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Research Triangle Park NC 27711

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May 1980

Air

EPA

Nonfossil Fueled Boilers

Emission Test Report
U.S. Sugar Company
Bryant, Florida

NONFOSSIL FUELED BOILERS

Emission Test Report
U.S. Sugar Company
Bryant, Florida

Project No.: 80-WFB-6

Prepared for

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

by

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SECTION 1

INTRODUCTION

The Bryant Mill of U.S. Sugar Corporation in Bryant, Florida was emission tested by Monsanto Research Corporation (MRC) for the U.S. Environmental Protection Agency (EPA) under Contract No. 68-02-2818, Work Assignment No. 25. The objective of the sampling program was to obtain emissions data from well-controlled sources within the nonfossil fuel boilers category that could possibly be used for the development of new source performance standards.

The field test work was monitored by Dan Bivins, Field Testing Section, Emission Measurement Branch, EPA. The sampling performed by MRC was directed by Charles F. Duncan as team leader. Gaseous and particulate emissions were determined at the outlet of the pollution control device serving Boiler #2. A composite sample of boiler feed was collected with each run so that a material balance could be attempted.

The sampling at the Bryant Mill was conducted by MRC during December 16-18, 1979. The collection methods employed were EPA Methods 1, 2, 3, 4, 5, 6, 7, and 9, with particulate sizing by Andersen cascade impactor.

Quality assurance/quality control in the sampling area covered such activities as instrument calibration, using standard or approved sampling methods, chain-of-custody procedures, and protocols for the recording and calculation of data. QA/QC in the analysis area involved using only validated analysis methods, periodic operator QC checking and training, sample QC by the use of splits, reference standards, and spikes, and interlaboratory audits.

SECTION 2

SUMMARY OF RESULTS

Pollutants which were measured for this emission test were particulate matter, particle size, CO_2, CO, SO_2, NO_x, and plume opacity. Table 1 presents the sampling and analysis schedule in condensed form.

TABLE 1. BRYANT PLANT SAMPLING AND ANALYSIS SCHEDULE

Sampling site	Total number of samples	Sample type	Sampling method	Minimum sampling time	Initial analysis	
					Type	Method
Scrubber outlet	3	Particulate matter	EPA 5	60 min		
Scrubber outlet	3	Particle-size distribution	Andersen			
Scrubber outlet	3	Integrated gas analysis	EPA 3		CO_2, O_2, CO	EPA 3
Scrubber outlet	3	SO_2	EPA 6, option 2	Same as Method 5		
Scrubber outlet	3 runs, 4 samples each	NO_x	EPA 7	15 min intervals		
Scrubber outlet	3	Opacity	EPA 9			
Scrubber outlet	3 samples, 2 fuel analyses each	ASTM			Ultimate analysis and heating value	ASTM

The Bryant Mill operates three waste-fired boilers fed with bagasse. The center boiler, Boiler #2, was tested. Boiler #2 utilizes dual scrubbers in parallel for pollution abatement. The outlet stack is located directly above the scrubbers.

Three test runs were performed, each consisting of 96 minutes of sampling time. Forty-eight traverse points were used, six points in each of the eight sampling ports. The first run was completed December 17. During the run, the boiler operated normally, in the range of 145,000 to 160,000 lb/hr of steam, until more than halfway through the test, when the bagasse feed was interrupted. The steam loading dropped to about 60,000 lb/hr and oil began to be burned. The test was interrupted several minutes after the drop in steam loading and was begun again after the bagasse feed rate and the boiler operation returned to normal almost 2 hours later. During the last several minutes of the test before the interruption, about 75 gal of oil was burned. Bagasse alone was burned the remainder of the run.

The remaining two runs of the test were completed on December 18. Through both runs the boiler operated normally and bagasse alone was burned. The steam loading ranged from 125,000 to 165,000 lb/hr, with an average of 151,000 lb/hr, in Run 2 and from 130,000 to 170,000 lb/hr, with an average of 144,000 lb/hr, in the third run. Both runs were within the normal operating range. During the third run, soot blowing was performed.

Tables 2 and 3 contain the summarized particulate emission data and stack gas parameters. Moisture in the stack gas was unusually high -- 32 percent H_2O. Integrated gas analysis results for each run are given in Table 4.

Table 5 contains a summary of the particle sizing results; each Andersen cascade impactor run was made after completing a Method 5 run. The #1 impactor test was discarded because the filter media was soaked with water. Due to the boiler #2 plume merging with the other boilers' plumes, opacity readings were not able to be made.

