Good 0

(M 13)

REPORT NO. Y-8479-6

LIGNITE
COMBUSTION
AP-42 Section 1.7
Reference Number
8

4/93

Note: This material is related to a section in *AP42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the file number, the AP42 chapter and then the section. The file name "rel01_c01s02.pdf" would mean the file relates to AP42 chapter 1 section 2. The document may be out of date and related to a previous version of the section. The document has been saved for archival and historical purposes. The primary source should always be checked. If current related information is available, it will be posted on the AP42 webpage with the current version of the section.

NITROGEN OXIDE EMISSIONS

AT

THE BASIN ELECTRIC POWER COOPERATIVE
LELAND OLDS STATION
STANTON, NORTH DAKOTA

216 MW
Pulverized-coal,
Horizontally Opposed fired

PREPARED FOR:

THE U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

Per Tim Osag, IS&B, at normal operation this boiler running at higher than necessary EA, hence 13.5 is probably upper limit

NOx:
13.5 lb NO2/ton (avg., full load)
9.0 lb NO2/ton (avg., full load, limited air)

SUBMITTED BY:

YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE
STAMFORD, CONNECTICUT 06906

→ 33% reduction

CO:
26 lb/ton (avg)
(0-55 lb/ton)

EPA Contract No. 68-02-1401
Task No. 6

December 2, 1974

I. INTRODUCTION

York Research Corporation, an independent consultant in Environmental Engineering, was retained by the United States Environmental Protection Agency, under Contract No. 68-02-1401, Task 6, to conduct a series of tests at the Basin Electric Power Cooperative, Leland Olds Station, Stanton, North Dakota.

The process tested was a Babcock and Wilcox lignite fired boiler, equipped with a cyclone dust collector.

Sampling of the exhaust gases was conducted from sampling ports located on the stack to determine nitrogen oxide concentrations, molecular weight evaluation, moisture determination, velocity, and flow.

The test team was comprised of one Project Director and four test engineers from York Research Corporation.

The primary purpose of the test program was to determine Nitrogen oxide emission levels. The results of the testing will enable the EPA to set up NOx emission regulations governing lignite fired boilers.

The secondary purpose of the program was a comparison in results between the present EPA Method 7 Nitrogen Oxide sampling and the Thermo Electron Corporation "chemiluminescent NOx Analyzer". NOx sampling was conducted at various boiler operating conditions, as well as a test to establish baseline conditions.

DRAFT COPY

DISCUSSION OF RESULTS

In determination of the NOx emissions the following results were obtained:

The NOx emission could be reduced by 31.8% by a reduction in excess air (at the test sampling point) from 29.2% to 18.2%, or a reduction in excess air at the furnace outlet from 25.25% to 15.0%. The reduction in excess air resulted in a 10.7% reduction in gas flow. Although these reductions in NOx were obtained by changing boiler operating conditions, no long runs were made under these conditions. Therefore York Research can not ascertain if the boiler can operate under these conditions permanently and maintain the same level of reduction.

The Teco NOx analyzer averaged 40-50 ppm higher than the EPA-7 test methods. This data covers only part of the test program since initial operation of the analyzer was poor, caused by a plugged capillary in the sampling line. This problem occurred because of inadequate filtration in the gas conditioning system, since extremely fine particle sizes were not expected from lignite firing. This was solved by the addition of a 0.3 micron fiberglass filter after our Conditioning system.

TABLE I

SUMMARY OF AVERAGED TEST RESULTS - LELAND OLDS

Date	Phase	Gas Flow (SCFMD)	Concentration (ppm) EPA 7	Concentration (ppm) Teco	lb/hr EPA-7	lb/hr Teco	Emission Rate (lb/MMBTU) EPA-7	Emission Rate (lb/MMBTU) Teco	Gms/10^6 cal EPA-7	Gms/10^6 cal Teco
10/1	Baseline	533,982	568	-	2159	-	.963	-	1.73	-
			(13)				.924	-	1.66	-
10/2	Baseline	520,126	507	-	1900	-				
			(4)							
10/2	Low Air	465,868	403	-	1334	-	.660	-	1.19	-
			(9)							
10/3	Baseline	523,640	556	-	2083	-	.972	-	1.75	-
			(5)							
10/3	Low Air	477,192	427	479	1479	1659	.690	.773	1.24	1.39
			(5)	(5)						
10/3	Baseline	534,387	631	672	2374	2529	1.10	1.17	1.98	2.10
			(9)	(9)						

Note: Number of samples used to determine average (avg)

											lb NO_2/ton
Average Baseline	528,034	566	*	2129	*	.990	*	1.78	*	13.5
Average low air	471,530	415	*	1407	*	.675	*	1.22	*	9.0

* Insufficient data

$2129 \frac{lb\ NO_x}{hr} \times \frac{1\ hr}{311{,}000\ lbs} \times \frac{2000\ lbs}{ton} = 13.5$

$\frac{1407 \times 2000}{311{,}000} = 9.0$

TABLE IA
AVERAGE EXCESS AIR
LELAND OLDS

		ORSAT DATA				
		CO_2	O_2	CO	N_2	EA*
Baseline	10/1	14.4	4.9	.25	80.45	29.7
	10/2	15.3	4.4	.33	80.63	25.6
Low Air	10/2	16.12	3.1	.38	80.4	16.4
Baseline	10/3	14.7	5.0	-	80.3	30.9
Low Air	10/3	15.86	3.6	.2	80.34	20.1
Baseline	10/3	14.8	4.96	.17	80.07	30.5
Avg. Baseline		14.8	4.81	.18	80.21	29.2
Avg. Low Air		15.99	3.35	.3	80.36	18.2

*Excess air calculations based on EPA equation

Baseline CO avg. = 0.18% = 1800 ppm

$\frac{lb\ CO}{hr}$ = 1800 ppm × 4.3×10^{-6} × 530,000 SCFM = 4102 $\frac{lb\ CO}{hr}$

4102 $\frac{lb\ CO}{hr}$ × $\frac{1\ hr}{316{,}000\ lb\ coal}$ × $\frac{2000\ lb}{ton}$ = 20 $\frac{lb}{ton}$

(0-55 lb/ton)

TABLE II
TEST RESULTS

Date	Time	Concentration (ppm) EPA-7	Concentration (ppm) Teco	lbs/hr EPA-7	lbs/hr Teco	lbs/MMBTU EPA-7	lbs/MMBTU Teco	Gms/10^6 cal EPA-7	Gms/10^6 cal Teco
10/1	Base Line Phase								
	1030	529	*	1899		.847		1.52	
	1100	544		1954		.841		1.56	
	1130	516		1982		.884		1.59	
	1200	518		1993		.889		1.60	
	1230	541		2081		.928		1.67	
	1300	568		2185		.975		1.75	
	1330	585		2197		.980		1.76	
	1400	606		2277		1.01		1.82	
	1430	620		2406		.939		1.69	
	1500	594		2306		1.03		1.85	
	1530	625		2407		1.07		1.93	
	1600	557		2146		.957		1.72	
	1630	576		2239		.999		1.79	
10/2	0830	529		1998		.971		1.74	
	0900	506		1914		.930		1.67	
	0930	475		1767		.859		1.55	
	1000	516		1919		.933		1.68	
	1030	Void		-		-		-	
	Low Air Phase								
	1400	425		1402		.690		1.24	
	1430	396		1306		.643		1.15	
	1500	444		1410		.694		1.25	
	1530	383		1215		.598		1.08	
	1600	377		1209		.596		1.07	
	1630	378		1213		.603		1.09	
	1700	391		1351		.671		1.20	
	1730	411		1423		.707		1.27	
	1800	426		1478		.735		1.32	
	Baseline Phase								
10/3	0830	531		2004		.935		1.68	
	0900	505		1904		.888		1.60	
	0930	535		2021		.944		1.69	
	1000	617		2338		1.09		1.96	
	1030	590	540	2159	1976	1.00	.922	1.81	1.66
	Low Air Phase								
	1230	453	510	1657	1865	.773	.870	1.39	1.56
	1300	420	420	1441	1441	.672	.672	1.21	1.21
	1330	425	440	1456	1507	.679	.703	1.22	1.26
	1400	457	505	1548	1710	.722	.798	1.30	1.44
	1430	381	520	1294	1766	.609	.824	1.08	1.48

TABLE II
TEST RESULTS

Date	Time	Concentration (ppm) EPA-7	lbs/hr Teco	lbs/hr EPA-7	lbs/hr Teco	lbs/MMBTU EPA-7	lbs/MMBTU Teco	Gms/10^6 cal EPA-7	Gms/10^6 cal Teco
	Base Line Phase								
	1500	620	630	2104	2137	.972	.987	1.75	1.78
	1530	623	660	2371	2511	1.10	1.16	1.97	2.09
	1600	636	660	2418	2509	1.11	1.15	2.01	2.08
	1630	623	700	2377	2670	1.09	1.23	1.98	2.22
	1700	592	680	2260	2595	1.04	1.20	1.88	2.16
	1730	626	680	2394	2600	1.10	1.20	1.99	2.16
	1800	670	680	2532	2569	1.17	1.18	2.10	2.14
	1830	657	680	2483	2569	1.15	1.18	2.06	2.14
	1900	634	680	2429	2605	1.12	1.20	2.02	2.16

* No readings due to plugged capillary

Note: Maxima and Minima values underlined for each phase

TABLE III

LELAND OLDS - NORTH DAKOTA

VOLUMETRIC FLOW

Date & Phase	Time	Plant Load (MW)	Duct Temp. (°F)	Orsat Data CO_2	O_2	CO	Moisture (%v/v)	Gas Flow Rates Actual (ACFMW)	Standard Dry (SCFMD)
10/1	1030	205	373	13.6	4.9	.4	15.0	981,215	503,699
	1130		378	14.5	5.0	.2	15.0	1,055,935	539,201
Baseline	1230		382	14.6	4.7	.4	15.0	1,061,956	539,509
	1330		380	14.6	4.8	.2	15.0	1,034,586	526,670
	1430		377	14.3	4.9	.2	13.2	1,043,344	544,128
	1530		383	14.6	5.0	.2	13.2	1,043,071	539,734
	1630		384	14.6	5.0	.2	13.2	1,055,114	544,934
10/2	0830	203	380	15.7	4.5	.6	13.3	1,034,039	529,925
	0930		385	15.3	4.3	.3	13.3	1,023,638	521,118
Baseline	1030		380	15.3	4.4	.1	13.3	995,994	509,335
10/2	1400	201	387	15.8	3.2	.6	20.2	994,078	462,869
	1500		392	16.2	3.2	.0	20.2	962,329	444,978
Low Air	1600	199	392	16.0	3.2	.4	20.2	974,098	450,096
	1700		391	16.4	2.8	.6	16.0	997,637	485,107
	1800		388	16.2	3.1	.3	16.0	996,542	486,289
10/3	0830	198	383	15.0	4.7	.1	13.7	1,046,355	528,447
	0930		388	14.6	5.0	.0	13.7	1,053,198	529,147
Baseline	1030		384	14.5	5.3	.0	13.7	1,017,617	513,325
10/3	1230	198	396	15.8	3.3	.2	13.7	965,614	480,609
	1330		395	15.8	4.0	.3	15.4	972,456	475,205
Low Air	1430		394	16.0	3.4	.1	15.4	972,456	475,762
10/3	1500	200	398	14.8	5.0	.2	14.4	1,082,210	533,218
	1600		393	14.5	5.3	.0	14.4	1,081,115	535,417
Baseline	1700		400	14.9	4.9	.3	14.4	1,091,789	536,495
	1800		399	15.0	4.8	.6	14.4	1,076,736	529,523
	1845		398	14.8	4.8	.1	14.4	1,091,242	537,283

