PARTICLE DATA LABORATORIES, LTD.

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April 22, 1977

Caterpillar Tractor Co.
Peoria, IL 61629

ATTN: Marvin Kagan, Design & Construction G.O.
PDL Project I5417, Caterpillar PO#GYJ 2481

Gentlemen:

Introduction

Particulate emission testing was conducted in the outlet stacks of Boilers #2 and 3 at the Joliet plant on March 29 and 30, 1977.

Purpose of this test series was to determine degree of compliance with particulate and sulfur oxide emission codes.

Stack emission testing was conducted following Illinois and US EPA methods as detailed in the Federal Register of Dec. 23, 1971 (ref. 1) and subsequent copies.

Emission testing was conducted by M. R. Jackson and E. L. Wallace and T. Crane of Particle Data Laboratories. Plant personnel operated the boiler during testing. Tests were witnessed by William Zenisek of State of Illinois EPA. Marshall Lewis of Zurn Air Systems monitored boiler operations during the test series.

Both boilers are spreader stokers equipped with single stage mechanical collectors and Zurn wet scrubbers. The scrubber liquor is maintained at pH 12 to effect sulfur oxide control as well as particulate control. No. 2 boiler is rated at 80,000 lbs/hr. and No. 3 boiler is rated at 100,000 lbs/hr. Each boiler exhausts through its own stack.

Purpose of this test series was to characterize the following parameters:

temperature ^{o}F
velocity fps
moisture % vol/vol
volume flow acfm and scfh db
Orsat CO_2 and O_2 % vol/vol
particulate concentration grains/scf
particulate emission rate lbs/hr. and lbs/10^6 BTU
sulfur oxide emission rate ppm, lbs/hr., and lbs/10^6 BTU
scrubber liquor carry-over rate
sulfur oxide scrubber inlet rate, lbs/hr, ppm.

This report contains an outline summary of the test and analytical methods and findings of this emission test series. Attached as appendices are complete and comprehensive details of all test and analytical methods, field test and laboratory analytical and coal analysis data.

Test Locations

a) Outlet from collector, Boiler #2. Two ports were provided in the 51" diameter stack at a height of approximately 25 feet above the ID fan. Total stack height is approximately 50 feet above the ID fan.

b) Outlet from collector, Boiler #3. Two ports were provided in the 58½" diameter stack at a height of approximately 25 feet above the ID fan. Total stack height is approximately 50 feet above the ID FAN.

c) Inlet to scrubber systems. One of 12 ports provided in one leg of the bifurcated scrubber inlet was used to obtain inlet sulfur oxide concentration data and Orsat analysis.

Summary of Test Methods

Boiler particulate emission testing was conducted following US EPA methods as detailed in the Federal Register (ref. 1) and subsequent copies and included Illinois EPA test methods.

The location of test points in the test plane was determined following Method 1 (ref. 1) included in Appendix A.

Stack gas velocity was determined following Method 2 (ref. 1) included in Appendix B.

Stack gas Orsat analysis for determination of gas density and molecular weight followed Method 3 (ref. 1) included in Appendix C. Orsat analysis was performed at the inlet to each scrubber since carbon dioxide would be abosrbed by the caustic scrubber liquor. Preliminary tests showed that up to 1% carbon dioxide could be removed by the scrubber.

Gas moisture content was determined by a condensation technique in ice-cooled impingers during each particulate run. The method follows that of ref. 1 as reproduced in Appendix D.

Stack gas velocity and moisture determinations were combined and conducted simultaneously with the particulate emissions tests.

Prior to shipping the equipment from this laboratory, the following items were checked for calibration:

1) the S-type pitot tube incorporated with the probe;
2) the temperature sensor incorporated with the probe;
3) the dry test gas meter of the train;
4) the calibrated orifice associated with the gas meter of the sampling train.

The method of particulate testing and sample analysis followed Method 5 of the Federal Register (ref. 1) as detailed in Appendix E. The particulate catch included nozzle, probe, cyclone, and prefilter washings and filter particulates. Reeve Angel 12.5 cm 900 AF glass fiber filters were used.

A nominal 5 foot stainless steel sampling probe was used with a stainless steel sampling nozzle for Boiler #3 and a nominal 3 foot stainless steel sampling probe was used for

A Joy Division, Western Precipitation EPA sampling train was used:

Boiler #	Control box serial #	Sample box serial # Run #1	Run #2	Run #3
2	CU2 2-09-124	SU2 2-07-129	SU2 3-04-1014	SU2 2-10-220
3	CU2 2-09-142	SU2 2-07-129	SU2 3-04-1014	- -

Sampling was performed for 2½ minutes at each of 28 points for boiler #2, and for 2½ minutes at each of 40 points for boiler #3.

Sulfur oxide emissions were determined following Method 6 (ref. 1) included in Appendix F.

Coal analysis and boiler operational data are presented in Appendix G.

Samples of scrubber liquor were taken by Zurn personnel for determination by Particle Data Laboratories of suspended and dissolved solids and sodium content. Analysis for sodium of the samples collected from the stack was performed for use in estimating the scrubber liquor carry-over rate.

The coal scales on both boilers were considered inaccurate at the coal feed rate required to maintain the steam load. Emission rate was therefore calculated on the F factor basis and also using heat input data calculated on the ASTM short form basis.

Boiler #3. On March 29, 1977, two particulate and four sulfur oxide runs were performed. The first particulate run was performed at a nominal load of 100,000 lbs/hr; the second run was performed at a nominal load of 80,000 lbs/hr. One sulfur oxide run was performed on the scrubber inlet duct.

Boiler #2. On March 30, 1977 three particulate and six sulfur oxide runs were performed on a nominal load of 70,000 lbs/hr. Two sulfur oxide runs were performed on the scrubber inlet duct.

Summary of Test Findings

The findings of this test series are summarized in Tables 1 to 6. The particulate emission field test data sheets, laboratory analysis data and calculation summaries are included in Appendix H.

The sulfur oxides field test data sheets, laboratory analysis data and calculation summaries are included in Appendix I.

Orsat analysis data are shown in Table 7. Molecular weight and pitot tube correction factor calculations are shown in Appendix J.

Calculation of F factors are presented in Appendix K. Scrubber carry-over data and calculations are presented in Appendix L.

Heat input data from thermal analysis are shown in Appendix M. Sample ash content data are shown in Appendix N. Nomenclature is given in Appendix O.

Discussion of Results

Tables 1 and 2 show the particle emission rate based upon F factor and calculated BTU heat input data. Appendix L shows scrubber carry-over contribution to the collected sample of between 16.3 and 19.0%. Assuming the most pessimistic number of 16.3% the maximum reduction in emission rate by installation of mist eliminators will be 16.3%.

Appendix N shows that approximately 20% of the particulate emission is combustible. Thus the maximum reduction in emission rate if all combustible material could be removed by the installation of over-fire air systems would be 20%.

It is thus concluded that the maximum reduction in emission rate by mist elimination and installation of over-fire air systems will be approximately 36%. This will result in the following emission rates:

		emission rate lbs/MBTU F factor	Heat input
Boiler #2	Run #1	.086	.072
	Run #2	.148	.128
	Run #3	.132	.098
Boiler #3	Run #1	.179	.131
	Run #2	.129	.109

Sulfur dioxide control efficiency of the scrubber may be calculated from the data of Tables 3, 4, 5 and 6 and shows approximate control efficiencies of 93% for Boiler #2 and 90% for Boiler #3. Since these efficiencies are based upon the averages of all test runs we consider it reasonable to quote the sulfur dioxide control efficiency of both scrubbers as near 90%.

It must be noted that the temperature drop across the economizer and the feed water temperature rise are both far lower than would be expected. It must therefore be assumed that either the instrumentation is faulty or the economizer tubes are coated due to poor operation of the soot blowers. As will be seen from Appendix N the indicated boiler efficiencies range from 67% to 75%.

Assuming some air in leakage between the boiler outlet and the Orsat measurement point we can assume a lower excess air rate than has been used for the efficiency calculation. However this would still result in a boiler efficiency range from approximately 72% to 80%.

Conclusions

Tests have been performed on Boilers #2 and #3 at the Caterpillar Joliet plant to determine the particulate and sulfur dioxide emission rates. Determination has been made of the contribution to the emission rate by scrubber liquor carry-over and from carbonaceous material.

We are pleased to have been of service to Caterpillar Tractor Co.

Respectfully submitted,

PARTICLE DATA LABORATORIES, LTD.

Meryl R. Jackson
President

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SUMMARY OF EMISSION TEST DATA

TABLE: 1

PLANT: Caterpillar Joliet

LOCATION: Stack boiler #2, coal fired

OPERATOR: M. Jackson, E. Wallace, T. Crane

TEST DATE: 3/30/77

REPETITION:	1	2	3
STACK GAS			
Temperature, av. °F	125.	125	125
Velocity av. fps	43.7	41.9	44.9
Volume flow x10^{6}scfh db	1.710	1.645	1.761
Moisture %	14.5	14.1	14.2
PARTICULATE SAMPLE			
Time, hrs:mins.	1:10	1:10	1:10
Volume scf db	46.285	44.867	47.954
Particulates collected, grams	.1932	.2315	.1901
Isokinetic ratio, I% 90 < I < 110	96.5	97.3	97.1
PROCESS RATE			
Fuel rate lbs/hr	-	-	-
Calorific value BTU/lb	10389	10514	10402
(H) heat input x10^6 BTU/hr	96.82	93.81	100.56
steam rate lbs/hr nominal	70,000	70,000	70,000
PARTICULATE			
concentration grains/scf db	.064	.080	.061
x10^6 lbs/scf db	6.379	11.377	8.741
Emissions lbs/hr	10.91	18.72	15.39
(E) lbs/10^6 BTU	.113	.200	.153
Emission rate lbs/10^6 BTU from F factor	.135	.231	.206

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SUMMARY OF EMISSION TEST DATA

TABLE: 2

PLANT: Caterpillar Tractor Joliet

LOCATION: Stack boiler #3, coal fired

OPERATOR: M. Jackson, E. Wallace, T. Crane

TEST DATE: 3/29/77

REPETITION:	1	2	3
STACK GAS			
Temperature, av. °F	130	130	
Velocity av. fps	36.0	34.3	
Volume flow x10 scfh db	1.878	1.730	
Moisture %	11.6	14.7	
PARTICULATE SAMPLE			
Time, hrs:mins.	1:40	1:40	
Volume scf db	54.354	51.289	
Particulates collected, grams	.3651	.2413	
Isokinetic ratio, I% 90 < I < 110	95.0	97.4	
PROCESS RATE			
Fuel rate lbs/hr	–	–	
Calorific value BTU/lb	10624	10820	
(H) heat input $x10^6$ BTU/hr	136.41	104.99	
steam rate lbs/hr nominal	100,000	80,000	
PARTICULATE			
concentration grains/scf db	.104	.073	
$x10^6$ lbs/scf db	14.811	10.374	
Emissions lbs/hr	27.82	17.95	
(E) lbs/10^6 BTU	.204	.171	
Emission rate lbs/10^6 BTU from F factor	.279	.202	

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SUMMARY OF EMISSION TEST DATA

TABLE:

PLANT: Caterpillar Joliet

LOCATION: Stack boiler #2, coal fired

OPERATOR: M. Jackson, E. Wallace, T. Crane

TEST DATE: 3/310/77

REPETITION:	1		2		3	
STACK GAS						
Temperature, av. °F	125		125		12 5	
Velocity av. fps	43.7		41.9		44.9	
Volume flow x10 scfh db	1.710		1.645		1.761	
Moisture %	14.5		14.1		14.2	
PROCESS RATE						
Fuel rate lbs/hr	-					
Calorific value BTU/lb wet	10389		10514		10402	
Heat input x10^6 BTU/hr	96.82		93.81		100.56	
Steam rate lbs/hr nominal	70,000		70,000		70,000	
SULFUR DIOXIDE						
Emissions lbs/hr	19.4	21.2	24.0	21.8	29.5	25.0
lbs/10^6 BTU	.200	.219	.256	.232	.293	.249
ppm	68.4	75.0	88.0	80.1	101.3	91.9
TRIOXIDE						
Emissions lbs/hr	1.4	1.7	6.5	1.6	1.5	2.0
lbs/10^6 BTU	.014	.018	.069	.017	.015	.020
ppm	4.1	4.9	19.1	4.7	4.4	5.9

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SUMMARY OF EMISSION TEST DATA

TABLE: 4

PLANT: Caterpillar Joliet

LOCATION: Stack Boiler #3, coal fired

OPERATOR: M. jackson, E. Wallace, T. Crane

TEST DATE: 3/29/77

REPETITION:	1		2		3
STACK GAS					
Temperature, av. °F	130		130		
Velocity av. fps	36.0		34.3		
Volume flow x10 scfh db	1.878		1.730		
Moisture %	11.6		14.7		
PROCESS RATE					
Fuel rate lbs/hr	-		-		
Calorific value BTU/lb wet	10624		10820		
Heat input x10^6 BTU/hr	136.41		104.99		
Steam rate lbs/hr nominal	100,000		70,000		
SULFUR DIOXIDE					
Emissions lbs/hr	20.2	23.8	36.8	50.5	
lbs/10^6 BTU	.148	.174	.351	.481	
ppm	65.1	76.5	128.7	176.3	
TRIOXIDE					
Emissions lbs/hr	2.1	5.6	8.3	5.8	
lbs/10^6 BTU	.015	.041	.079	.055	
ppm	5.4	14.5	23.3	16.1	

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SUMMARY OF EMISSION TEST DATA

TABLE: 5

PLANT: Caterpillar Joliet

LOCATION: Boiler #2 coal fired, inlet to scrubber

OPERATOR: M. Jackson, E. Wallace, T. Crane

TEST DATE: 3/30/77

REPETITION:	1	2	3
STACK GAS			
Temperature, av. °F			
Velocity av. fps			
Volume flow x10 scfh db			
Moisture %			
PROCESS RATE			
Fuel rate lbs/hr			
Calorific value BTU/lb wet			
Heat input x10^6 BTU/hr			
Steam rate lbs/hr nominal			
SULFUR DIOXIDE			
Emissions lbs/hr	226.4	255.7	
lbs/10^6 BTU			
ppm	800.1	939.3	
TRIOXIDE			
Emissions lbs/hr	58.3	34.9	
lbs/10^6 BTU			
ppm	164.7	102.4	

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SUMMARY OF EMISSION TEST DATA

TABLE: 6

PLANT: Caterpillar Joliet

LOCATION: Boiler #3 coal fired, inlet to scrubber

OPERATOR: M. Jackson, E. Wallace, T. Crane

TEST DATE: 3/29/77

REPETITION:	1	2	3
STACK GAS			
Temperature, av. °F			
Velocity av. fps			
Volume flow x10 scfh db			
Moisture %			
PROCESS RATE			
Fuel rate lbs/hr			
Calorific value BTU/lb wet			
Heat input x10^6 BTU/hr			
Steam rate lbs/hr nominal			
SULFUR DIOXIDE			
Emissions lbs/hr	345.6		
lbs/10^6 BTU			
ppm	1111.8		
TRIOXIDE			
Emissions lbs/hr	28.5		
lbs/10^6 BTU			
ppm	73.5		

Table 7.

Orsat Gas Analysis at Scrubber Inlet

Date	Boiler	Time	% CO_2	% O_2	% N_2
3/29	3	9:30	9.6	9.6	80.6
		9:45	9.4	9.8	80.8
		10:00	9.6	9.6	80.8
		10:15	11.2	7.7	81.1
		10:30	11.4	7.7	80.9
		11:00	11.0	8.3	80.7
3/29	3	12:55	9.5	9.5	81.0
		1:10	10.0	9.6	80.4
		1:25	10.2	9.3	80.5
		1:40	10.2	9.2	80.6
		2:00	10.0	9.2	80.8
		2:15	9.8	9.5	80.7
		2:35	9.4	9.7	80.9
3/30	2	10:00	9.2	9.6	81.2
		10:20	9.0	10.0	81.0
		10:40	9.1	9.9	81.0
		10:55	9.2	9.9	80.9
3/30	2	11:20	10.0	9.0	81.0
		11:40	10.0	9.0	81.0
		12:10	9.2	9.9	80.9
		12:30	8.8	10.2	81.0
3/30	2	12:45	7.2	11.9	80.9
		1:05	8.4	10.9	80.7
		1:20	8.2	10.9	80.9
		1:40	8.6	10.4	81.0

References:

1. FEDERAL REGISTER, Vol. 36 #247, Part II, Dec. 23, 1971.

Appendices:

APPENDIX A:	SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES
APPENDIX B:	DETERMINATION OF STACK GAS VELOCITY (TYPE S PITOT TUBE)
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APPENDIX A: SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

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METHOD 1. SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. Principle and Applicability.

1.1 Principle. A sampling site and the number of traverse points are selected to aid in the extraction of a representative sample.

1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the New Source Performance Standards. Unless otherwise specified, this method is not intended to apply to gas streams other than those emitted directly to the atmosphere without further processing.

2. Procedure.

2.1 Selection of a sampling site and minimum number of traverse points.

2.1.1 Select a sampling site that is at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, contraction, or visible flame. For rectangular cross section, determine an equivalent diameter from the following equation:

$$\text{equivalent diameter} = 2\,\frac{(\text{length})(\text{width})}{\text{length}+\text{width}} \qquad \text{eq. 1-1}$$

2.1.2 When the above sampling site criteria can be met, the minimum number of traverse points is twelve.

2.1.3 Some sampling situations render the above sampling site criteria impractical. When this is the case, choose a convenient sampling location and use Fig. 1-1 to determine the minimum number of traverse points. Under no conditions should a sampling point be selected within 1 inch of the stack wall. To obtain the number of traverse points for stacks or ducts with a diameter less than 2 feet, multiply the number of points obtained from Fig. 1-1 by 0.67.

2.1.4 To use Fig. 1-1 first measure the distance from the chosen sampling location to the nearest upstream and downstream disturbances. Determine the corresponding number of traverse points for each distance from Fig. 1-1. Select the higher of the two numbers of traverse points, or a greater value, such that for circular stacks the number is a multiple of 4, and for rectangular stacks the number follows the criteria of section 2.2.2.

2.2 Cross-sectional layout and location of traverse points.

2.2.1 For circular stacks locate the traverse points on a least 2 diameters according to Fig. 1-2 and Table 1-1. The traverse axes shall divide the stack cross section into equal parts.

2.2.2 For rectangular stacks divide the cross section into as many equal rectangular areas as traverse points, such that the ratio of the length to the width of the elemental areas is between 1 and 2. Locate the traverse points at the centroid of each equal area according to Fig. 1-3.

3. References.

Determining Dust Concentration in a Gas Stream, ASME Performance Test Code #27, New York NY 1957.

Devorkin, Howard, et al, Air Pollution Source Testing Manual, Air Pollution Control District, Los Angeles, CA Nov. 1963.

Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases, Western Precipitation Div. of Joy Mfg. Co., Los Angeles, CA, Bulletin WP-50, 1968.

Standard Method for Sampling Stacks for Particulate Matter, in 1971 Book of ASTM Standards, Part 23, Philadelphia PA, 1971, ASTM Designation D-2928-71.

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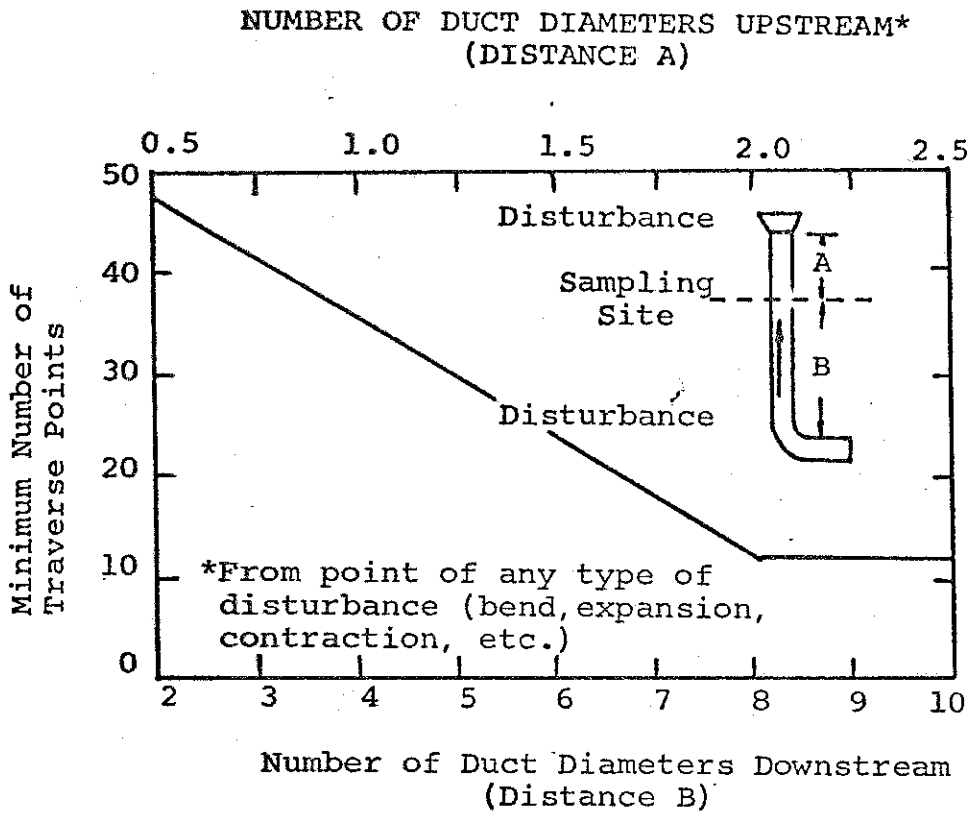

Figure 1-1. Minimum number of traverse points.

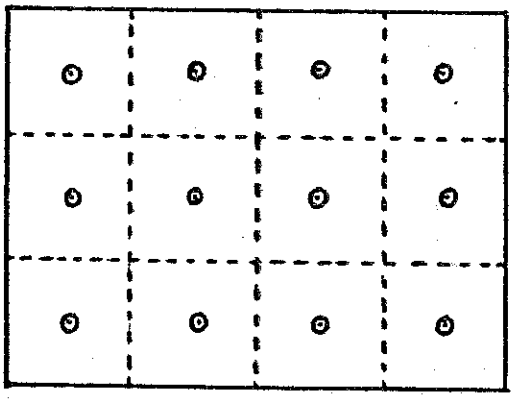

Fig. 1-2. Cross section of circular stack divided into 12 equal areas, showing location of traverse points at centroid of each area.

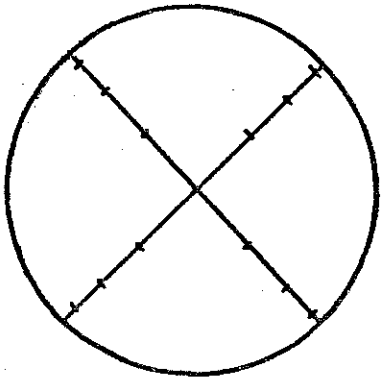

Fig. 1-3. Cross section of rectangular stack divided into 12 equal areas, with traverse points at centroid of each area.

Table 1-1. Location of traverse points in circular stacks
(Percent of stack diameter from inside wall to traverse point)

Traverse point number on a diameter	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	85.4	65.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.1	23.0
10					97.5	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.9	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

APPENDIX B: DETERMINATION OF STACK GAS VELOCITY (TYPE S PITOT TUBE)

METHOD 2. DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE (TYPE S PITOT TUBE)

1. Principle and Applicability.

1.1 Principle. Stack gas velocity is determined from the gas density and from measurement of the velocity head using a Type S (Stauscheibe or reverse type) pitot tube.