Samples for SO_2 emissions were taken concurrently with particulate emission runs by using the back half of the Method 5 train. Due to the very low sulfur content of the bagasse feed, emissions of SO_2 were below the detection limit (3.4 mg SO_2/m^3) of Method 6, and no data are presented.

Samples for NO_x emissions were collected just after each particulate emission test and are summarized in Table 6.

Composite fuel samples of bagasse were taken with each run from the conveyor feeding the boiler, and ultimate analysis and fuel values were determined. A fuel oil sample from run #1 was also collected and analyzed for fuel value. Table 7 presents the fuel analysis results.

A summary of boiler operating conditions during testing is given in Table 8. Average steam temperatures and pressures were determined by averaging 15-min readings in order to calculate steam enthalpy.

TABLE 2. PARTICULATE EMISSION DATA AND STACK GAS PARAMETERS, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979 (ENGLISH UNITS)

Run number	Date	Time, min	Stack temperature, °F	Flow, dscfm	H_2O, %	Isokinetic, %	Emissions			
							Actual			Corrected to 12% CO_2
							gr/dscf	lb/hr	lb/mm Btu	gr/dscf
1	12/17/79	96	161	58,515	31.3	105.7	0.1298	65.1	0.3505	0.1442
2	12/18/79	96	164	58,720	33.1	105.6	0.1001	50.4	0.2547	0.1082
3	12/18/79	96	162	58,825	31.7	101.6	0.1135[a]	57.2	0.3034	0.1205[a]
Average		96	162	58,687	32.0		0.1145	57.6	0.3029	0.1243

[a]Run #3 included a soot blow.

TABLE 3. PARTICULATE EMISSION DATA AND STACK GAS PARAMETERS, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979 (METRIC UNITS)

Run number	Date	Time, min	Stack temperature, °C	Flow, dncmpm	H_2O, %	Isokinetic, %	Emissions			
							Actual			Corrected to 12% CO_2
							gr/dncm	kg/hr	kg/GJ	gr/dncm
1	12/17/79	96	72	1,657	31.3	105.7	0.2971	29.5	0.1506	0.3301
2	12/18/79	96	73	1,663	33.1	105.6	0.2292	22.9	0.1097	0.2478
3	12/18/79	96	72	1,666	31.7	101.6	0.2599[a]	26.0	0.1307	0.2760[a]
Average		96	72	1,662	32.0		0.2621	26.1	0.1303	0.2846

[a]Run #3 included a soot blow.

TABLE 4. SUMMARY OF INTEGRATED GAS ANALYSES, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Run number	Date	CO_2, %	CO, %	O_2, %	N_2, %	MW lb/lb mole
1	12/17/79	10.8	0.0	9.2	80.0	30.1
2	12/18/79	11.1	0.0	9.0	79.9	30.1
3	12/18/79	11.3	0.0	9.4	79.3	30.2
Average		11.1	0.0	9.2	79.7	30.1

TABLE 5. SUMMARY OF ANDERSEN PARTICLE SIZING RESULTS, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Run No. 1

Discarded

Run No. 2

Flow rate = 0.927 acfm
Isokinetic rate = 107.1%

Stage	Size range	Percent in size range	Cumulative % <size range
Preimpactor	>10.50	3.99	94.55
0	>10.50	1.46	94.55
1	6.50 - 10.50	3.06	91.52
2	4.30 - 6.50	7.98	83.54
3	2.95 - 4.30	11.30	72.24
4	1.88 - 2.95	12.40	59.94
5	0.94 - 1.88	12.90	46.94
6	0.58 - 0.94	19.15	27.79
7	0.39 - 0.58	16.49	11.30
Filter	0.0 - 0.39	11.30	0

Run No. 3

Flow rate = 0.908 acfm
Isokinetic rate = 105.5%

Stage	Size range	Percent in size range	Cumulative % <size range
Preimpactor	>10.60	6.56	91.43
0	>10.60	2.01	91.43
1	6.60 - 10.60	4.28	87.14
2	4.40 - 6.60	7.47	79.67
3	3.00 - 4.40	8.66	71.01
4	1.90 - 3.00	8.66	62.35
5	0.96 - 1.90	10.48	51.87
6	0.59 - 0.96	20.60	31.27
7	0.40 - 0.59	16.68	14.59
Filter	0.0 - 0.40	14.59	0

