FLUE GAS SAMPLING DURING THE COMBUSTION OF SOLVENT REFINED COAL IN A UTILITY BOILER

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Abstract

Solvent Refined Coal was burned in a commercial utility boiler. Flue gas samples were collected using EPA-5, ASME and Source Assessment Sampling System (SASS) trains and grab sampling methodologies. Results of available analyses are reported.

SUMMARY

On June 10th, 1977 Solvent Refined Coal (SRC) was burned in a commercial utility boiler for the first time, for the purpose of determining whether SRC could replace coal as a primary fuel in a pulverized coal-fired boiler. In addition to boiler efficiency tests, flue gas samples were collected using EPA-5, ASME, and Source Assessment Sampling System (SASS) trains.

In previous phases of this program, coal was burned in the same boiler. Similar tests were performed; results were compared with the Phase III SRC test. The results of the comparison indicate that SRC can be used as a replacement for coal in a conventional pulverized coal-fired boiler. Results of the grab sample analysis indicated no detectable levels of C_1 -C_6 hydrocarbons. SO_2 and NO_x emissions/million Btu were approximately the same as those from burning low sulfur coal. Higher concentrations of NO_x were probably attributable to high combustion temperature or higher organic nitrogen in the fuel, although emissions of NO_x were essentially the same as for coal.

A combustion test at Georgia Power Company's Plant Mitchell, located near Albany, Georgia, was performed to determine whether (SRC) can be burned in a pulverized coal-fired boiler. This three-phase test marked the first time that SRC has been burned in a utility boiler. In addition to boiler and precipitator efficiency tests, a detailed inventory of air emissions, including polynuclear aromatic hydrocarbons, was performed.

In Phase I of this program, low sulfur Kentucky coal was burned in the existing, unmodified 22-1/2 MW pulverized coal boiler. Following replacement of the original burners with dual register burners and accompanying modifications, Phase II of the test was conducted. In this phase, as in Phase I, the boiler was fired with low sulfur Kentucky coal. In Phase III, discussed in detail in this report, following adjustment of the burners and the pulverizers, SRC was burned. This SRC had been produced at the Fort Lewis pilot plant from Western Kentucky coals having a sulfur content of approximately 4 percent and ash content of 10 to 12 percent. Sulfur and ash in the SRC as produced were approximately 0.6 percent and 0.1 to 0.2 percent, respectively. At the time of the combustion test the SRC had been stored onsite in the open for approximately one year. Analytical results showed essentially the same sulfur content but an average ash content of approximately 0.6 percent. However, after removal of certain surface contamination by washing, the ash content of the bulk SRC was in the same range as the ash determination in the material shipped. Further investigation is underway to determine the cause of this difference. In each of the three phases of the program, the boiler was operated at full (~ 21 MW), medium (~ 14 MW), and low (~ 7 MW) load conditions.

Precipitator efficiency tests were run, ash resistivity was determined, and air emission levels were evaluated using EPA-5 and ASME trains. In addition to particulates, a number of gases, including CO_2, CO, NO_x, O_2, and SO_2 were monitored.

During Phases II and III, additional flue gas sampling was conducted using a SASS train to collect samples for a modified EPA Level 1 laboratory analysis. Grab samples also were obtained for on-site analysis for C_1 - C_6 hydrocarbons, SO, N_2, CO, CO_2, and O_2.