1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the New Source Performance Standards.

2. Apparatus.

2.1 Pitot tube - type S (Fig. 2-1), or equivalent, with a coefficient within ±5% over the working range.

2.2 Differential pressure gauge - inclined manometer, or equivalent, to measure velocity head to within 10% of the minimum value.

2.3 Temperature gauge - thermocouple or equivalent attached to the pitot tube to measure stack temperature to within 1.5% of the minimum absolute stack temperature.

2.4 Pressure gauge - mercury-filled U-tube manometer, or equivalent, to measure stack pressure to within 0.1 in. Hg.

2.5 Barometer - to measure atmospheric pressure to within 0.1 in. Hg.

2.6 Gas analyzer - to analyze gas composition for determining molecular weight.

2.7 Pitot tube - standard type, to calibrate type S pitot tube.

3. Procedure.

3.1 Set up the apparatus as shown in Fig. 2-1. Make sure all connections are tight and leak free. Measure the velocity head and temperature at the traverse points specified by Method 1.

3.2 Measure the static pressure in the stack.

3.3 Determine the stack gas molecular weight by gas analysis and appropriate calculations as indicated in Method 3.

4. Calibration.

4.1 To calibrate the pitot tube, measure the velocity head at some point in a flowing gas stream with both a type S pitot tube and a standard type pitot tube with known coefficient. Calibration should be done in the laboratory and the velocity of the flowing gas stream should be varied over the normal working range. It is recommended that the calibration be repeated after use at each field site.

4.2 Calculate the pitot tube coefficient using eq. 2-1.

$$C_{p_{test}} = C_{p_{std}}\sqrt{\frac{\Delta p_{std}}{\Delta p_{test}}} \qquad \text{eq. 2-1}$$

where:

$C_{p_{test}}$ = pitot tube coefficient of type S pitot tube

$C_{p_{std}}$ = pitot tube coefficient of standard type pitot tube (if unknown, use 0.99)

Δp_{std} = velocity head measured by standard type pitot tube

Δp_{test} = velocity head measured by type S pitot tube.

4.3 Compare the coefficients of the type S pitot tube determined first with one leg and then the other pointed downstream. Use the pitot tube only if the two coefficients differ by no more than 0.01.

5. Calculations.

Use eq. 2-2 to calculate the stack gas velocity.

$$(V_s)_{avg} = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{(T_s)_{avg}}{P_s M_s}} \qquad \text{eq. 2-2}$$

where:

$(V_s)_{avg}$ = stack gas velocity, feet per second (fps)

K_p = $85.48 \frac{ft.}{sec.} \left(\frac{lb.}{lb.\ mole\text{-}°R}\right)^{1/2}$ when these units are used.

C_p = pitot tube coefficient, dimensionless

$(T_s)_{avg}$ = average absolute stack gas temperature, °R

$(\sqrt{\Delta p})_{avg}$ = average velocity head of stack gas, inches H_2O (see Fig. 2-2)

P_s = absolute stack gas pressure, inches Hg.

M_s = molecular weight of stack gas (wet basis), lb./lb.-mole $M_d(1-B_{wo})+18B_{wo}$

M_d = dry molecular weight of stack gas (from Method 3).

B_{wo} = proportion by volume of water vapor in the gas stream (from Method 4).

Figure 2-2 shows a sample recording sheet for velocity traverse data. Use the averages in the last two columns of Fig. 2-2 to determine the average stack gas velocity from eq. 2-2.

Use eq. 2-3 to calculate the stack gas volumetric flow rate.

$$Q_s = 3600(1-B_{wo})V_sA\left(\frac{T_{std}}{(T_s)_{avg}}\right)\left(\frac{P_s}{P_{std}}\right) \qquad \text{eq. 2-3}$$

where:

Q_s = volumetric flow rate, dry basis, standard conditions, $ft^3/hr.$

A = cross sectional area of stack, $ft.^2$

T_{std} = absolute temperature at standard conditions, 530°R

P_{std} = absolute pressure at standard conditions, 29.92 inches Hg.

6. References.

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Vennard, J. K., Elementary Fluid Mechanics, John Wiley and Sons, New York NY, 1947.

PARTICLE DATA LABORATORIES, LTD.

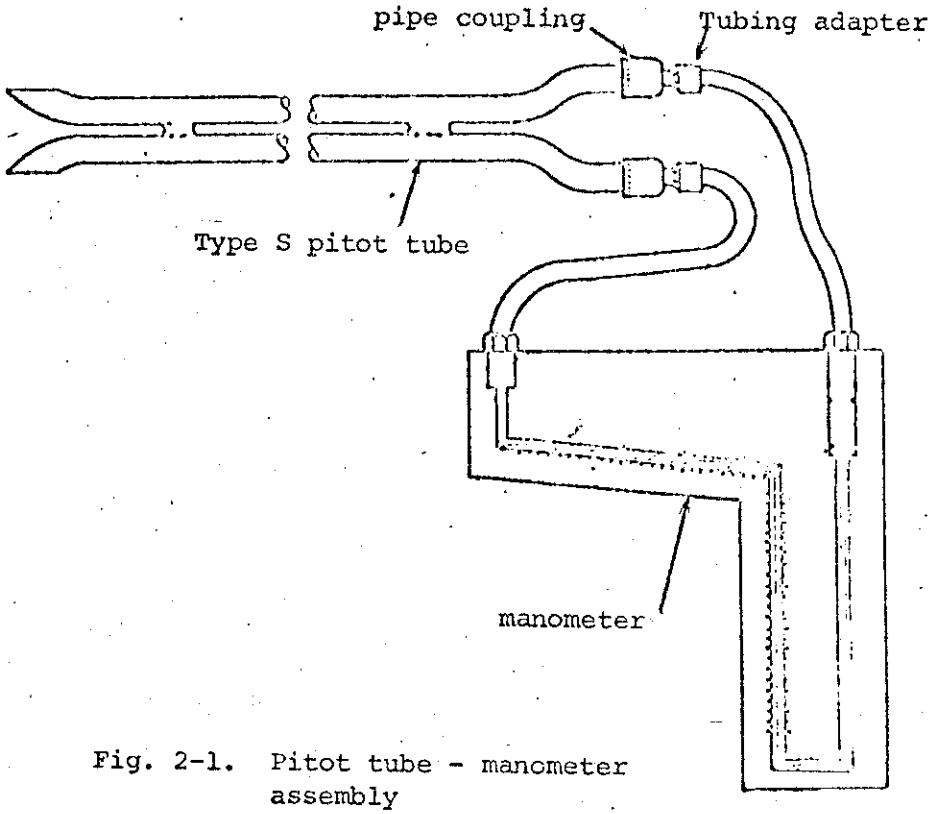

Fig. 2-1. Pitot tube - manometer assembly

PLANT _____
DATE _____
RUN NO. _____
STACK DIAMETER, in. _____
BAROMETRIC PRESSURE, in.Hg. _____
STATIC PRESSURE IN STACK (P_D), in.Hg. _____
OPERATORS _____

SCHEMATIC OF STACK CROSS SECTION

Traverse point number	Velocity head, in. H_2O	$\sqrt{\Delta_p}$	Stack temperature (T_s), °F
	AVERAGE:		

Fig. 2-2. Velocity traverse data

APPENDIX C: GAS ANALYSIS FOR CARBON DIOXIDE, EXCESS AIR, AND DRY MOLECULAR WEIGHT

METHOD 3. GAS ANALYSIS FOR CARBON DIOXIDE, EXCESS AIR, AND DRY MOLECULAR WEIGHT

1. Principle and applicability.

1.1 Principle. An integrated or grab gas sample is extracted from a sampling point and analyzed for its components using an Orsat analyzer.

1.2 Applicability. This method should be applied only when specified by the test procedures for determining compliance with the New Source Performance Standards. The test procedure will indicate whether a grab sample or an integrated sample is to be used.

2. Apparatus.

2.1 Grab sample (fig. 3-1).

2.1.1 Probe - Stainless steel or Pyrex* glass, equipped with a filter to remove particulate matter.

2.1.2 Pump - One-way squeeze bulb, or equivalent, to transport gas sample to analyzer.

2.2 Integrated sample (Fig. 3-2)

2.2.1 Probe - Stainless steel or Pyrex* glass, equipped with a filter to remove particulate matter.

2.2.2 Air-cooled condenser or equivalent - to remove any excess moisture.

2.2.3 Needle valve - to adjust flow rate.

2.2.4 Pump - Leak-free, diaphragm type or equivalent, to pull gas.

2.2.5 Rate meter - to measure a flow range from 0 to 0.035 cfm.

2.2.6 Flexible bag - Tedlar* or equivalent, with a capacity of 2 to 3 cu.ft. Leak test the bag in the laboratory before using.

2.2.7 Pitot tube - S-type or equivalent, attached to the probe so that the sampling flow rate can be regulated proportional to the stack gas velocity when velocity is varying with time or a sample traverse is conducted.

2.3 Analysis.

2.3.1 Orsat analyzer, or equivalent.

3. Procedure.

3.1 Grab sampling.

3.1.1 Set up the equipment as shown in Fig. 3-1, making sure all connections are leak-free. Place the probe in the stack at the sampling point and purge the sampling line.

3.1.2 Draw sample into the analyzer.

3.2 Integrated sampling.

3.2.1 Evacuate the flexible bag. Set up the equipment as shown in Fig. 3-2 with the bag disconnected. Place the probe in the stack and purge the sampling line. Connect the bag, making sure that all connections are tight and there are no leaks.

3.2.2 Sample at a rate proportional to the stack velocity.

3.3 Analysis.

3.3.1 Determine the CO_2, O_2, and CO concentrations as soon as possible. Make as many passes as are necessary to give constant readings. If more than 10 passes are necessary, replace the absorbing solution.

3.3.2 For grab sampling, repeat the sampling and analysis until 3 consecutive samples vary no more than 0.5% by volume for each component being analyzed.

3.3.3 For integrated sampling, repeat the analysis of the sample until 3 consecutive analyses vary no more than 0.2% by volume for each component being analyzed.

4. Calculations.

4.1 Carbon dioxide. Average the three consecutive runs and report the result to the nearest 0.1% CO_2.

4.2 Excess air. Use Eq. 3-1 to calculate excess air, and average the runs. Report the result to the nearest 0.1% excess air.

$$\% \text{ EA} = \frac{(\%O_2) - 0.5(\%CO)}{0.264(\%N_2) - (\%O_2) + 0.5(\%CO)} \times 100 \qquad \text{Eq. 3-1}$$

where:

% EA = percent excess air.

% O_2 = percent oxygen by volume, dry basis

% N_2 = percent nitrogen by volume, dry basis

% CO_2 = percent carbon monoxide by volume, dry basis

0.264 = ratio of oxygen to nitrogen in air by volume.

4.3 Dry molecular weight. Use Eq. 3-2 to calculate dry molecular weight and average the runs. Report the result to the nearest tenth.

$$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2+\%CO) \qquad \text{Eq. 3-2}$$

where:

M_d = dry molecular weight, lb/lb-mole

$\%\ CO_2$ = percent carbon dioxide by volume, dry basis

$\%\ O_2$ = percent oxygen by volume, dry basis

$\%\ N_2$ = percent nitrogen by volume, dry basis

0.44 = molecular weight of carbon dioxide divided by 100

0.32 = molecular weight of oxygen divided by 100

0.28 = molecular weight of nitrogen and CO divided by 100.

5. References.

Atlshuller, A.P. et al, Storage of Gases and Vapors in Plastic Bags, Int. J. Air & Water Pollution, 6:75-81, 1963.

Conner, E.D. and J.S. Nader, Air Sampling with Plastic Bags, J. of American Indus. Hygiene Assn., 25:291-297, May-June 1964.

Devorkin, Howard et al, Air Pollution Source Testing Manual, Air Pollution Control Dist., Los Angeles, CA, Nov. 1963.

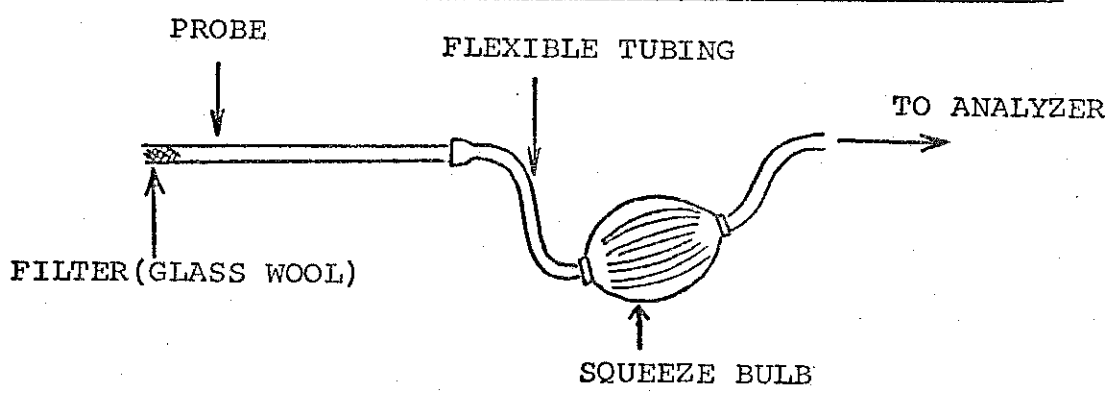

Fig. 3-1. Grab Sampling Train.

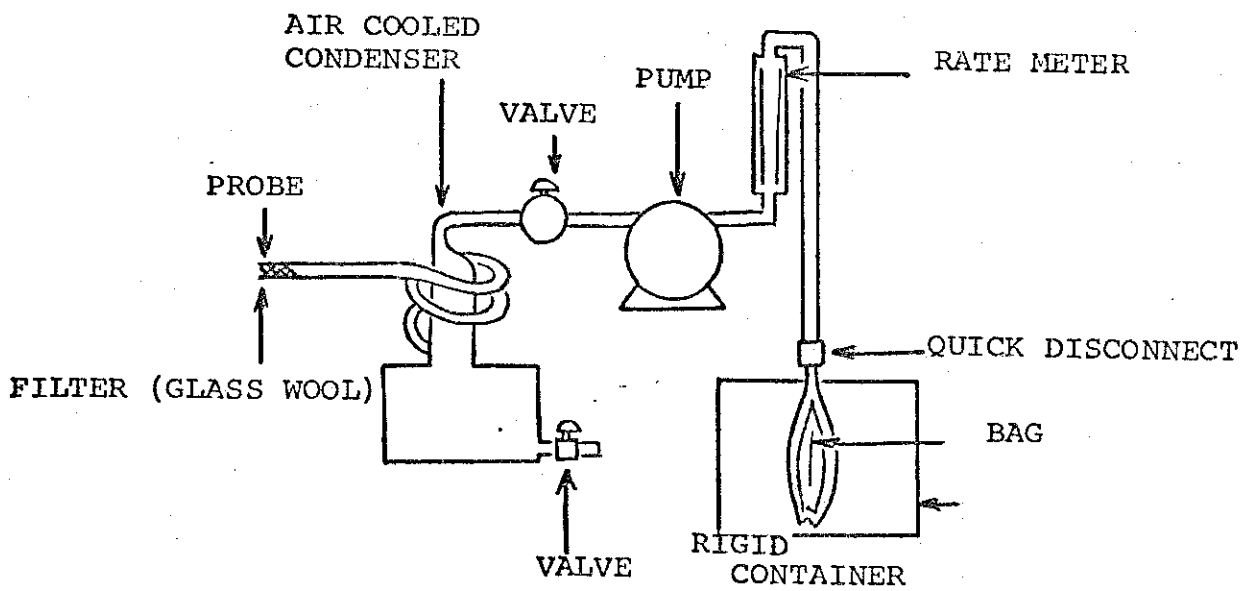

Fig. 3-2. Integrated Gas Sampling Train.

*trade name.

APPENDIX D: DETERMINATION OF MOISTURE IN STACK GASES

METHOD 4. DETERMINATION OF MOISTURE IN STACK GASES

1. Principle and Applicability.

1.1 Principle. Moisture is removed from the gas stream, condensed, and determined volumetrically.

1.2 Applicability. This method is applicable for the determination of moisture in stack gas only when specified by test procedures for determining compliance with New Source Performance Standards. This method does not apply when liquid droplets are present in the gas stream[1] and the moisture is subsequently used in the determination of stack gas molecular weight.

Other methods such as drying tubes, wet bulb-dry bulb techniques, and volumetric condensation techniques may be used.

2. Apparatus.

2.1 Probe - stainless steel or Pyrex[2] glass sufficiently heated to prevent condensation and equipped with a filter to remove particulate matter.

2.2 Impingers - two midget impingers, each with 30 ml. capacity or equivalent.

2.3 Ice bath container - to condense moisture in impingers.

2.4 Silica gel tube (optional) - to protect pump and dry gas meter.

2.5 Needle valve - to regulate gas flow rate.

2.6 Pump - leak-free, diaphragm type or equivalent, to pull gas through train.

2.7 Dry gas meter - to measure to within 1% of the total sample volume.

2.8 Rotameter - to measure a flow range from 0 to 0.1 cfm.

2.9 Graduated cylinder - 25 ml.

2.10 Barometer - sufficient to read to within 0.1 inch Hg.

2.11 Pitot tube - S-type or equivalent, attached to probe so that the sampling flow rate can be regulated proportional to the stack gas velocity when velocity is varying with time or a sample traverse is conducted.

3. Procedure.

3.1 Place exactly 5 ml. distilled water in each impinger. Assemble the apparatus without the probe as shown in Fig. 4-1. Leak check by plugging the inlet to the first impinger and drawing a vacuum. Insure that flow through the dry gas meter is less than 1% of the sampling rate.

3.2 Connect the probe and sample at a constant rate of 0.075 cfm or at a rate proportional to the stack gas velocity. Continue sampling until the dry gas meter registers 1 cu ft. or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Fig. 4-2.

3.3 After collecting the sample, measure the volume increase to the nearest 0.5 ml.

4. Calculations.

4.1 Volume of water vapor collected.

$$V_{wc} = \frac{(V_f - V_i)\rho_{H_2O}\, RT_{std}}{P_{std} M_{H_2O}} = 0.0474 \frac{ft^3}{ml.}(V_f - V_i) \qquad \text{Eq. 4-1}$$

where:

V_{wc} = Volume of water vapor collected (standard conditions), cu.ft.

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

R = Ideal gas constant, 21.83 inches Hg-cu.ft./lb.mole-°R

ρ_{H_2O} = density of water, 1 g./ml.

T_{std} = absolute temperature at standard conditions, 530°R

P_{std} = absolute pressure at standard conditions, 29.92 inches Hg.

M_{H_2O} = molecular weight of water, 18 lb/lb-mole.

4.2 Gas volume.

$$V_{mc} = V_m \left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right) = 17.71 \frac{°R}{in.Hg}\left(\frac{V_m P_m}{T_m}\right) \qquad \text{Eq. 4-2}$$

[1] If liquid droplets are present in the gas stream, assume the stream to be saturated, determine the average stack gas temperature by traversing according to Method 1, and use a psychrometric chart to obtain an approximation of the moisture percentage.

[2] Trade name.

where:

V_{mc} = dry gas volume through meter at standard conditions, cu.ft.

V_m = dry gas volume measured by meter, cu.ft.

P_m = barometric pressure at the dry gas meter, inches Hg.

P_{std} = pressure at standard conditions, 29.92 inches Hg.

T_{std} = absolute temperature at standard conditions, 530°R.

T_m = absolute temperature at meter (°F+460), °R.

4.3 Moisture content.

$$B_{wo} = \frac{V_{wc}}{V_{wc}+V_{mc}} + B_{wm} = \frac{V_{wc}}{V_{wc}+V_{mc}} + (0.025) \qquad \text{Eq. 4-3}$$

where:

B_{wo} = proportion by volume of water vapor in the gas stream, dimensionless

V_{wc} = volume of water vapor collected (standard conditions), cu.ft.

V_{mc} = dry gas volume through meter (standard conditions), cu.ft.

B_{wm} = approximate volumetric proportion of water vapor in the gas stream leaving the impingers, 0.025.

5. References.

Air Pollution Engineering Manual, Danielson, J.A. (ed.), US. DHEW, PHS, Natl. Center for Air Pollution Control, Cincinnati, OH, PHS Publ. #999-AP-40, 1967.

Devorkin, Howard et al, Air Pollution Source Testing Manual, Air Pollution Control Dist., Los Angeles CA, Nov. 1963.

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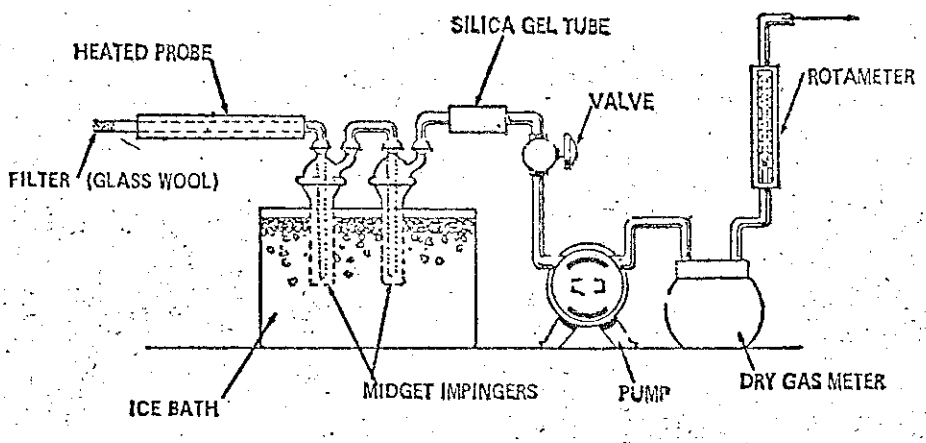

Fig. 4-1. Moisture sampling train.

LOCATION _____ COMMENTS

TEST _____

DATE _____

OPERATOR _____

BAROMETRIC PRESSURE _____

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), ft^3	ROTAMETER SETTING ft^3/min	METER TEMPERATURE, °F

Fig. 4-2. Field moisture determination.

APPENDIX E: DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

METHOD 5. DETERMINATION OF PARTICULATE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. Particulate matter is withdrawn isokinetically from the source and its weight is determined gravimetrically after removal of uncombined water.

1.2 Applicability. This method is applicable for the determination of particulate emissions from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Apparatus.

2.1 Sampling train. The design specifications of the particulate sampling train used by EPA (Fig. 5-1) are described in APTD-0581. Commercial models of this train are available.

2.1.1 Nozzle - stainless steel (316) with sharp, tapered leading edge.

2.1.2 Probe - Pyrex* glass with a heating system capable of maintaining a minimum gas temperature of 250°F at the exit end during sampling to prevent condensation from occurring. When length limitations (greater than about 8 ft.) are encountered at temperatures less than 600°F, Incoloy 825* or equivalent may be used. Probes for sampling gas streams at temperatures in excess of 600°F must have been approved by the administrator.

2.1.3 Pitot tube - S-type or equivalent, attached to probe to monitor stack gas velocity.

2.1.4 Filter Holder - Pyrex* glass with heating system capable of maintaining minimum temperature of 225°F.

2.1.5 Impingers/Condenser - 4 impingers connected in series with glass ball joint fittings. The first, third, and fourth impingers are of the Greenburg-Smith design, modified by replacing the tip with a ½-inch ID glass tube extending to ½-inch from the bottom of the flask. The second impinger is of the Greenburg-Smith design with the standard tip. A condenser may be used in place of the impingers provided that the moisture content of the stack gas can still be determined.