TABLE IV

SUMMARY OF PLANT OPERATING DATA

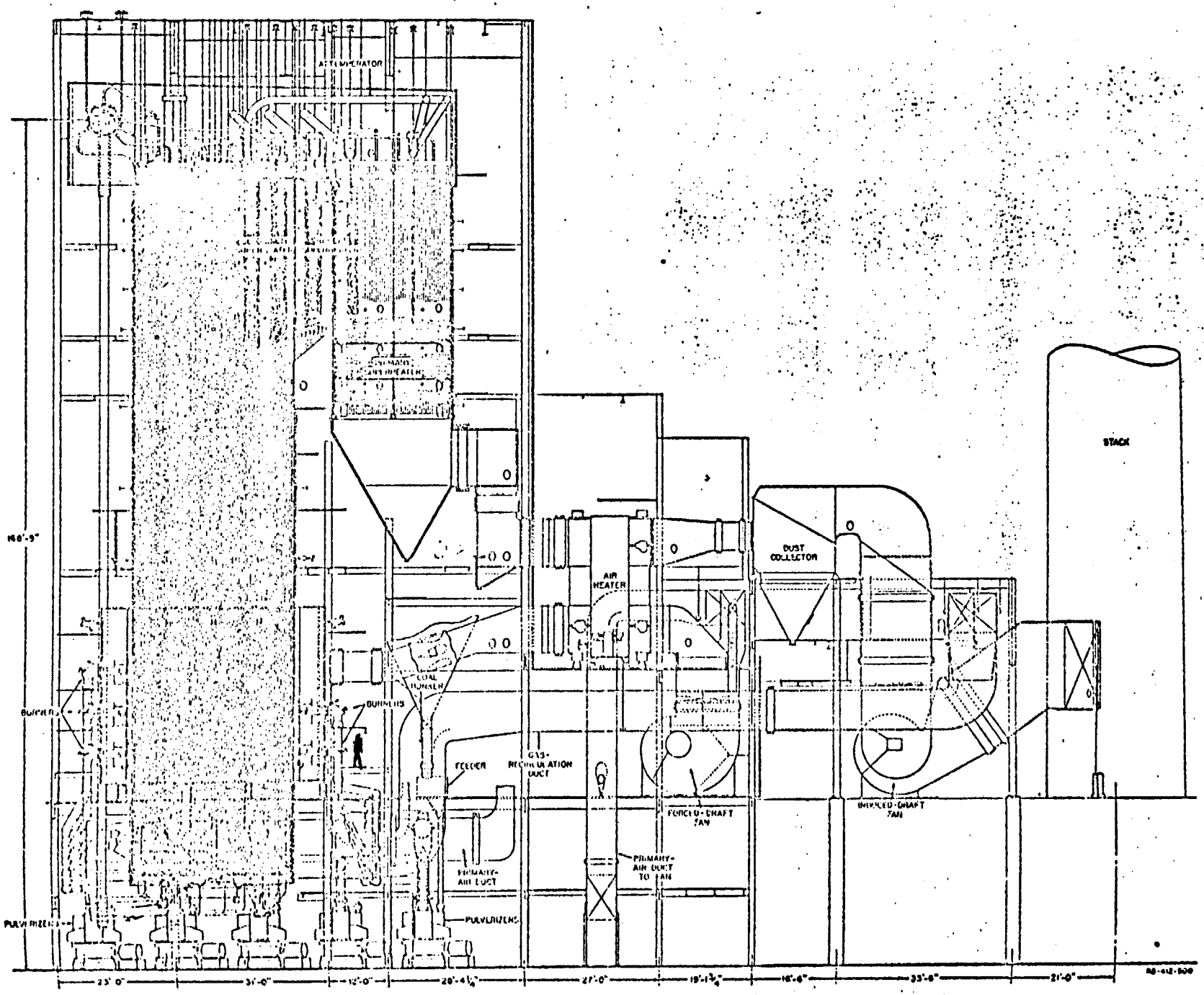
LELAND OLDS BOILER NO. 1

Date	Time	Gross MW	Coal Feed Rate (lbs/hr, as recd)	BTU/lb Coal	Gross Heat Input MMBTU/hr	% Excess O_2*	% Excess Air*	Test Phase
10/1/74	10.30-16.30	205	322,000	6960	2241	4.5	27	Base Line
10/2/74	08.30-10.30	203	318,000	6465	2056	4.4	26	Base Line
	14.00-16.00	201	314,000	6465	2030	2.9	16	Low Air
	16.00-18.00	199	311,000	6465	2011	2.5	13	Low Air
10/3/74	08.30-10.30	198	310,000	6909	2142	4.3	25	Base Line
	12.30-14.30	198	310,000	6909	2142	2.5	13	Low Air
	15.00-19.00	200	313,000	6909	2163	3.9	23	Base Line
AVG BASELINE		– 201.5 MW	316,000					
Low Air		–	312,000					

* Measured before Air Heater. Excess O_2 is measured with L&N paramagnetic analyzer.

III. PROCESS DESCRIPTION AND OPERATION

The Leland Olds Station #1 is a 216 M.W. steam electric plant. The boiler, designed by Babcock and Wilcox, burns pulverized lignite which is fired through horizontally opposed burners. The lignite is pulverized in one of ten pulverizers, each pulverizer feeding two burners. The burners are arranged in three rows of four burners each on the front wall and two rows of four burners each on the rear wall. The plant was first put into operation in 1966.



BASIN ELECTRIC POWER CO-OPERATIVE
BISMARCK, NORTH DAKOTA

(P)

Re 9
Sec 1.7
12/75

NITROGEN OXIDES EMISSION MEASUREMENTS
FROM LIGNITE-FIRED POWER PLANT

NOT FOR DISTRIBUTION

EMB Projects Report No.
75-LSG-3

Overall avg NO_x: 7.1 lb/ton

Plant Tested

Texas Utility Company, Inc.
Fairfield, Texas

September 30 and October 1, 2, 3 and 4, 1974
October 10, 11 and 12, 1974

Prepared for

Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Measurement Branch
Research Triangle Park,
North Carolina 27711

by

MONSANTO RESEARCH CORPORATION
Dayton Laboratory
1515 Nicholas Road
Dayton, Ohio 45407

Contract No. 68-02-1404, Task No. 3

assumed for new boiler, @ 40% eff.

$600\ mW \times 9\times10^6\ \frac{Btu/hr}{mW} \cdot \frac{1\ lb\ coal/hr}{6.1\times10^3\ Btu/hr} \times \frac{1\ ton\ coal/hr}{2000\ lb\ coal/hr} = 442\ \frac{ton}{hr} = 393\ ton/hr$ → assume ~400 ton/hr

8×10^6

$442\ \frac{ton}{hr} \times \frac{2000\ lb\ coal}{ton} \times \frac{90\ SCFD}{lb\ coal}\Big|_{48\%\ O_2} \times \frac{1\ hr}{60\ min} = 1.32\times10^6\ \frac{SCFD}{min}$ @ 4.8% O_2

$1000\ \frac{SCFD}{min}\Big|_{6\%\ O_2} = 1.47\times10^6\ \frac{SCFD}{min}$ @ 6% O_2

checks with range on Table 2-9

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II. PROCESS DESCRIPTION AND OPERATION

PROCESS DESCRIPTION

The Big Brown Power Station in Fairfield, Texas has two 575 megawatt tangentially fired boilers. The fuel used to fire these boilers is Texas lignite, a form of soft coal mined in Freestone County in Texas. In this area, a layer of lignite is mined by power shovel after removing 12.2-18.3 meters (40-60 feet) of overburden by dragline. The lignite layer, which averages about 2 meters (6 feet) in depth, extends over many acres. The lignite is hauled over a private roadway from the mining area to the plant. After the lignite is removed the displaced earth is redistributed and the area replanted.

The lignite flow diagram shown in Figure 1 indicates the path of the fuel from the mine through the plant. The primary crusher reduces the lignite to pieces of less than 15 centimeters (6 inches) in size. This material is stockpiled or fed directly to the secondary crusher as required by the fuel requirements of the plant. At the secondary crusher the fuel is reduced to less than 0.02 meter (3/4 inch) in size. It is then fed to storage silos by conveyor. Each boiler has eight storage silos and the conveyor fuel can be directed to maintain a sufficient supply in all silos. Lignite samples for analysis were taken from the dual conveyors that feed each bank of silos at each boiler.

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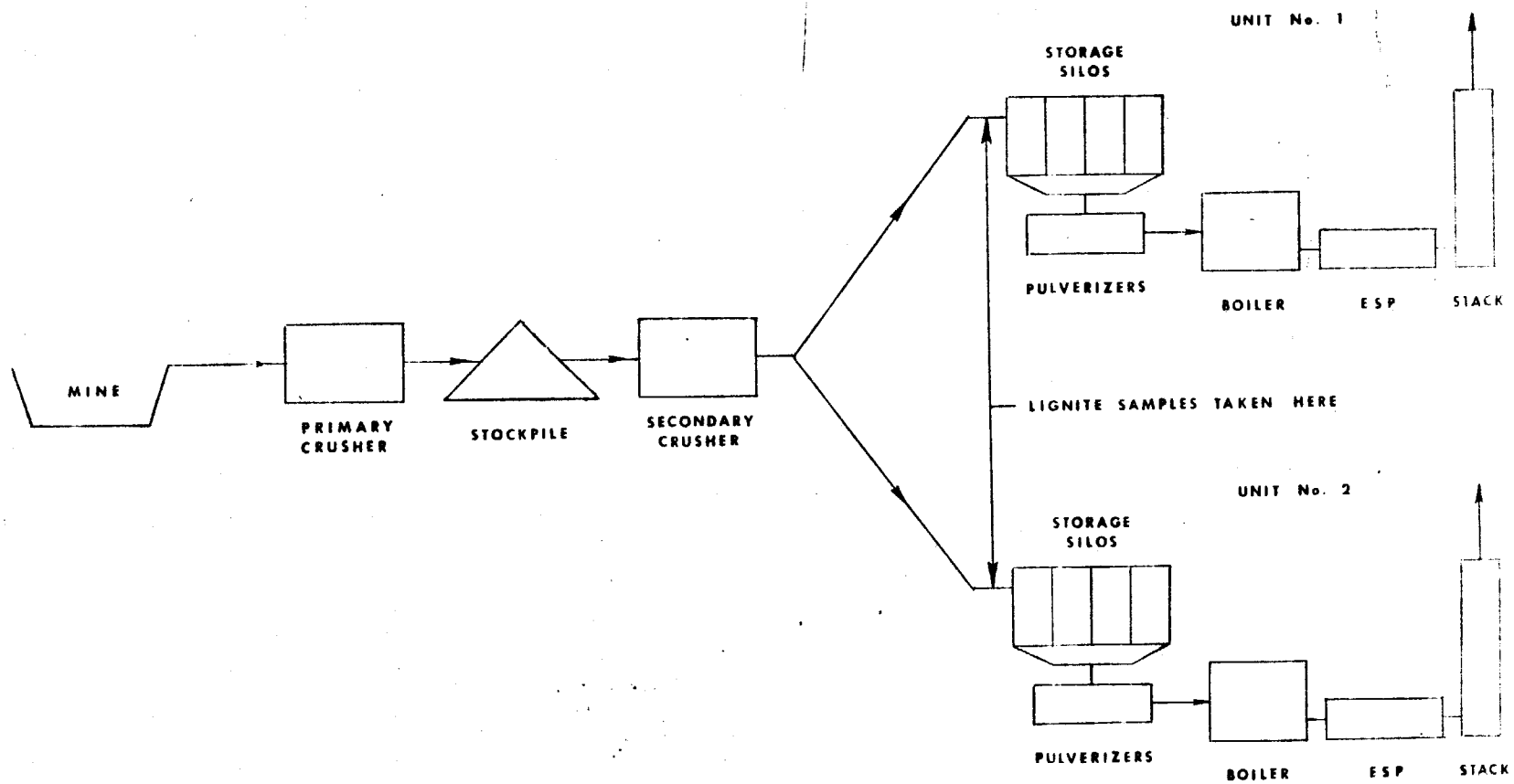

Figure 1. Lignite flow diagram

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From the silos the coal is fed to a pulverizer that further reduces the size so that 6[illegible] will pass a 20[illegible] mesh screen. The boilers are fired in eight steps and the two sections of each boiler have four nozzles for emitting the pulverized fuel and air. This arrangement is termed "corner firing" by the plant personnel. Each silo and pulverizer feeds the eight nozzles at each of eight levels in each boiler. As a result, it is possible to vary burner conditions; e.g., the amount of overfire air can be increased by halting the flow of coal to the top series of nozzles and emitting only air in this area. The boiler typically has a capacity of 1,823,000 kilograms (4,025,000 pounds) of steam per hour at 2,689,000 kilograms per square meter (3,825 pound per square inch) at 538°C (1000°F.) 600mw × 7×10³ lb steam/hr / mw = 4200,000 # steam/hr - good check.

The particulate emissions from the boilers are controlled by electrostatic precipitators. The flows from the ESP's are carried through breechings to a single stack 121.92 meters (400 feet) high and 7.39 meters (291 inches) in diameter.

PROCESS OPERATION

The testing program was designed to obtain information on the NO_x emissions as related to changes in the excess air and overfire air, and to demonstrate the reproducibility from one boiler to the other as well as from day to day. As the boilers were fired in layers, it was possible to vary the air emitted to the burners and obtain variations in firing as desired. During each sampling day, a combination of normal and modified operation allowed data to be collected on the NO_x emissions under various modified firing conditions.

The schedule of operating conditions is shown in Table 1.

