0.2408		28.7		46.44		< 0.55
		Total		61.8		100.00		

Test: Date:

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1								
2								
3								
4								
5								
6								
7								
8								
Back Up Filter								
		Total						

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date				
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb				
Fuel Sulfur Content - %				
Fuel Ash Content - %				
Fuel Moisture Content %				

Operating Data for Cat Cracker

Date	Fresh Feed (BBL/day)	Total Feed (BBL/day)	HCCO RECYCLE RATE (BBL/day)	SLURRY RATE (BBL/day)	Catalyst Circulation Rate (TONS/min)
11/12	34485	35811	489	835	20.6
11/17	34769	35991	485	716	19.8

HCCO → Heavy Cat Cycle Oil

ORSAT FIELD DATA

Location Amoco - Cat Cracker Comments:

Date 11/12 & 11/17

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
11/12 1000	16.4	2.0	0.0
1100	16.6	1.3	0.0
11/17 1130	16.8	2.2	0.0
1520	17.2	1.4	0.0

Plant Amoco

Run No. 1

Location Cat Cracker

Date 11/12

Operator Griscom, Klein

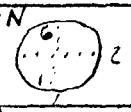
Meter ΔH@ 1.022

C Factor 0.40

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.



Ambient Temp °F 50

Bar. Press "Hg 29.42

Assumed Moisture % 20

Probe Tip Dia., In. 1/4

Probe Length 10 ft

Avg. ΔP 0.8 Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg.~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-6	10:30	2142.930	0,90	0,92	0.92	120	45	10.0	225		-0.8	550
1-5	:35	2147	0,85	0.86	0.86	175	44	9.5	235	200		560
1-4	:40	2150	0,75	0,76	0.76	195	45	8.5	260	170		565
1-3	:45	2153.7	0,85	0,86	0,86	210	45	9.5	290			560
1-2	:50	2157	0,95	0,96	0,96	230	45	10.5	305			560
1-1	:55	2161	0.85	0,86	0,86	240	48	10.0	320			540
off	11:00	2163,860										
2-6	12:00	2163.860	0.82	0,85	0,85	160	50	9,5	320	180		545
2-5	:05	2167.8	0,80	0,82	0.82	250	48		325	240		550
2-4	:10	2171	0,9	0,92	0,92	270	55	10.5	330			555
2-3	:15	2174,8	1.1	1.1	1.1	285	68	13.5	335			550
2-2	:20	2178,5	1.1	1.1	1.1	290	68		335			550
2-1	:25	2182.5	1.1	1.1	1.1	300	70		340			540
off	12:30	2185.730										
		V_m = 42,80	0,914		0.926							552.1

PARTICULATE CLEANUP SHEET

Date: 11/2/75 Plant: Amoco

Run Number: #1 Location Of Sample Port: Cracker Recon

Operator: _____ Barometric Pressure: 29.42

Sample Box No. _____ Ambient Temperature 50°F

Impinger H_2O Silica Gel

Volume After Sampling 521 ml Weight After 521 g

Impinger Prefilled With 200 ml Weight Before 500 g

Volume Collected 321 ml Moisture Weight 21.0 g Moisture Total 34.2 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results _____ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results 0.0329g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.	
14				Filter Particulate Weight 0.0330 g
				Total Particulate Weight 0.0659 g

% Moisture By Volume

Plant Amoco

Run No. 2

Location Cat Cracker

Date 11/17

Operator Griscom, Klein

Meter ΔH@ 1.022

C Factor 0.3

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Filter #15

Ambient Temp °F 65

Bar. Press "Hg 29.68

Assumed Moisture % 30

Probe Tip Dia., In. 1/4

Probe Length 10 ft

Avg. ΔP _____ Avg. ΔH _____

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-6	11:35	2185.840	0.9	0.66	0.66	165	65	7.0	265		-0.9	580
2-5	11:40	2189	0.85	0.62	0.62	210	55	6.5	295	260		585
2-4	:45	2192	0.75	0.54	0.54	240	55	6.0	320	290		590
2-3	:50	2194.5	0.95	0.68	0.68	255	58		340			585
2-2	:55	2197.5	1.0	0.72	0.72	265	59		350			585
2-1	12:00	2201	0.95	0.68	0.68	270	60	7.0	350			560
off	12:05	2203.480										
1-6	12:40	2203.480	0.95	0.68	0.68	170	70	7.0	284			580
1-5	:45	2206.5	0.90	0.66	0.66	230	60	7.0	303	250		583
1-4	:50		0.75	0.54	0.54	253	64		325	275		583
1-3	:55	2212.5	0.9	0.66	0.66	260	68	7.0	335			580
1-2	1:00	2215	1.0	0.72	0.72	275	66		340			580
1-1	:05	2218	0.9	0.66	0.66	280	63	7.0	315			560
off	1:10	2221.050										
		V_m = 35.21	0.900		0.652							579.3