2.1.6 Metering system - vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 5°F, dry gas meter with 2% accuracy, and related equipment, or equivalent, as required to maintain an isokinetic sampling rate and to determine sample volume.

2.1.7 Barometer - To measure atmospheric pressure to ±0.1 inches Hg.

2.2 Sample recovery.

2.2.1 Probe brush - at least as long as probe.

2.2.2 Glass wash bottles - two.

2.2.3 Glass sample storage containers.

2.2.4 Graduated cylinder - 250 ml.

2.3 Analysis

2.3.1 Glass weighing dishes.

2.3.2 Desiccator

2.3.3 Analytical balance - to measure to ±0.1 mg.

2.3.4 Trip balance - 300 g. capacity, to measure to ±0.05 g.

3. Reagents.

3.1 Sampling.

3.1.1 Filters - glass fiber, MSA 1106 BH*, or equivalent, numbered for identification and preweighed.

3.1.2 Silica gel - indicating type, 6-16 mesh, dried at 175° C. (350°F) for 2 hours.

3.1.3 Water.

3.1.4 Crushed ice.

3.2 Sample recovery.

3.2.1 Acetone - reagent grade.

3.3 Analysis

3.3.1 Water.

3.3.2 Desiccant - Drierite,* indicating.

---

*Trade name.

4. Procedure.

4.1 Sampling.

4.1.1 After selecting the sampling site and the minimum number of sampling points, determine the stack pressure, temperature, moisture, and range of velocity head.

4.1.2 Preparation of collection train. Weigh to the nearest gram approximately 200 g. of silica gel. Label a filter of proper diameter, desiccate[1] for at least 24 hours and weigh to the nearest 0.5 mg. in a room where the relative humidity is less than 50%. Place 100 ml. of water in each of the first two impingers, leave the third impinger empty, and place approximately 200 g. of preweighed silica gel in the fourth impinger. Set up the train without the probe as in Fig. 5-1. Leak check the sampling train at the sampling site by plugging up the inlet to the filter holder and pulling a 15 in. Hg vacuum. A leakage rate not in excess of 0.02 cfm at a vacuum of 15 in. Hg is acceptable. Attach the probe and adjust the heater to provide a gas temperature of about 250°F at the probe outlet. Turn on the filter heating system. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the glass leaving the last impinger as low as possible and preferably at 70°F or less. Temperatures above 70°F may result in damage to the dry gas meter from either moisture condensation or excessive heat.

4.1.3 Particulate train operation. For each run, record the data required on the example sheet shown in Fig. 5-2. Take readings at each sampling point, at least every 5 minutes. and when significant changes in stack conditions necessitate additional adjustments in flow rate. To begin sampling, position the nozzle at the first traverse point with the tip pointing directly into the gas stream. Immediately start the pump and adjust the flow to isokinetic conditions. Sample for at least 5 minutes at each traverse point; sampling time must be the same for each point. Maintain isokinetic sampling throughout the sampling period. Nomographs are available which aid in the rapid adjustment of the sampling rate without other computations. APT-0576 details the procedure for using these nomographs. Turn off the pump at the conclusion of each run and record the final readings. Remove the probe and nozzle from the stack and handle in accordance with the sample recovery process described in section 4.2.

4.2 Sample recovery. Exercise care in moving the collection train from the test site to the sample recovery area to minimize the loss of collected sample or the gain of extraneous particulate matter. Set aside a portion of the acetone used in the sample recovery as a blank for analysis. Measure the volume of water from the first three impingers, then discard. Place the samples in containers as follows:

Container no. 1 - Remove the filter from its holder, place in this container, & seal.

Container no. 2 - Place loose particulate matter and acetone washings from all sample-exposed surfaces prior to the filter in this container and seal. Use a razor blade, brush, or rubber policeman to lose adhering particles.

Container no. 3 - Transfer the silica gel from the fourth impinger to the original container and seal. Use a rubber policeman as an aid in removing silica gel from the impinger.

4.3 Analysis. Record the data required on the example sheet shown in Fig. 5-3. Handle each sample container as follows:

Container no. 1 - Transfer the filter and any loose particulate matter from the sample container to a tared glass weighing dish, desiccate, and dry to a constant weight. Report results to the nearest 0.5 mg.

Container no. 2 - Transfer the acetone washings to a tared beaker and evaporate to dryness at ambient temperature and pressure. Desiccate and dry to a constant weight. Report results to the nearest 0.5 mg.

Container no. 3 - Weight the spent silica gel and report to the nearest gram.

---

[1]Dry using Drierite at 70°F ±10°F.

5. Calibration.

Use methods and equipment which have been approved by the administrator to calibrate the orifice meter, pitot tube, dry gas meter, and probe heater. Recalibrate after each test series.

6. Calculations.

6.1 Average dry gas meter temperature and average orifice pressure drop. See data sheet (Fig. 5-2).

6.2 Dry gas volume. Correct the sample volume measured by the dry gas meter to standard conditions (70°F, 29.92 inches Hg) by using Eq. 5-1.

$$V_{m_{std}} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar}+\frac{\Delta H}{13.6}}{P_{std}}\right) = \left(17.71\ \frac{°R}{in.Hg}\right) V_m \left(\frac{P_{bar}+\frac{\Delta H}{13.6}}{T_m}\right) \qquad \text{Eq. 5-1}$$

where:

$V_{m_{std}}$ = volume of gas sample through the dry gas meter (standard conditions), cu.ft.

V_m = volume of gas sample through the dry gas meter (meter conditions), cu.ft.

T_{std} = absolute temperature at standard conditions, 530°R.

T_m = average dry gas meter temp., °R.

P_{bar} = barometric pressure at the orifice meter, inches Hg.

ΔH = average pressure drop across the orifice meter, inches H_2O.

13.6 = specific gravity of mercury.

P_{std} = absolute pressure at standard conditions, 29.92 inches Hg.

6.3 Volume of water vapor.

$$V_{w_{std}} = V_{l_c}\left(\frac{\rho_{H_2O}}{M_{H_2O}}\right)\left(\frac{RT_{std}}{P_{std}}\right) = \left(0.0474\frac{cu.ft.}{ml.}\right) V_{l_c} \qquad \text{Eq. 5-2}$$

where:

$V_{w_{std}}$ = volume of water vapor in the gas sample (standard conditions), cu.ft.

V_{l_c} = Total volume of liquid collected in impingers and silica gel (see Fig. 5-3), ml.

ρ_{H_2O} = molecular weight of water, 18 lb/lb-mole.

R = ideal gas constant, 21.83 in. Hg-cu.ft/lb-mole°R.

T_{std} = absolute temperature at standard conditions, 530°R.

P_{std} = absolute pressure at standard conditions, 29.92 inches Hg.

6.4 Moisture content.

$$B_{wo} = \frac{V_{w_{std}}}{V_{m_{std}}+V_{w_{std}}} \qquad \text{Eq. 5-3}$$

where:

B_{wo} = proportion by volume of water vapor in the gas stream, dimensionless

$V_{w_{std}}$ = volume of water in the gas sample (standard conditions), cu.ft.

$V_{m_{std}}$ = volume of gas sample through the dry gas meter (standard conditions), cu.ft.

6.5 Total particulate weight. Determine the total particulate catch from the sum of the weights on the analysis data sheet (Fig. 5-3).

6.6 Concentration.

6.6.1 Concentration in gr/scf

$$c'_s = \left(0.0154\frac{gr.}{mg.}\right)\left(\frac{M_n}{V_{m_{std}}}\right) \qquad \text{Eq. 5-4}$$

where:

c'_s = concentration of particulate matter in stack gas, gr/scf, dry basis

M_n = total amount of particulate matter collected, mg.

$V_{m_{std}}$ = volume of gas sample through dry gas meter (standard conditions), cu.ft.

6.6.2 Concentration in lb/cu.ft.

$$c_s = \frac{\left(\frac{1}{453,000}\frac{lb.}{mg.}\right)M_n}{V_{m_{std}}} = 2.205\times10^{-6}\frac{M_n}{V_{m_{std}}} \qquad \text{Eq. 5-5}$$

where:

c_s = concentration of particulate matter in stack gas, lb/scf, dry basis.

453,600 = Mg/lb.

M_n = total amount of particulate collected, mg.

$V_{m_{std}}$ = volume of gas sample through dry gas meter (standard conditions), cu.ft.

6.7 Isokinetic variation.

$$I = \frac{\left[\frac{V_{l_o}(\rho H_2O)R}{M_{H_2O}} + \frac{V_m}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right]}{\theta V_s P_s A_n} \times 100 =$$

$$\frac{\left(1.667\frac{min.}{sec.}\right)\left[\left(0.00267\frac{in.Hg\text{-}cu.ft.}{Ml\text{-}°R}\right)V_{l_o} + \frac{V_m}{T_m}\left(P_{bar} + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta V_s P_s A_n} \qquad \text{Eq. 5-6}$$

where:

I = percent of isokinetic sampling.

V_{l_o} = total volume of liquid collected in impingers and silica gel (see Fig. 5-3), ml.

ρH_2O = density of water, 1 g/ml.

R = ideal gas constant, 21.83 in. Hg-cu. ft./lb. mole-°R

M_{H_2O} = molecular weight of water, 18 lb/lb-mole.

V_m = Volume of gas sample through the dry gas meter (meter conditions) cu.ft.

T_m = absolute average dry gas meter temperature (see Fig. 5-2), °R.

P_{bar} = barometric pressure at sampling site, inches Hg.

ΔH = average pressure drop across the orifice (see Fig. 5-2), inches H_2O

T_s = absolute average stack gas temperature (see Fig. 5-2), °R

θ = total sampling time, min.

V_s = stack gas velocity calculated by Method 2, Eq. 2-2, ft/sec.

P_s = absolute stack gas pressure, inches Hg.

A_n = cross-sectional area of nozzle, sq. ft.

6.8 Acceptable results. The following range sets the limit on acceptable isokinetic sampling results:

If $90\% \leq I \leq 110\%$, the results are acceptable; otherwise, reject the results and repeat the test.

7. References.

Addendum to Specifications for Incinerator Testing at Federal Facilities, PHS, NCAPC, Dec. 6, 1967.

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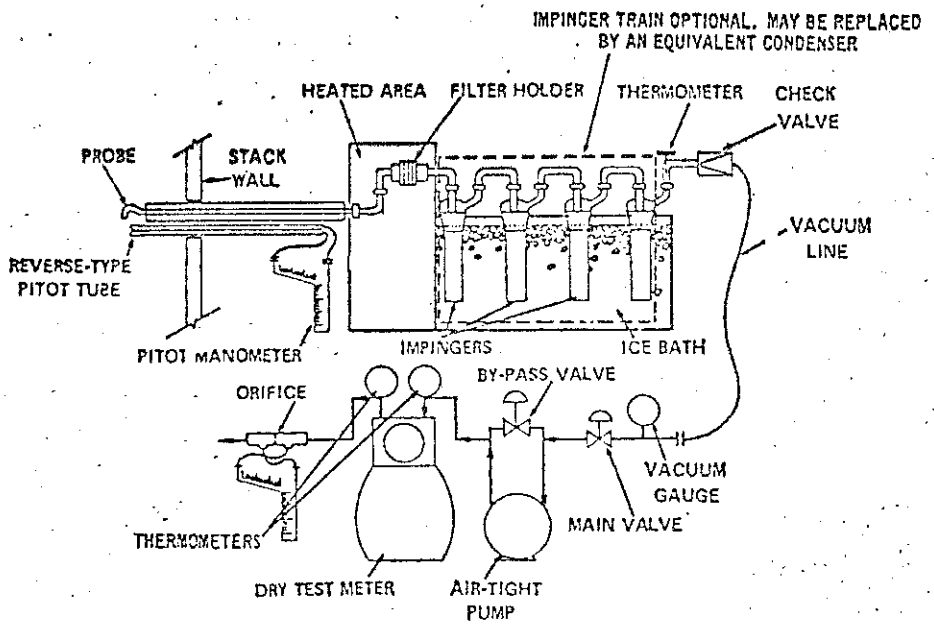

Fig. 5-1 Particulate sampling train.

PLANT_____
LOCATION_____
OPERATOR_____
DATE_____
RUN NO._____
SAMPLE BOX NO._____
METER BOX NO._____
METER $\Delta H@$_____
C FACTOR_____

SCHEMATIC OF STACK CROSS SECTION

AMBIENT TEMPERATURE_____
BAROMETRIC PRESSURE_____
ASSUMED MOISTURE, %_____
HEATER BOX SETTING_____
PROBE LENGTH, in._____
NOZZLE DIAMETER, in._____
PROBE HEATER SETTING_____

TRAVERSE POINT NUMBER	SAMPLING TIME (θ, min)	STATIC PRESSURE (P_s, in. Hg)	STACK TEMPERATURE (T_s, °F)	VELOCITY HEAD (ΔP_s)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH), in. H_2O	GAS SAMPLE VOLUME (V_m, ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		SAMPLE BOX TEMPERATURE, °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F
							INLET ($T_{m_{in}}$), °F	OUTLET ($T_{m_{out}}$), °F		
TOTAL							Avg.	Avg.		
AVERAGE							Avg.			

Fig. 5-2 Particulate field data

PLANT_____
DATE_____
RUN NO._____

CONTAINER NUMBER	WEIGHT OF PARTICULATE COLLECTED, mg		
	FINAL WEIGHT	TARE WEIGHT	WEIGHT GAIN
1			
2			
TOTAL			

	VOLUME OF LIQUID WATER COLLECTED		
	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g	
FINAL			
INITIAL			
LIQUID COLLECTED			
TOTAL VOLUME COLLECTED		g*	ml

CONVERT WEIGHT OF WATER TO VOLUME BY DIVIDING TOTAL WEIGHT INCREASE BY DENSITY OF WATER. (1 g. ml):

$$\frac{\text{INCREASE, g}}{(1\ \text{g/ml})} = \text{VOLUME WATER, ml}$$

Fig. 5-3 Analytical Data

APPENDIX F: DETERMINATION OF SULFUR OXIDE EMISSIONS

PARTICLE DATA LABORATORIES, LTD.

METHOD 6-- DETERMINATION OF SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES

1. Principle and applicability.

1.1 Principle. A gas sample is extracted from the sampling point in the stack. The acid mist, including sulfur trioxide, is separated from the sulfur dioxide. The sulfur dioxide fraction is measured by the barium-thorin titration method.

1.2 Applicability. This method is applicable for the determination of sulfur dioxide emissions from stationary sources only when specified by the test procedures for determining compliance with New Source Performance Standards.

2. Apparatus.

2.1 Sampling. See Figure 6-1.

2.1.1 Probe- Pyrex[1] glass, approximately 5 to 6 mm. ID, with a heating system to prevent condensation and a filtering medium to remove particulate matter including sulfuric acid mist.

2.1.2 Midget bubbler- One, with glass wool packed in top to prevent sulfuric acid mist carryover.

2.1.3 Glass wool.

2.1.4 Midget impingers- Three.

2.1.5 Drying tube- Packed with 6 to 16 mesh indicating-type silica gel, or equivalent, to dry the sample.

2.1.6 Valve- Needle valve, or equivalent, to adjust flow rate.

2.1.7 Pump- Leak-free, vacuum type.

2.1.8 Rate meter- Rotameter or equivalent, to measure a 0-10 s.c.f.h. flow range.

2.1.9 Dry gas meter- Sufficiently accurate to measure the sample volume within 1%.

2.1.10 Pitot tube- Type S, or equivalent, necessary only if a sample traverse is required, or if stack gas velocity varies with time.

2.2 Sample recovery.

2.2.1 Glass wash bottles- Two.

2.2.2 Polyethylene storage bottles- To store impinger samples.

2.3 Analysis.

2.3.1 Pipettes- Transfer type, 5 ml. and 10 ml. sizes (0.1 ml. divisions) and 25 ml. size (0.2 ml. divisions).

2.3.2 Volumetric flasks- 50 ml., 100 ml., and 1,000 ml.

2.3.3 Burettes- 5 ml. and 50 ml.

2.3.4 Erlenmeyer flask- 125 ml.

3. Reagents

3.1 Sampling

3.1.1 Water- Deionized, distilled.

3.1.2 Isopropanol, 80%- Mix 80 ml. of isopropanol with 20 ml. of distilled water.

3.1.3 Hydrogen peroxide, 3%- dilute 100 ml. of 30% hydrogen peroxide to 1 liter with distilled water. Prepare fresh daily.

3.2 Sample recovery.

3.2.1 Water- Deionized, distilled.

---

[1] Trade name.

3.2.2 Isopropanol, 80%.

3.3 Analysis.

3.3.1 Water- Deionized, distilled.

3.3.2 Isopropanol.

3.3.3 Thorin indicator- 1-(o-arsonophenylazo)-2-naphthol-3,6-disulfonic acid, disodium salt (or equivalent). Dissolve 0.20 g. in 100 ml. distilled water.

3.3.4 Barium perchlorate (0.01 N)- Dissolve 1.95 g. of barium perchlorate $Ba(ClO_4)_2 \cdot 3H_2O$ in 200 ml. distilled water and dilute to 1 liter with isopropanol. Standardize with sulfuric acid. Barium chloride may be used.

3.3.5 Sulfuric acid standard (0.01 N)- Purchase or standardize to $\pm$ 0.0002 N against 0.01N NaOH which has previously been standardized against potassium acid phthalate (primary standard grade).

4. Procedure.

4.1 Sampling.

4.1.1 Preparation of collection train. Pour 15 ml. of 80% isopropanol into the midget bubbler and 15 ml. of 3% hydrogen peroxide into each of the first two midget impingers. Leave the final midget impinger dry. Assemble the train as shown in Figure 6-1. Leak check the sampling train at the sampling site my plugging the probe inlet and pulling a 10 inches Hg vacuum. A leakage rate not in excess of 1% of the sampling rate is acceptable. Carefully release the probe inlet plug and turn off the pump. Place crushed ice around the impingers. Add more ice during the run to keep the temperature of the gases leaving the last impinger at 70°F. or less.

4.1.2 Sample collection. Adjust the sample flow rate proportional to the stack gas velocity. Take readings at least every five minutes and when significant changes in stack conditions necessitate additional adjustments in flow rate. To begin sampling, position the tip of the probe at the first sampling point and start the pump. Sample proportionally throughout the run. At the conclusion of each run, turn off the pump and record the final readings. Remove the probe from the stack and disconnect it from the train. Drain the ice bath and purge the remaining part of the train by drawing clean ambient air through the system for 15 minutes.

4.2 Sample recovery. Disconnect the impingers after purging. Discard the contents of the midget bubbler. Pour the contents of the midget impingers into a polyethylene shipment bottle. Rinse the three midget impingers and the connecting tubes with distilled water and add these washings to the same storage container.

4.3 Sample analysis. Transfer the contents of the storage container to a 50 ml. volumetric flask. Dilute to the mark with deionized, distilled water. Pipette a 10 ml. aliquot of this solution into a 125 ml. Erlenmeyer flask. Add 40 ml. of isopropanol and two to four drops of thorin indicator. Titrate to a pink endpoint using 0.01 N barium perchlorate. Run a blank with each series of samples.

5. Calibration.

5.1 Use standard methods and equipment which have been approved by the Administrator to calibrate the rotameter, pitot tube, dry gas meter, and probe heater.

5.2 Standardize the barium perchlorate against 25 ml. of standard sulfuric acid containing 100 ml. of isopropanol.

6. Calculations.

6.1 Dry gas volume. Correct the sample volume measured by the dry gas meter to standard conditions (70°F. and 29.92 inches Hg) by using equation 6-1.

$$V_{m_{std}} = V_m \left(\frac{T_{std}}{T_m}\right)\left(\frac{P_{bar}}{P_{std}}\right) = 17.71 \frac{^{o}R}{in.Hg}\left(\frac{V_m P_{bar}}{T_m}\right) \qquad \text{equation 6-1}$$

where:

$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (standard conditions), cu.ft.
V_m = Volume of gas sample through the dry gas meter (meter conditions), cu. ft.
T_{std} = Absolute temperature at standard conditions, 530°R.
T_m = Average dry gas meter temperature, °R.
P_{bar} = Barometric pressure at the orifice meter, inches Hg.
P_{std} = Absolute pressure at standard conditions, 29.92 inches Hg.

6.2 Sulfur dioxide concentration.

$$C_{SO_2} = \left(7.05 \times 10^{-5} \frac{lb.-l.}{g.-ml.}\right) \frac{(V_t - V_{tb})\underline{N}\left(\frac{V_{soln}}{V_a}\right)}{V_{m_{std}}} \qquad \text{equation 6-2}$$

where:

C_{SO_2} = Concentration of sulfur dioxide at standard conditions, dry basis, lb./cu. ft.
7.05×10^{-5} = Conversion factor, including the number of grams per gram equivalent of sulfur dioxide (32 g./g.-eq.), 453.6 g./lb., and 1,000 ml./l., lb.-l./g.-ml.
V_t = Volume of barium perchlorate titrant used for the sample, ml.
V_{tb} = Volume of barium perchlorate titrant used for the blank, ml.
N = Normality of barium perchlorate titrant, g.-eq./l.
V_{soln} = Total solution volume of sulfur dioxide, 50 ml.
V_a = Volume of sample aliquot titrated, ml.
$V_{m_{std}}$ = Volume of gas sample through the dry gas meter (standard conditions), cu. ft., see Equation 6-1.

PARTICLE DATA LABORATORIES, LTD.

7. References.

Atmospheric Emissions from Sulfuric Acid Manufacturing Processes, U.S. DHEW, PHS, Division of Air Pollution, Public Health Service Publication No. 999-AP-13, Cincinnati, Ohio, 1965.

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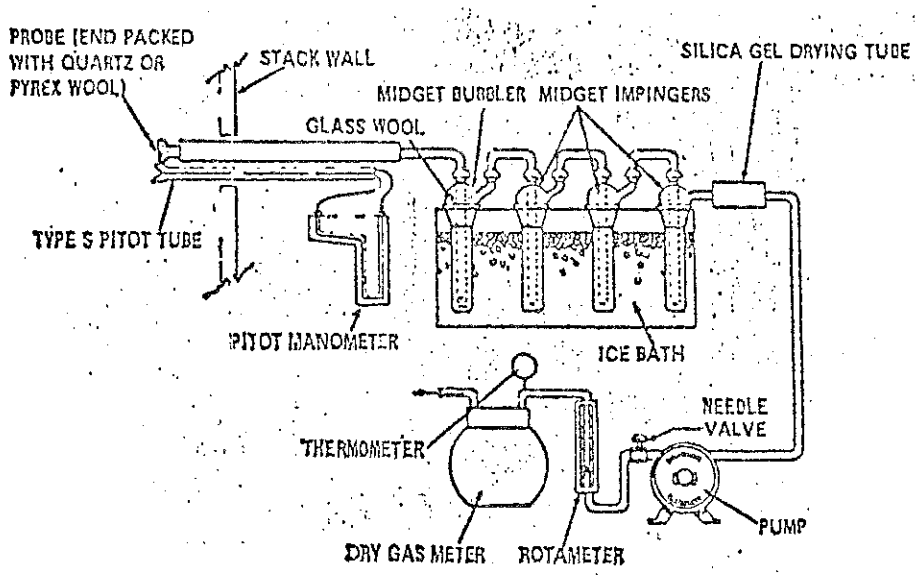


Figure 6-1. SO_2 sampling train.