A diagram of the SASS train is shown in Figure 1. This sampling device includes

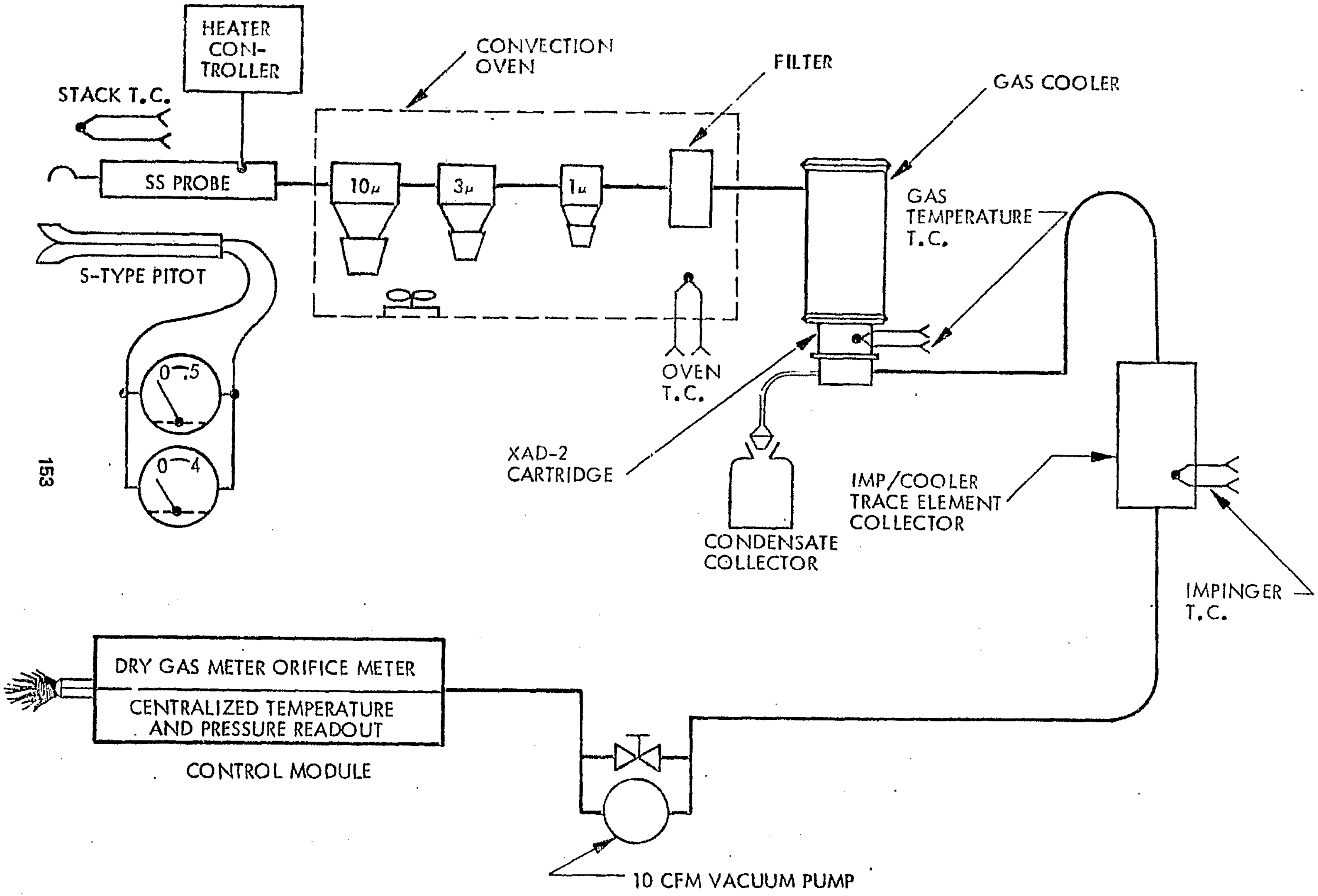

Figure 1. Source assessment sampling schematic.

cyclones and a filter to collect particulates, a sorbent trap to collect C_7 - C_{16} hydrocarbons, impingers, and associated temperature controls, pumps, and meters. The sample is obtained from the flue gas duct by means of a probe inserted through the duct work and positioned to intersect the gas flow at a point having flow characteristics representative of the bulk flow.

Particulates are removed from the sample first, passing it through a series of cyclones. For the SRC tests, these cyclones were maintained at a temperature of 400 F. Particulates are collected in three size ranges, $> 10\mu$, 3 to 10μ , and 1 to 3μ , respectively. The cyclones are followed by a standard fiberglass filter, which collects a fourth size range, $< 1\mu$.

Gas leaving the filter is cooled to approximately 68°F and passed through a cartridge containing XAD-2 resin. This resin absorbs a broad range of organic compounds. Condensate produced when the gas is cooled is collected in a condensate trap.

A series of three impingers follows the resin cartridge. The first contains hydrogen peroxide solution, which removes reducing components to prevent deterioration of the following impinger solutions. The second and third impingers, containing ammonium thiosulfate and silver nitrate, collect volatile inorganic trace elements.

Next, the gas passes through a dehydrating agent, to protect the pump which follows. Finally, the gas flow rate is metered, and the gas is vented.