PARTICULATE CLEANUP SHEET

Date: 11/17/75 Plant: Amoco

Run Number: 2 Location Of Sample Port: Cracker Precip

Operator: _____ Barometric Pressure: 29.68

Sample Box No. _____ Ambient Temperature 65 °F

Impinger H_2O Silica Gel

Volume After Sampling 508 ml Weight After 503.5 g

Impinger Prefilled With 200 ml Weight Before 500 g

Volume Collected 308 ml Moisture Weight 3.5 g Moisture Total 311.5 g

---

Dry Probe and Cyclone Catch: Container No. _____

Extra No. _____ Weight Results 0.0518 g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash: Container No. _____

Extra No. _____ Weight Results _____ g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
15			

Filter Particulate Weight 0.0329 g

Total Particulate Weight 0.0847 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 11/12 & 11/17

Plant Amoco - Cat Cracker

Sample Collected By Klein

Field Data	11/12		11/17					
Clock Time	1015	1115	1210	1235	1305	1500	1530	1540
Flask number	1	2	3	4	5	6	7	8
Volume of flask (ml)*	2047	2038	2039	2028	2025	2052	2052	2056
Pressure before sampling in. Hg.	2.5	—	—	—	—	—	—	—
Pressure after sampling, in. Hg.	29.42	29.42	29.61	29.61	29.61	29.61	29.61	29.61
Flask temperature, ^{o}F	70	70	90	90	90	90	90	90

* Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/17/75

Plant Amoco Location Cracker Precipitator

Bar. Pressure 29.61 "Hg Comments: Precipitator not in operation

Ambient Temp 70 °F

Run No 1

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
2:25	2221.050	0.8	0.1	585	220	168	180	72
2:30	2222.3	0.8	0.1	585	280	170	190	67
2:35	2223.6	0.8	0.1	585	350	170	160	66
2:40	2224.9	0.75	0.1	590	295	170	155	66
2:45								
2:50	2227.3	0.8	0.1	590	315	177	190	66
off 2:55	2228.510							

Comments: 7.46 ft^3

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/17/75

Plant AMOCO Location Center Precipitator

Bar. Pressure _____ "Hg Comments: Precipitator not operating

Ambient Temp 70 °F

Run No 2

Power Stat Setting _____

Filter Used: Yes _____ No ____

Operator Griscom, Klein

Clock Time	Meter ($Ft.^3$)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
3:45	2228.510	0.8	0.1	590	250	170	140	70
4:00	2232.2	0.75	0.1	595	310	173	160	68
4:10	2234.3	0.8	0.1	600	305		145	60
4:20	2237.3	0.8	0.1	600	315	166	145	62
4:33	2240.515							

Comments: 12.175 ft^3
4/3 nml.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/4-77-014		

4. TITLE AND SUBTITLE	5. REPORT DATE
REGIONAL AIR POLLUTION STUDY Point Source Emission Inventory	March 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	**8. PERFORMING ORGANIZATION REPORT NO.**
Fred E. Littman, Robert W. Griscom, and Otto Klein	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	**10. PROGRAM ELEMENT NO.**
Rockwell International Air Monitoring Center 11650 Administration Drive Creve Coeur, MO 63141	1AA603 **11. CONTRACT/GRANT NO.** 68-02-1081 Task Order 55
12. SPONSORING AGENCY NAME AND ADDRESS	**13. TYPE OF REPORT AND PERIOD COVERED**
Environmental Sciences Research Laboratory - RTP,NC Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, N.C. 27711	Final **14. SPONSORING AGENCY CODE** EPA/600/09

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Emission data from stationary point sources in the St. Louis Interstate Air Quality Control Region were gathered during 1975. Data for "criteria" pollutants were obtained on an hourly basis. Emissions from large sources were based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year, were based on annual data modified by a detailed operating pattern. Examples of the data are presented in the report. The full set of data are available from the RAPS Data Bank.

An emission factor verification program was initiated by testing typical sources using standard EPA methods. Results indicate good agreement for SO_2 values. Data for NO_x and particulates originating from combustion sources indicate that the existing factors are too high by variable but substantial amounts.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Air pollution *Emission *Data *Collection	St. Louis, MO Stationary point sources	13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	354
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