APPENDIX G: COAL ANALYSIS AND BOILER OPERATIONAL DATA

Coal Analysis Data

Proximate analysis		Ultimate analysis	3-27-77 Boiler #2			3-28-77 Boiler #3	
As received	Dry basis	Dry basis	Test #1	Test #2	Test #3	Test #1	Test #2
% moisture			16.13	16.23	16.13	17.22	16.15
% ash			9.64	10.09	9.88	10.00	10.96
% volatile matter			40.46	39.27	40.01	43.36	41.24
% fixed carbon			33.77	34.41	33.92	29.42	31.65
BTU			10,389	10,514	10,402	10,624	10,820
% sulfur			2.33	2.35	2.33	2.21	2.45
	% ash		11.53	12.07	11.82	12.02	13.19
	% volatile matter		48.38	46.96	47.85	52.13	49.66
	% fixed carbon		40.09	40.97	40.57	35.85	37.15
	% BTU		12,422	12,571	12,441	12,771	12.728
	% sulfur		2.78	2.81	2.79	2.65	2.95
		% carbon	78.12	78.36	78.22	77.52	76.10
		% hydrogen	4.95	4.90	4.92	5.26	5.09
		% nitrogen	1.80	1.77	1.78	1.80	1.89
		% sulfur	1.67	2.81	1.98	2.65	2.95
		% ash	11.53	12.07	12.00	12.02	13.19
		% oxygen	0.82	0.80	0.82	0.75	0.78

PARTICLE DATA LABORATORIES, LTD.

(MARCH 27 BOILER CHART)

TEST No. 1 MARCH ~~28~~ 29
SCRUBBER No. 3

	TIME 9:10	9:45	10:10
BOILER PANEL			
STEAM FLOW #/HR	98,000	105,000	115,000
STEAM METER (x1000)	80,589	80641	80674
AIR FLOW #/HR	74,000	74,000	74,600
BLR. OUT TEMP. °F (gas)	470	470	470
ECONOUT T. (gas)	460	450	460
FURN. DRAFT	0.05	0.1	0.04
BLR. OUT DRAFT	0.5	0.5	0.45
ECON. OUT DRAFT	5.6	5.6	5.6
I.D. INLET DRAFT	7.4	7.4	7.4
I.D. FAN AMPS	41	41.3	41.2
CO_2 FURN. OUT	11.5	11	11
CO BOILER OUT	11.5	8.5	11
COAL SCALES	INOPERABLE	—	—
COAL SAMPLE	No		
ECON. IN WATER °F	260	260	260
ECONOUT WATER °F	300	290	310
STEAM PRESS.	158	120	150
SCRUBBER ΔP	12	12	12
SCRUBBER pH	6.2	6.2	6.2
RINGELMAN	NA	NA	NA

(log over)

log Test No. March 23

A. pulled ashes & collector immediately before running test

B. Lost #1 Boiler (gas) during test and #3 running to pick up load. Steam load chart went to about 120,000#. Operator put #1 back on line ASAP to try to stabilize #3 load. Note spike on steam chart

C. Lost A stoker on #3 @ 10:00

D. Due to low demand for steam operator refaining to open relief valve to vent steam directly from drum. Plus steam is being generated, but is not going through the steam meter. As a result, boiler control is poor and actual heat input is higher than would be indicated by steam flow.

(March 28
Boiler Chart)

Test No. 2 March 29
Scrubber No. 3

Boiler Panel	1:00	1:40	2:50				
Steam #/HR	80,000	82,000	82000				
Steam Meter (x1200)	80889	80935	81013				
Air Flow #/HR	52,000	60,000	60,000				
Bcr. out Gas (°F)	460	460	465				
Econ out Gas (°F)	440	445	450				
Furn Draft	0.01	0.05	0.08				
Bcr out Draft	0.25	.25	0.25				
Econ out Draft	3.5	4.2	4.2				
Fd. inlet Draft	4	5.2	5.5				
Dfan Amps	36	38	44				
O_2 furn. out	11.5	11.5	10				
O_2 [illegible]	11.5		10				
Coal Scales	NA.	—	—				
Coal Sample							
°F Econ. in water	265	265	265				
°F Econ out water	300	300	300				
Steam Press.	155	155	150				
Scrubber ΔP	12	12	12				
Scrubber pH	6.2	6.2	6.2				
[illegible]	—						
(log over)							

A. Due to low demand for steam, it was impossible to control #3 boiler at 100,000 #/HR. Load was dropped to 80,000 #/HR for test #2 to allow boiler operation to stabilize.

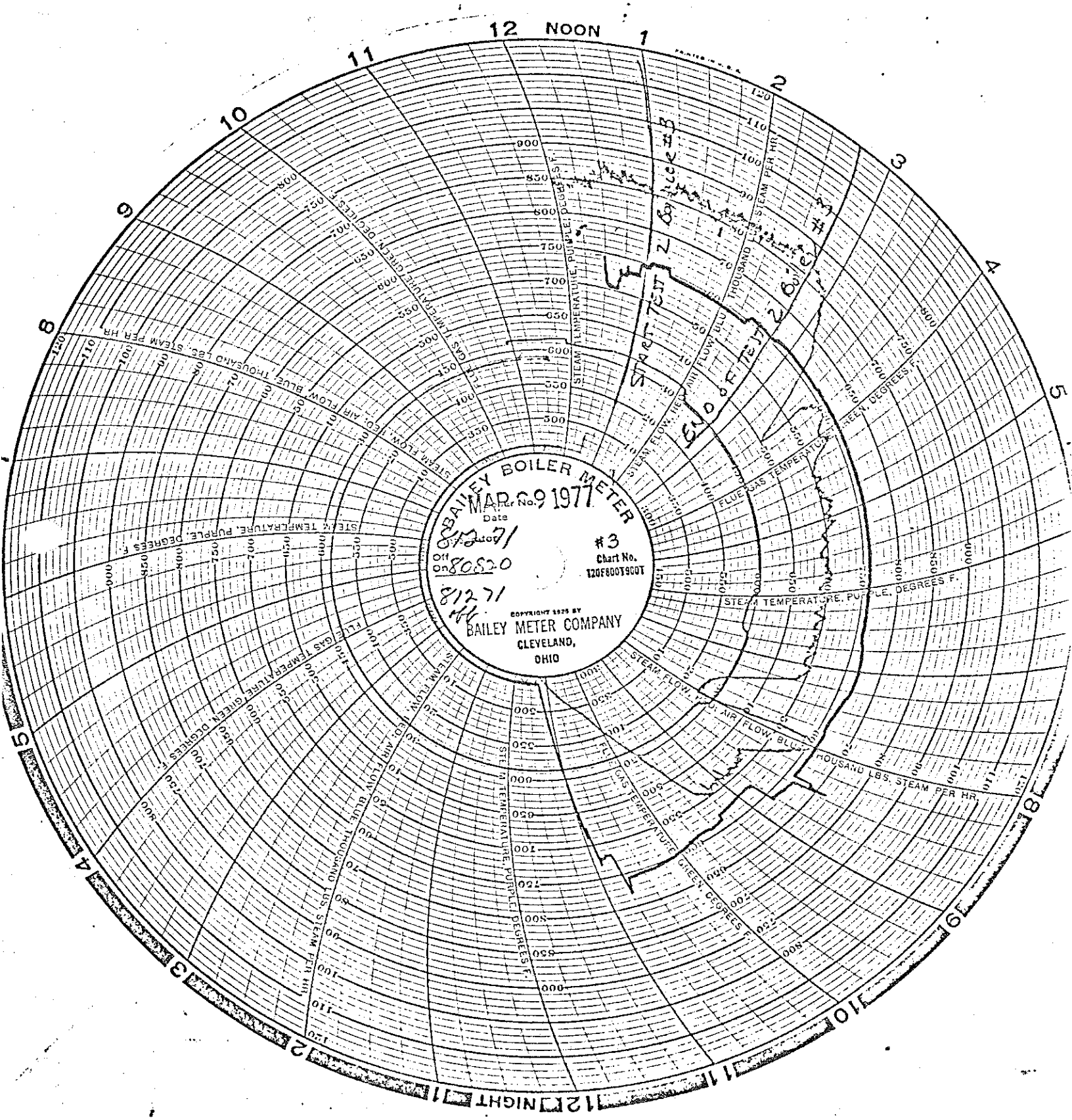
B. At about 1:20 boiler was smoking, so underfire air was increased to eliminate smoke - (tail on plume).

TEST 1,2 March 30

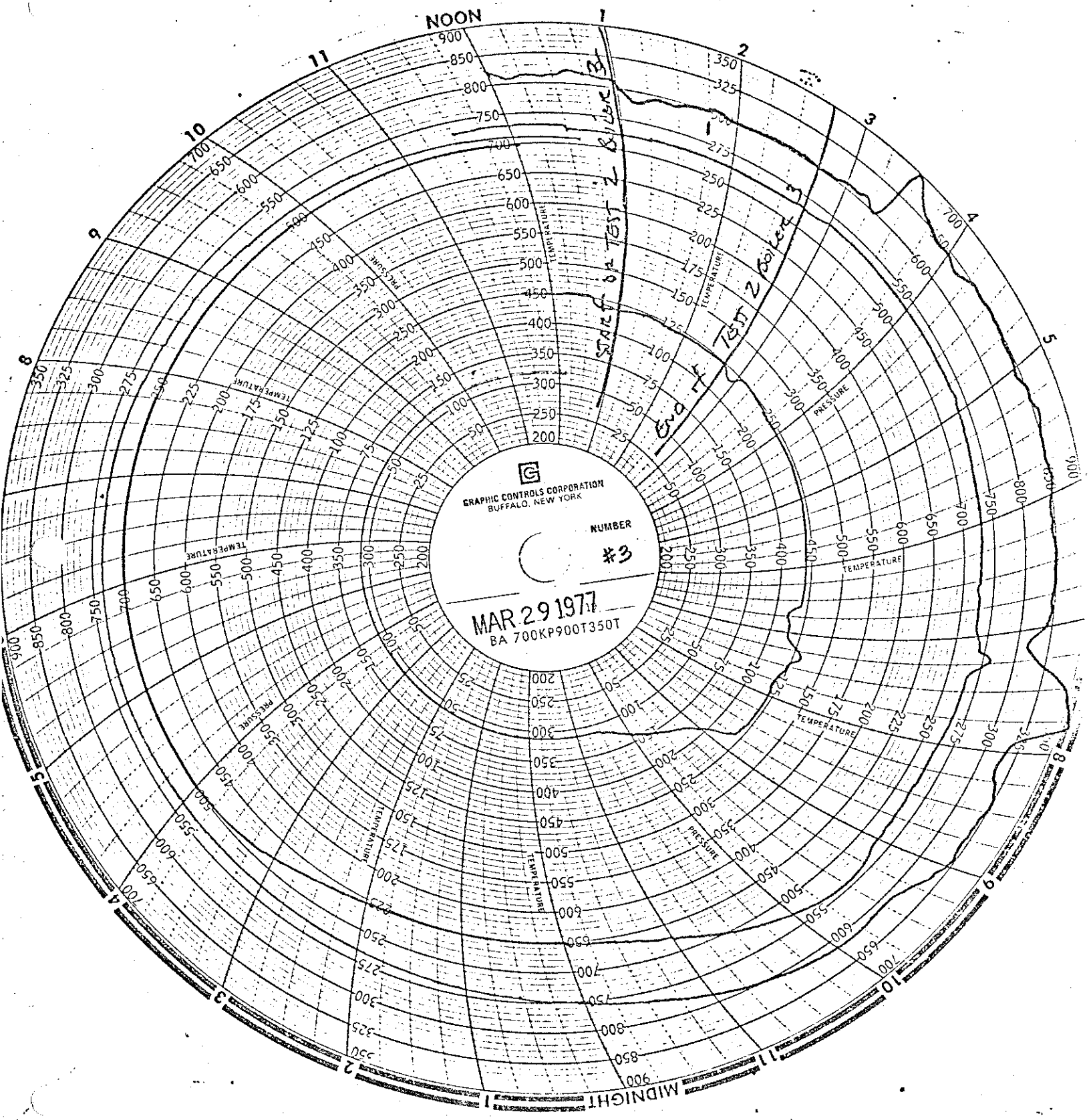
Boiler #2

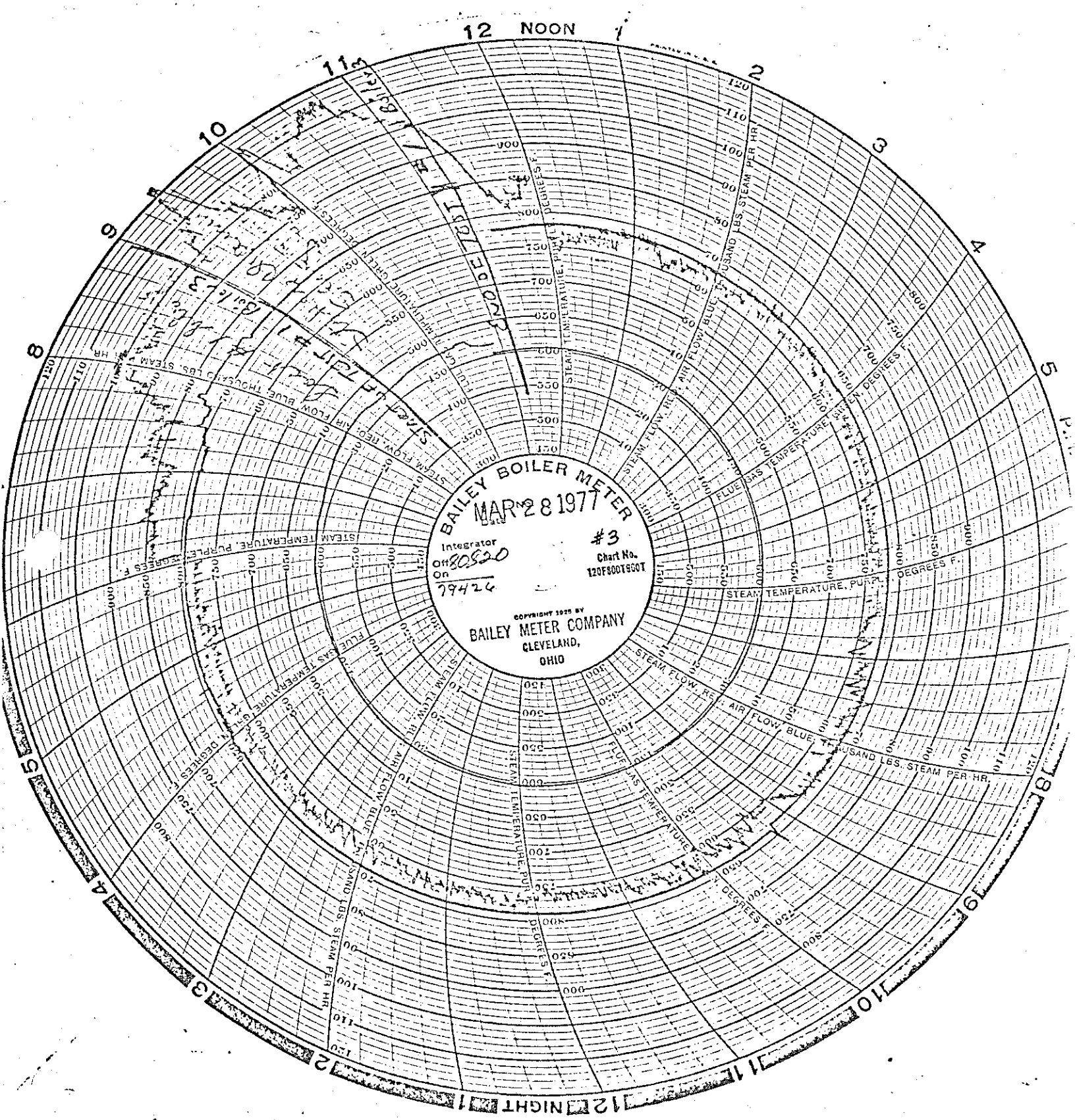
	TEST 1		TEST 2		TEST 3	
Boiler Power	10:00	11:00	11:20	12:20	12:50	1:50
Steam #/HR	75,000	70,000	70,000	72,000	70,000	70,000
Meter (x100)	772610	772680	772773	772774	772809	772871
Air Flow #/HR	78,000	82,000	78,000	79,000	80,000	81,000
Burout °F	550	550	550	550	550	550
Economout °F	475 ~~405~~	475	470	470	470	470
Furn. Draft	0.05	0.05	0.05	0.1	.05	.05
Burout Draft	1.45	1.6	1.46	1.45	1.5	1.5
Economout Draft	4.3	4.7	4.3	4.2	4.6	4.6
I.D. Inlet Draft	7.2	7.8	7.1	7.1	7.5	7.5
I.D. fan Amps	37	37.5	36	36	37	37
O_2 collector	9.5	8.5	10	10	10	10
O_2 Burout	9.5	—				
Coal Scales	414704	414744	-756	-796	816	856
°F Economizer	265	260	260	260	260	260
°F Economizer	305	300	295	295	295	295
Steam Press	140#	145	150	150	145	145
Peighman	1	1.5	2.5	3	1.5	2
Scrubber OP	12"	12	12	12	12	12
pH	6.5	6.5	6.5	6.5	6.5	6.5

A. Excess Air was adjusted to achieve best appearance on plume.
B. Some smoking was observed when trying to get excess air down below a CO_2 of 9.5
C. D. Best thinks maybe there is still some "old coal" from previous supply in bunker.
D. Just before beginning test, dampers at outlet of boiler and inlet and outlet of economizer were checked. Note gas temp change @ 9:00.
E. Opacity on meter varied from 2 to 4 at random during test and corresponded to no noticeable change in boiler operation.
F. Pulled ashes & soot just before test.
G. Ran #2 test at lower excess air but more tail was present on plume.

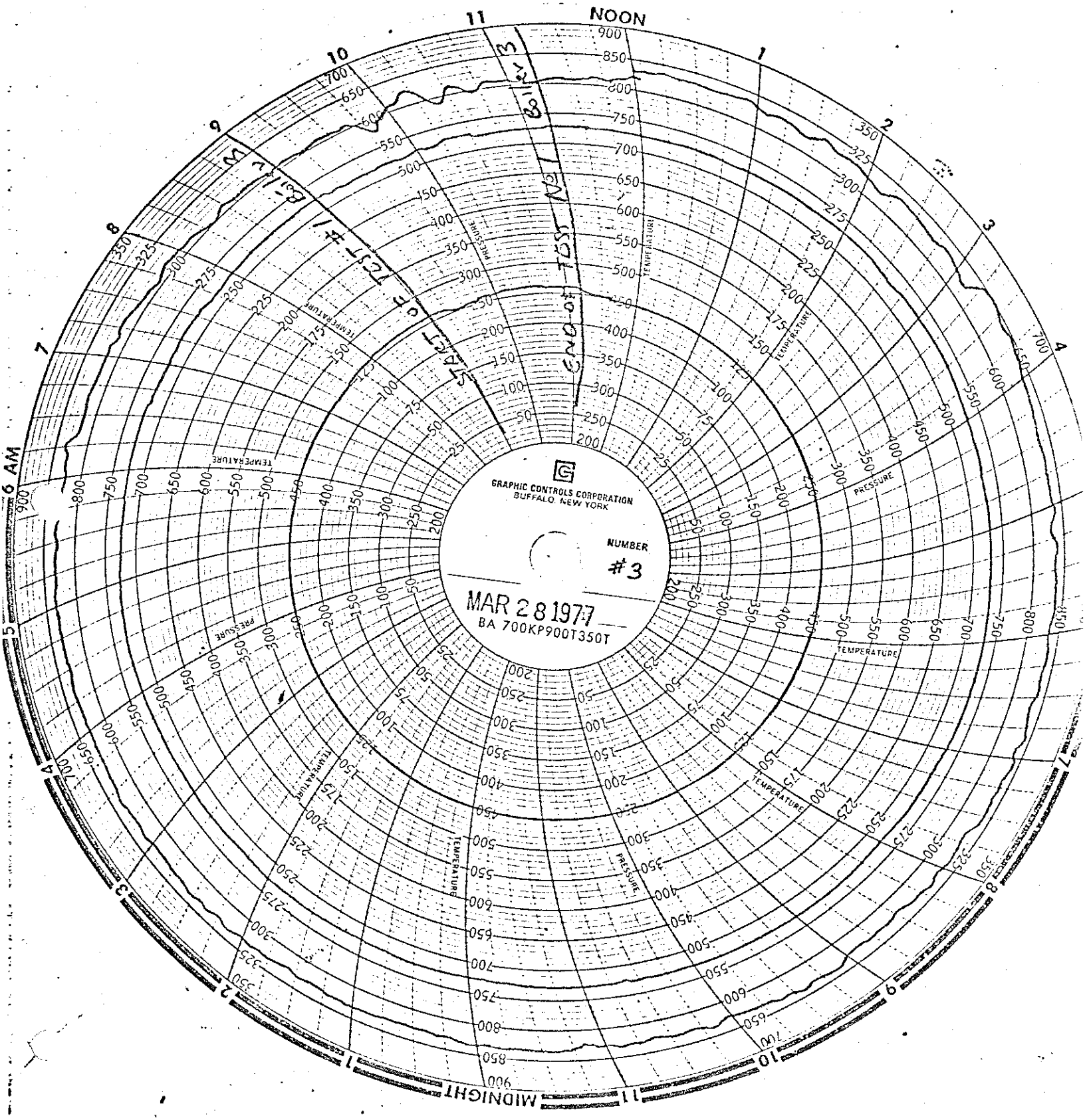


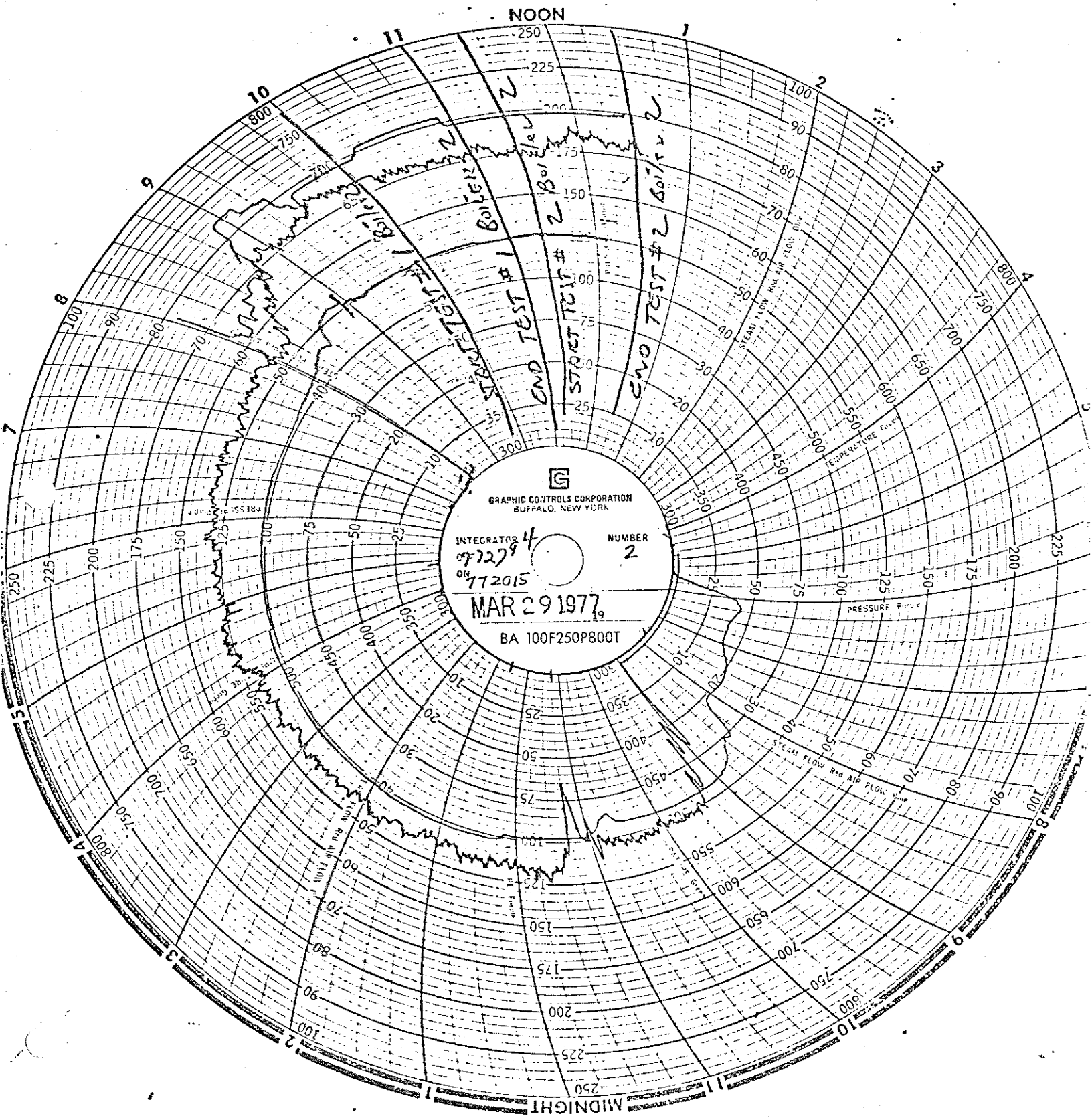
NOON
NIGHT
BAILEY BOILER METER
MAR 29 1977
Date
Off
On 80820
#3
Chart No.
120F800T900T
COPYRIGHT 1975 BY
BAILEY METER COMPANY
CLEVELAND,
OHIO
START TEST 2 Boiler #3
END OF TEST 2 Boiler #3
STEAM TEMPERATURE, PURPLE, DEGREES F.
FLUE GAS TEMPERATURE, GREEN, DEGREES F.
STEAM FLOW, RED, AIR FLOW, BLUE, THOUSAND LBS. STEAM PER HR.