TABLE 6. SUMMARY OF NO_x EMISSIONS, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Run number	Date	ppm	lb/dscf ($\times 10^{-6}$)	lb/hr[a]	lb/mm Btu ($\times 10^{-3}$)	gm/ncm ($\times 10^{-2}$)	kg/hr[a]	kg/GJ ($\times 10^{-4}$)
1-1	12/17/79	0.572	0.068	0.237	1.276	0.108	0.108	5.511
1-2		0.402	0.048	0.167	0.899	0.076	0.076	3.906
1-3		0.525	0.062	0.218	1.174	0.099	0.099	5.502
1-4		0.751	0.089	0.312	1.680	0.142	0.141	7.196
Average		0.563	0.067	0.234	1.257	0.106	0.106	5.529
2-1	12/18/79	1.222	0.145	0.510	2.577	0.232	0.231	11.064
2-2		1.119	0.132	0.467	2.360	0.212	0.212	10.154
2-3		0.580	0.069	0.242	1.223	0.110	0.110	5.268
2-4		0.079	0.093	0.329	1.663	0.150	0.149	7.137
Average		0.928	0.110	0.387	1.956	0.176	0.176	8.406
3-1	12/18/79	0.751	0.089	0.314	1.665	0.142	0.142	7.138
3-2		1.090	0.129	0.455	2.413	0.207	0.206	10.355
3-3		1.776	0.210	0.742	3.936	0.337	0.336	16.890
3-4		0.367	0.043	0.153	0.811	0.069	0.069	3.468
Average		0.996	0.118	0.416	2.206	0.189	0.188	9.463

[a]Based on corresponding Method 5 run for volumetric flow rate.

TABLE 7. SUMMARY OF FUEL ULTIMATE ANALYSES, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Bagasse conveyor feed to boiler	Carbon %	Hydrogen %	Nitrogen %	Sulfur %	Ash %	Oxygen %	Fuel value (Btu/lb)
Run #1							
as rcvd	19.99	8.87	0.15	0.01	0.47	70.51	3,406
dry basis	46.59	5.90	0.36	0.01	1.09	46.05	7,939
Run #2							
as rcvd	18.38	9.00	0.15	0.01	1.13	71.33	3,210
dry basis	46.38	5.77	0.39	0.01	2.85	44.60	8,101
Run #3							
as rcvd	19.57	8.90	0.17	0.01	0.67	70.68	3,480
dry basis	46.31	5.88	0.40	0.01	1.58	45.82	8,233
Fuel oil (No. 6) from Run #3	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]	18,524

[a]Ultimate analysis on fuel oil not performed.

TABLE 6. SUMMARY OF NO_x EMISSIONS, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Run number	Date	ppm	lb/dscf ($\times 10^{-6}$)	lb/hr[a]	lb/mm Btu	gm/ncm	kg/hr[a]	kg/GJ ($\times 10^{-3}$)
1-1	12/17/79	57.2	6.76	23.7	0.1276	0.1083	10.77	55.11
1-2		40.2	4.76	16.7	0.0899	0.0762	7.58	39.06
1-3		52.5	6.21	21.8	0.1174	0.0994	9.89	55.02
1-4		75.1	8.88	31.2	0.1680	0.1423	14.15	71.96
Average		56.3	6.65	23.4	0.1257	0.1066	10.60	55.29
2-1	12/18/79	122.2	14.46	51.0	0.2577	0.2317	23.11	110.64
2-2		111.9	13.25	46.7	0.2360	0.2122	21.17	101.54
2-3		58.0	6.86	24.2	0.1223	0.1099	10.97	52.68
2-4		7.9	9.35	32.9	0.1663	0.1498	14.94	71.37
Average		92.8	10.98	38.7	0.1956	0.1759	17.55	84.06
3-1	12/18/79	75.1	8.88	31.4	0.1665	0.1423	14.22	71.38
3-2		109.0	12.90	45.5	0.2413	0.2065	20.65	103.55
3-3		177.6	21.02	74.2	0.3936	0.3366	33.65	168.90
3-4		36.7	4.34	15.3	0.0811	0.0695	6.94	34.68
Average		99.6	11.79	41.6	0.2206	0.1887	18.87	94.63

[a]Based on corresponding Method 5 run for volumetric flow rate.

TABLE 7. SUMMARY OF FUEL ULTIMATE ANALYSES, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

Bagasse conveyor feed to boiler	Carbon %	Hydrogen %	Nitrogen %	Sulfur %	Ash %	Oxygen %	Fuel value (Btu/lb)
Run #1							
as rcvd	19.99	8.87	0.15	0.01	0.47	70.51	3,406
dry basis	46.59	5.90	0.36	0.01	1.09	46.05	7,939
Run #2							
as rcvd	18.38	9.00	0.15	0.01	1.13	71.33	3,210
dry basis	46.38	5.77	0.39	0.01	2.85	44.60	8,101
Run #3							
as rcvd	19.57	8.90	0.17	0.01	0.67	70.68	3,480
dry basis	46.31	5.88	0.40	0.01	1.58	45.82	8,233
Fuel oil (No. 6) from Run #3	-[a]	-[a]	-[a]	-[a]	-[a]	-[a]	18,524

[a]Ultimate analysis on fuel oil not performed.