Using the SASS train, each test run provided a total of nine samples, all of which included solids fractions, condensate, resin, impinger liquids, and rinses. After weighing, several of the initial samples were combined for further analysis. Results will indicate the presence or absence of several classes of organic compounds as well as inorganic components and trace elements. In addition to the abbreviated Level 1 anaysis, the samples will be analyzed to determine whether or not selected polynuclear aromatic compounds, having carcinogenic properties, were present.

Grab samples of the flue gas were collected using a Tedlar bag and a stainless steel probe. The samples were extracted from the stack by means of varistaltic pump, which can obtain leak-free samples over a short period of time. On-site analysis was performed (usually within thirty minutes of sampling) by injecting gases captured in the sample bag into a gas chromatograph. Parameters identified included C_1 - C_6 hydrocarbons, CO, SO_2, O_2, N_2, and CO_2.

Daily composites of the coal used during Phase II and the SRC used during Phase III were also prepared. Bottom ash samples were collected as well.

Participants in the SRC combustion tests included:

- Southern Company Services — co-sponsor and owner
- ERDA — co-sponsor and supplier of SRC
- Southern Research Institute (SRI)-SASS Train Sampling and Resistivity
- TRW — Grab sampling and on-site analysis for CO, CO_2, SO_2, N_2, O_2, and C_1 - C_6 hydrocarbons.
- York Research — EPA-5 and ASME trains, gaseous emissions, precipitator efficiency
- Babcock & Wilcox — Boiler efficiency
- Rust Engineering (Subsidiary of Wheelabrator-Frye) with SRI — Resistivity;
- Wheelabrator-Frye — modeling of precipitator for control of SRC combustion particulates
- Hittman Associates, Inc. — Development of sampling plan for the SASS train and grab samples, coordination of these efforts, and responsibility for subsequent SASS train sample analysis and interpretation.

Figure 2 depicts the location of the precipitator and sampling ports. Boiler #1 was the test boiler. Load conditions (i.e., full, medium, and low) were varied daily. During the first nine days of testing, samples were collected at the inlet and outlet of precipitator #1. Test ports A_1, A_2, B_1, and B_2 were used for this emission testing. ASME and EPA-5 trains were used simultaneously to collect samples both at inlet ports A_1 or A_2, and outlet ports B_1 or B_2. SASS train samples and grab samples for on-site analysis were collected either at inlet