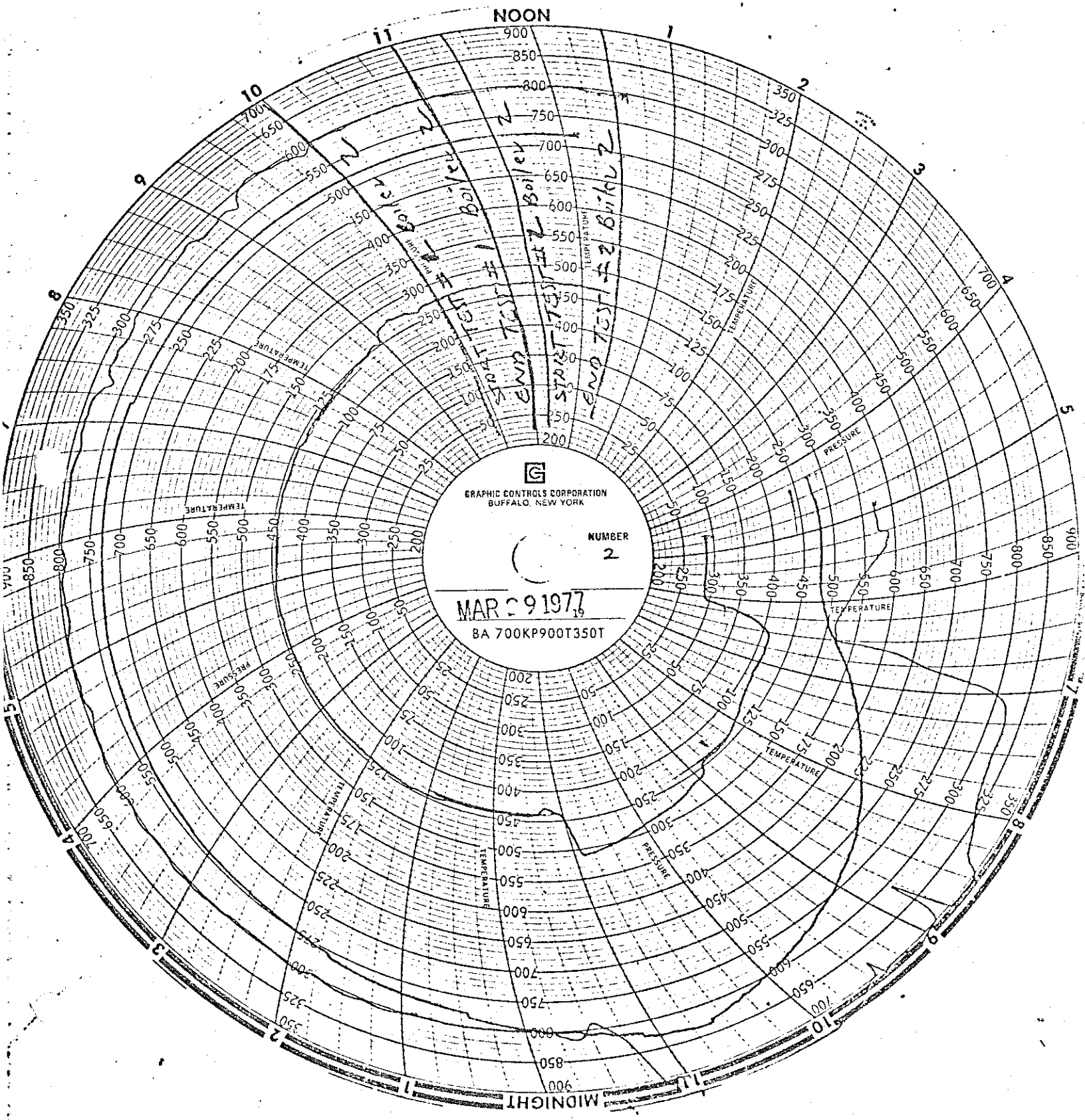

NOON
MIDNIGHT
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
NUMBER
#3
MAR 29 1977
BA 700KP900T350T
TEMPERATURE
PRESSURE
START OF TEST 2 BOILER 3
END OF TEST 2 BOILER 3

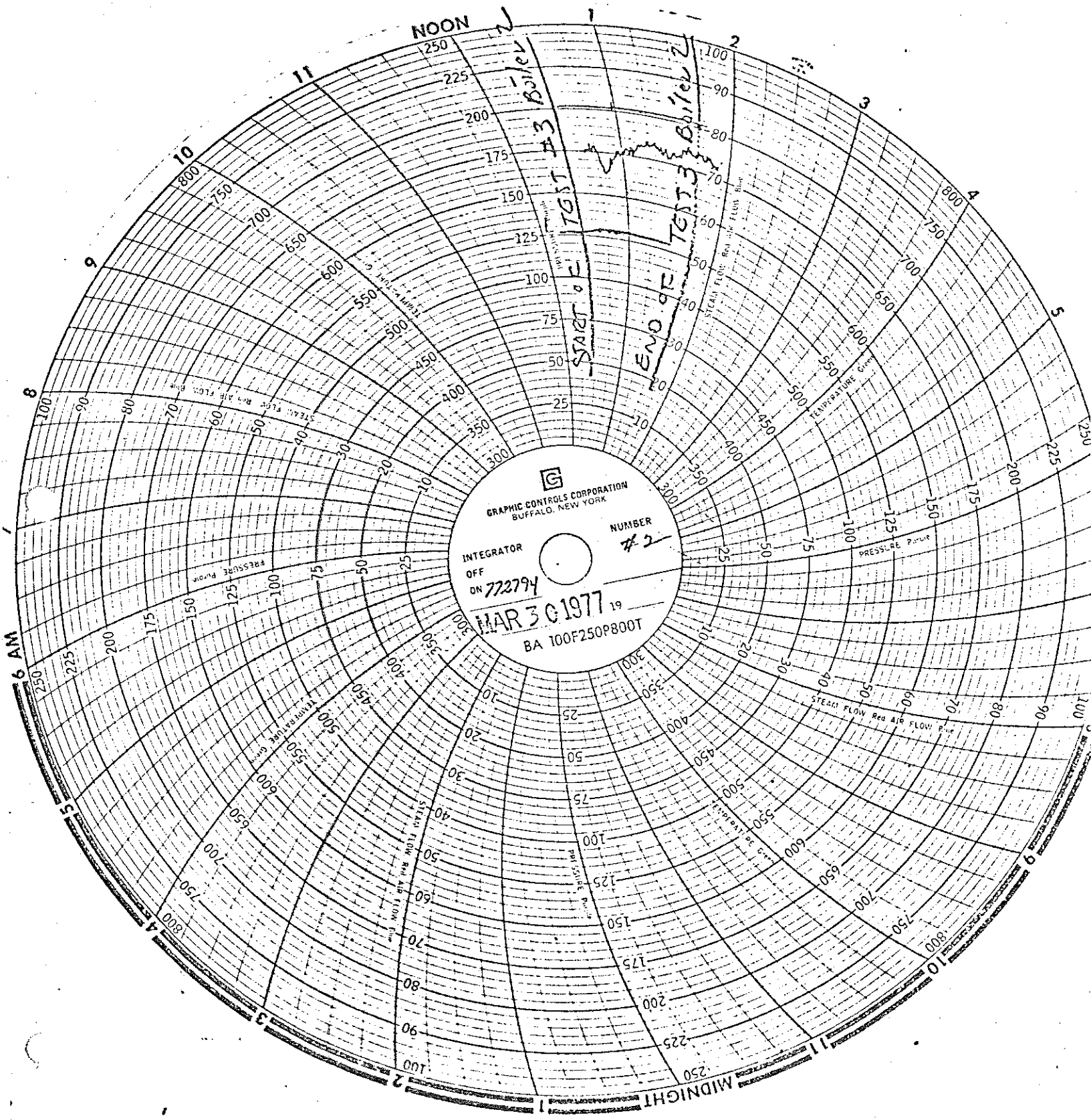


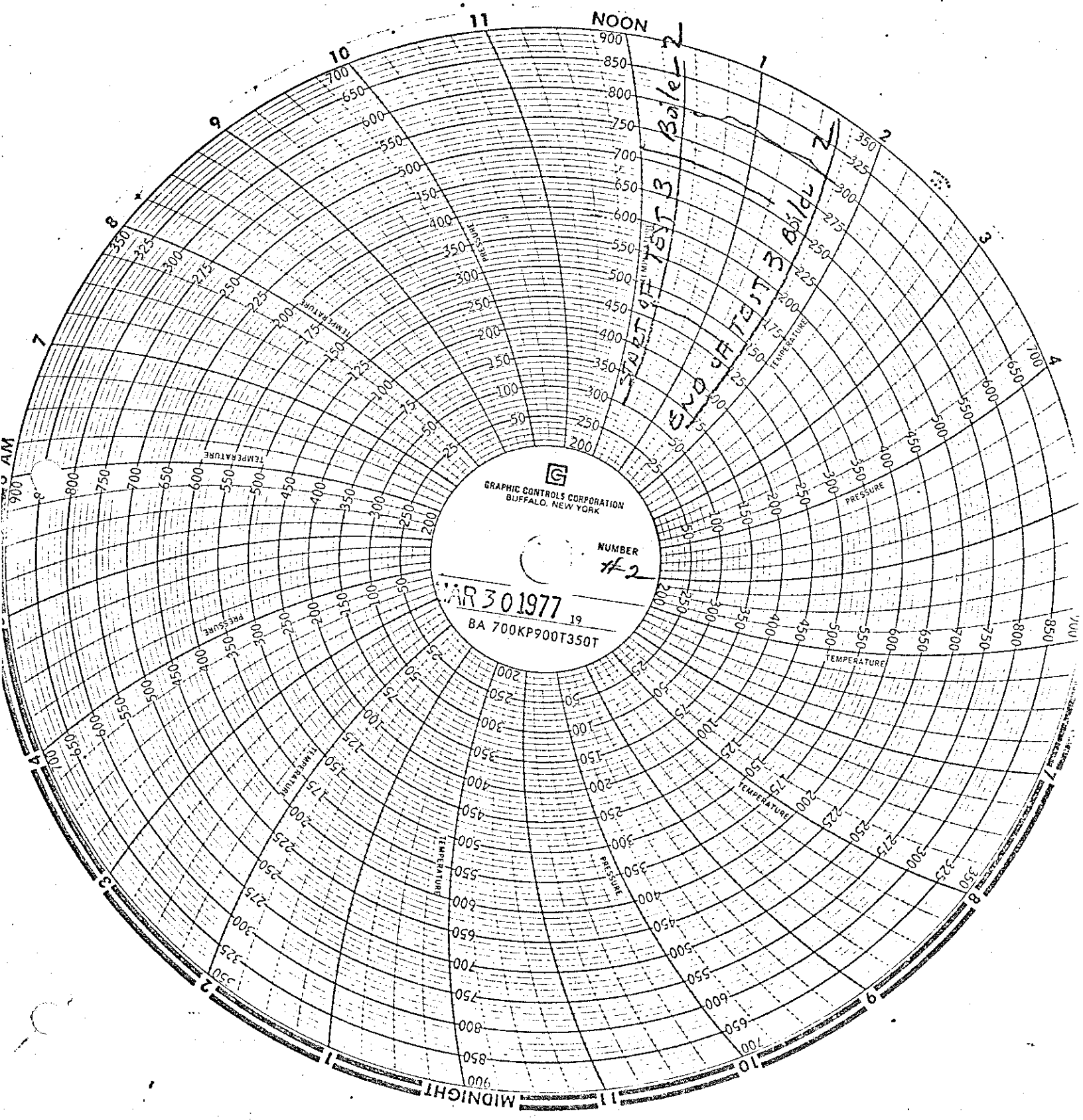
BAILEY BOILER METER
MAR 28 1977
Date
Integrator
Off 80520
On
79426
#3
Chart No.
120F800T960T
COPYRIGHT 1925 BY
BAILEY METER COMPANY
CLEVELAND,
OHIO
NOON
NIGHT
STEAM TEMPERATURE, PURPLE, DEGREES F.
FLUE GAS TEMPERATURE, GREEN, DEGREES F.
STEAM FLOW, RED, AIR FLOW, BLUE, THOUSAND LBS. STEAM PER HR.


NOON
MIDNIGHT
6 AM
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
NUMBER
#3
MAR 28 1977
BA 700KP900T350T
TEMPERATURE
PRESSURE


NOON
MIDNIGHT
START TEST #1 Boiler 2
END TEST #1 Boiler 2
START TEST #2 Boiler 2
END TEST #2 Boiler 2
STEAM FLOW Red AIR FLOW Blue
TEMPERATURE Green
PRESSURE Purple
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
INTEGRATOR 4
NUMBER 2
ON 772015
MAR 29 1977
BA 100F250P800T


NOON
MIDNIGHT
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
NUMBER
2
MAR 29 1977
BA 700KP900T350T
TEMPERATURE
PRESSURE
START TEST #1 Boiler 2
END TEST #1 Boiler 2
START TEST #2 Boiler 2
END TEST #2 Boiler 2


NOON
MIDNIGHT
6 AM
START of TEST #3 Boiler 2
END of TEST 3 Boiler 2
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
INTEGRATOR
OFF
ON 772794
NUMBER
#2
MAR 30 1977 19
BA 100F250P800T
STEAM FLOW Red AIR FLOW Blue
TEMPERATURE Green
PRESSURE Purple


NOON
MIDNIGHT
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
NUMBER
#2
MAR 30 1977
19
BA 700KP900T350T
PRESSURE
TEMPERATURE
Start of Test 3 Bale 2
End of Test 3 Bale 2

APPENDIX H: PARTICULATE EMISSION FIELD TEST DATA, LABORATORY ANALYSIS DATA AND CALCULATION SUMMARIES

PARTICLE DATA LABORATORIES, LTD.

SOURCE: Caterpillar Joliet Bldg #3 3/29/77

TEST NUMBER:

Volume of sample at standard conditions, dry basis

$$V_{mstd} = \left[17.71 \frac{^oR}{in\ Hg}\right] V_m \left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m}\right] = 54.354 \text{ cu.ft.}$$

Volume water vapor in sample at standard conditions

$$V_{wstd} = \left[0.0474 \frac{cu.ft.}{ml}\right] V_{lc} = 7.11 \text{ cu.ft.}$$

Moisture content in stack gas

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = .116$$

Particle concentration in stack gas on dry basis

$$c'_s = \left[0.0154 \frac{gr}{mg}\right] \left[\frac{M_n}{V_{mstd}}\right] = .1036 \text{ grains/sc}$$

$$= 2.205\ 10^{-6} \frac{M_n}{V_{mstd}} = 14.811\ 10^{-6} \text{ lbs/scf}$$

Stack gas volume flow rate on dry basis

$$Q_s = 3600\ (1-B_{wo})\ V_s A \left[\frac{T_{std}\ P_s}{T_s\ avg\ P_{std}}\right] = 1878163 \text{ scfh}$$

Process rate or BTU rating P_W = _____

Emission Rate

$Q_s\ c'_s$ = 27.817 lbs/hr

$\frac{Q_s\ c'_s}{P_W}$ = _____ lbs/ 3.0691

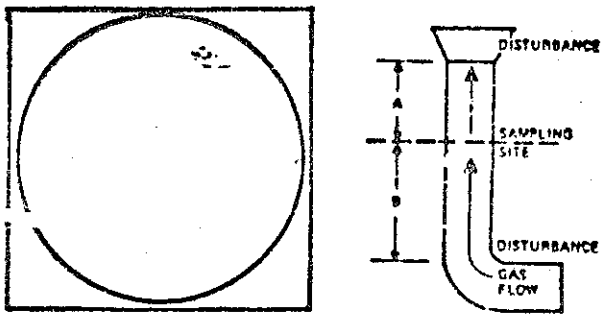
$$I = \frac{(1.667 \frac{min}{sec})\ T_s \left[(0.00267 \frac{in.Hg.cu.ft.}{ml\ ^oR}) V_{lc} + \frac{V_m}{T_m}(P_{bar} + \frac{\Delta H}{13.6})\right]}{\theta V_s P_s A_n} = 95.0 \%$$

(A_n = .00341 sq.ft.)

P_s = 29.27 T_s = 590 A_s = 18.66 V_s = 35.99

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT ZAT
DATE 3-27
LOCATION B3 STACK
OPERATOR BLW
STACK NO.
RUN NO. 1
SAMPLE BOX NO. GREEN
METER BOX NO. BLUE

AMBIENT TEMPERATURE 50
BAROMETRIC PRESSURE 29.3
ASSUMED MOISTURE, % 16
PROBE LENGTH, in. 5 FT
NOZZLE DIAMETER, in. 1/4
STACK DIAMETER, in. 58.5
PROBE HEATER SETTING
HEATER BOX SETTING 250

METER $\Delta H_@$
C FACTOR
PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT	[illegible]	[illegible]
TARE WEIGHT	[illegible]	[illegible]
WEIGHT GAIN	[illegible]	[illegible]
TOTAL		[illegible]

[illegible] .9625 .8729

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
1	2[illegible] 902.5	-.4	130 590	.25	.5000	.20		531.70	.45	40	250	40		27.51
2	905		590	.50	.7071	.49		32.85	.63	40	250	40		[illegible]
3	907.5		590	.50	.7071	.49		34.43	.68	40	250	40		[illegible]
4	910		120 580	.50	.7071	.51		36.005	.64	40	250	40		[illegible]
5	912.5		130 590	.50	.7071	.49		37.60	.63	40	250	40		[illegible]
6	915		590	.50	.7071	.49		39.20	.63	45	250	40		[illegible]
7	917.5		590	.50	.7071	.49		40.78	.63	45	250	40		[illegible]
8	920		590	.50	.7071	.49		42.36	.63	45	250	40		[illegible]
9	922.5		590	.40	.6324	.35		43.94	.56	50	250	40		[illegible]
10	925		590	.25	.5000	.20		45.35	.45	50	250	40		[illegible]
11	927.5		590	.25	.5000	.20		46.48	.45	50	250	40		[illegible]
12	930		590	.25	.5000	.20		47.60	.45	50	250	40		[illegible]
13	932.5		590	.30	.5477	.24		48.72	.49	50	250	40		32.32
14	935		590	.30	.5477	.24		49.94	.49	50	250	40		[illegible]
15	937.5		590	.30	.5477	.24		51.16	.49	50	250	40		[illegible]
TOTAL 16	940							52.38						
AVERAGE														

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL	220	100			220
INITIAL	100	100			210
LIQUID COLLECTED	120				20
TOTAL VOLUME COLLECTED					[illegible]

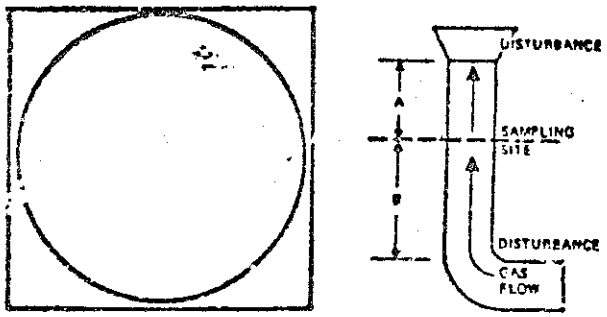
ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: $2.43 \times \sqrt{\Delta P \times ST}$

VELY 8.937

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT _____
DATE _____
LOCATION _____
OPERATOR _____
STACK NO. _____
RUN NO. 1 P2
SAMPLE BOX NO. _____
METER BOX NO. _____

AMBIENT TEMPERATURE _____
BAROMETRIC PRESSURE _____
ASSUMED MOISTURE, % _____
PROBE LENGTH, in. _____
NOZZLE DIAMETER, in. _____
STACK DIAMETER, in. _____
PROBE HEATER SETTING _____
HEATER BOX SETTING _____

METER $\Delta H_@$ _____
C FACTOR _____
PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT	8.737	
WEIGHT GAIN		
TOTAL		

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
17	947.5		590	.50	.7071	.49		52.38	.63	50	250	40		41.73
18	945		590	.50	.7071	.49		53.26	.63	55	250	40		41.53
19	942.5		590	.50	.7071	.49		55.54	.63	55	250	40		41.73
20	950		590	.50	.7071	.49		57.12	.63	55	250	40		41.73
	952.5							58.20						
21	957.5		590	.40	.6325	.35		58.30	.56	55	250	40		37.33
22	1000		590	.40	.6325	.35		60.11	.56	55	250	40		37.33
23	1002.5	CHANGE FILTER						61.51						
24	1030		590	.35	.5915	.29		61.51	.53	50	250	40		34.93
25	1032.5		590	.35	.5915	.29		62.84	.53	50	250	40		34.93
26	1035		590	.35	.5915	.29		64.16	.53	50	250	40		34.93
27	1037.5		590	.35	.5915	.29		65.48	.53	50	250	40		34.93
28	1040		590	.30	.5477	.25		66.80	.50	50	250	40		32.53
29	1042.5		590	.30	.5477	.25		68.05	.50	50	250	40		32.53
TOTAL 5	1045		590	.50	.5477	.25		69.30	.50	50	250	40		32.53
AVERAGE								70.55						

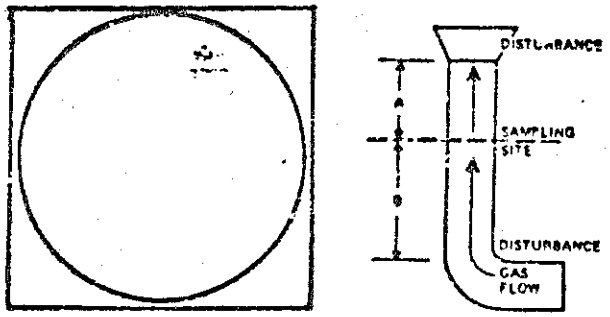
VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8.737

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT _____
DATE _____
LOCATION _____
OPERATOR _____
STACK NO. _____
RUN NO. 1B
SAMPLE BOX NO. _____
METER BOX NO. _____

AMBIENT TEMPERATURE _____
BAROMETRIC PRESSURE _____
ASSUMED MOISTURE, % _____
PROBE LENGTH, in. _____
NOZZLE DIAMETER, in. _____
STACK DIAMETER, in. _____
PROBE HEATER SETTING _____
HEATER BOX SETTING _____

METER $\Delta H_@$ _____
C FACTOR _____
PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
TOTAL		

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOC lps
31	1047.5		590	.30	.5477	.25		70.55	.50	50	250	40		32.33
32	1050		590	.30	.5477	.25		71.80	.50	50	250	40		32.32
33	1052.5		590	.30	.5477	.25		73.05	.50	50	250	40		32.33
34	1055		590	.50	.7071	.49		74.30	.63	50	250	40		41.74
35	1057.5		590	.50	.7071	.49		75.98	.63	50	250	40		41.74
36	1100		590	.50	.7071	.49		77.55	.63	50	250	40		41.74
37	1102.5		590	.60	.7746	.61		79.12	.69	50	250	40		45.22
38	1105		590	.60	.7746	.61		80.75	.69	50	250	40		[illegible]
39	1107.5		590	.60	.7746	.61		82.68	.69	50	250	40		[illegible]
40	1110		590	.60	.7746	.61		84.40	.69	50	250	40		[illegible]
	1112.5							86.12						
TOTAL						.356		54.42						
AVERAGE			590.		.6047.									