TABLE 8. SUMMARY OF BOILER OPERATIONS DURING TESTING, U.S. SUGAR-BRYANT MILL, DECEMBER 17-18, 1979

	Run 1		Run 2	Run 3
Date	12/17/79		12/18/79	12/18/79
Time start	5:35	8:02	1:22	7:20
Time end	4:22	7:18	11:25	5:25
Total min	73	44	117	115
Steam meter end	530	682	948	392
Steam meter start	445	629	801	254
Total, tons steam	85	53	147	138
Total steam used, lb	276,000		294,000	276,000
Average steam loading, lb/hr	142,000		151,000	144,000
Average steam temperature, °F	575.6		580.6	577.8
Average steam pressure, psig	202.2		202.2	196.7
Steam heat output, mm Btu/hr	185.71		197.87	188.54
Steam heat output, GJ/hr	195.94		208.77	198.93
Bagasse feed rate, ton/hr[a]	41.0		41.0	41.0
No. 6 fuel oil feed rate, gal	75		0	0

[a]Rough estimate based on steam loading provided by EPA contractor observing emission test.

The bagasse feed rate was not measured in the test because no technique for doing so could be devised. There did not appear to be any reasonably accurate method of determining the amount of bagasse carried by the conveyor, dropped off into each feed chute, or moved by the feeder. The mill personnel have never measured or estimated the bagasse feed rate directly and could not offer any suggestions for doing it.

The mill does not have any instrumentation that monitors the scrubber. The only surveillance of the scrubber consists of visually checking the water collected in the bottom of the unit to ensure that it is at the proper level. During the test, the water level was correct, and the scrubber appeared to operate properly.

The test boiler operated normally during all test runs. Even with the drastic drop in steam production in run #1, the average steam load in that run was high enough to present normal operation. Thus, the emission samples taken should be representative of normal boiler operation.

SECTION 3

PROCESS DESCRIPTION

Bagasse is a waste product of the sugar cane extraction process and has a heating value of about 3,600 Btu/lb (wet). The bagasse represents about 30% of the weight of raw sugar cane. In order for the sugar cane mill to avoid a large solid waste disposal problem and to minimize power cost requirements, bagasse is used as the primary fuel for on-site process steam production. No. 6 fuel oil is used to start the boilers and maintain steam production when the bagasse feed fails or become too wet; the Bryant Mill has more bagasse than they can utilize and uses as little fuel oil as possible. Figure 1 shows the schematic process flow diagram for the Bryant Mill.