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Table 1. SCHEDULE OF CONDITIONS

Date	Time	Condition
Stack Unit #2		
9/30	1200 - 1630	Baseline
10/01	900 - 1130	Baseline
	1130 - 1430	Low excess air
	1430 - 1600	Baseline
10/02	900 - 930	Baseline
	930 - 1230	All burners on
	1230 - 1500	Baseline
10/03	700 - 900	High excess air
	900 - 1000	Baseline
	1000 - 1300	Maximum overfire
	1300 - 1400	Baseline
10/04	900 - 930	Baseline
	930 - 1230	Low air, all burners
	1230 - 1330	Baseline
	1330 - 1600	No run
Stack Unit #1		
10/10	900 - 1130	Baseline
	1130 - 1430	Low excess air
	1430 - 1750	Baseline
10/11	900 - 1030	Baseline
	1030 - 1330	All burners on
	1330 - 1500	Baseline
10/12	900 - 930	Baseline
	930 - 1230	Maximum overfire
	1230 - 1600	Baseline

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During each testing period only the boiler being tested was operating. Approximately 600 MW of electricity was being produced during testing. The generators can produce a maximum of 616 MW of electricity.

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III. SUMMARY AND DISCUSSION OF RESULTS

The NO_x, CO_2, O_2 and moisture content, and stack velocity and temperature were obtained at the stacks of the Big Brown steam plant during both normal operation and under various conditions of modified operation. The results of the sampling program on a day by day basis are given in Tables 2-9 and Figures 2-9. The Method 7 NO_x data are given in ppm of NO_2 and a dry basis. The Dynasciences data were read directly from the recording chart using 247 ppm NO in nitrogen as the calibration gas mixture.

Emissions from Boiler No. 2 were measured during the first week of sampling (Sept. 30 to Oct. 4). The boiler was operated under normal conditions on the first day to provide baseline emission rate data. The initial samples, analyzed for CO_2 and O_2 content, indicated only air. The monitor values for NO_x were about 100 ppm rather than about 350 ppm as expected. The probe system, consisting of two stainless probes and one glass probe in a common sheath, was sealed around the probes and also between the sheath and port. The monitor and integrated gas samples were initially withdrawn at the rate required for each instrument. The fact that the gas samples contained only air indicated that the gas would have to be withdrawn at a rate sufficient to overcome the effect of the 30 m/sec stack gas velocity. The probes were therefore connected to metal bellows pumps

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Table 2

Summary of Test Results - September 30, 1974

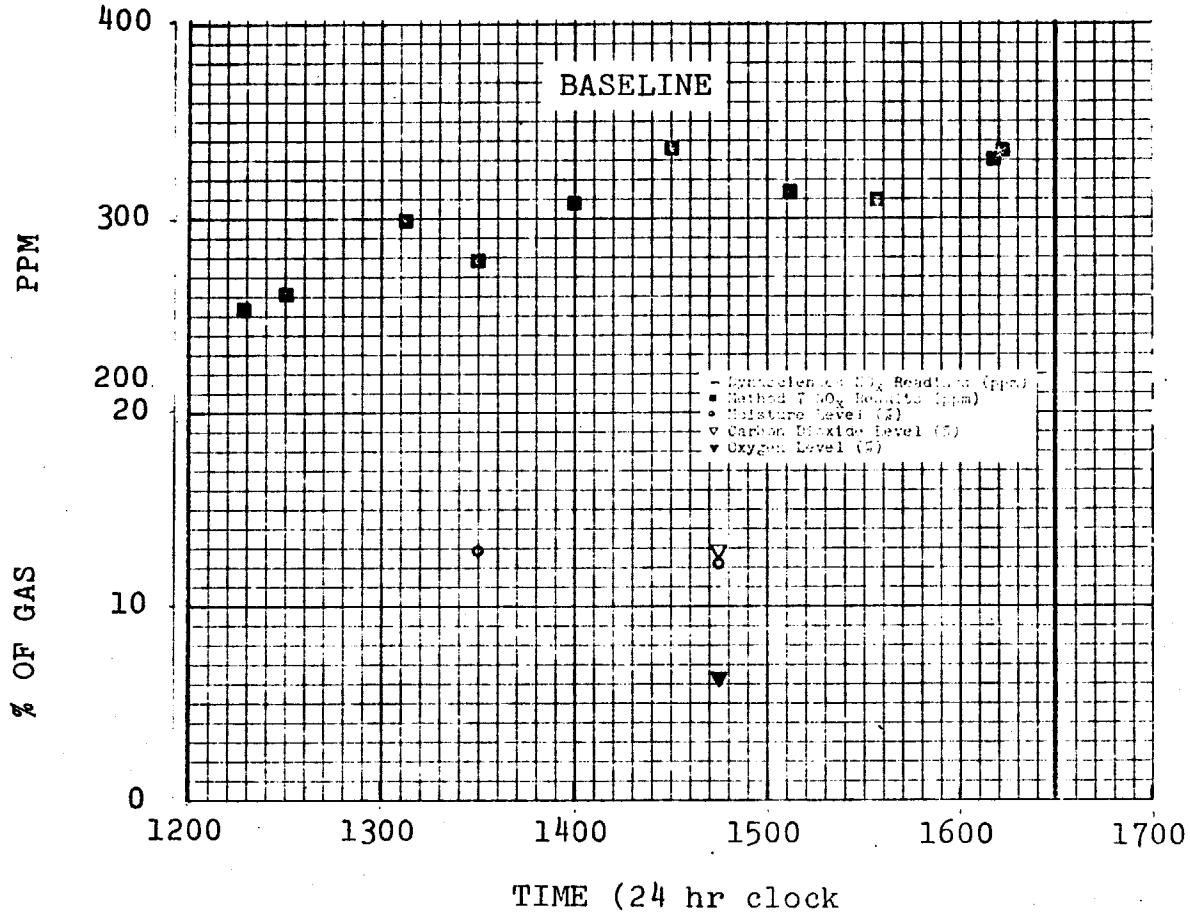
assume 400 ton coal/hr

	STACK #2							VOLUMETRIC FLOW RATE				EMISSION RATE		
								STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	lb NO_x/ton
1200							1.19	564	2.16	1019			
1212	254										2180	989	5.5
1230	262										2240	1020	5.6
1300							1.20	566	2.16	1020			
1308	299										2570	1170	6.4
1330	279				12.9						2390	1080	6.0
1400	309						1.21	569	2.17	1023	2650	1200	6.6
1430	338	110									2900	1320	7.3
1445			6.3	12.9	12.2	30.3							
1500							1.19	561	2.16	1021			
1507	314	110									2700	1220	6.8
1534	310	100									2660	1210	6.7
1611	331	90									2830	1280	7.1
1613	336	90									2880	1310	7.2

base line

6.5

FIGURE 2. SUMMARY OF TEST RESULTS - SEPTEMBER 30, 1974



assume 400 tons/hr

Table 3

Summary of Test Results - October 1, 1974

	STACK #2							VOLUMETRIC FLOW RATE				EMISSION RATE		
								STANDARD		ACTUAL				
	TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	
	0945					16.0		1.15	542	2.17	1020			
	0950			4.6	14.0		30.4					2370	1080	5.9
	1000											2780	1260	7.0
base line	1010	289		5.2	13.4		30.4	1.15	541	2.18	1030	2820	1280	7.1
	1045	338	410	5.2	13.9		30.4	1.14	540	2.17	1020	2730	1240	6.8
	1120	345	370											
	1130	335		7.6	11.7		30.2	1.14	538	2.16	1020	2590	1170	6.5
	1140													
	1145			4.1	15.0		30.6	1.14	538	2.16	1020			
	1200	317		5.3	13.7		30.3							
low E.A.	1230	328	390					1.14	538	2.17	1020			
	1245		395	11.0	8.7		29.8	1.16	547	2.18	1030			
	1307		[illegible]			15.1								
	1310			8.1	11.2		30.1	1.16	549	2.21	1040	2870	1300	7.2
	1331	346	375									2320	1050	5.8
	1345			10.0	9.7									
	1400	280	385			14.7								
	1415			5.4	13.9		28.6	1.16	547	2.19	1030			
	1430	(75)	395									2930	1330	7.3
	1445			4.4	14.5		28.6	1.15	545	2.19	1030	3430	1550	8.6
	1500	357	372											
base line	1530	413	385	6.5	13.0		28.5	1.17	550	2.21	1040	2840	1290	7.1
	1545													
	1600	339	380											6.9

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FIGURE 3. SUMMARY OF TEST RESULTS - OCTOBER 1, 1974

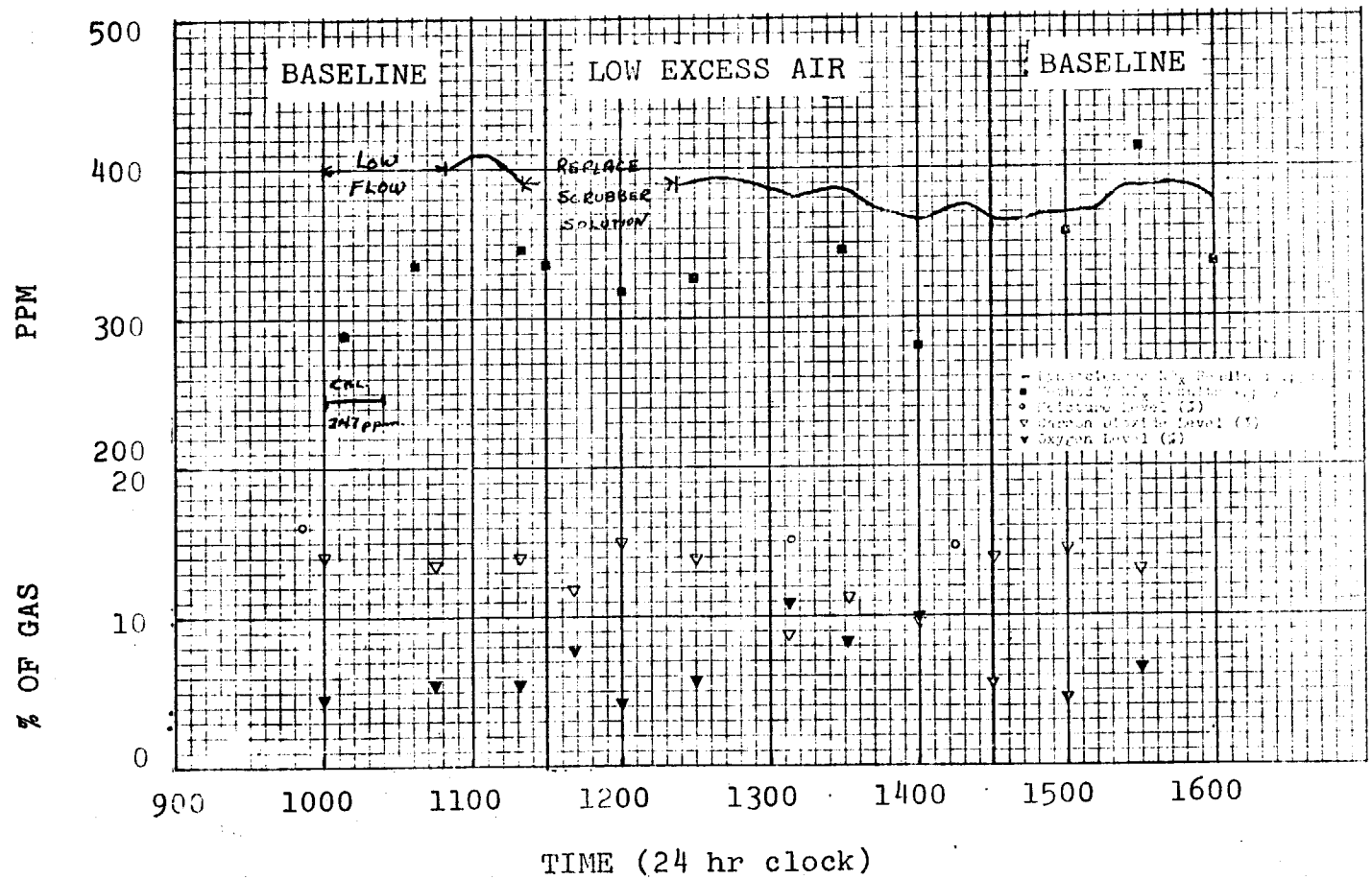

Table 4

Summary of Test Results - October 2, 1974

	STACK #2							VOLUMETRIC FLOW RATE				EMISSION RATE		
								STANDARD		ACTUAL				
	TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	[illegible]
base line	0910	268		5.10	13.5		30.4					2320	1050	[illegible] 8
	0915							1.21	571	2.23	1050			
	0940	(96)	225											
	0947			5.3	13.6		30.4	1.21	571	2.23	1050			
	1000					13.4								
	1015	334	350	4.7	14.2		30.5					2870	1300	7.2
	1030	307	380					1.19	562	2.21	1040	2620	1190	6.6
	1050		370	4.5	14.5		30.5							
	1115							1.19	563	2.22	1050			
	1122		320	4.3	14.9		30.6							
	1130	354	310									3020	1370	7.6
	1200	(570)	315											
	1215							1.17	551	2.22	1050			
	1230	(2887)	315											
	1245					15.6								
	1300	346	250									2910	1320	7.3
base line	1340	(5905)	280					1.17	552	2.25	1060			
	1400	304	320	4.8	14.6		30.5					2550	1160	6.4
	1420							1.18	556	2.26	1070			
	1430		320	4.4	14.6		30.5							
	1440	309	325									2610	1180	6.5
	1455	(701)	335	6.4	13.1		30.4							
	1520							1.18	558	2.26	1070			6-8