60° temp Comp

CHECK TEMP SENSOR ON 5 FTER

3569.

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8.937 J = 35.99

PARTICLE DATA LABORATORIES, LTD.

SOURCE: Caterpillar Joliet. Boiler # 3. 3/29/77.

TEST NUMBER: 2.

Volume of sample at standard conditions, dry basis

$$V_{mstd} = \left[17.71 \frac{^oR}{in\ Hg}\right] V_m \left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m}\right] = 51.289 \text{ cu.ft.}$$

Volume water vapor in sample at standard conditions

$$V_{wstd} = \left[0.0474 \frac{cu.ft.}{ml}\right] V_{lc} = 8.864 \text{ cu.ft.}$$

Moisture content in stack gas

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = .147$$

Particle concentration in stack gas on dry basis

$$c'_s = \left[0.0154 \frac{gr}{mg}\right] \left[\frac{M_n}{V_{mstd}}\right] = .0726 \text{ grains/sc}$$

$$= 2.205\ 10^{-6} \frac{M_n}{V_{mstd}} = 10.374\ 10^{-6} \text{ lbs/scf}$$

Stack gas volume flow rate on dry basis

$$Q_s = 3600\ (1-B_{wo})\ V_s A \left[\frac{T_{std}\ P_s}{T_s\ avg\ P_{std}}\right] = 1729891 \text{ scfh}$$

Process rate or BTU rating P_W = _____

Emission Rate

$Q_s\ c'_s$ = 17.95 lbs/hr

$\frac{Q_s\ c'_s}{P_W}$ = _____ lbs/

2.8960.

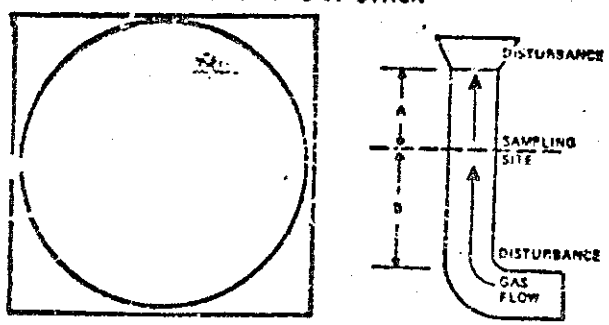
$$I = \frac{(1.667 \frac{min}{sec})\ T_s \left[(0.00267 \frac{in.Hg.cu.ft.}{ml\ ^oR}) V_{lc} + \frac{V_m}{T_m}(P_{bar} + \frac{\Delta H}{13.6})\right]}{\theta V_s P_s A_n}$$

(A_n = .00341 sq.ft.) = 77.39 %

t_s = 34.33. P_s = 29.29. A_s = 18.66 T_s = 590

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT CAT
DATE 3-28
LOCATION
OPERATOR ELW
STACK NO.
RUN NO. 2
SAMPLE BOX NO. BLUE
METER BOX NO. BLUE

AMBIENT TEMPERATURE
BAROMETRIC PRESSURE 29.3
ASSUMED MOISTURE, %
PROBE LENGTH, in.
NOZZLE DIAMETER, in. 1/4
STACK DIAMETER, in. 58.5
PROBE HEATER SETTING
HEATER BOX SETTING

METER $\Delta H_@$
C FACTOR
PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT	20463	46.2183
TARE WEIGHT	[illegible]	46.2160
WEIGHT GAIN	[illegible]	.0577
TOTAL		.2413.

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F R	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
1	2.5 12.5	[illegible]	590	.20	.4472	.15		586.25	.40	55	250	40		26.37
2	1257.5		590	.50	.7071	.49		87.25	.63	55	250	40		41.74
3	100		590	.50	.7071	.49		88.82	.63	55	250	40		41.74
4	102.5		590	.50	.7071	.49		90.40	.63	55	250	40		41.74
5	105		590	.40	.6325	.34		91.98	.56	55	250	40		37.33
6	107.5		590	.40	.6325	.34		93.38	.56	55	250	40		37.33
7	110		590	.40	.6325	.34		94.78	.56	60	250	45		37.33
8	112.5		590	.40	.6325	.34		96.18	.56	60	250	45		37.33
9	115		590	.40	.6325	.34		97.58	.56	60	250	45		37.33
10	117.5		590	.40	.6325	.34		98.98	.56	60	250	45		37.33
11	120		590	.30	.5477	.24		600.38	.49	60	250	45		32.32
12	122.5		590	.30	.5477	.24		01.60	.49	60	250	45		32.32
13	125		590	.30	.5477	.24		02.82	.49	60	250	45		32.32
14	127.5		590	.30	.5477	.24		04.04	.49	60	250	45		32.32
15	130		590	.20	.4472	.15		05.62	.40	60	250	45		26.37
TOTAL 16	132.5		590	.20	.4472	.15		06.62	.40	60	250	45		26.37
AVERAGE														557.65

T.t. 13.9145. T.t. 4.92. 07.62.

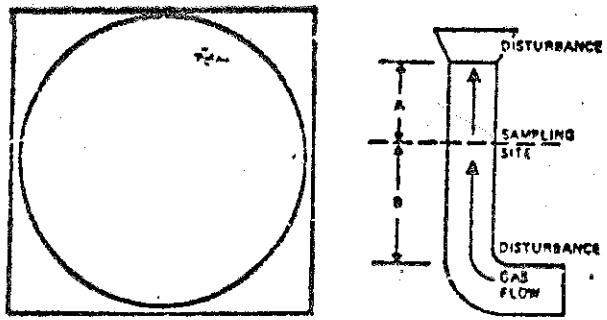
VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL	[illegible]	[illegible]			[illegible]
INITIAL	100	100			[illegible]
LIQUID COLLECTED	[illegible]				[illegible]
TOTAL VOLUME COLLECTED					[illegible]

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8,937

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT _____
DATE _____
LOCATION _____
OPERATOR _____
STACK NO. _____
RUN NO. 2 R
SAMPLE BOX NO. _____
METER BOX NO. _____

AMBIENT TEMPERATURE _____
BAROMETRIC PRESSURE _____
ASSUMED MOISTURE, % _____
PROBE LENGTH, in. _____
NOZZLE DIAMETER, in. _____
STACK DIAMETER, in. _____
PROBE HEATER SETTING _____
HEATER BOX SETTING _____

METER $\Delta H_@$ _____
C FACTOR _____
PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
TOTAL		

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
17	135		590	.20	.4472	.15		07.62	.40	65	250	45		26.39
18	137.5		590	.20	.4472	.15		08.62	.40	65	250	45		26.39
19	140		590	.30	.5477	.24		09.62	.49	65	250	45		32.33
20	142.5		590	.30	.5477	.24		10.84	.49	65	250	45		32.33
	145							12.06						
21	150		590	.30	.5477	.24		12.06	.49	65	250	45		32.33
22	152.5		590	.30	.5477	.24		13.28	.49	65	250	45		32.33
23	155		590	.30	.5477	.24		14.50	.49	70	250	45		32.33
24	157.5		590	.30	.5477	.24		15.72	.49	70	250	45		32.33
25	200		590	.25	.5	.19		16.94	.45	70	250	45		29.57
26	202.5		590	.25	.5	.19		18.06	.45	70	250	45		29.57
27	205		590	.25	.5	.19		19.18	.45	70	250	45		29.57
28	207.5		590	.25	.5	.19		20.30	.45	70	250	45		29.57
29	210		590	.25	.5	.19		21.42	.45	70	250	45		29.57
30	212.5		590	.25	.5	.19		22.54	.45	70	250	45		29.57
TOTAL 31	215		590	.25	.5	.19		23.66	.45	70	250	45		29.57
AVERAGE						3.07								

7.6608

CHECK UMBILICAL FOR STACK TEMP

453.22

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

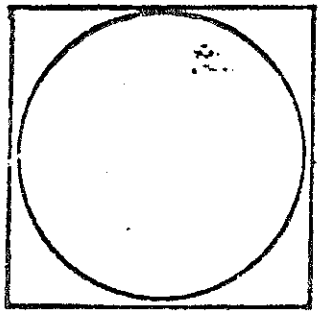
ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					

COMMENTS.

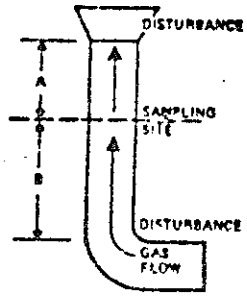
8.937

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION



PLANT _____

DATE _____

LOCATION _____

OPERATOR _____

STACK NO. _____

RUN NO. 2 P3

SAMPLE BOX NO. _____

METER BOX NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

ASSUMED MOISTURE, % _____

PROBE LENGTH, in. _____

NOZZLE DIAMETER, in. _____

STACK DIAMETER, in. _____

PROBE HEATER SETTING _____

HEATER BOX SETTING _____

METER ΔH_a _____

C FACTOR _____

PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
32	211.5		590	.25	.5000	.19		24.78	.45	70	250	50		28.57
33	220		590	.30	.5477	.24		25.90	.49	70	250	50		32.33
34	222.5		590	.30	.5477	.24		27.12	.49	75	250	50		32.33
35	225		590	.40	.6325	.34		28.34	.56	75	250	50		32.33
36	227.5		590	.50	.7071	.50		29.75	.63	75	250	50		41.74
37	230		590	.50	.7071	.50		31.33	.63	75	250	50		41.74
38	232.5		590	.50	.7071	.50		32.90	.63	75	250	50		41.74
39	235		590	.50	.7071	.50		34.47	.63	75	250	50		41.74
40	237.5		590	.50	.7071	.50		36.04	.63	75	250	50		41.74
	240							37.61						
				Tot	5.7624	2.51								35.2
TOTAL														
AVERAGE			590		.5723	.288		51.36						33.65

60° temp Comp.

$\bar{J}$ = 34.33

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8.737

PARTICLE DATA LABORATORIES, LTD.

SOURCE: Caterpillar Joliet Boiler #2 3/30/77

TEST NUMBER: 1,

Volume of sample at standard conditions, dry basis

$$V_{mstd} = \left[17.71 \frac{^oR}{in\ Hg}\right] V_m \left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m}\right] = \underline{46.285.}\ cu.ft.$$

Volume water vapor in sample at standard conditions

$$V_{wstd} = \left[0.0474 \frac{cu.ft.}{ml}\right] V_{lc} = \underline{7.821}\ cu.ft.$$

Moisture content in stack gas

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \underline{.145.}$$

Particle concentration in stack gas on dry basis

$$c'_s = \left[0.0154 \frac{gr}{mg}\right] \left[\frac{M_n}{V_{mstd}}\right] = \underline{.06441}\ grains/sc$$

$$= 2.205\ 10^{-6} \frac{M_n}{V_{mstd}} = \underline{6.3791\ 10^{-6}}\ lbs/scf$$

Stack gas volume flow rate on dry basis

$$Q_s = 3600\ (1-B_{wo})\ V_s\ A \left[\frac{T_{std}\ P_s}{T_s\ avg\ P_{std}}\right] = \underline{1709692}\ scfh$$

Process rate or BTU rating P_W = _____

Emission Rate

$Q_s\ c'_s$ = 10.9063. lbs/hr

$\frac{Q_s\ c'_s}{P_W}$ = _____ lbs/

2.61351

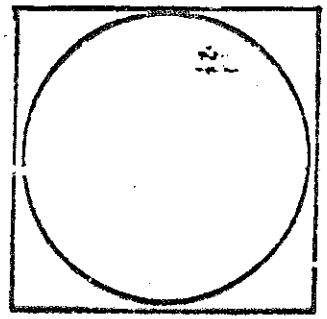
$$I = \frac{(1.667 \frac{min}{sec})\ T_s \left[(0.00267 \frac{in.Hg.cu.ft.}{ml\ \ ^oR})\ V_{lc} + \frac{V_m}{T_m}\ (P_{bar} + \frac{\Delta H}{13.6})\right]}{\theta V_s P_s A_n}$$

(A_n = .00341 sq.ft.) = 96.5 %

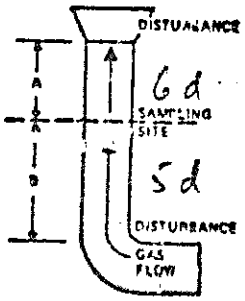
V_s = 43.73 A = 14.181 P = 29.53 T = [illegible]

PARTICULATE FIELD DATA

EMATIC OF STACK



CROSS SECTION



PLANT CAT DOC 2F

DATE 3-30

LOCATION B1 NORTH STACK

OPERATOR ELW

STACK NO.

RUN NO. 1

SAMPLE BOX NO. GREEN

METER BOX NO. BLUE

AMBIENT TEMPERATURE 45

BAROMETRIC PRESSURE 29.6

ASSUMED MOISTURE, % 16

PROBE LENGTH, in. 3 FT

NOZZLE DIAMETER, in. 1/4

STACK DIAMETER, in. 5

PROBE HEATER SETTING

HEATER BOX SETTING 250

METER $\Delta H_@$

C FACTOR

PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT	.4104	46.0022
TARE WEIGHT	[illegible]	46.1495
WEIGHT GAIN	.1355	.0577
TOTAL	.1932	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F/R	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	45.53 VELOCITY fps
1	2.5 1000	-.45	129 585	.60	.7746	.64		642.15	.68	40	250	40		[illegible]
2	1002.5		585	.60	.7746	.64		43.88	.69	40	250	40		45.52
3	1005		585	.60	.7746	.64		45.60	.69	40	250	40		45.52
4	1007.5		585	.60	.7746	.64		47.32	.69	50	250	45		45.52
5	1010		585	.50	.7071	.50		49.04	.63	50	250	45		41.56
6	1012.5		585	.50	.7071	.50		50.63	.63	50	250	45		41.8
7	1015		585	.40	.6325	.36		52.20	.57	50	250	45		32.17
8	1017.5		585	.40	.6325	.36		53.62	.57	50	250	45		32.17
9	1020		585	.50	.7071	.50		55.04	.63	50	250	45		41.56
10	1022.5		585	.60	.7746	.64		56.62	.69	50	250	45		45.52
11	1025		585	.60	.7746	.64		58.34	.69	50	250	45		45.52
12	1027.5		585	.60	.7746	.64		60.07	.69	50	250	45		45.52
13	1030		585	.60	.7746	.64		61.80	.69	50	250	45		45.52
14	1032.5		585	.60	.7746	.64		63.52	.69	50	250	45		45.52
	1035							65.24						
TOTAL														
AVERAGE														

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL	250	100			215
INITIAL	100	100			200
LIQUID COLLECTED	150				15
TOTAL VOLUME COLLECTED					115

YESTERDAY 29.3

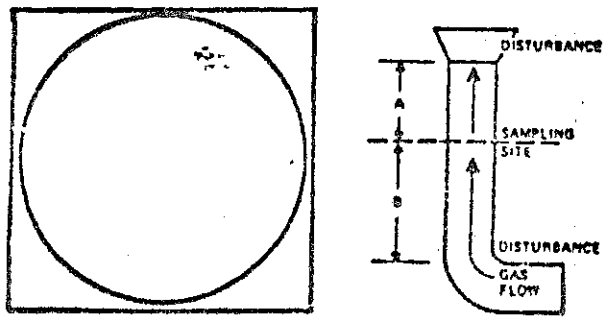
ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS:

8.937

PARTICULATE FIELD DATA

IEMATIC OF STACK



CROSS SECTION

PLANT [illegible]
DATE
LOCATION
OPERATOR
STACK NO.
RUN NO. 1 P2
SAMPLE BOX NO.
METER BOX NO.

AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
ASSUMED MOISTURE, %
PROBE LENGTH, in.
NOZZLE DIAMETER, in.
STACK DIAMETER, in.
PROBE HEATER SETTING
HEATER BOX SETTING

METER $\Delta H_@$
C FACTOR
PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
15	1037.5		585	.60	.7746	.61		65.24	.69	50	250	45		45.52
16	1040		585	.60	.7746	.61		66.96	.69	50	250	45		45.52
17	1042.5		585	.60	.7746	.61		68.68	.69	50	250	45		45.52
18	1045		585	.60	.7746	.61		70.40	.69	50	250	45		45.52
19	1047.5		585	.60	.7746	.61		72.12	.69	50	250	45		45.52
20	1050		585	.60	.7746	.61		73.84	.69	50	250	45		45.52
21	1052.5		585	.60	.7746	.61		75.56	.69	50	250	45		45.52
22	1055		585	.50	.7071	.50		77.28	.63	55	250	45		41.57
23	1057.5		585	.40	.6325	.35		78.87	.56	55	250	45		37.17
24	1100		585	.40	.6325	.35		80.25	.56	55	250	45		37.17
25	1102.5		585	.50	.7071	.50		81.68	.63	60	250	45		41.56
26	1105		585	.50	.7071	.50		83.26	.63	60	250	45		41.56
27	1107.5		585	.50	.7071	.50		84.84	.63	60	250	45		41.56
28	1110		585	.50	.7071	.50		86.42	.63	60	250	45		41.56
	1112.5							88.00						
TOTAL														
AVERAGE			585		.7350	.553		45.85		60 temp comp				43.20

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8.937 y = 43.73

PARTICLE DATA LABORATORIES, LTD.

SOURCE: Caterpillar Joliet Bldg # 2 3/30/77.

TEST NUMBER: 2.

Volume of sample at standard conditions, dry basis

$$V_{mstd} = \left[17.71 \frac{^oR}{in\ Hg}\right] V_m \left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m}\right] = 44.867 \text{ cu.ft.}$$

Volume water vapor in sample at standard conditions

$$V_{wstd} = \left[0.0474 \frac{cu.ft.}{ml}\right] V_{lc} = 7.394 \text{ cu.ft.}$$

Moisture content in stack gas

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = .141$$

Particle concentration in stack gas on dry basis

$$c'_s = \left[0.0154 \frac{gr}{mg}\right] \left[\frac{M_n}{V_{mstd}}\right] = .0796 \text{ grains/sc}$$

$$= 2.205\ 10^{-6} \frac{M_n}{V_{mstd}} = 11.377 \cdot 10^{-6} \text{ lbs/scf}$$

Stack gas volume flow rate on dry basis

$$Q_s = 3600\ (1-B_{wo})\ V_s A \left[\frac{T_{std}}{T_{s\ avg}} \frac{P_s}{P_{std}}\right] = 1645023 \text{ scfh}$$

Process rate or BTU rating P_W = _____

Emission Rate

$Q_s c'_s$ = 18.7154 lbs/hr

$\frac{Q_s c'_s}{P_W}$ = _____ lbs/

2.53341

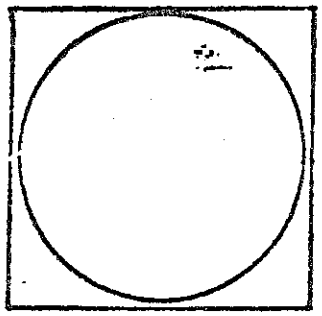
$$I = \frac{(1.667 \frac{min}{sec})\ T_s \left[(0.00267 \frac{in.Hg.cu.ft.}{ml\ ^oR}) V_{lc} + \frac{V_m}{T_m}(P_{bar} + \frac{\Delta H}{13.6})\right]}{\theta V_s P_s A_n}$$

(A_n = .00034 sq.ft.) = 97.3 %

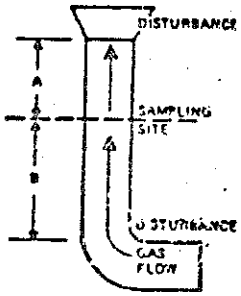
V_s = 41.88 T_s = 585 P_s = 25.57 A_n = 14.86

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION



PLANT CAT

DATE 3-30

LOCATION B2

OPERATOR KLW

STACK NO.