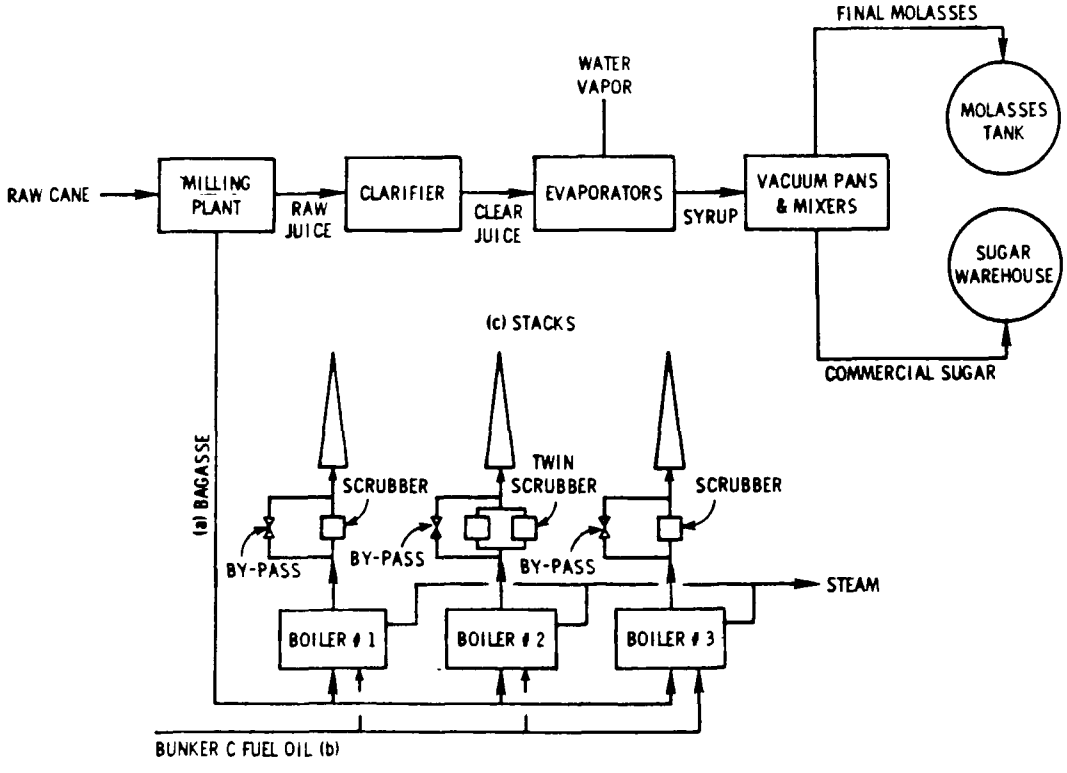

Figure 1. Schematic process flow diagram: Bryant Mill, U.S. Sugar Corp.

At their mill in Bryant, U.S. Sugar Corp. operates three bagasse boilers producing process steam (see Figure 2). All three identical boilers are Riley Stoker Corp. vibrating-grate spreader-stoker boilers, designed for a continuous steam production rate of 120,000 lb/hr and a two-hour peak rate of 132,000 lb/hr. However, Boiler #2 normally operates continuously (with a full bagasse feed rate) in the range of 130,000 to 160,000 lb steam/hr. The overall thermal efficiency for a typical bagasse boiler unit is 55% (ranging from 50% to 70%). In comparison with large fossil-fired steam generators this efficiency range is rather low; however, since bagasse is a plentiful by-product fuel, thermal efficiencies are of secondary importance.

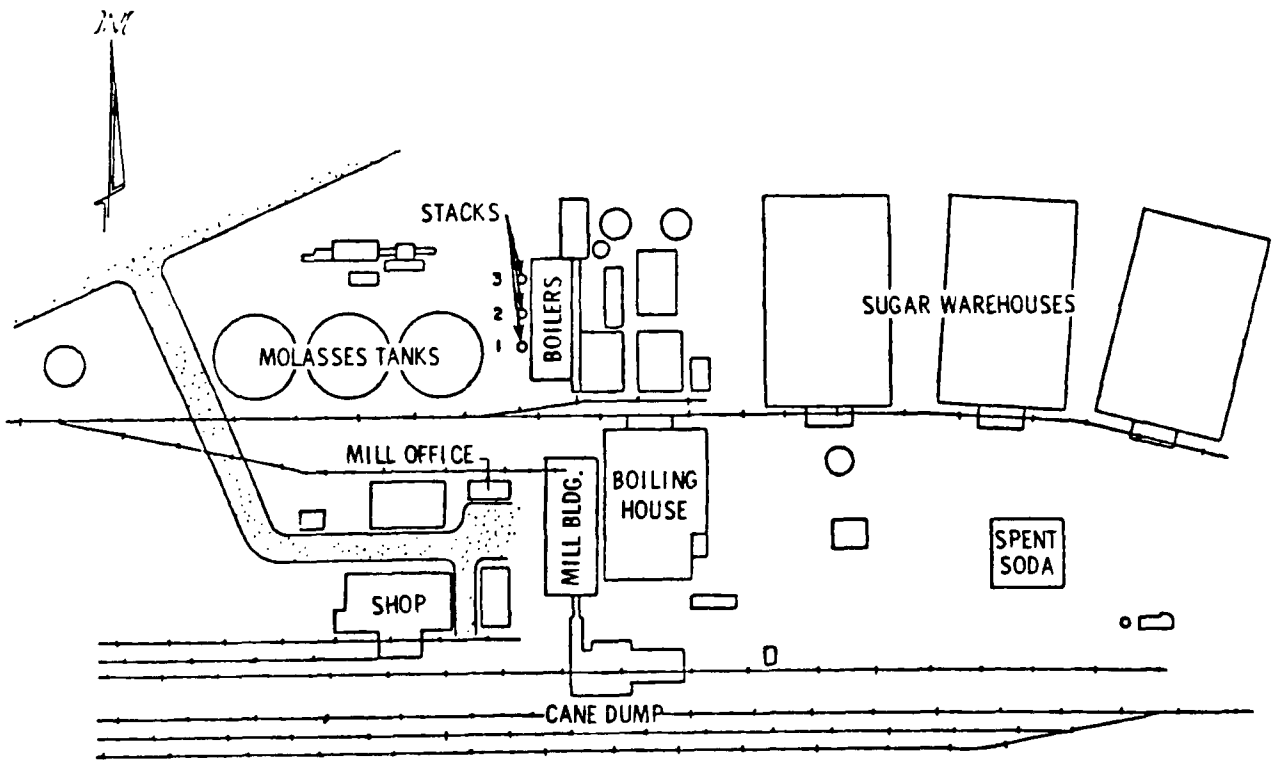

Figure 2. Plot plan: Bryant Mill, U.S. Sugar Corp.