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FIGURE 4. SUMMARY OF TEST RESULTS - OCTOBER 2, 1974

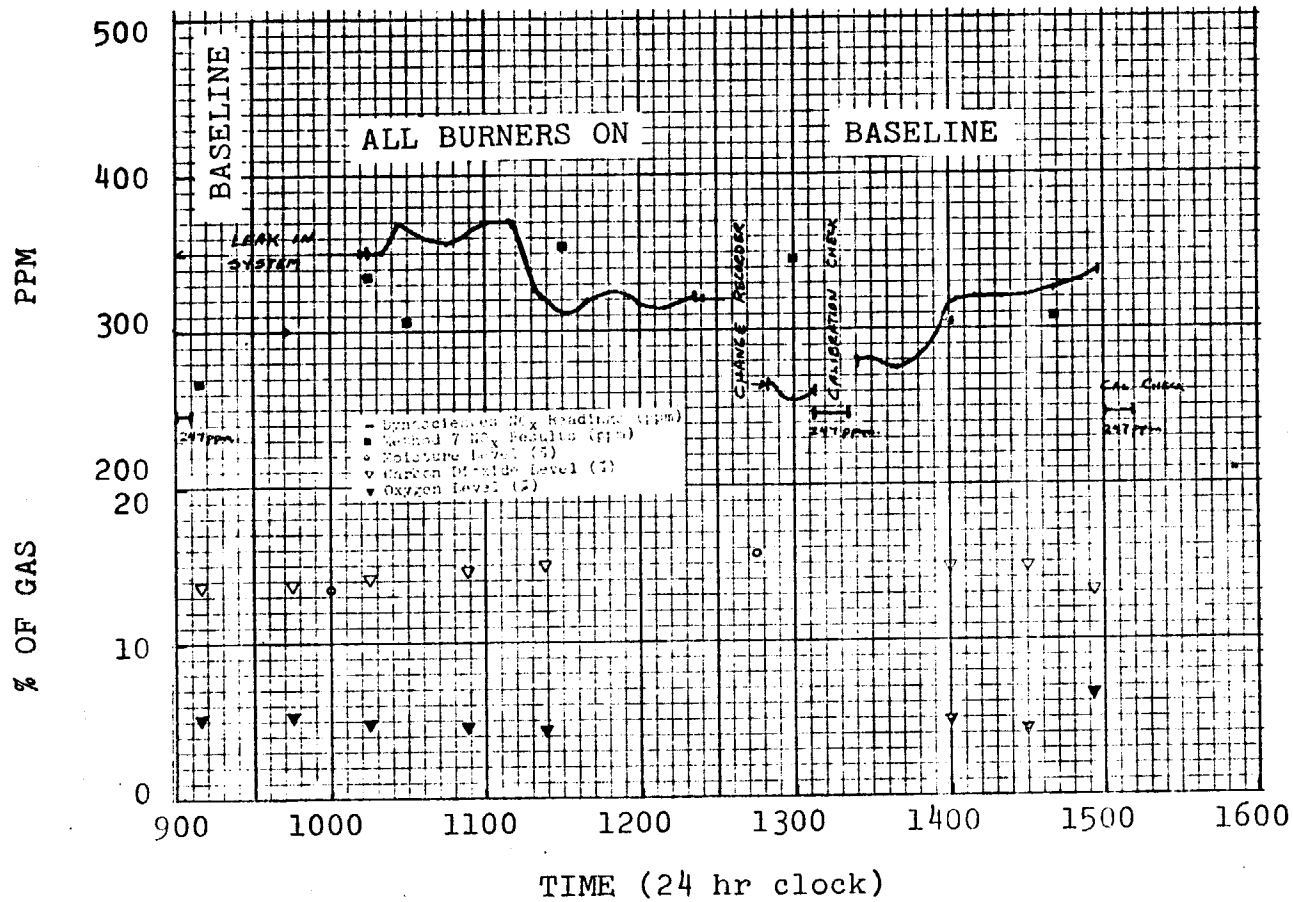

Table 5

Summary of Test Results - October 3, 1974

STACK #2							VOLUMETRIC FLOW RATE				EMISSION RATE		
							STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	THERMOSCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	lb NOx/ lm
0715	306		5.0	14.2		30.5					3000	1360	7.5
0725							1.37	648	2.28	1080			
0750					4.9								
0800	300		5.2	13.9		30.4	1.37	648	2.28	1080	2940	1330	7.4
0820							1.38	653	2.30	1090			
0833	(262)		5.0	14.0		30.4							
0900	308		5.75	13.1		30.3	1.39	654	2.31	1090	3070	1390	7.7
0935			5.7	13.3		30.4							
0940							1.23	579	2.67	1260			
1000	(559)	370	5.4	13.5		30.4	1.23	579	2.66	1260			
1020							1.19	561	2.31	1090			
1030	(3057)	435	7.0	12.2		30.2							
1100	267		5.8	13.4		30.4	1.19	559	2.30	1090	2270	1030	5.7
1125							1.19	559	2.33	1100			
1130	295		5.1	13.9	18.2	30.4					2500	1130	6.3
1200	209		5.6	13.2		30.3	1.18	555	2.32	1090	1760	798	4.4
1215							1.17	554	2.32	1090			
1230	(470)	200	5.2	13.8		30.4							
1300	(2942)	200	5.8	13.1		30.3	1.23	581	2.32	1090			
1315					14.1								
1330	(393)	220	4.8	14.3		30.5							
1340							1.23	580	2.32	1090			
1400	(1089)	250											
1410			4.9	14.2		30.5	1.23	580	2.32	1090			
1420	(528)	275											

High 5.7

Low 4.4

6.5

FIGURE 5. SUMMARY OF TEST RESULTS - OCTOBER 3, 1974

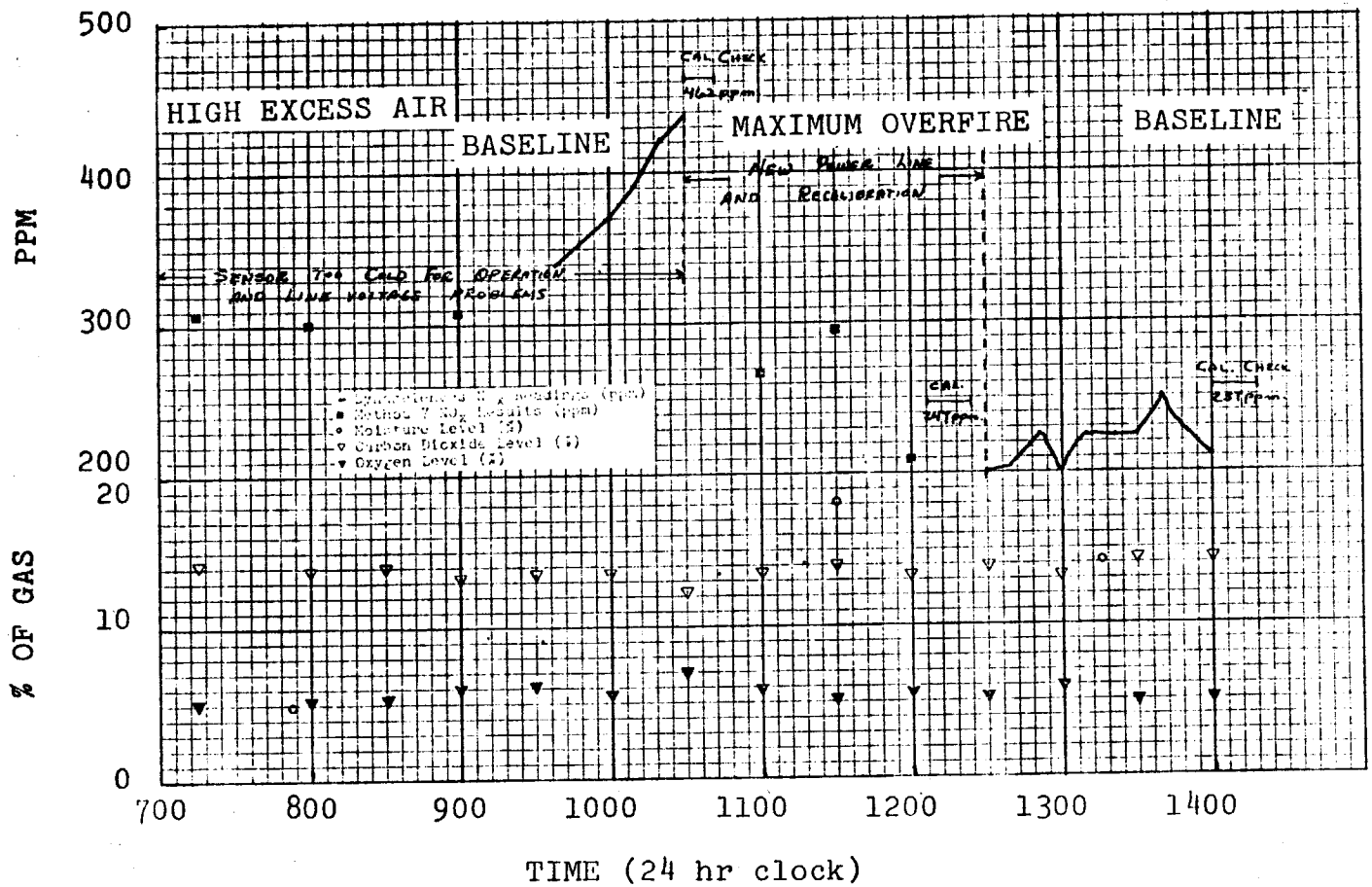

Table 6

Summary of Test Results - October 4, 1974

STACK #2							VOLUMETRIC FLOW RATE				EMISSION RATE		
							STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2 (%)	CO_2 (%)	MOISTURE (%)	NW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	lb-NOx/hr
0900	(565)		6.0	13.1	11.7	30.3							
0915							1.27	599	2.29	1080			
0930	(475)	375	6.2	12.6		30.5	1.27	597	2.28	1080			
1000	(385)	500	4.9	13.9		30.4							
1015							1.26	594	2.29	1080			
1030	358		4.9	13.9		30.4	1.26	594	2.29	1080	3230	1470	8.1
1100	268		6.3	12.9		30.3					2570	1170	6.4
1115							1.25	589	2.28	1080			
1130	311	310	4.5	14.5		30.5	1.25	588	2.28	1080	2780	1260	7.0
1200	(447)	275	4.6	14.4		30.5							
1215							1.24	587	2.27	1070			
1230	(2687)	85	5.0	14.0		30.4	1.23	582	2.27	1070			
1300	275	55	5.95	13.1		30.3					2480	1130	6.2
1310							1.26	594	2.32	1090			
1320	271				12.4						2440	1110	6.1