RUN NO. 2

SAMPLE BOX NO. BLUE

METER BOX NO. BLUE

AMBIENT TEMPERATURE 59

BAROMETRIC PRESSURE 29.6

ASSUMED MOISTURE, % 16

PROBE LENGTH, in. 3 FT

NOZZLE DIAMETER, in. 14

STACK DIAMETER, in. 51

PROBE HEATER SETTING

HEATER BOX SETTING 250

METER $\Delta H_@$

C FACTOR

PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WAS
FINAL WEIGHT	1.0271	47.6843
TARE WEIGHT	[illegible]	47.6278
WEIGHT GAIN	.1748	.0569
TOTAL	.2315	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER C FM INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCITY fps
1	2.5 1120		585	.40	.6325	.37		688.00	.57	70	250	45		37.17
2	1122.5		585	.40	.6325	.37		89.42	.57	70	250	45		37.17
3	1125		585	.40	.6325	.37		90.84	.57	70	250	45		37.17
4	1127.5		585	.40	.6325	.37		92.26	.57	70	250	45		37.17
5	1130		585	.40	.6325	.37		93.68	.57	70	250	45		37.17
6	1132.5		585	.40	.6325	.37		95.10	.57	70	250	45		37.17
7	1135		585	.40	.6325	.37		96.52	.57	70	250	45		37.17
8	1137.5		585	.40	.6325	.37		97.94	.57	70	250	45		37.17
9	1140		585	.40	.6325	.37		99.36	.57	70	250	45		37.17
10	1142.5		585	.50	.7071	.49		100.78	.63	70	250	45		41.57
11	1145		585	.50	.7071	.49		02.36	.63	70	250	45		41.57
12	1147.5		585	.60	.7746	.64		03.94	.70	70	250	45		45.53
13	1150		585	.60	.7746	.64		05.68	.70	70	250	45		45.53
14	1152.5		585	.60	.7746	.64		07.43	.70	70	250	45		45.53
	1155							09.18						
TOTAL														
AVERAGE														

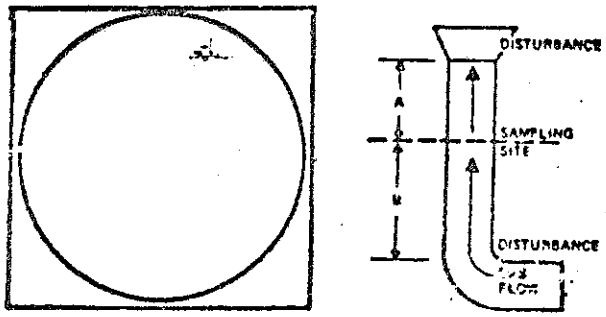
VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL	240	100			216
INITIAL	100	100			200
LIQUID COLLECTED	140				16
TOTAL VOLUME COLLECTED					[illegible]

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS: 8.937

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT _____

DATE _____

LOCATION _____

OPERATOR _____

STACK NO. _____

RUN NO. 2 PE

SAMPLE BOX NO. _____

METER BOX NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

ASSUMED MOISTURE, % _____

PROBE LENGTH, in. _____

NOZZLE DIAMETER, in. _____

STACK DIAMETER, in. _____

PROBE HEATER SETTING _____

HEATER BOX SETTING _____

METER $\Delta H_@$ _____

C FACTOR _____

PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
15	1157.5		585	.60	.7746	.64		9.18	.70	70	250	45		45.53
16	1200		585	.70	.8367	.72		10.93	.75	70	250	45		48.12
17	1202.5		585	.60	.7746	.64		12.81	.70	70	250	45		45.53
18	1205		585	.60	.7746	.64		14.56	.70	70	250	45		45.53
19	1207.5		585	.60	.7746	.64		16.31	.70	70	250	45		45.53
20	1210		585	.50	.7071	.50		18.06	.63	70	250	45		41.12
21	1212.5		585	.50	.7071	.50		19.65	.63	70	250	45		41.12
22	1215		585	.40	.6325	.36		21.22	.57	70	250	45		32.12
23	1217.5		585	.50	.7071	.50		22.64	.63	70	250	45		41.12
24	1220		585	.50	.7071	.50		24.22	.63	70	250	45		41.12
25	1222.5		585	.50	.7071	.50		25.80	.63	70	250	45		41.12
26	1225		585	.50	.7071	.50		27.38	.63	70	250	45		41.12
27	1227.5		585	.60	.7746	.64		28.95	.70	70	250	45		45.53
28	1230		585	.60	.7746	.64		30.70	.70	70	250	45		45.53
	1232.5							32.45						
TOTAL														
AVERAGE			585		.7068	.5054		44.45	60 temp comp					41.54

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS:

8.737

J^2 41.88

PARTICLE DATA LABORATORIES, LTD.

SOURCE: Calcipella Joliet Brick # 2 3/30/77

TEST NUMBER: 3.

Volume of sample at standard conditions, dry basis

$$V_{mstd} = \left[17.71 \frac{^oR}{in\ Hg}\right] V_m \left[\frac{P_{bar} + \frac{\Delta H}{13.6}}{T_m}\right] = 47.954 \text{ cu.ft.}$$

Volume water vapor in sample at standard conditions

$$V_{wstd} = \left[0.0474 \frac{cu.ft.}{ml}\right] V_{lc} = 7.940 \text{ cu.ft.}$$

Moisture content in stack gas

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = .142$$

Particle concentration in stack gas on dry basis

$$c'_s = \left[0.0154 \frac{gr}{mg}\right] \left[\frac{M_n}{V_{mstd}}\right] = .06117 \text{ grains/sc}$$

$$= 2.205\ 10^{-6} \frac{M_n}{V_{mstd}} = 8.7411\ 10^{-6} \text{ lbs/scf}$$

Stack gas volume flow rate on dry basis

$$Q_s = 3600\ (1-B_{wo})\ V_s A \left[\frac{T_{std}\ P_s}{T_s\ avg\ P_{std}}\right] = 1761202 \text{ scfh}$$

Process rate or BTU rating P_W = _____

Emission Rate

$Q_s c'_s$ = 15.3948 lbs/hr

$\frac{Q_s c'_s}{P_W}$ = _____ lbs/

$$I = \frac{(1.667 \frac{min}{sec})\ T_s \left[(0.00267 \frac{in.Hg.cu.ft.}{ml\ ^oR}) V_{lc} + \frac{V_m}{T_m}(P_{bar} + \frac{\Delta H}{13.6})\right]}{\theta V_s P_s A_n}$$

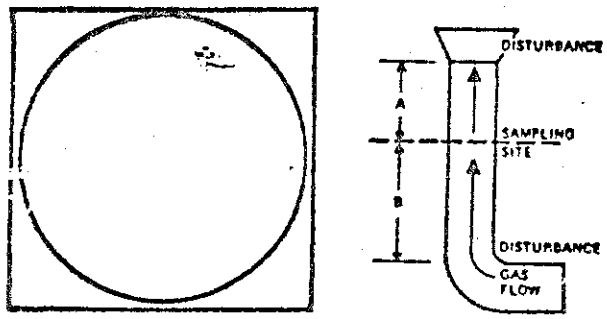
2.7077

(A_n = .00341 sq.ft.) = 97.1 %

P_s = 29.57. V_s = 44.89. T_s = 585. A_n = 14.186

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT [illegible]

DATE [illegible]

LOCATION

OPERATOR [illegible]

STACK NO.

RUN NO. 3

SAMPLE BOX NO.

METER BOX NO.

AMBIENT TEMPERATURE

BAROMETRIC PRESSURE

ASSUMED MOISTURE, %

PROBE LENGTH, in.

NOZZLE DIAMETER, in.

STACK DIAMETER, in.

PROBE HEATER SETTING

HEATER BOX SETTING

METER $\Delta H_@$

C FACTOR

PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT	[illegible]	47.9272
TARE WEIGHT	[illegible]	49.8758
WEIGHT GAIN	[illegible]	.0514
.138	TOTAL	.1901

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
1	1249.5	-.45	555	.60	.7746	.61		32.45	70	70	250	50		45.53
2	1245		555	.60	.7746	.61		34.29	70	70	250	50		45.53
3	1247.5		555	.70	.8367	.72		35.95	75	70	250	50		49.17
4	1251		555	.60	.7746	.61		37.82	70	70	250	50		45.53
5	1252.5		555	.60	.7746	.61		39.[illegible]	70	70	250	50		45.53
6	1255		555	.50	.7071	.50		41.32	.63	70	250	50		41.55
7	1257.5		555	.40	.6325	.36		42.91	.57	70	250	50		37.17
8	100		555	.40	.6325	.36		44.33	.57	70	250	50		37.17
9	102.5		555	.50	.7071	.50		45.76	.63	70	250	50		41.55
10	105		555	.50	.7071	.50		47.3[illegible]	.63	70	250	50		41.55
11	107.5		555	.60	.7746	.61		48.82	.70	70	250	50		45.53
12	110		555	.60	.7746	.61		50.67	.70	70	250	50		45.53
13	112.5		555	.70	.8367	.72		52.42	.72	70	250	50		49.17
14	115		555	.60	.7746	.61		54.30	.70	70	250	50		45.53
	117.5							56.05						
TOTAL														
AVERAGE														

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL	250	100			217.5
INITIAL	100	100			200
LIQUID COLLECTED	150	-			17.5
TOTAL VOLUME COLLECTED	[illegible]				[illegible]

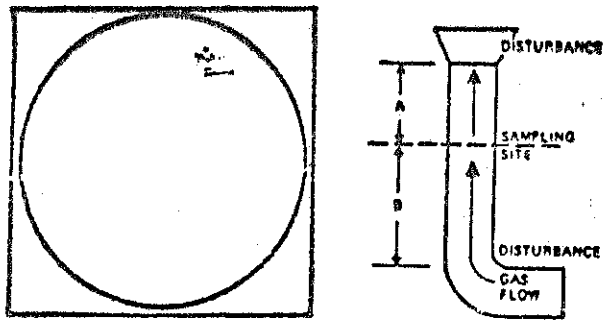
ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS:

8.937

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION

PLANT CAT
DATE 3-30
LOCATION
OPERATOR FLW
STACK NO.
RUN NO. 3P2
SAMPLE BOX NO.
METER BOX NO.

AMBIENT TEMPERATURE
BAROMETRIC PRESSURE
ASSUMED MOISTURE, %
PROBE LENGTH, in.
NOZZLE DIAMETER, in.
STACK DIAMETER, in.
PROBE HEATER SETTING
HEATER BOX SETTING

METER $\Delta H_@$
C FACTOR
PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg

SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCI fps
15	120		585	.60	.7746	.61		56.05	70	70	250	50		40.52
16	122.5		585	.40	.6325	.36		57.50	70	70	250	50		33.17
17	125		585	.40	.6325	.36		59.22	70	70	250	50		33.17
18	127.5		585	.50	.7071	.50		60.64	70	70	250	50		41.58
19	130		585	.50	.7071	.50		62.23	70	70	250	50		41.58
20	132.5		585	.50	.7071	.50		63.50	70	70	250	50		41.58
21	135		585	.40	.6325	.36		65.78	70	70	250	50		33.17
22	137.5		585	.60	.7746	.61		66.50	70	70	250	50		49.52
23	140		585	.60	.7746	.61		68.55	70	70	250	50		49.52
24	142.5		585	.70	.8367	.72		70.30	70	70	250	50		59.17
25	145		585	.70	.8367	.72		72.18	70	70	250	50		59.17
26	147.5		585	.70	.8367	.72		74.06	70	70	250	50		59.17
27	150		585	.80	.8944	.80		75.94	70	70	250	50		66.17
28	152.5		585	.80	.8944	.80		77.95	70	70	250	50		66.17
	155							79.75						
TOTAL						.575								
AVERAGE			585		.7544			47.50	60°F temp comp.					43.77

COMMENTS: 8,937

2/ : 44.89

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

APPENDIX I: SULFUR OXIDES FIELD TEST DATA SHEETS, LABORATORY ANALYSIS DATA AND CALCULATION SUMMARIES

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet. Bib #2. 3/20/79.

TEST NUMBER: 1-1. Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .763. cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.132 10^-5 lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 19.4 lb/hr.	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	60.4 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .08410^-5 lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 1.4. lb/hr	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	4.1 ppm		

Sample taken at: 10^00

Sampling time: Mins.

S: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bile #2 3/20/77.

TEST NUMBER: 1-2 Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .763. cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.242 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 21.2 lb/hr.	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	75.0 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .102 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 1.7 lb/hr	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	4.9 ppm		

Sample taken at: 10 in

Sampling time: 25. Mins.

S: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bnl #2. 3/30/77.

TEST NUMBER: 2-1. outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis			
$V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .759 cu.ft.	x 0.02821	_____ M^3
Concentration of sulfur dioxide at standard conditions, dry basis			
$C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.456 10^{-5} lb/scf	x 16.08×10^6	_____ mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 24.0 lb/hr.	x 0.4536	_____ kg/hr
	= _____ lb/10^6BTU	x 1.8	_____ kg/10^6 kg-cals
	88.0 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis			
$C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .396 10^{-5} lb/scf	x 16.08×10^6	_____ mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 6.5 lb/hr	x 0.4536	_____ kg/hr
	= _____ lb/10^6BTU	x 1.8	_____ kg/10^6 kg-cals
	19.1 ppm		

Sample taken at: 11:20

Sampling time: 25. Mins.

SO: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bldg #2 3/30/77.

TEST NUMBER: 2-2 Outlet.

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis			
$V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .759 cu.ft.	x 0.02821	____ M^3
Concentration of sulfur dioxide at standard conditions, dry basis			
$C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.326 10^{-5} lb/scf	x 16.08 x 10^6	____ mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 21.8 lb/hr.	x 0.4536	____ kg/hr
	= ____ lb/10^6BTU	x 1.8	____ kg/10^6 kg-cals
	80.1 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis			
$C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .098 10^{-5} lb/scf	x 16.08 x 10^6	____ mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 1.6 lb/hr	x 0.4536	____ kg/hr
	= ____ lb/10^6BTU	x 1.8	____ kg/10^6 kg-cals
	4.7 ppm		

Sample taken at:

Sampling time: Mins.

SO_2: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Catapulla Joliet Mile #2 3/30/77.

TEST NUMBER: 3-1. outlet.

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .907 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.676 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 29.5 lb/hr.	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	101.3 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .091 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 1.5 lb/hr	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	4.4 ppm		

Sample taken at: 1"

Sampling time: 30 Mins.

S: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bile #2 3/30/77.

TEST NUMBER: 3-2 Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .756 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{[V_t - V_{tb}] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.521 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 25.0 lb/hr.	x 0.4536	kg/hr
	= ____ lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	91.9 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{[V_t - V_{tb}] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .122 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 2.0 lb/hr	x 0.4536	kg/hr
	= ____ lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	5.9 ppm		

Sample taken at: 1 30.

Sampling time: 25 Mins.

S[illegible] µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Plant #2 3/30/77

TEST NUMBER: 1 inlet.

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= 300 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 13.242 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 226.4 lb/hr.	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	800.1 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 3.408 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 56.3 lb/hr	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	164.7 ppm		

Sample taken at: 10 30

Sampling time: 10. Mins.

S[illegible] µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet . Bile #2 - 3/30/79

TEST NUMBER: 2 sheet.

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis			
$V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .300 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis			
$C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 15.5451 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 255.7 lb/hr.	x 0.4536	kg/hr
	= 939.3 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals
Concentration of sulfur trioxide at standard conditions, dry basis			
$C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 2.119 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 34.9. lb/hr	x 0.4536	kg/hr
	= 102.4 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals

Sample taken at: 11^{20}

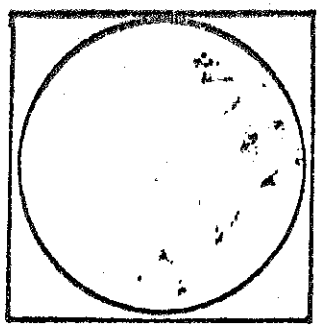
Sampling time: Mins.

SO µg

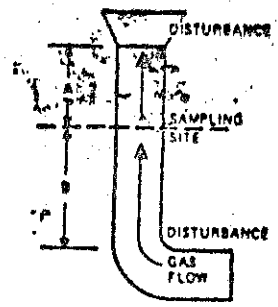
SO_3: µg

PARTICULATE FIELD DATA

CHEMATIC OF STACK



CROSS SECTION



PLANT Cat Tele

DATE 3/20

LOCATION

OPERATOR

STACK NO. #2 boiler

RUN NO. 1-1 / 2-1

SAMPLE BOX NO.

METER BOX NO. 50X

AMBIENT TEMPERATURE

BAROMETRIC PRESSURE

ASSUMED MOISTURE, %

PROBE LENGTH, in.

NOZZLE DIAMETER, in.

STACK DIAMETER, in.

PROBE HEATER SETTING

HEATER BOX SETTING

METER $\Delta H_@$

C FACTOR

PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED,		
SAMPLE	FILTER	PROBE W
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOC fps
	10:0	out (10)	#1					490.360	55	#2	10⁴⁰ .500	55°F		
	100							.510	"					
	10							660	"					
	15							810	"					
	20							1.060	"					
	25							1.210	"		1.250			
	10³⁰	inlet	S port	fn #1				7.410	65					
	35													
	40							7.710	"					
	11²⁰							7.710	"					
	11⁴⁰	"	S port	fn #2				8.010	"					
TOTAL														
AVERAGE														

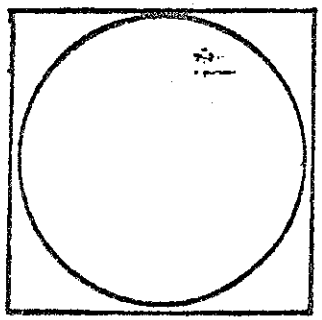
VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

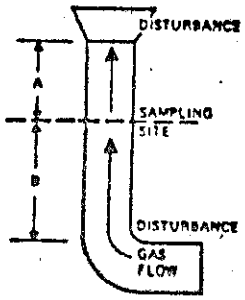
COMMENTS:

PARTICULATE FIELD DATA

EMATIC OF STACK



CROSS SECTION



PLANT _____

DATE 7/30/77

LOCATION _____

OPERATOR SVX

STACK NO. _____

RUN NO. Run #2

SAMPLE BOX NO. _____

METER BOX NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

ASSUMED MOISTURE, % _____

PROBE LENGTH, in. _____

NOZZLE DIAMETER, in. _____

STACK DIAMETER, in. _____

PROBE HEATER SETTING _____

HEATER BOX SETTING _____

METER $\Delta H_@$ _____

C FACTOR _____

PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WAS
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
TOTAL		

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s) ($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in. H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCITY fps
		Run 2-1	[illegible]				.200	58		115	.5000	58	
			112				.350			120			
			25				.500			125			
			30				.650			130			
			38				.800			135			
			144				0.950			2	1.25	✓	
		3-1	[illegible] 1.00				3.1000	60		113	.100	60	
			105				.150			120			
			110				.300			125			
			115				.450			125			
			120				.600			130			
			125				.750			135	.850	4	
			130				.900	0					
TOTAL													
AVERAGE													

VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

COMMENTS:

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Boiler #3 3/29/77

TEST NUMBER: 1-1 Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .737 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.078 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 20.2 lb/hr.	x 0.4536	kg/hr
	= 65.1 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .112 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 2.1 lb/hr	x 0.4536	kg/hr
	= 5.4 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals

Sample taken at: 905

Sampling time: 25 Mins.

SO_2: µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bld. #3. 3/29/77

TEST NUMBER: 1-2. Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .737 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{[V_t - V_{tb}] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.266 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 23.8 lb/hr.	x 0.4536	kg/hr
	= 76.5 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{[V_t - V_{tb}] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 3.00 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 5.6 lb/hr	x 0.4536	kg/hr
	= 14.5 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals

Sample taken at: 10^{00}

Sampling time: 25 Mins.

S[illegible] µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Boiler #3 3/29/77.

TEST NUMBER: 2-1 outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .746 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 2.130 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 36.8 lb/hr.	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	128.7 ppm		
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .482 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 8.3 lb/hr	x 0.4536	kg/hr
	= lb/10^6BTU	x 1.8	kg/10^6 kg-cals
	23.3 ppm		

Sample taken at: 1 70

Sampling time: 25 Mins.

(µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bldg # 3. 3/29/79

TEST NUMBER: 2-2 Outlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{^oR}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .746 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 2.917 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 50.5 lb/hr.	x 0.4536	kg/hr
	= 176.3 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{\left[V_t - V_{tb}\right] N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= .333 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 5.8 lb/hr	x 0.4536	kg/hr
	= 16.1 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals

Sample taken at: 220.

Sampling time: 25 Mins.

S. µg

SO_3: µg

PARTICLE DATA LABORATORIES, LTD.

SULFUR OXIDES

SOURCE: Caterpillar Joliet Bldg #3 3/21/77.

TEST NUMBER: Inlet

PDL PROJECT NO.

	ENGLISH UNITS (29.92in. 70°F)	CONVERSION FACTOR	METRIC UNITS (760mm 20°C)
Volume of sample at standard conditions, dry basis $V_{mstd} = 17.71 \frac{°R}{in.Hg} \left[\frac{V_m P_{bar}}{T_m}\right]$	= .291 cu.ft.	x 0.02821	M^3
Concentration of sulfur dioxide at standard conditions, dry basis $C_{SO_2} = \left[7.05\ 10^{-5} \frac{lb.l}{g\text{-}ml}\right] \frac{[V_t - V_{tb}]\, N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 18.400 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur dioxide = $C_{SO_2} \cdot Q_s$	= 345.6 lb/hr.	x 0.4536	kg/hr
	= 1111.8 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals
Concentration of sulfur trioxide at standard conditions, dry basis $C_{SO_3} = \left[5.64\ 10^{-5} \frac{lb.l.}{g.ml.}\right] \frac{[V_t - V_{tb}]\, N \left[\frac{V_{soln}}{V_a}\right]}{V_{mstd}}$	= 1.520 10^{-5} lb/scf	x 16.08 x 10^6	mg/M^3
Emission rate sulfur trio ide = $C_{SO_3} \cdot Q_s$	= 28.5 lb/hr	x 0.4536	kg/hr
	= 73.5 ppm lb/10^6BTU	x 1.8	kg/10^6 kg-cals

Sample taken at: 11⁰⁵

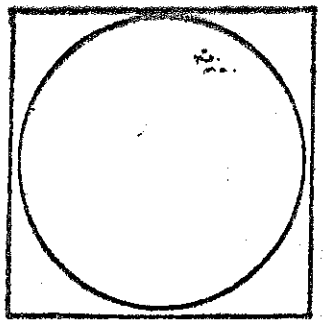
Sampling time: 5 Mins.

SO_2: µg

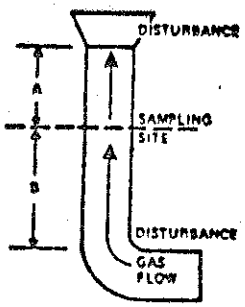
SO_3: µg

PARTICULATE FIELD DATA

1 MATIC OF STACK



CROSS SECTION



PLANT _____

DATE _____

LOCATION SOx

OPERATOR _____

STACK NO. 3/29/77

RUN NO. inlet

SAMPLE BOX NO. 3.

METER BOX NO. _____

AMBIENT TEMPERATURE _____

BAROMETRIC PRESSURE _____

ASSUMED MOISTURE, % _____

PROBE LENGTH, in. _____

NOZZLE DIAMETER, in. _____

STACK DIAMETER, in. _____

PROBE HEATER SETTING _____

HEATER BOX SETTING _____

METER $\Delta H_@$ _____

C FACTOR _____

PROCESS WEIGHT RATE _____

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WAS
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft^3	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCITY fps
Inlet.	1105.	12."						207.076	73					
								207.396						
outlet. 2		1 170						8.222	62					
		175						8.37	"					
		180						8.52	"					
		185						8.67	"					
		190						8.82	"					
		155						8.972	"					
		2.20						9.250	"					
		2.25						9.400	"					
		70						9.550	"					
		75						9.700	"					
		40						9.850	"					
TOTAL		41.						10.000	"					
AVERAGE														

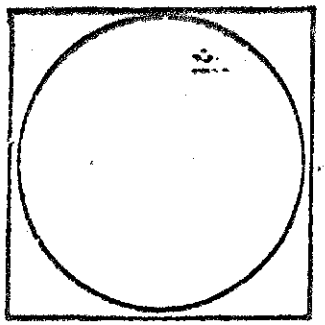
VOLUME OF LIQUID WATER COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g
FINAL					
INITIAL					
LIQUID COLLECTED					
TOTAL VOLUME COLLECTED					

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

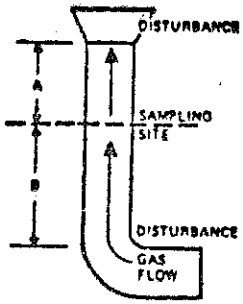
COMMENTS:

PARTICULATE FIELD DATA

SCHEMATIC OF STACK



CROSS SECTION



80 x

PLANT [illegible]

DATE 3/29/77

LOCATION

OPERATOR [illegible]

STACK NO. #3

RUN NO. 1

SAMPLE BOX NO. Outlet

METER BOX NO.