Normal utilization of bagasse in boiler #2 is approximately 64,000 to 82,000 lb/hr. Bagasse alone is burned about 90 percent of the time; fuel oil is burned with a low bagasse feed rate or alone during a disruption of bagasse feed.

One chain conveyor feeds bagasse to all boilers, with a small amount of bagasse falling from each link into each feed chute. There are three feed chutes to the test boiler. A rotary feeder in each chute regulates the bagasse feed rate through the chute.

All three identical boilers are followed by spray impingement scrubber units, similar to the diagram in Figure 3, however, Boiler #2 has a pair of smaller scrubbers in parallel rather than a single scrubber. The scrubbers on Boiler #2 are Joy Manufacturing Co. Turbulaire scrubbers, Size 40, Type D, installed in 1973. A by-pass duct is provided for emergency use, such as for cleaning due to plugging of the scrubber. The scrubbers are placed as close as possible to the boiler air heater containing the water tubes because a single I.D. fan pulls exhaust gases through the scrubbers rather than pushing, and internal drag forces are minimized to save energy. The scrubbers are then ducted to an exhaust stack which terminates 65 ft above ground level. A diagrammatic sketch of the control equipment and site is given in Figure 4.

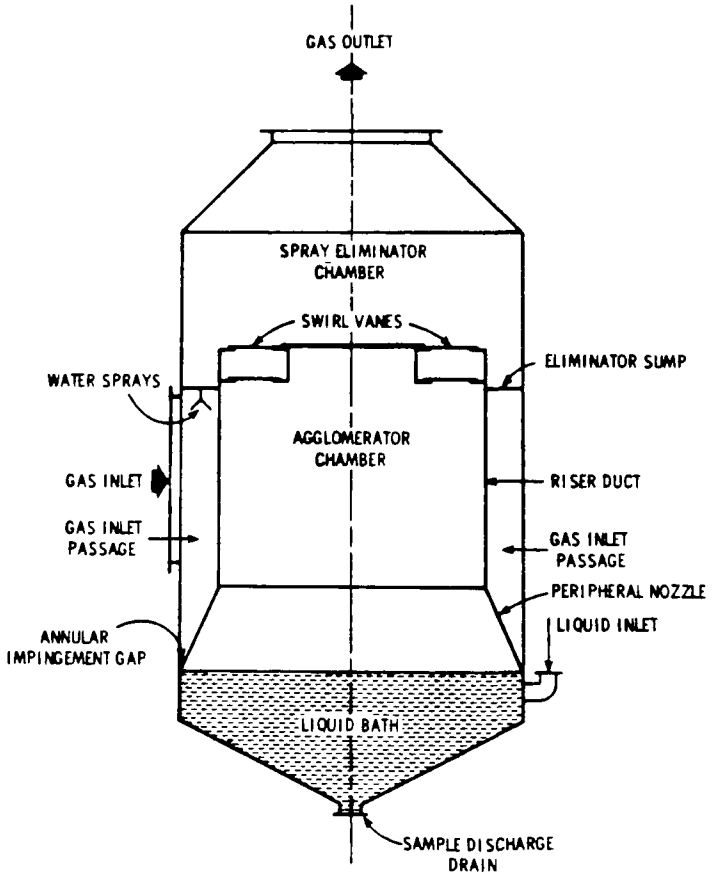

Figure 3. Spray impingement scrubber.