6-8

FIGURE 6. SUMMARY OF TEST RESULTS - OCTOBER 4, 1974

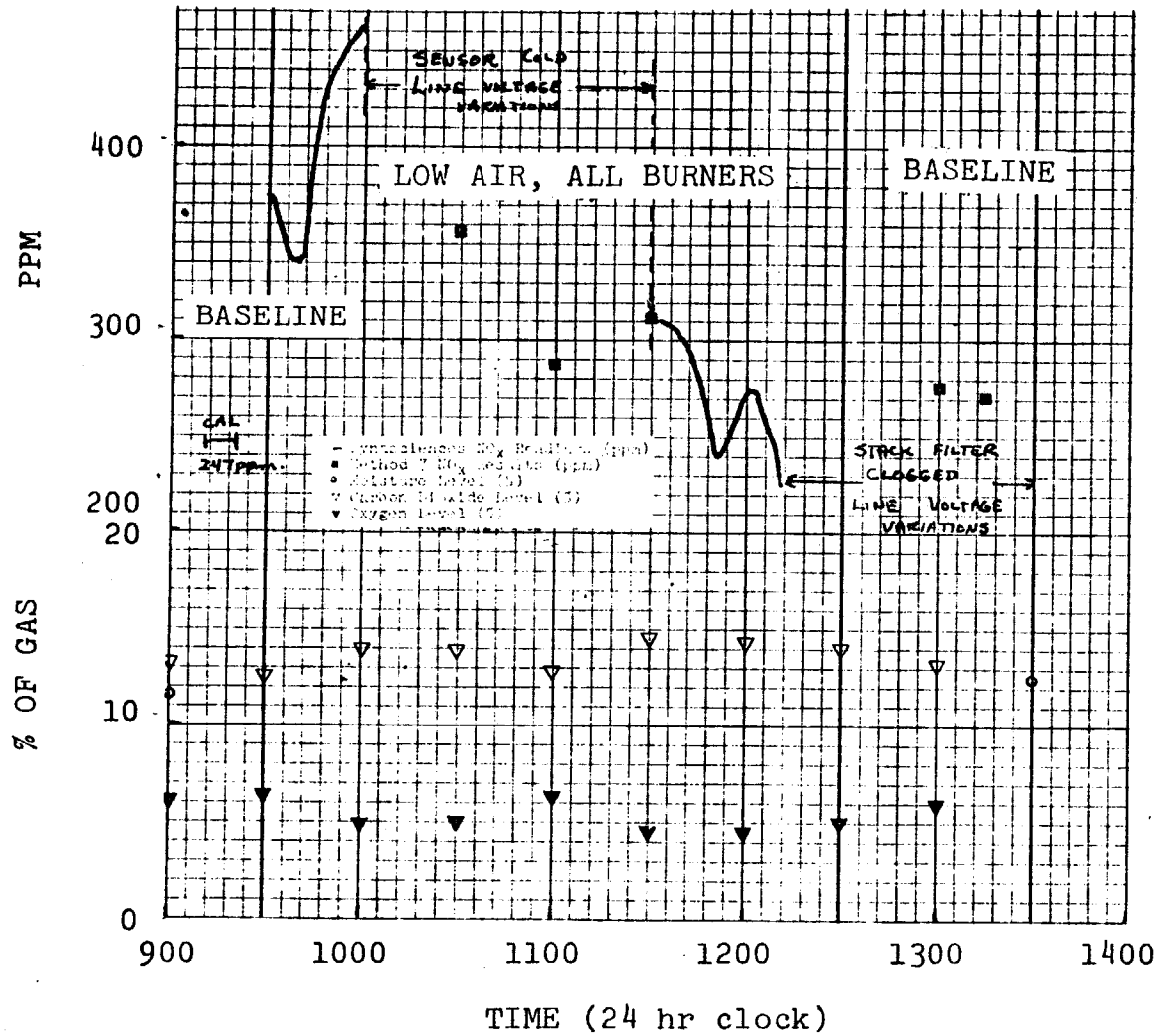

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Table 7

Summary of Test Results - October 10, 1974

STACK #1								VOLUMETRIC FLOW RATE				EMISSION RATE		
								STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	
1230		370											
1300		380											
1305					11.9								
1330	342	375	5.25	13.7		28.9	1.58	747	2.95	1390	3870	1760	9.7
1400	318	375	5.3	13.7		28.9	1.43	675	2.66	1250	3260	1480	8.2
1430	197	365	6.3	12.7		29.0	1.44	682	2.70	1270	2020	920	5.1
1500	180	390	4.7	14.3	13.6	28.6					1850	839	4.6
1530	278	380	4.6	14.4		28.8					2830	1280	7.1
1540							1.42	669	2.69	1270			
1600	337	400	4.75	14.3		28.8	1.44	680	2.73	1290	3460	1570	8.7
1630	357	405	4.75	14.2		28.8	1.40	661	2.73	1290	3580	1620	9.0
1700	314	395	5.65	13.2		28.8	1.40	661	2.73	1290	3140	1420	7.9
1730	305	405	4.65	14.2	12.9	28.8	1.44	680	2.71	1280	3140	1430	7.9
1740							1.44	680	2.71	1280			
1750	378	405									3900	1770	9.8
1800			5.35	13.6		28.8							
													7.8

6 gas

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FIGURE 7. SUMMARY OF TEST RESULTS - OCTOBER 10, 1974

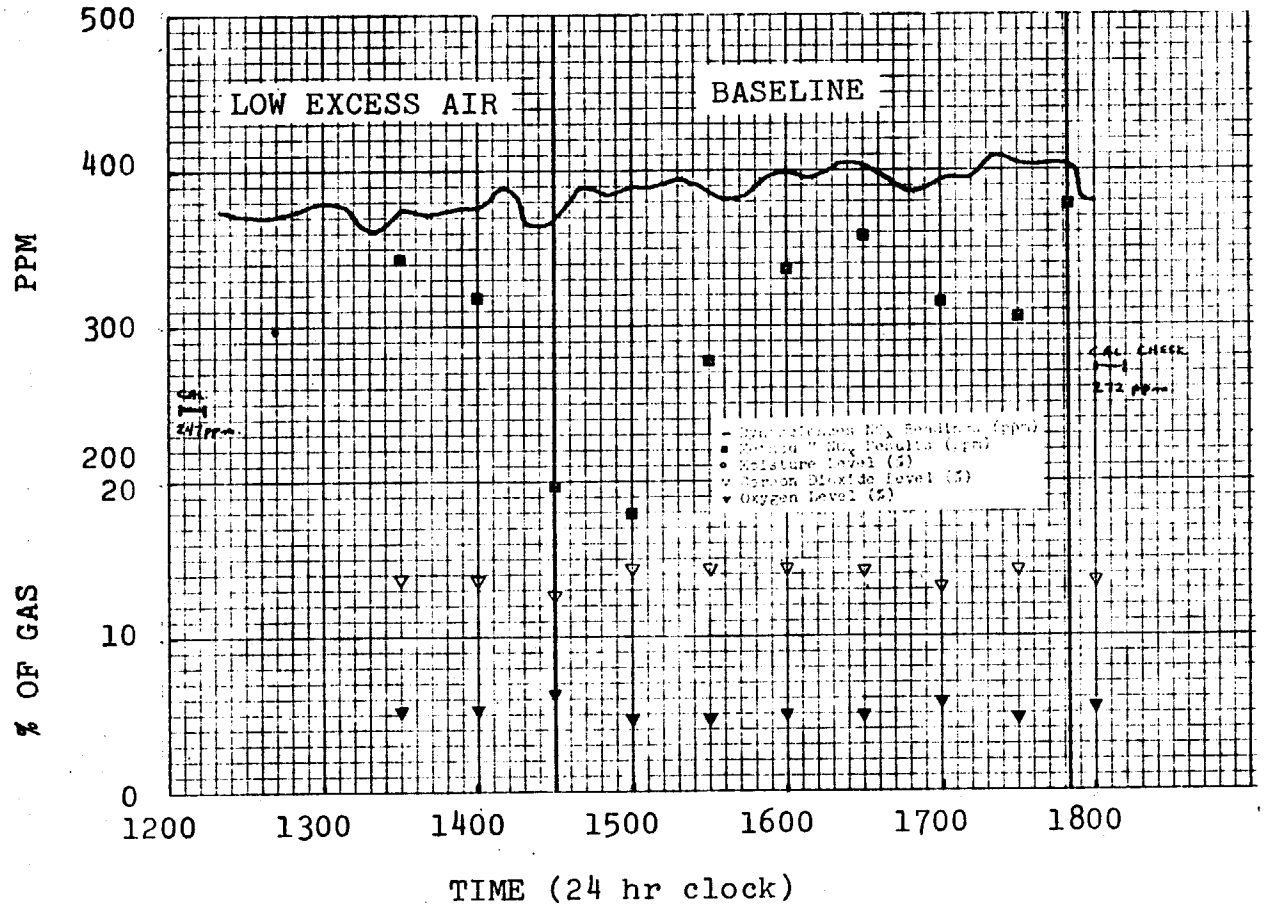

Table 8

Summary of Test Results - October 11, 1974

STACK #1							VOLUMETRIC FLOW RATE				EMISSION RATE		
							STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/	
0900		295											
0908			4.75	14.2		30.5	1.23	580	2.23	1050	2410	1090	6.0
0910	274	285			11.6								
0930	288	285					1.23	580	2.23	1050	2530	1150	6.3
base 0937			6.10	12.9		30.3							
1000		300	4.45	14.4		30.5	1.23	582	2.23	1050			
1009	301	285									2660	1200	6.7
1030	317	360	5.15	13.8		30.4	1.24	587	2.23	1050	2820	1280	7.1
1100	349	370	4.60	14.1		30.4	1.27	599	2.28	1080	3170	1440	7.9
1130	368	375	5.35	13.5		30.4	1.26	597	2.28	1080	3320	1510	8.3
1200	361	370	4.65	14.4		30.5	1.27	600	2.29	1080	3280	1490	8.2
1230	327	365	4.65	14.3		30.5	1.27	599	2.29	1080	2970	1350	7.4
1300	295	370	5.40	14.5	12.0	30.5	1.27	597	2.28	1080	2670	1210	6.7
1330		360	6.60	12.4		30.2	1.26	596	2.29	1080			
1350	321	355									2990	1360	7.5
1400	420	310	4.45	14.5		30.5	1.34	631	2.40	1130	4030	1830	10.1
base 1430	335	320	6.10	14.0		30.5	1.35	635	2.40	1130	3240	1470	8.1
1438					11.2								
1500	292	320	4.55	14.4		30.5	1.35	635	2.40	1130	2830	1280	7.1
													7.5

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FIGURE 8. SUMMARY OF TEST RESULTS - OCTOBER 11, 1974