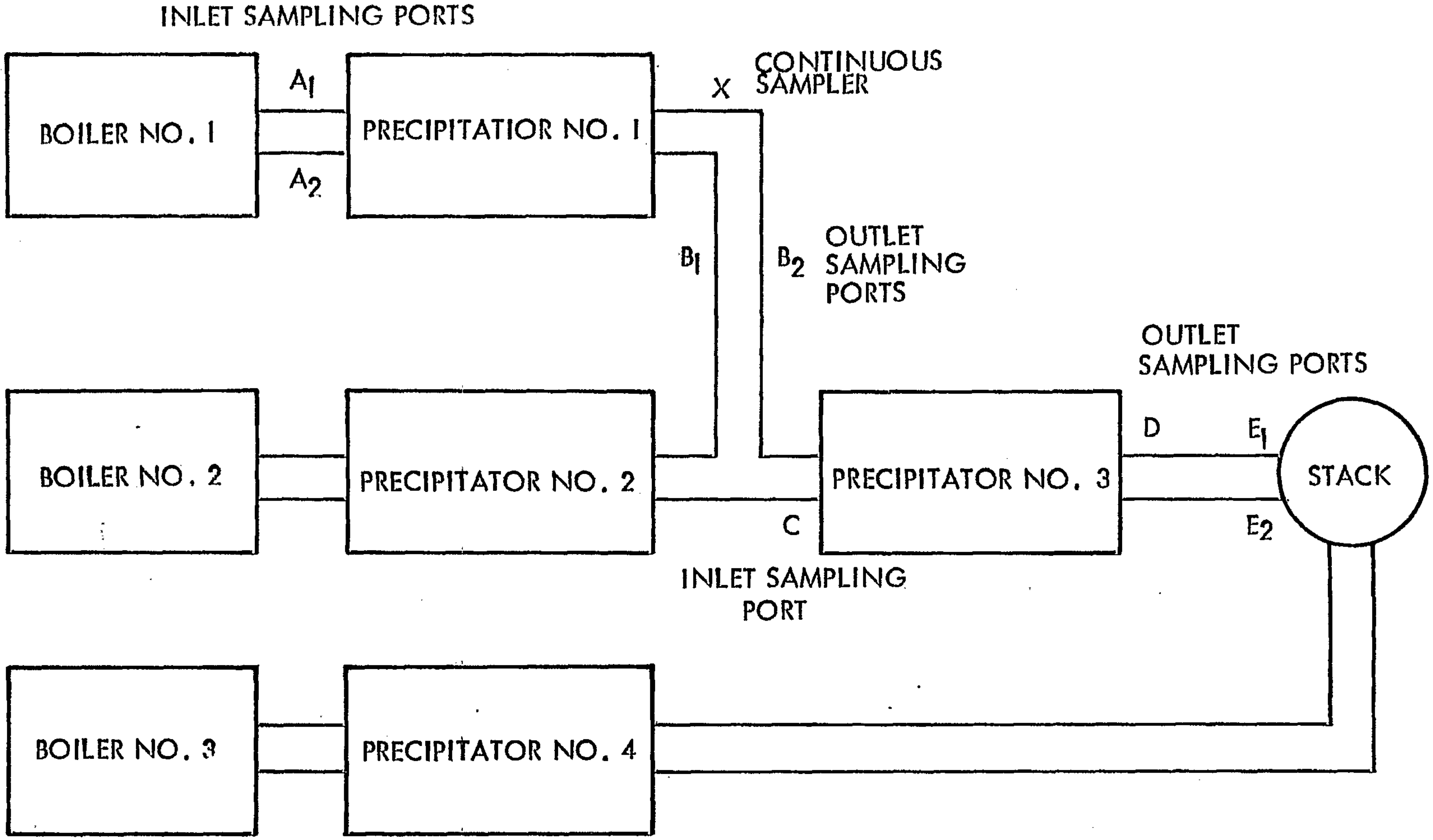

Figure 2. The location of the boilers, precipitators and sampling ports at Plant Mitchell.

port A_1 or outlet port B_1. Point X indicates the location of the continuous sampler for monitoring gases such as SO_2 and NO_x.

Since precipitator #1 is a 1946 vintage Research Cottrell unit with perforated plates, Rust Engineering and Wheelabrator-Frye requested that two additional days of tests be performed on precipitator #3, a newer, more up-to-date,unit. Data gathered could be used in the future for modeling purposes. To facilitate these tests, boiler #2 and precipitators #1 and #2 were shut down. Samples were collected at ports C, D, E_1 and E_2. ASME and EPA-5 samples were simultaneously collected at ports C, E_1, and E_2. SASS train and grab samples for on-site analysis were collected at outlet port D.

PHASES II & III TESTING

In both Phase II, coal combustion, and Phase III, SRC combustion, the boiler was operated at full, medium and low load conditions. In addition, at the conclusion of Phase III, the boiler was operated "wide open", approximately 23.5 MW, for several days.

Because only one SASS train was available, it was impossible simultaneously to collect samples at both the inlet and outlet ports to the precipitator. During each phase the SASS train location was varied to permit sampling at both ports. During each SASS run, a grab sample for on-site analysis was collected at the same location. EPA-5 and ASME trains operated concurrently at both the inlet and outlet of the precipitator being tested and while the SASS train was in operation.

The schedules for Phases II and III were developed by Mr. Richard McRanie of Southern Company Services after consultation with participants. The load condition and test precipitator were designated for each day of testing. Tables 1 and 2 indicate these schedules as well as the sampling location for the SASS train.

During Phase II, which began May 24, 1977, low sulfur Kentucky coal was burned in the boiler. No significant operational problems were noted during this phase. The burners operated as expected and flue gas samples were collected. Phase II concluded on June 6, 1977, after eleven days of testing.