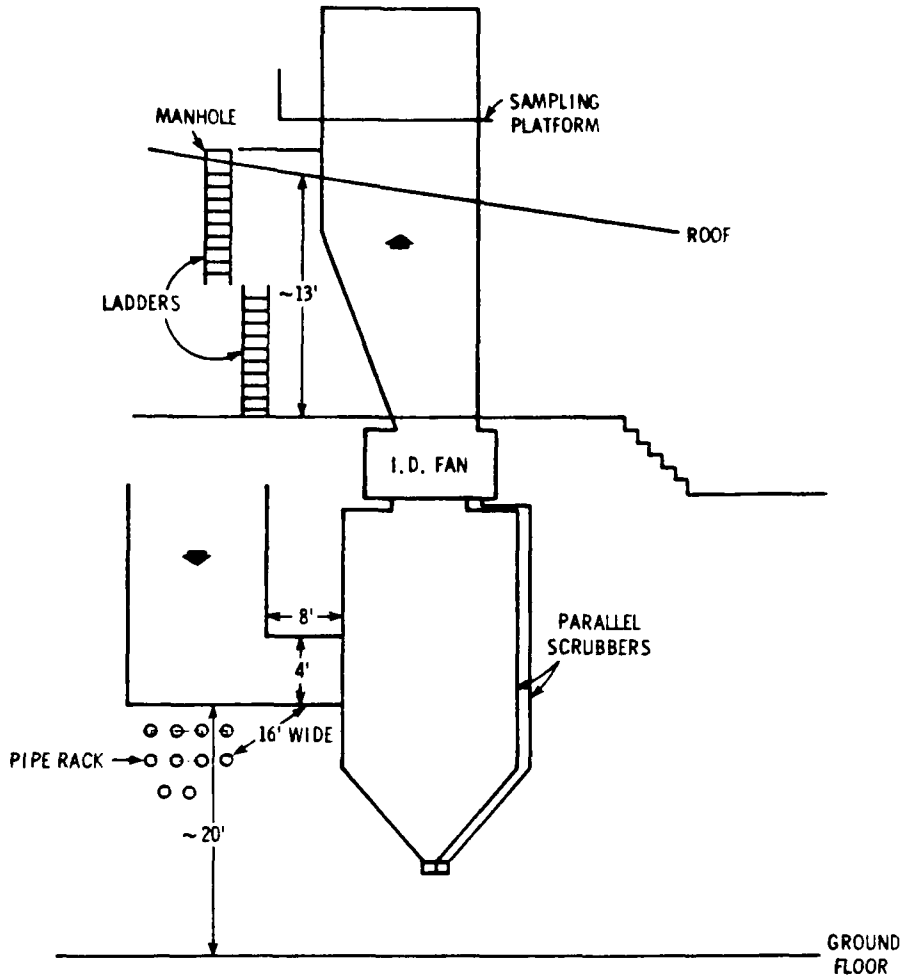

Figure 4. Diagram of Bryant Plant emission control equipment.

The mill operates seasonally, from November through March; normal operating time is 24 hr/day, 7 day/wk.

SECTION 4

LOCATION OF SAMPLING POINTS

At the scrubber inlet on Boiler #2 no suitable locations existed which could meet minimum downstream stack diameter criteria. The scrubber outlet was sampled at the installed stack sampling platform

A diagram of the Boiler #2 exhaust stack above the roof on the scrubber outlet is shown in Figure 5. A rectangular stack 40 in. x 82 in. extends about 10.9 ft above the roof line, and is situated between the stacks of Boilers #1 and #3. Eight 3 in. diameter ports are installed 56 in. above the platform floor. The sampling platform has a guard railing on which is bolt-mounted a 15 in. railing extension placed so that a probe can be supported on it. The top of the stack is 27 in. above the port centerline; the downstream equivalent diameter criteria are narrowly met. The nearest upstream disturbance is a reduction 2.8 diameters away.