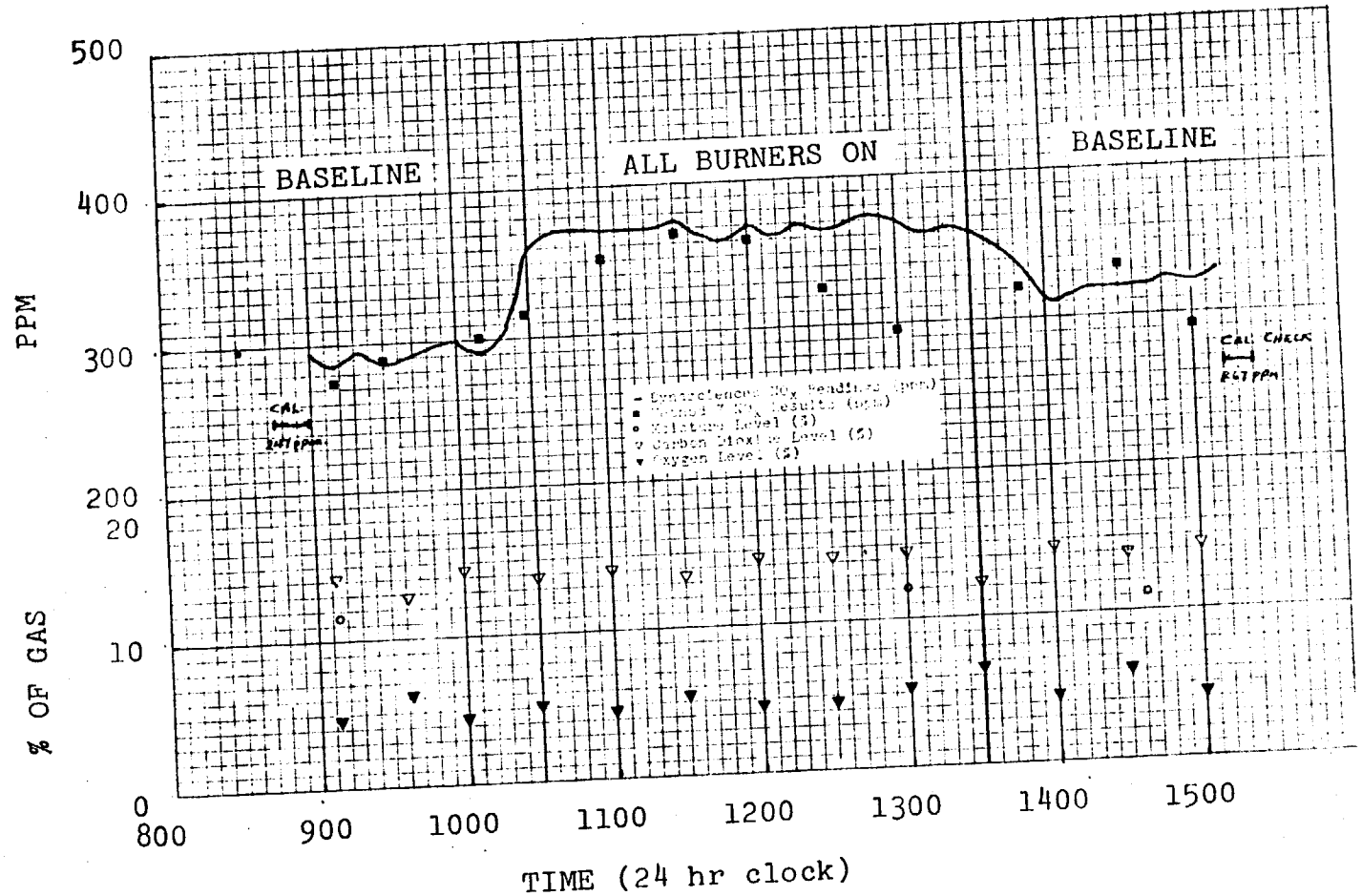

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Table 9

Summary of Test Results - October 12, 1974

STACK #1							VOLUMETRIC FLOW RATE				EMISSION RATE		
							STANDARD		ACTUAL				
TIME	METHOD 7 NO_x (PPM)	DYNASCIENCE NO_x (PPM)	O_2(%)	CO_2(%)	MOISTURE (%)	MW DRY GAS	DSCFM (10^6)	Nm^3/sec)	ACFM (10^6)	(m^3/sec)	LB/ /HR	(KG/HR)	MMBtu/hr
0900	290	330	5.85	13.2		30.3	1.48	697	2.69	1270	3070	1390	7.7
0925					14.2								
0930	294	315	6.2	12.9		30.3	1.48	697	2.69	1270	3110	1410	7.8
1000	294	328	7.2	11.6		30.1	1.49	705	2.73	1290	3130	1420	7.8
1030	308	330	6.6	12.4		30.2	1.48	696	2.72	1280	3270	1480	8.2
1100	255	334	5.3	13.7		30.4	1.46	690	2.70	1270	2670	1210	6.7
1130	321	323	5.3	13.8		30.4	1.46	690	2.70	1270	3360	1520	8.4
1152					15.2								
1200	309	335	5.3	13.7		30.4					3170	1440	7.9
1205							1.43	675	2.65	1250			
1230	313	325									3200	1450	8
1245			5.6	14.8		30.6	1.43	673	2.65	1250			
1300	245	345	5.6	13.4		30.4	1.55	731	2.78	1310	2720	1240	6.8
1330	329	350					1.55	732	2.78	1310	3650	1650	9.1
1345			5.4	13.7		30.4							
1400	333	350	5.9	13.2		30.3					3580	1620	9.0
1410							1.50	707	2.70	1270			
1415					12.5								
1430	316	330	5.75	13.3		30.4	1.50	707	2.70	1270	3390	1540	8.5
1500	191	320	5.8	13.6		30.4	1.51	710	2.74	1290	2070	938	5.2
1530	298	305	6.0	13.1		30.3	1.51	711	2.74	1290	3230	1460	8.1
1600		313	5.5	13.7		30.4	1.48	696	2.69	1270			

7.8

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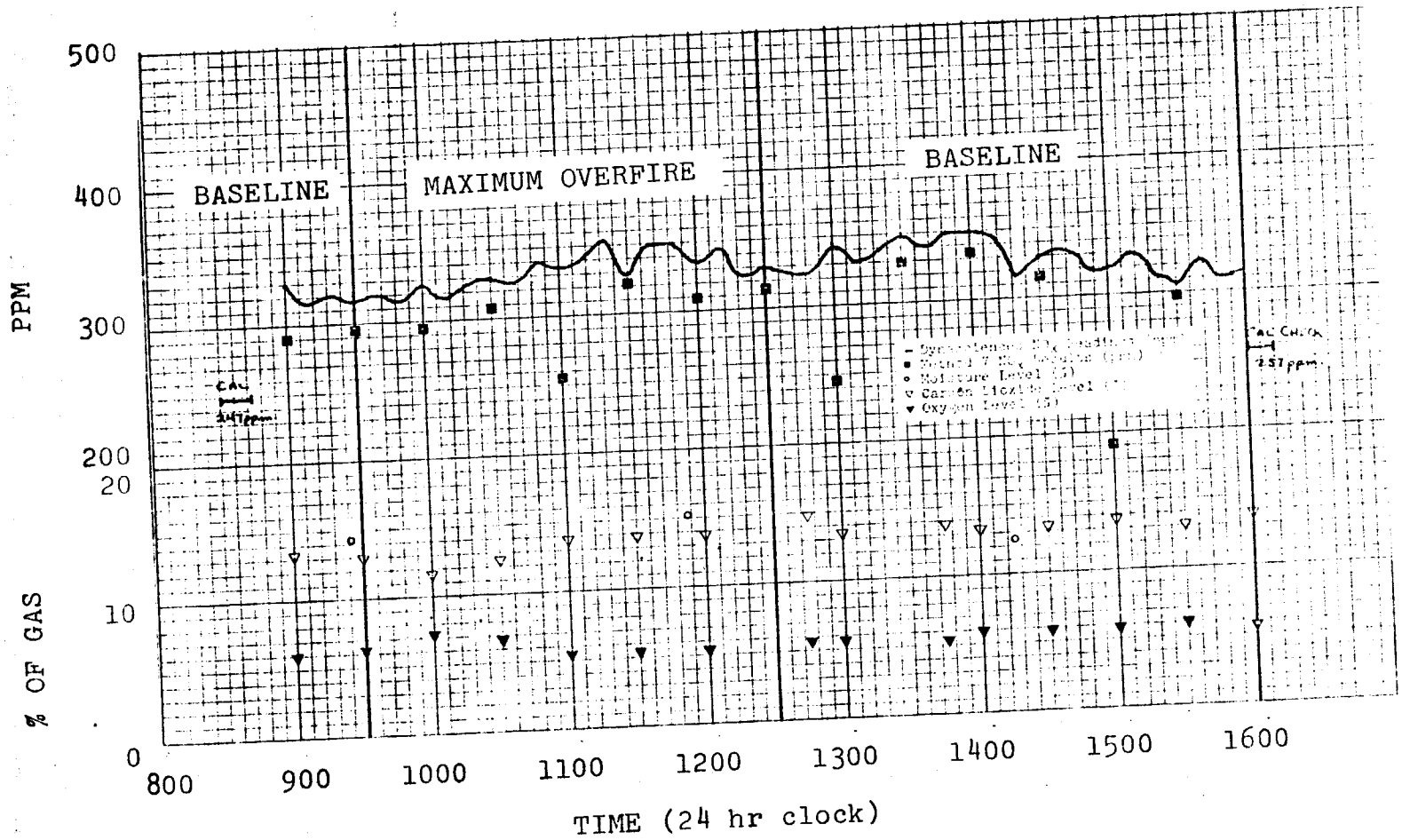
FIGURE 9. SUMMARY OF TEST RESULTS - OCTOBER 12, 1974



operated at maximum capacity and samples were withdrawn from "T"s in these lines at flow rates comparable to those of the monitor (28 l/hr) and the integrated gas sampler 28(l/min.) After this correction, reasonable values were obtained from the monitor and the gas sampler.

Numerous experimental problems were encountered with the monitor. It was observed that the indicated value increased rapidly with increasing ambient temperature and that low ambient (10°C and below) temperature prevented stabilization on the calibration gas. This effect was observed on both Oct. 3 and Oct. 4. According to the literature supplied with the monotor, operation is possible from +5 to 49°C. However, if the ambient temperature varies, the calibration will change. For the second week the monitor was heated to about 40°C to maintain a constant sensor temperature and thus eliminate major drifts. Operation during the second week was reliable and valid data were obtained.

The results obtained from the Method 7 NO_x determinations are quite varied and indicate that the scatter of data obtained from one operating condition is greater than the variation in NO_x due to an operating change. The procedures used were as specified in the Federal Register. Identical techniques were employed for sampling and the analysis of all samples with one exception. During the analysis of one group of samples, representing for the most part baseline conditions from Oct. 1 to Oct. 4, it was found that the hood fan ceased operation and condensate from the hood dripped into the samples, giving high NO_x results. The data for these samples are given in parentheses on the data sheets.

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Line voltage variations were a major problem on the Boiler No. 2 studies, and at the times when all sampling units were in operation, line voltage was observed to drop as low as 92 volts. The low voltage affected the digital thermometer, and the Dynasciences monitor and recorder. A separate power cord was installed for sampling on Oct. 3 and 4, but the voltage in this circuit was also shown to be variable.

The test data from September 30 indicate the following NO_x baseline data: an average of 303 ppm, a moisture level of 12.9%, and gas emissions contents of 6.3% O_2 and 12.9% CO_2. On successive days the baseline data vary greatly, indicating that even when the plant is operating under "normal" operation, the NO_x concentration is quite variable. The studies on Boiler No. 1 indicate less variation in the NO_x baseline data, especially as measured with the monitor, but even on this unit the variation is significant. As a result, it is necessary to observe the baseline data obtained before and after an operating parameter was changed in order to evaluate the change in NO_x concentration resulting from that change.

The changes in operating conditions and the expected and observed changes in NO_x concentration are tabulated in Table 10.

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Table 10. VARIATIONS IN OPERATION AND EFFECT ON NO_x CONCENTRATION

Operating Parameter	Date	Effect on NO_x Emissions: Expected Change	Observed Change	Magnitude ppm *
Boiler 2				
Low excess air	10/1	Reduce		10
All burners on	10/2	Increase	Increase	20
High excess air	10/3	Increase	Slight increase	10
Maximum overfire	10/3	Reduce	Reduce	30
Low air-all burners	10/4	Reduce	Increase	20
Boiler 1				
Low excess air	10/10	Reduce	Reduce	30
All burners on	10/11	Increase	Increase	70
Maximum overfire	10/12	Reduce	Slight increase	10

* Estimates based on trends shown in Figures 2-9.

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The problems encountered during the first week of sampling were corrected before the program began on Boiler No. 1. As a result, the data obtained from the second week are reliable, and the effects of process variables can be observed.

During the sampling program coal samples were gathered for analysis of the moisture, volatility, ash, sulfur and Btu content. These samples were gathered from the conveyors feeding the silos above the pulverizers at half-hour intervals. The samples were composited on site and a portion of each composite was returned to Dayton in sealed plastic bottles for analysis. The results of the analyses are shown in Table 11. As the samples tended to lose weight during weighing due to loss of moisture all samples were oven dried at 100°C and the dry Btu content was determined. These values were used to calculate the Btu content on the as-received basis.

In reviewing the sampling program, there are five recommendations we feel are important to future programs of this type:

1. The Dynasciences or similar monitors should be powered with a separate supply, and 12V dc power would be preferred.
2. The monitor should be heated and maintained at a constant temperature above ambient temperature.
3. All electronic instrumentation (digital thermometer and recorders) should have a power circuit isolated from that for instrument heating and other fluctuating sources.
4. Continuous monitor methods are preferred over grab type sampling as in Method 7 for NO_x. While Method 7 is

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TABLE 11. LIGNITE ANALYSIS

	9-30-74	10-1-74	10-2-74	10-3-74	10-4-74	10-10-74	10-11-74	10-12-74
% MOISTURE	30.5	33.4	33.1	32.4	33.9	32.8	31.8	30.7
% VOLTILE	6.49	11.15	10.07	4.82	14.03	8.67	20.90	5.43
% ASH	13.16	11.41	10.35	12.64	14.01	10.93	10.81	12.74
% FIXED CARBONS	49.82	44.09	46.49	50.17	38.10	47.65	36.52	51.16
% SULFUR	.87	.77	.78	.75	.81	.74	.93	.59
Btu/lb. (Oven Dried)	8980	9060	9680	9160	8810	9600	9160	9230
Btu/lb. (As Recv.)	6240	6040	6480	6190	5820	6450	6250	6390

AVG Btu/lb (as recd) = ~~6165~~ 6232

employed as a standard against which monitor operation is evaluated, the variations in the data are significant. A larger number of NO_x samples should be obtained, and duplicates taken at the same time intervals would be desirable.

5. Consideration must be given to the design of the probe used to sample the gaseous components to eliminate air being drawn into the probe tip area. Drawing a large volume of sample into the probe and then removing a portion of this sample for analysis is recommended when high stack velocity situations are encountered. This method reduces the response time of the system and also assures that adequate stack gas will be supplied to the instrument.

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12/74

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NITROGEN OXIDE EMISSIONS

AT

THE MINNKOTA POWER COOPERATIVE
MILTON R. YOUNG STATION
CENTER, NORTH DAKOTA

234 mw, Cyclone-fired

Per Tim Osag, ISB, this cyclone running at as low a EA as possible, hence, this is probably lower limit

NO_x:
12.2 lb/ton, at base load
10.0 lb/ton, at limited air, at base load
12.8 " ", at high air, " " "

PREPARED FOR:

THE U. S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

CO: 19 lb/ton (0-60 lb/ton)

SUBMITTED BY:

YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE
STAMFORD, CONNECTICUT 06906

EPA Contract No. 68-02-1401
Task No. 6

December 2, 1974

DRAFT

I. INTRODUCTION

York Research Corporation, an independent consultant in Environmental Engineering, was retained by the U. S. Environmental Protection Agency, under Contract No. 68-02-1401, Task 6, to conduct a series of tests at the Minnkota Power Cooperative, Milton R. Young Station, Center, North Dakota. The process tested was a Babcock and Wilcox lignite fired boiler, equipped with a cyclone dust collector.