Combustion of SRC, Phase III, began on June 10th, 1977. Sampling began on June 13, 1977 and continued through June 24, 1977. A few additional days of testing were scheduled starting June 25th; however SASS and grab samples were not collected because of the experiments being conducted. The schedule called for variation in load levels, air to SRC feed ratios, and precipitator rapping. Because

TABLE 1

PHASE II - COAL COMBUSTION TEST SCHEDULE

Date	Load Condition	SASS Train Sampling Location
May 24	Full	Outlet ESP #1
May 25	Medium	Outlet ESP #1
May 26	Low	Outlet ESP #1
May 27	Full	Outlet ESP #1
May 28	Full	Inlet ESP #1
May 29	Medium	Inlet ESP #1
May 30	Medium	Outlet ESP #1
May 31	Low	Outlet ESP #1
June 1	Low	Inlet ESP #1
June 5	Full	Outlet ESP #3
June 6	Full	Outlet ESP #3

TABLE 2

PHASE III - SRC COMBUSTION TEST SCHEDULE

Date	Load Condition	SASS Train Sampling Location
June 13	Full	Outlet ESP #1
June 14	Medium	Outlet ESP #1
June 15	Low	Outlet ESP #1
June 16	Full	Outlet ESP #1
June 17	Full	Inlet ESP #1
June 18	Low	Inlet ESP #1
June 19	Low	Outlet ESP #1
June 20	Medium	Inlet ESP #1
June 21	Medium	Outlet ESP #1
June 22	Full	Outlet ESP #3
June 23	Full	Outlet ESP #3
June 24	"wide open"	Outlet ESP #1

of the short duration of these conditions, it was impossible to complete a SASS train run which typically is of five-hour duration.

ANALYTICAL RESULTS

Results of the SASS train analyses are not available at this time. Figure 3 shows the planned analytical procedures. Samples from both Phase II (coal) and Phase III (SRC) runs will be analyzed. One coal and one SRC sample also will be tested for trace elements.

Results which are available at this time include the on-site analyses presented in Tables 3 and 4. Analyses of the coal and SRC, and calculated emissions are presented in Tables 5, 6, and 7.

The C_1 to C_6 hydrocarbons were determined by means of a flame ionization detector in a Perkin-Elmer gas chromatograph. During the first three days of Phase II, the test limits were 5 ppm due to improper grounding of the instrument. During the remainder of the tests, the detectable limit was 0.5 ppm. The O_2, N_2, CO and CO_2 and SO_2 levels were measured with a thermal conductivity detector in an A.I.D. portable gas chromatograph. The accuracy of this instrument is ± two percent of the reading taken.

NO_x and SO_2 were continuously monitored. Thermo electron analyzers were used to measure nitrogen oxides and sulfur oxides. The accuracy of these instruments is ± 10 ppm.

Results of the on-site analysis of grab samples are included in the following section of this report. The following conclusions can be drawn about SRC combustion:

- When compared on a pounds of SO_2 per million Btu basis, SRC flue gas shows only approximately 67 percent as much SO_2 discharge as does coal flue gas, during the course of this test.
- When the coal sulfur content was approximately the same as the SRC sulfur content, SO_2 emissions per million Btu were equivalent.
- Pounds of NO_x per million Btu are lower in the SRC flue gas than in the coal flue gas, by approximately 15 percent, during the course of this test.
- O_2 levels during SRC runs ran slightly below levels measured in coal combustion. This is directly related to control room operations. Control room data will be available later.
- SO_2 and NO_x concentrations were highest at full load and lowest at low load conditions.
- C_1 - C_6 hydrocarbons were not detected during either Phase II or Phase III. The detection limit for these components was 0.5 ppm.

OBSERVATIONS AND CONCLUSIONS

No major problems were encountered with the combustion of SRC. Generally, the boiler operated smoothly. On Wednesday, June 15th, however, fire was lost in the boiler for about one hour and the SASS train run was lost. The cause of the problem was believed to be failure of the fuel to reach the burner. This could not directly be attributed to the SRC. Another run was lost when pieces of polyethylene sheet, upon which the SRC was stored, were accidentally scooped up by the front end loader removing the SRC from the storage pile, and fed into the pulverizers. The pulverizers jammed and the run was cancelled.

Results of the test are limited at this time. Future analytical results will be incorporated in a final report. The following preliminary observations can be made. These observations were made either in the field or during preparation of samples for shipment to the laboratory.