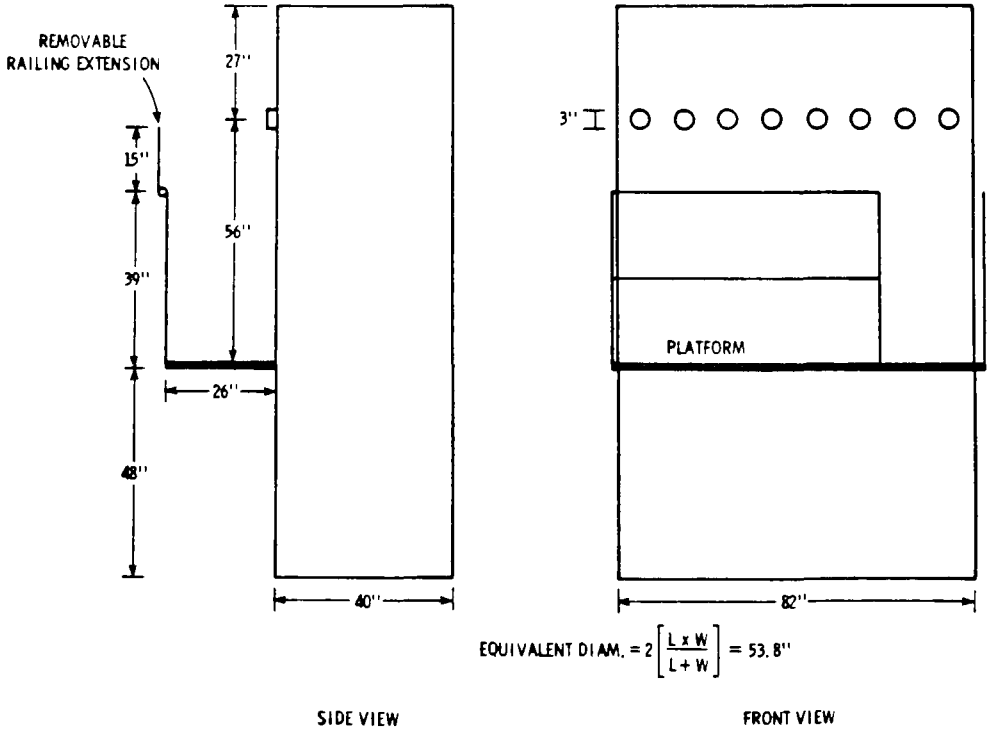

Figure 5. Scrubber outlet/roof stack sampling location.

SECTION 5

SAMPLING AND ANALYTICAL PROCEDURES

The U.S. Sugar Corp., Bryant Mill was sampled for particulate matter, particle size, SO_2, NO_x, integrated gas analysis, and fuel analysis.

The following describes the methods used.

SAMPLING PROCEDURES

Particulate

Sampling for particulates was performed using the method outlined in the Federal Register, Method 5, "Determination of Particulate Emissions from Stationary Sources," modified so that the sample box temperature was maintained at 325°F instead of 250°F.

Particle Size

Sampling for particle size was performed using an Andersen cascade impactor with seven stages and a back-up filter. Because of the presence of entrained water or highly saturated stack gases, it was decided to utilize an impactor preseparator to protect the impactor substrates and jet stages from the effects of water. This was thought superior to a heated impactor because heating may change stage collection efficiencies.

The sampling train used consisted of the following equipment listed in order of the flow: a 10 mm diameter probe tip; a curved (90°) probe tip to Andersen head connector; cyclonic preseparator; standard Andersen heads; a 4 ft stainless steel probe; a Smith-Greenburg impinger with water, then one charged with color indicating silica gel; and an EPA-5 console equipped with a dry gas meter, digital electronic thermometer and an inclined manometer. Also, an S-type pitot tube was connected to the probe so the stack velocity could be continually monitored.

A total of three particle sizing runs were made. Each run was conducted for 13 to 20 min under isokinetic conditions.

At the completion of each run, the moisture collected was measured and the Andersen heads were opened and oven-dried for three hours. After drying, each stage was weighed, then the filter was removed and the stage assemblies were cleaned, desiccated and reweighed to provide partial tare weights. The tare weights of the filters were taken during the assembly of the heads (after desiccation for 24 hr).

All weight measurements were made with a Mettler analytical balance. The balance was calibrated daily and rezeroed before each weight determination. Calculations were performed using the methods and tables provided in the Andersen manual.

Sulfur Dioxide

Sampling for SO_2 was performed using the alternate method outlined in Section 2.1 of the Federal Register, Method 6, "Determination of Sulfur Dioxide Emissions from Stationary Sources." SO_2 was determined simultaneously with particulate matter by replacing the Method 5 water impinger system with a Method 8 isopropanol-filter-peroxide system.

Nitrogen Oxides

Sampling for NO_x was performed using the method outlined in the Federal Register, Method 7, "Determination of Nitrogen Oxide Emissions from Stationary Sources."

Integrated Gas Analysis

Exhaust gas analysis was performed using the method outlined in the Federal Register, Method 3, "Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight."

Fuel

Three samples of bagasse were grabbed from the boiler feed conveyor during each Method 5 run, plus one sample of fuel oil during Run #1.

ANALYTICAL PROCEDURES

Particulate, SO_2, NO_x, Gas Analysis

All analytical procedures were performed using the methods described in EPA Methods 3, 5, 6, and 7, previously mentioned in the Sampling Procedures Section.

Fuel

Analysis of the bagasse feed was performed using ASTM D 3178 for carbon and hydrogen, ASTM D 3176 for oxygen, ASTM D 3179 for

nitrogen, ASTM D 3177 for sulfur, and ASTM D 3174 for ash. Fuel value was determined using ASTM D 2015.

Quality Assurance/Quality Control

Results of quality control tests are furnished with the analytical data sheets provided in Appendix C.

APPENDICES

A. Complete Emission Results
B. Field Data Sheets
C. Analytical Data Sheets
D. Boiler Operating Data
E. Project Participants