Sampling of the exhaust gases was conducted from sampling ports located on the stack, to determine nitrogen oxide concentrations, molecular weight evaluation, moisture determination, velocity, and flow.

The test team was comprised of one Project Director and four test engineers from York Research.

The primary purpose of the test program was to determine Nitrogen oxide emission levels. The results of the testing will enable the EPA to set up NOx emission regulations governing lignite fired boilers.

The secondary purpose of the program was a comparison in results between the present EPA Method 7 nitrogen oxide sampling and the Thermo Electron Corporation "chemiluminescent NOx analyzer". NOx sampling was conducted at various boiler operating conditions, as well as a test to establish baseline conditions.

DISCUSSION OF RESULTS

In determination of the NOx emissions the following results were obtained:

The NOx emission could be reduced by 16.7% by a reduction in excess air (at the test sampling point) from 20.85% to 18.7% or a reduction in excess air at the furnace outlet from 21.5% to 17%. The reduction in excess air resulted in a 1.0% reduction in gas flow.

By increasing the excess air to 24% (3% increase in gas volume) the NOx emissions were increased by 3.8%. Although these variations in NOx were obtained by changing boiler operating conditions, no long runs were made under these conditions. Therefore York Research cannot ascertain if the boiler can operate under these conditions permanently and maintain the same level of reduction.

The Teco NOx analyzer averaged 15-30 ppm higher than the EPA-7 test methods. This data covers only part of the test program since initial operation of the analyzer was poor, caused by a plugged capillary in the sampling line. This problem occurred because of inadequate filtration in the gas conditioning system, since extremely fine particle sizes were not expected from lignite firing. This was solved by the addition of a 0.3 micron fiberglass filter after our Conditioning system. From our experience at the Olds Station and these modifications lost data was minimized.

TABLE I
SUMMARY OF AVERAGED TEST RESULTS
MILTON YOUNG

Date	Phase/ Duct	Flow (SCFMD)	Concentration (PPM)		Emission Rate (lb/hr)		Emission Rate (lb/MMBTU)		Emission Rate (Gm/10^6 cal)	
			EPA-7	Teco	EPA-7	Teco	EPA-7	Teco	EPA-7	Teco
10/5	Prelim/1	NM	427(3)	453(3)	NM	-	NM	-	NM	-
	Prelim/2	NM	462(3)	NM	NM	-	NM	-	NM	-
	Average	NM	444	NM	NM	-	NM	-	NM	-
10/7	Baseline/1	306,346	532(3)	581(7)	1163	1270	.428	.468	.770	.842
	Baseline/2	303,521	640(3)	700(1)	1373	1503	.506	.554	.917	.996
	Total	609,867	586	640	2536	2773	.934	1.022	1.680	1.838
10/8	AM Baseline/1	330,343	560(5)	581(3)	1322	1373	.508	.528	.914	.950
	AM Baseline/2	314,682	NM	-	NM	-	NM	-	NM	-
	Total	645,116	NM	-	NM	-	NM	-	NM	-
	AM Low Air/1	313,926	461(5)	470(5)	1032	1052	.398	.405	.716	.730
	AM Low Air/2	307,787	NM	-	NM	-	NM	-	NM	-
	Total	621,713	NM	-	NM	-	NM	-	NM	-
	PM Baseline/1	329,812	551(5)	559(5)	1295	1313	.499	.506	.898	.911
	PM Baseline/2	315,073	520(3)	545(1)	1167	1222	.450	.471	.810	.849
	Total	644,885	536	552	2462	2535	.949	.978	1.708	1.760

Note: Number of samples used to determine average (avg.)

TABLE I
SUMMARY OF AVERAGED TEST RESULTS
MILTON YOUNG

Date	Phase/ Duct	Flow (SCFMD)	Concentration (PPM)		Emission Rate (lb/hr)		Emission Rate (lb/MMBTU)		Emission Rate (Gm/10^6 cal)	
			EPA-7	Teco	EPA-7	Teco	EPA-7	Teco	EPA-7	Teco
10/9	Baseline/1	307,136	491(5)	528(4)	1075	1155	.404	.434	.727	.780
	Baseline/2	308,738	NM	-	NM	-	NM	-	NM	-
	Total	615,874	NM	-	NM	-	NM	-	NM	-
	High Air/1	329,243	609(5)	617(5)	1427	1446	.529	.536	.952	.965
	High Air/2	322,985	626(3)	640(1)	1444	1476	.536	.548	.965	.986
	Total	652,228	617	628	2871	2922	1.065	1,084	1.917	1.951
	Baseline/1	316,547	635(5)	622(5)	1439	1410	.531	.520	.956	.936
	Baseline/2	316,837	NM	-	NM	-	NM	-	NM	-
	Total	633,384	NM	-	NM	-	NM	-	NM	-
10/10	Baseline/1	309,868	534(5)	536(5)	1178	1182	.440	.441	.792	.795
	Baseline/2	309,642	NM	-	NM	-	NM	-	NM	-
	Total	619,510	NM	-	NM	-	NM	-	NM	-
	High Air/1	325,610	519(5)	542(5)	1204	1257	.450	.470	.810	.846
	High Air/2	316,319	517(3)	540(1)	1194	1221	.447	.457	.805	.822
	Total	641,929	518	541	2398	2478	.897	.927	1.615	1.668

TABLE I
SUMMARY OF AVERAGED TEST RESULTS
MILTON YOUNG

Phase/Duct	Gas Flow (SCFMD)	Concentration (PPM)		Emission Rate (lb/hr)		Emission Rate (lb/MMBTU)		Emission Rate (Gm/10^6 cal)	
		EPA-7	Teco	EPA-7	Teco	EPA-7	Teco	EPA-7	Teco
Average Baseline/1	316,691	551 (38)	568 (29)	1224	1284	.468	.483	.843	.869
Average Baseline/2	311,416	580 (6)	623 (2)	1270	1363	.478	.513	.860	.923
Total Baseline (6 Test Periods)	628,106	566	596	2494	2647	.946	.996	1.703	1.793
Average Low Air/1	313,926	461 (5)	470 (5)	1032	1052	.398	.405	.716	.730
Average Low Air/2	307,787	NM	NM	NM	NM	NM	NM	NM	NM
*Total Low Air (1 Test Period)	621,713	NM	NM	2044	2083	.788	.802	1.418	1.446
Average High Air/1	327,427	564 (10)	580 (10)	1316	1352	.490	.503	.882	.905
Average High Air/2	319,652	572 (6)	590 (2)	1319	1349	.492	.503	.886	.905
Total High Air (2 Test Periods)	647,079	568	585	2635	2701	.982	1.006	1.768	1.810

AVG. BASELINE: $2494 \frac{lb\ NO_x}{hr} \times \frac{1\ hr}{409{,}000\ lbs} \times \frac{2000\ lbs}{ton} = 12.2$ lb NO_x/ton on as-rec'd basis

AVG LOW AIR: $2044 \times \frac{1}{409{,}000} \times 2000 = 10.0$

AVG HI AIR: $2635 \times \frac{1}{412{,}000} \times 2000 \sim 12.8$

*Totals based on Duct 1 emissions times ratio of total flow to Duct 1 flow.

TABLE IA
AVERAGE EXCESS AIR
MILTON YOUNG

		ORSAT DATA				
		CO_2	O_2	CO	N_2	EA*
Baseline	10/7	15.91	3.71	.07	80.31	21.0
	10/8 AM	16.0	4.05	.0	79.95	23.7
	10/8 PM	16.05	3.5	.1	80.35	19.4
	10/9 AM	16.05	3.7	.45	79.8	19.8
	10/9 PM	16.0	3.75	.1	80.15	21.2
	10/10	16.3	3.6	.15	79.95	20.0
Low Air	10/8	16.3	3.5	.35	79.85	18.7
High Air	10/9	15.35	4.05	.1	80.5	23.2
	10/10	15.8	3.85	.15	80.2	21.7
Avg. Baseline		16.05	3.72	.145	80.09	20.85
Avg. Low Air		16.3	3.5	.35	79.85	18.7
Avg. High Air		15.58	3.95	.125	80.35	22.45

*Excess air calculations based on EPA equation

avg CO = .145% = 1450 ppm

$\frac{lb\,CO}{hr}$ 1450 ppm × 4.3×10⁻⁶ × 630,000 scfm = 3928

3928 lb/hr × 1 lb / 470,000 lb coal × 2000 lb coal / ton = 19 lb/ton

(roughly 0 - 60 lb/ton)

TABLE II
TEST RESULTS

Date	Time	Concentration (ppm) EPA-7	Concentration (ppm) Teco	lbs/hr* EPA-7	lbs/hr* Teco	lbs/MMBTU* EPA-7	lbs/MMBTU* Teco	Gms/10^6 cal* EPA-7	Gms/10^6 cal* Teco
	Preliminary - 1 Duct - 1								
10/5	1410	394	400			-	-	-	-
	1415	425	460						
	1420	461	500						
	Preliminary - 1 Duct - 2								
	1445	461							
	1455	485							
	1500	440							
	Base Line Duct - 1								
10/7	0830	489	480	1119	1100	.412	.405	.742	.729
	0900	500	480	1145	1099	.422	.405	.759	.729
	0930	412	365	943	835	.348	.308	.625	.554
	1000	385		880		.324		.583	
	1030	421		898		.331		.595	
	1100	546		1166		.429		.773	
	1130	479		1061		.391		.703	
	1200	594	700	1315	1550	.484	.570	.871	1.03
	1230	625	700	1332	1491	.490	.549	.883	.989
	1300	578		1232		.454		.817	
	1330	628	680	1356	1468	.499	.541	.899	.973
	1400	666	665	1438	1435	.529	.528	.953	.951
	1430	597		1238		.456		.820	
	Base Line Duct - 2								
10/7	1215	639		1372		.505		.909	
	1215	609	700	1308	1503	.482	.554	.867	.996
	1215	671		1440		.530		.954	
	Base Line Duct - 1								
10/8	0800	564		1311		.483		.869	

* These emissions are calculated for each duct to determine total emission. The emission from both ducts must be added together.

Note: The maxima and minima for each test phase is underlined.

TABLE II
TEST RESULTS
(Continued)

Date	Time	Concentration (ppm) EPA-7	Concentration (ppm) Teco	lbs/hr* EPA-7	lbs/hr* Teco	lbs/MMBTU* EPA-7	lbs/MMBTU* Teco	Gms/10^6 cal* EPA-7	Gms/10^6 cal* Teco
	0830	566	600	1315	1396	.484	.537	.871	.966
	0900	562	600	1341	1431	.494	.550	.889	.991
	0900	530		1266		.466		.839	
	1000	577	545	1377	1302	.507	.501	.912	.902
	Low Air Duct - 1								
10/8	1030	447	460	1001	1030	.387	.397	.663	.715
	1100	408	430	914	963	.337	.371	.606	.668
	1130	484	480	1082	1070	.398	.41	.717	.74
	1200	482	480	1079	1070	.397	.41	.715	.74
	1230	483	500	1082	1120	.398	.43	.717	.77
	Base Line Duct - 1								
10/8	1300	524	540	1237	1274	.455	.492	.820	.885
	1330	558	560	1318	1322	.485	.510	.873	.918
	1400	542	565	1270	1323	.468	.510	.842	.918
	1430	560	560	1312	1312	.483	.483	.869	.869
	1500	571	570	1338	1335	.493	.515	.887	.927
	Base Line Duct - 2								
10/8	1315	516		1157		.426		.767	
	1315	554	545	1243	1222	.458	.471	.824	.849
	1315	491		1100		.405		.729	
	Base Line Duct - 1								
10/9	0800	473		1039		.383		.689	
	0830	503	520	1106	1143	.407	.429	.733	.772
	0900	503	520	1097	1134	.404	.426	.727	.766
	0930	472	520	1029	1133	.379	.425	.682	.766
	1000	506	550	1105	1201	.407	.451	.732	.811
	High Air Duct - 1								
10/9	1030	581	605	1379	1435	.508	.533	.914	.959
	1100	586	600	1390	1423	.512	.528	.921	.950
	1130	655	620	1523	1442	.561	.535	1.009	.963
	1200	598	620	1391	1442	.512	.535	.922	.963
	1230	624	640	1450	1487	.534	.552	.961	.993

TABLE II
TEST RESULTS
(Continued)