- Particulates collected by the SASS train during combustion of SRC were approximately seventy percent carbon. This compares with a typical coal fly ash carbon content of less than ten percent. The high level of carbon is probably due to the boiler type. This 22-1/2 MW boiler was originally designed to burn oil, later modified to burn coal, and further modified prior to Phase II testing. In addition, since the ash content of SRC is much lower than that of coal, identical combustion efficiencies for coal and SRC would result in a proportionately higher carbon content in the fly ash, even though the

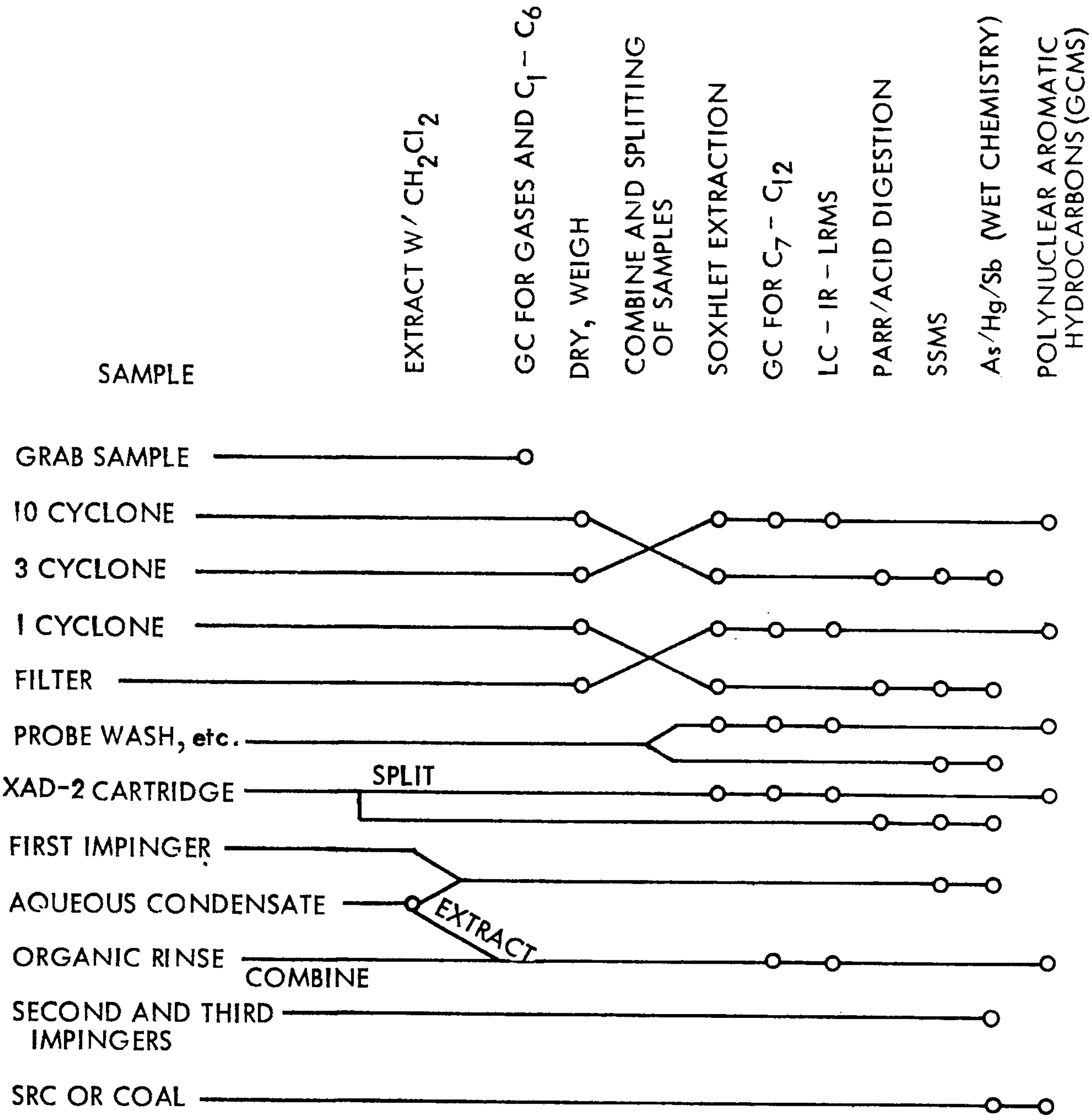

Figure 3. Analytical schematic.