AMBIENT TEMPERATURE

BAROMETRIC PRESSURE 29.3

ASSUMED MOISTURE, %

PROBE LENGTH, in.

NOZZLE DIAMETER, in.

STACK DIAMETER, in.

PROBE HEATER SETTING

HEATER BOX SETTING

METER $\Delta H_@$

C FACTOR

PROCESS WEIGHT RATE

WEIGHT OF PARTICULATE COLLECTED, mg		
SAMPLE	FILTER	PROBE WA
FINAL WEIGHT		
TARE WEIGHT		
WEIGHT GAIN		
	TOTAL	

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STATIC PRESSURE (in. H_2O)	STACK TEMPERATURE (T_s), °F	VELOCITY HEAD (ΔP_s)	($\sqrt{\Delta P_s}$)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH) in., H_2O ACTUAL	DESIRED	GAS SAMPLE VOLUME (V_m), ft³	GAS SAMPLE TEMPERATURE AT DRY GAS METER INLET ($T_{m_{IN}}$), °F	OUTLET ($T_{m_{OUT}}$), °F	SAMPLE BOX TEMPERATURE °F	TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER °F	PUMP VACUUM in. Hg gauge	VELOCIT fps
	905 A	-.4	590					486.050		58				41
	910		"					86.200		58				40
	915		"					86.350		58				
	920		"					86.500		58				
	925		"					650		"				
	930		"					800		"				
	10-00							487.200						
								.350						
								.500						
								.650						
								.800						
								.950						
TOTAL														
AVER														

[illegible] 9.6 9.6. inlet 11.0

COMMENTS:

LIQUID COLLECTED	IMPINGER VOLUME ml 1	2	3	4	SILICA GEL WEIGHT, g

ORSAT MEASUREMENT	TIME	CO_2	O_2	CO	N_2
1					
2					
3					
4					

APPENDIX J: MOLECULAR WEIGHT AND PITOT CORRECTION FACTOR CALCULATIONS

PARTICLE DATA LABORATORIES, LTD.

Boiler #3 3/29/77

	Run #1	Run #2
CO_2 %	10.4	9.9
O_2%	8.8	9.4
N_2%	80.0	80.7
H_2O%	11.6	14.7
M_d	30.02	29.96
M_s	28.62	28.20
Pitot factor	.83	.83
$V = x\sqrt{\Delta PT_s}$	2.45	2.47

PARTICLE DATA LABORATORIES, LTD.

Boiler #2 3/30/77

	Run #1	Run #2	Run #3
CO_2%	9.1	9.5	8.1
O_2%	9.9	9.5	11.0
N_2%	81.0	81.0	80.9
H_2O%	14.5	14.1	14.2
M_d	29.85	29.90	29.74
M_s	28.13	28.22	28.07
Pitot factor	.83	.83	.83
$V = x\sqrt{\Delta PT_s}$	2.46	2.45	2.46

APPENDIX K: CALCULATION OF F FACTOR

PARTICLE DATA LABORATORIES, LTD.

Calculations for "F" Factor

$$F = \left(\frac{10^6(3.64\%H+1.53\%C+0.57\%S+0.14\%N-0.46\%O)}{GCV}\right)$$

GCV = BTU/lb. coal

$$E = CF\left(\frac{20.9}{20.9-\%O_2}\right)$$

C = particle concentration in stack gas, lbs/scf db

E = particulate emission rate, lbs/10^6 BTU

		F (d scf/10^6 BTU)	E (lbs/10^6 BTU)
Boiler 2	test 1	11139	.135
	test 2	11074	.231
	test 3	11139	.206

PARTICLE DATA LABORATORIES, LTD.

Calculations for "F" Factor

$$F = \left(\frac{10^6(3.64\%H+1.53\%C+0.57\%S+0.14\%N-0.46\%O)}{GCV}\right)$$

GCV = BTU/lb. coal

$$E = CF\left(\frac{20.9}{20.9-\%O_2}\right)$$

C = particle concentration in stack gas, lbs/scf db

E = particulate emission rate, lbs/10^6 BTU

		F (d scf/10^6 BTU)	E (lbs/10^6 BTU)
Boiler 3	test 1	10898	.279
	test 2	10728	.202
	test 3		

APPENDIX L: SCRUBBER CARRY-OVER DATA AND CALCULATIONS

PARTICLE DATA LABORATORIES, LTD.

Sodium Analysis of Collected Samples

Date	Boiler #	Run #	Probe wash mg Na net	filter mg Na net	total sodium mg
3/29	3	1	3.2	10.2	13.4
3/30	2	1	0.20	5.2	5.4

PARTICLE DATA LABORATORIES, LTD.

Analysis of Scrubber Liquors

Date	Boiler #	Run #	Suspended solids ppm	Total dissolved solids ppm	Sodium content ppm
3/29	3	1	616	92448	18000
		2	1356	108810	18000
3/30	2	1	1474	109676	19000
		2	1192	110234	18000
		3	1168	111526	18000

PARTICLE DATA LABORATORIES, LTD.

Calculation of Carry-over

	Date/Run #/Boiler #	
	3/29 Run #1 Boiler #3	3/30 Run #1 Boiler #2
Conc. Na in scrubber ppm	18000	19000
Na in sample mg	13.4	5.4
Vol. of liquid carry-over from Na content ml	0.744	0.284
Total solids conc. in scrubber ppm	93064	111150
Mass solid in sample from carry-over mg	69.24	31.57
Total sample collected mg	365.1	193.2
Carry-over solids as % of total collected	19.0	16.3
Non-carry-over solids collected mg	295.9	161.6
Corrected emission rates lbs/hr	22.53	9.13
lbs/MBTU from F factor	.226	.113
lbs/MBTU from heat input data	.165	.094

Fly ash Na_2O ≈ .76 %. of ash. @ Morton & Aurora.
.74×.76 = .56 % of ash is Na. @ Morton.

APPENDIX M: HEAT INPUT DATA FROM THERMAL ANALYSIS

SUMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

TEST NO. 2-1 BOILER NO. 2 DATE

OWNER OF PLANT CATERPILLAR LOCATION

TEST CONDUCTED BY PARR DATA LABS. LTD. OBJECTIVE OF TEST DURATION

BOILER MAKE & TYPE RATED CAPACITY 80,000 #/H

STOKER TYPE & SIZE

PULVERIZER, TYPE & SIZE BURNER, TYPE & SIZE

FUEL USED MINE COUNTY STATE SIZE AS FIRED

	PRESSURES & TEMPERATURES		
1	STEAM PRESSURE IN BOILER DRUM	psia	* 165
2	STEAM PRESSURE AT S. H. OUTLET	psia	—
3	STEAM PRESSURE AT R. H. INLET	psia	—
4	STEAM PRESSURE AT R. H. OUTLET	psia	—
5	STEAM TEMPERATURE AT S. H. OUTLET	F	—
6	STEAM TEMPERATURE AT R H INLET	F	—
7	STEAM TEMPERATURE AT R.H. OUTLET	F	—
8	WATER TEMP. ENTERING (ECON.) (~~BOILER~~)	F	260
9	STEAM QUALITY % MOISTURE OR P.P.M.		—
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	* 70
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	* 70
12	TEMPERATURE OF FUEL	F	—
13	GAS TEMP. LEAVING (~~Boiler~~) (Econ.) (~~Air Htr.~~)	F	475
14	GAS TEMP. ENTERING AH (if conditions to be corrected to guarantee)	F	—

	UNIT QUANTITIES		
15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	—
16	ENTHALPY OF (SATURATED) (~~SUPERHEATED~~) STM.	Btu/lb	* 1195.6
17	ENTHALPY OF SAT. FEED TO (~~BOILER~~) (ECON.)	Btu/lb	228.5
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	—
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	—
20	HEAT ABS. LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	967.1
21	HEAT ABS./LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	—
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	* .123
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	* 2526
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.6238
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	17.19

	HOURLY QUANTITIES		
26	ACTUAL WATER EVAPORATED	lb/hr	72,500
27	REHEAT STEAM FLOW	lb/hr	—
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	—
29	TOTAL HEAT INPUT (Item 28 × Item 41) / 1000	kB/hr	CALC.
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	—
31	TOTAL HEAT OUTPUT (Item 26×Item 20)+(Item 27×Item 21)+Item 30 / 1000	kB/hr	70,115

	FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET		
32	CO_2	% VOL	9.1
33	O_2	% VOL	9.9
34	CO	% VOL	—
35	N_2 (BY DIFFERENCE)	% VOL	81.0
36	EXCESS AIR	%	83.23

	FUEL DATA						
	COAL AS FIRED PROX. ANALYSIS	% wt		OIL			
37	MOISTURE	16.13	51	FLASH POINT F*			
38	VOL MATTER	—	52	Sp. Gravity Deg. API			
39	FIXED CARBON	—	53	VISCOSITY AT SSU* BURNER / SSF			
40	ASH	9.67	44	TOTAL HYDROGEN % wt			
	TOTAL		41	Btu per lb			
41	Btu per lb AS FIRED	10,418					
42	ASH SOFT TEMP.* ASTM METHOD			GAS	% VOL		
	COAL OR ~~OIL~~ AS FIRED ULTIMATE ANALYSIS	(SEE SHT #1)	54	CO			
43	CARBON	65.52	55	CH_4 METHANE			
44	HYDROGEN	4.15	56	C_2H_2 ACETYLENE			
45	OXYGEN	.69	57	C_2H_4 ETHYLENE			
46	NITROGEN	1.51	58	C_2H_6 ETHANE			
47	SULPHUR	1.40	59	H_2S			
40	ASH	9.67	60	CO_2			
37	MOISTURE	16.13	61	H_2 HYDROGEN			
	TOTAL			TOTAL			
	COAL PULVERIZATION			TOTAL HYDROGEN % wt			
48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.			
49	FINENESS % THRU 50 M*		63	Btu PER CU FT			
50	FINENESS % THRU 200 M*		41	Btu PER LB			
64	INPUT-OUTPUT EFFICIENCY OF UNIT %			ITEM 31 × 100 / ITEM 29	NOT AVAIL.		

	HEAT LOSS EFFICIENCY	Btu/lb A.F. FUEL	% of A.F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1670.9	16.04
66	HEAT LOSS DUE TO MOISTURE IN FUEL	199.8	1.92
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	462.6	4.44
68	HEAT LOSS DUE TO COMBUST. IN REFUSE*	310.7	2.98
69	HEAT LOSS DUE TO RADIATION	73.0	.7
70	UNMEASURED LOSSES *	156.3	1.50
71	TOTAL		22.58
72	EFFICIENCY = (100 – Item 71)		72.42

HEAT INPUT = HEAT OUTPUT ÷ EFF.

= 70,115 ÷ .7242 = 96.82 × 10^6 Btu/HR.

* NOTE: SAME VALUE FOR ALL TESTS

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

HEAT INPUT @ 82% EFF. = 70,115 ÷ .82 = 85.51

CALCULATION SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

Revised September, 1965

OWNER OF PLANT *CATERPILLAR* TEST NO. *2-1* BOILER NO. *2* DATE

30	HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR × [ITEM 15 − ITEM 17 / 1000] = ... kB/hr
24	*If impractical to weigh refuse, this item can be estimated as follows* DRY REFUSE PER LB OF AS FIRED FUEL = % ASH IN AS FIRED COAL / (100 − % COMB. IN REFUSE SAMPLE) CARBON BURNED PER LB AS FIRED FUEL = ITEM 43 (65.52) / 100 − [ITEM 22 (.123) × ITEM 23 (2.526) / 14,500 (.0214)] = .6238 NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.
25	DRY GAS PER LB AS FIRED FUEL BURNED = $\frac{11CO_2 + 8O_2 + 7(N_2 + CO)}{3(CO_2 + CO)}$ × (LB CARBON BURNED PER LB AS FIRED FUEL + $\frac{3}{8}$ S) = (11 × ITEM 32 (9.1) + 8 × ITEM 33 (9.9) + 7 (ITEM 35 (81.0) + ITEM 34 (—)) / (3 × (ITEM 32 (9.1) + ITEM 34 (—)))) × [ITEM 24 (.6238) + ITEM 47 (1.40) / 267] = 17.19 (.6290)
36	EXCESS AIR† = 100 × $\frac{O_2 - \frac{CO}{2}}{.2682N_2 - (O_2 - \frac{CO}{2})}$ = 100 × $\frac{\text{ITEM 33} - \frac{\text{ITEM 34}}{2}}{.2682\,(\text{ITEM 35}) - (\text{ITEM 33} - \frac{\text{ITEM 34}}{2})}$ = 83.73

	HEAT LOSS EFFICIENCY	Btu/lb AS FIRED FUEL	LOSS/HHV × 100 =	LOSS %
65	HEAT LOSS DUE TO DRY GAS = LB DRY GAS PER LB AS FIRED FUEL × C_p × (t_{lvg} − t_{air}) Unit = ITEM 25 (17.19) × 0.24 (ITEM 13) − (ITEM 11) (.475 .70) = ...	16.70.9	65/41 × 100 =	16.04
66	HEAT LOSS DUE TO MOISTURE IN FUEL = LB H_2O PER LB AS FIRED FUEL × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = ITEM 37 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ... (1276.6, 38)	199.8	66/41 × 100 =	1.92
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2 = $9H_2$ × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = 9 × ITEM 44 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ... (1276.6, 38)	462.6	67/41 × 100 =	4.44
68	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = ITEM 22 (.123) × ITEM 23 (2.526) = 310.7 = SAME FOR ALL TESTS	310.7	68/41 × 100 =	2.98
69	HEAT LOSS DUE TO RADIATION* = TOTAL BTU RADIATION LOSS PER HR / (LB AS FIRED FUEL − ITEM 28) ..... = FROM ABMA RAD. LOSS CHART	73.0	69/41 × 100 =	.7
70	UNMEASURED LOSSES ** NORMALLY 1.5% SAME FOR ALL TESTS	156.3	70/41 × 100 =	1.50
71	TOTAL	2873.3	.....	27.58
72	EFFICIENCY = (100 − ITEM 71)	.....	.....	72.42

† For rigorous determination of excess air see Appendix 9.2 – PTC 4.1-1964

* If losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may by provided for by assigning a mutually agreed upon value for Item 70.

Maurice L. Kelsey + Assoc., Inc.

4-21-77

Caterpillar

Heat Input Calculations For PDL

As Received Ultimate Coal Analysis Calculations

As Rec'd Analysis = Dry Basis X (100 - % Moist)

Test No. 2-1: 100 - 16.13 Moist = 83.87%

.8387 X %C = .8387 X 78.12 = 65.52

%H = " X 4.95 = 4.15

%N = " X 1.80 = 1.51

%S = " X 1.67 = 1.40

%O = " X .82 = .69

%Ash = " X 11.53 = 9.67

Btu = " X 12,422 = 10,418

Test No. 2-2: 100 - 16.23 = 83.77

C = 65.64

H = 4.10

N = 1.48

S = 2.35

O = .67

A = 10.11

Btu = 10,531

Test No. 2-3 = 100 - 16.13 = 83.87%

C = 65.60

H = 4.13

N = 1.49

S = 1.66

O = .69

A = 10.06

Btu = 10,434

Test No. 3-1 = 100 - 17.22 = 82.78

C = 64.17

H = 4.35

N = 1.49

S = 2.19

O = .62

A = 9.95 Btu = 10,572

Test No. 3-2 = 100 - 16.15 = 83.85

C = 63.81

H = 4.27

N = 1.58

S = 2.47

O = .65

A = 11.06 Btu = 10,672

Average Btu all tests = 10,525

Average Ash for all tests = 10.17%

Caterpillar - PDL

Calculations of Items 22 & 23 on ASME Short Form

Average Ash Content of Coal = 10.17 %

Average Coal Btu = 10,525 Btu/lb or 21.05 X10^6 Btu/ton

Assumptions based on typical spreader stoker without flyash reinjection:

70% of ash to ashpit (Carbon to ash pit = 5%)

30% " " " out boiler in flue gas

Total ash + carbon emission out of boiler last pass (to collector) = 4.6 lbs/10^6 Btu input.

Per ton coal burned: Total Ash = .1017 X 2000 lbs = 203.4 lbs

Ash to ash pit/ton = .7 X 203.4 = 142.4 lbs

Ash out stk. = .3 X 203.4 = 61.0 lbs

203.4 lbs

Total ash plus carbon out of stk./ton burned = 4.6 X 21.05 = 96.8 lbs

Carbon leaving boiler last pass = 96.8 − 61 = 35.8 lbs

Carbon in ash pit = .5 X 142.4 = 7.1 lbs

Total Carbon = 42.9 lbs/ton coal burned.

Total ash + carbon = 203.4 + 42.9 = 246.3 lbs

Item 22 = Dry refuse/lb. fuel = 246.3 lbs ÷ 2000 lbs/ton = *.123

Item 23 = Btu/lb. in refuse (42.9 lbs carbon X 14,500) ÷ 246.3 = *2526 Btu/lb.

*Note: Use these values for calc. of all 5 tests.

Caterpillar - PDL

Heat Input Calculations

See Test No. 2-1 on ASME FORM FOR COMPLETE CALC.

TEST No. →	2-2	2-3	3-1	3-2
DATA:				
(1) STM. FLOW - LBS/HR	71,000	70,000	106,000	82,000
(2) STM. ENTHALPY - BTU/LB	1195.6	1195.6	1195.6	1195.6
(3) Feedwater - Inc. Econ. - Enthalpy	228.5	228.5	228.5	233.5
(4) Heat Output - BTU X10⁶/HR - [1x(2-3)]	67.66	67.70	102.51	78.89
(5) Item 24 = Carb. burned/lb. fuel	.6350	.6346	.6203	.6167
(6) Item 25 = Dry gas/lb. fuel	16.89	19.60	15.12	15.79
(7) Item 36 = Excess AIR - %	77.7	102.8	68.4	76.8
(8) % Loss - Dry gas - % (Item 65)	15.39	21.19	13.28	13.31
(9) " " - Moist. in fuel - % (Item 66)	1.91	1.91	2.00	1.85
(10) " " H_2 COMB. - % (Item 67)	4.33	4.40	4.56	4.41
(11) " " Comb. in refuse - % (Item 68)	2.98	2.98	2.98	2.98
(12) " " Rad. loss - % (Item 69)	.70	.70	.53	.71
(13) " " Unmeasured - % (Item 70)	1.50	1.50	1.50	1.50
(14) Total losses - % (Item 71)	26.81	32.68	24.85	24.86
(15) Heat loss Eff. - % (Item 72)	73.19	67.32	75.15	75.14
Calculated:				
Heat Input - Btu X10⁶/hr. ((4) ÷ (15))	93.81	100.56	136.41	104.99
Normal Heat Input @ 82% Bl. eff.				
(4) ÷ .82 =	83.73	82.56	125.01	96.21

APPENDIX N: SAMPLE ASH CONTENT DATA

Combustible Content of Samples

Boiler #	Bottom ash loss on ignition %	Method 5 collected sample % probe wash	filter
3	26.45	27.8	7.2
2	2.00	44.2	12.0

Calculation of Combustible Fraction of Emission Particles

Boiler	Run	Sample weights probe wash mg	Sample weights filter catch mg	Total sample weight mg	Wt. combustible probe wash mg	Wt. combustible filter catch mg	Total sample combust-ible	% combust-ible
3	1	173.1	192.0	365.1	48.12	13.82	61.94	17.0
	2	52.7	188.6	241.3	14.65	13.58	28.23	11.7
2	1	57.7	135.5	193.2	25.50	16.26	41.76	21.6
	2	56.7	174.8	231.5	25.06	20.98	46.04	19.9
	3	51.4	138.7	190.1	22.72	16.64	39.36	20.7

PARTICLE DATA LABORATORIES, LTD.

APPENDIX O: NOMENCLATURE

A	Cross sectional area of stack, $ft.^2$
An	Cross-sectional area of nozzle, sq.ft.
B_{wm}	Approximate volumetric proportion of water vapor in the gas stream leaving the impingers, 0.025
B_{wo}	Proportion by volume of water vapor in the gas system, dimensionless
C	Concentration of NO_x as NO_2 (dry basis), lb/s.c.f.
CO	Percent carbon monoxide by volume, dry basis
C_p	Pitot tube coefficient dimensionless
$C_{p\ std}$	Pitot tube coefficient of standard type pitot tube (if unknown, use 0.99)
$C_{p\ test}$	Pitot tube coefficient of type S pitot tube
C_s	Concentration of particulate matter in stack gas, lb./s.c.f., dry basis
C_{SO_2}	Concentration of sulfur dioxide at standard conditions, dry basis, lb./cu.ft.
EA	Percent excess air
ΔH	Average pressure drop across the orifice, inches H_2O
H_2O	Density of water, lg./ml.
I	Percent of isokinetic sampling
m	Mass of NO_2 in gas sample, mg.
M_d	Dry molecular weight, lb./lb-mole
M_{H_2O}	Molecular weight of water, 18 lb./lb-mole
M_n	Total amount of particulate matter collected, mg.
M_s	Molecular weight of stack gas (wet basis) lb./lb-mole
N	Normality of barium perchlorate titrant, g.-eq/l
N_2	Percent nitrogen by volume, dry basis
O_2	Percent oxygen by volume, dry basis
$(\sqrt{\Delta p})$avg.	Average velocity head of stack gas, inches H_2O
P_{bar}	Barometric pressure at the orifice meter, inches Hg.
P_f	Final absolute pressure of flask, inches Hg.

ρ_{H_2O}	Density of water, 1g./ml.
P_i	Initial absolute pressure of flask, inches Hg.
P_m	Barometric pressure at the dry gas meter, inches Hg.
P_s	Absolute stack gas pressure, inches Hg.
P_{std}	Absolute pressure at standard conditions, 29.92 in.Hg.
Δp_{std}	Velocity head measured by standard type pitot tube
Δp_{test}	Velocity head measured by type S pitot tube
Q_s	Volumetric flow rate, dry basis, standard conditions, cu.ft./hr.
R	Ideal gas constant, 21.83 inches Hg-cu.ft./lb. mole-^oR
T_f	Final absolute temperature of flask, ^oR
T_i	Initial absolute temperature of flask, ^oR
T_m	Average dry gas meter temperature, ^oR
$(Ts)_{avg.}$	Average absolute stack gas temperature, ^oR
T_{std}	Absolute temperature at standard conditions, 530^oR
V_a	Volume of sample aliquot titrated, ml.
V_f	Final volume of impinger contents, ml.
V_i	Initial volume of impinger contents, ml.
V_{lc}	Total volume of liquid collected in impingers & silica gel.ml.
V_m	Dry gas volume measured by meter, cu.ft.
V_{mc}	Dry gas volume through meter (standard conditions), cu.ft.
$V_{m\ std.}$	Volume of gas sample through the dry gas meter (standard conditions) cu.ft.
V_s	Stack gas velocity, ft. per second (f.p.s.)
$(V_s)_{avg.}$	Stack gas velocity, feet per second (f.p.s.)
V_{sc}	Sample volume at standard conditions (dry basis) ml.
V_{soln}	Total solution volume of sulfur dioxide, 50 ml.
V_t	Volume of barium perchlorate titrant used for the sample, ml.
V_{tb}	Volume of barium perchlorate titrant used for the blank, ml.
V_{wc}	Volume of water vapor collected (standard conditions) cu.ft.
$V_{w}std$	Volume of water in the gas sample (standard conditions) cu.ft.