Date	Time	Concentration (ppm) EPA-7	Concentration (ppm) Teco	lbs/hr* EPA-7	lbs/hr* Teco	lbs/MMBTU* EPA-7	lbs/MMBTU* Teco	Gms/10^6 cal* EPA-7	Gms/10^6 cal* Teco
	High Air Duct - 2								
10/9	1145	632		1459		.537		.967	
	1145	610	640	1407	1476	.518	.548	.932	.986
	1145	635		1465		.539		.971	
	Base Line Duct - 1								
10/9	1300	621	620	1381	.378	.508	.509	.915	.916
	1330	615	610	1368	1356	.504	.501	.907	.901
	1400	631	630	1445	1442	.532	.532	.958	.958
	1430	684	640	1567	1466	.577	.541	1.038	.974
	1500	626	610	1434	1397	.528	.516	.950	.928
	Base Line Duct - 1								
10/10	0800	518	540	1150	1199	.423	.441	.762	.794
	0830	517	520	1148	1154	.423	.425	.761	.765
	0900	550	540	1209	1186	.445	.437	.801	.786
	0930	560	560	1232	1232	.454	.454	.817	.817
	1000	524	520	1152	1143	.424	.421	.763	.757
	High Air Duct - 1								
10/10	1030	503	530	1175	1238	.433	.456	.779	.8199
	1100	518	540	1211	1262	.446	.465	.802	.836
	1130	464	540	1070	1245	.394	.458	.709	.824
	1200	538	540	1242	1246	.457	.459	.823	.826
	1230	573	560	1322	1291	.487	.475	.876	.856
	High Air Duct - 2								
10/10	1145	513		1185		.436		.785	
	1145	506	540	1169	1221	.430	.457	.775	.822
	1145	532		1228		.452		.814	

TABLE III

MILTON YOUNG - NORTH DAKOTA

VOLUMETRIC FLOW

Date & Phase	Time	Plant Load (MW)	Duct No.	Duct Temp. (°F)	Orsat Data CO_2	Orsat Data O_2	Orsat Data CO	Moisture (%v/v)	Gas Flow Rates Actual (ACFMW)	Gas Flow Rates Standard Dry (SCFMD)
10/7	0830	251	1	309	15.8	4.2	.0	12.68	612,680	321,028
			2	323					578,510	297,704
Baseline	0930		1	300	14.8	4.2	.2		605,370	320,954
			2						565,080	300,384
	1030		1	306	16.0	3.4	.1	15.1	585,480	299,442
			2	309					587,860	299,487
	1130		1	291	16.0	3.6	.0		594,490	310,715
			2	302					598,740	309,608
	1230		1	284	16.0	3.7	.0	14.61	566,780	299,020
			2	289					572,050	300,941
	1330		1	305	16.0	3.9	.1		587,617	302,665
			2	269					576,313	310,305
	1430		1	318	16.8	3.0	.1		573,772	290,595
			2	259					558,764	306,216
10/8	0800	252	1	309	16.0	4.0	.0	10.3	605,495	326,036
			2	327					597,826	313,336
Baseline	0900		1	321	16.0	4.1	.0		633,968	334,832
			2	326					599,884	316,028
10/8	1030	251	1	319	16.3	3.5	.5	10.76	577,378	314,001
			2	327					576,060	310,100
Low Air	1130		1	318	16.3	3.5	.2		590,710	313,850
			2	317					576,187	305,474
10/8	1300	251	1	326	15.9	3.9	.2	12.7	628,967	331,114
			2	333					600,809	314,584
Baseline	1400		1	324	16.2	3.1	.0		620,055	328,510
			2	328					598,655	315,562
10/9	0800	252	1	310	16.0	3.8	.6	13.93	585,798	308,188
			2	308					579,909	306,810
Baseline	0900		1	310	16.1	3.6	.3		581,799	306,083
			2	314					591,353	310,667
10/9	1030	254	1	312	15.4	3.9	.2	12.82	625,679	332,550
			2	320					610,680	322,458
High Air	1130		1	317	15.3	4.2	.0		614,890	325,935
			2	341					631,539	323,512

TABLE III

MILTON YOUNG - NORTH DAKOTA

VOLUMETRIC FLOW

(Continued)

Date & Phase	Time	Plant Load (MW)	Duct No.	Duct Temp. (°F)	Orsat Data CO_2	Orsat Data O_2	Orsat Data CO	Moisture (%v/v)	Gas Flow Rates Actual (ACFMW)	Gas Flow Rates Standard Dry (SCFMD)
10/9	1300	256	1	321	16.0	3.8	.2	12.76	591,154	311,962
			2	330					615,137	319,931
Baseline	1400		1	328	16.0	3.7	.0		613,982	321,131
			2	344					614,339	313,743
10/10	0800	252	1	313	16.3	3.8	.1	12.84	592,804	311,518
			2	326					601,542	312,064
Baseline	0900		1	309	16.3	3.4	.2		579,742	308,218
			2	314					581,841	307,219
10/10	1030	251	1	312	15.9	3.6	.3	12.21	618,847	327,605
			2	326					591,600	308,746
High Air	1130		1	319	15.7	4.1	.0		617,085	323,614
			2	333					626,330	323,892

TABLE IV

SUMMARY OF PLANT OPERATING DATA

MILTON YOUNG BOILER NO. 1

OPERATING CONDITIONS

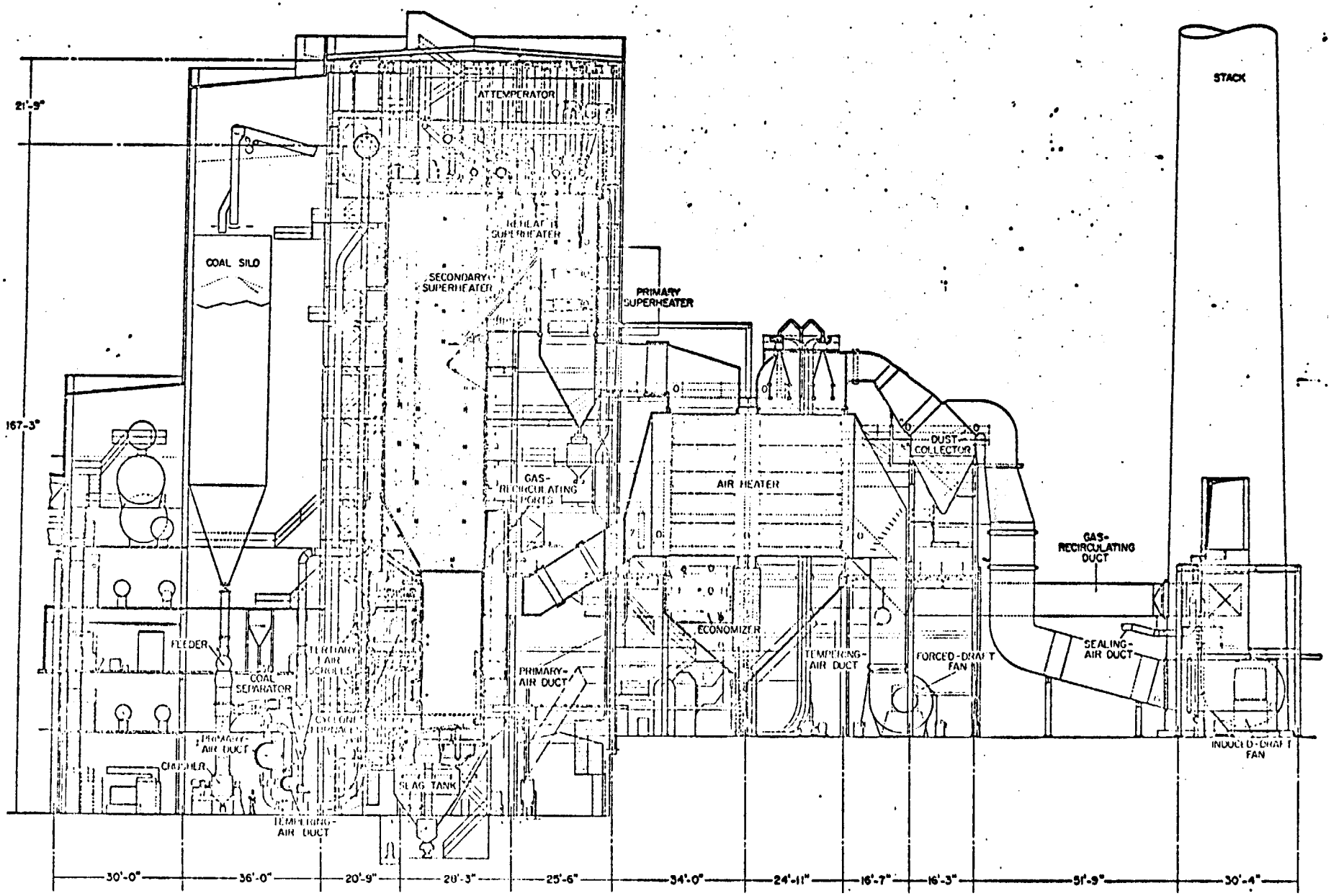
Date	Time	Gross MW	Coal Feed Rate (lbs/hr, as recd)	BTU/lb Coal	Gross Heat Input MMBTU/hr	% Excess Burner Air*	% Excess Total Air*	Test Phase
10/7/74	08.30-14.30	251	409,000	6641	2716	6	21	Base Line
10/8/74	08.00-10.00	252	410,000	6341	2600	7	22	Base Line
	10.30-12.30	251	409,000	6341	2593	2	17	Low Air
	13.00-15.00	251	409,000	6341	2593	7	22	Base Line
10/9/74	08.00-10.00	252	410,000	6497	2664	7	22	Base Line
	10.30-12.30	254	415,000	6497	2696	9	24	High Air
	13.00-15.00	256	417,000	6497	2709	6	21	Regular Air
10/10/74	08.00-10.00	252	410,000	6535	2679	6	21	Base Line
	10.30-12.30	251	409,000	6535	2673	6**	24	High Air
	AVG BASELINE -	252	410,000	~6500				
	HIGH AIR		412,000					
	LOW AIR		409,000					

* Measured between air heater tube banks. Excess air is measured with Bailey Model A610, Type OC1530A Analyzer.

** This value appears different than expected from data trend.

III. PROCESS DESCRIPTION AND OPERATION

Milton R. Young Station #1 is a 234 MW steam electric plant which burns crushed lignite (¼" size) in a boiler desinged by Babcock and Wilcox, using cyclone burners. There are a total of five burners located on the front wall of the furnace. Crushed lignite is fired tangentially into each burner at a high velocity creating a vortex effect. The burner temperature is maintained at a sufficiently high temperature to melt the fly ash and thereby create a molten layer of ash on the inside surface of the burner. The ash is continuously tapped from the burner and is drained out through the bottom of the furnace. In order to maintain the high temperatures within the burner relatively low excess air is used. Additional air is added to the hot gases after they leave the burners. This plant was put into operation in 1970 and, at the present time, is the only operating cyclone design firing lignite. However, three additional units, all 440 MW, are currently under construction.



MINNKOTA POWER COOPERATIVE, INC.
CENTER POWER PLANT – UNIT NO. 1
CENTER, NORTH DAKOTA
B & W CONTRACT NO. RB-457

MILTON R. YOUNG STATION

V. SAMPLING AND ANALYTICAL PROCEDURES

The sampling at each plant consisted of the following tests:

Nitrogen Oxides - EPA Method 7
Nitrogen Oxides - NOx Analyzer
Orsat - EPA Method 3
Moisture Determination - EPA Method 4
Velocity and Flow - EPA Method 2

Nitrogen Oxides

The Nitrogen Oxide emissions were determined by two methods. The first was by use of grab flasks, following procedures outlined in EPA Method 7 (Figure 3) the second method was by Thermo Electron Corporation, "Chemiluminescent NOx Analyzer".

The principle of operation for this analyzer involves a phenomenon once classified as a laboratory curiosity. The chemiluminescent reaction of NO and O_3 provides the basis for this improved group of instruments.

Light emission results when electrically excited NO_2 molecules revert to their ground state.

To measure NO concentrations, the gas sample to be analyzed is blended with O_3 in a flow reactor. The resulting chemiluminescence is monitored through an optical filter by a high sensitivity photomultiplier positioned at one end of the reactor. The filter-photomultiplier combination responds to light in a narrow wavelength band unique to the above reaction. The flow parameters can be adjusted in such a way that the output from the photomultiplier is linearly proportional to the NO concentration.

To measure NOx concentrations, the sample gas flow is diverted through an NO_2-to-NO converter. The chemiluminescent response in the flow reactor to the converter effluent is linearly proportioned to the NOx concentration entering the converter. (See Figure #4)

Orsat

Gas composition was determined using leveling bottles and orsat unit. Each sample was integrated over a period of approximately one hour (See Figure #5)

Moisture

The percent moisture in the flue gas was determined by following procedures outlined in EPA Method 4 (see Figure 6)

Velocity and Flow

The velocity and flow at the sampling point was determined by

following procedures outlined in EPA Method 2 (See Figure 7).

Coal Sampling

Approximately 5-10 lbs of coal were collected from each feeder equally spaced over a two hour period. A new coal sample was collected to correspond with each excess air change and baseline test phase. Each sample was riffled twice after collection from each feeder and the pretained portion was added to the composite pile.

At the end of each test the composite pile was then riffled and reduced to two quarts.