TABLE 3

ON-SITE ANALYSIS OF GRAB SAMPLES PHASE II - COAL COMBUSTION
MAY 24 TO JUNE 6, 1977

	On-Site Gas Chromatograph Analysis										Continuous Sampler				
Date	$C_1^{(4)}$	$C_2^{(4)}$	$C_3^{(4)}$	$C_4^{(4)}$	$C_5^{(4)}$	$C_6^{(4)}$	$CO^{(3)}$	$O_2^{(1)}$	$CO_2^{(1)}$	$N_2^{(1)}$	$SO_x^{(1)}$	$SO_x^{(2)}$	$NO_x^{(2)}$	Time	Load Condition	Sample Location
5/26	ND	ND	ND	ND	ND	ND	ND	13.31%	7.40%	79.29%	254	260	110	1500	Low	0-1
5/31	ND	ND	ND	ND	ND	ND	ND	14.24%	7.50%	78.26%	329	360	110	1140	Low	0-1
6/02	ND	ND	ND	ND	ND	ND	ND	14.91%	6.56%	78.53%	174	200	100	0300	Low	I-1
5/25	ND	ND	ND	ND	ND	ND	ND	15.73%	5.51%	78.76%	413	500	170	1400	Med	0-1
5/29	ND	ND	ND	ND	ND	ND	ND	13.70%	7.59%	78.71%	209	220	160	1400	Med	I-1
5/30	ND	ND	ND	ND	ND	ND	ND	12.60%	7.35%	80.05%	413	400	150	1240	Med	0-1
5/24	--	--	--	--	--	--	--	------	-----	------	---	745	225	1200	Full	0-1
5/27	ND	ND	ND	ND	ND	ND	ND	13.78%	6.65%	79.66%	311	330	215	1530	Full	0-1
5/28	ND	ND	ND	ND	ND	ND	ND	11.25%	9.86%	78.89%	381	330	220	1420	Full	I-1
6/05	ND	ND	ND	ND	ND	ND	ND	12.14%	9.31%	78.55%	214	200	170	1330	Full	0-3
6/06	ND	ND	ND	ND	ND	ND	ND	11.16%	9.69%	79.15%	210	180	110	1030	Full	0-3

ND - None Detected

I-1 - Inlet to precipitator - 1

0-1 - Outlet to precipitator - 1

(1) - ± 2% of total concentration

(2) - ± 10 ppm

(3) - 40 ppm detectable limit

0-3 - Outlet to precipitator - 3

SO_x and NO_x values are in ppm

(4) - 5 ppm detectable limit 5/25, 5/26, and 5/27, 0.5 ppm detectable limit 5/28 through 6/06

TABLE 4

ON-SITE ANALYSIS OF GRAB SAMPLES PHASE III - SRC COMBUSTION
JUNE 13 TO JUNE 24, 1977

	On-Site Gas Chromatograph Analysis										Continuous Sampler				
Date	C_1(4)	C_2(4)	C_3(4)	C_4(4)	C_5(4)	C_6(4)	CO(3)	O_2(1)	CO_2(1)	N_2(1)	SO_x(1)	SO_x(2)	NO_x(2)	Time	Load Condition	Sample Location
6/15	ND	ND	ND	ND	ND	ND	ND	14.79%	5.88%	79.33%	198	225	125	1030	Low	0-1
6/18	ND	ND	ND	ND	ND	ND	ND	13.25%	6.73%	80.02%	216	220	120	1200	Low	I-1
6/19	ND	ND	ND	ND	ND	ND	ND	14.00%	6.26%	79.74%	218	235	125	1230	Low	0-1
6/14	ND	ND	ND	ND	ND	ND	ND	13.65%	7.53%	78.82%	248	260	160	1200	Med	0-1
6/20	--	--	--	--	--	--	--	------	-----	------	---	---	----	----	Med	0-1
6/21	--	--	--	--	--	--	--	------	-----	------	---	---	----	----	Med	I-1
6/13	ND	ND	ND	ND	ND	ND	ND	11.39%	9.86%	78.75%	371	325	190	1300	Full	0-1
6/16	ND	ND	ND	ND	ND	ND	ND	10.62%	9.12%	80.26%	410	335	190	1145	Full	0-1
6/17	ND	ND	ND	ND	ND	ND	ND	11.11%	9.15%	79.74%	404	345	190	1100	Full	I-1
6/22	ND	ND	ND	ND	ND	ND	ND	11.20%	9.25%	79.55%	400	345	200	1030	Full	0-3
6/23	ND	ND	ND	ND	ND	ND	ND	10.75%	8.90%	80.35%	393	325	220	1000	Full	0-3
6/24	ND	ND	ND	ND	ND	ND	ND	10.76%	9.29%	79.95%	449	380	260	1100	23.5	0-1

ND - None Detected

I-1 - Inlet to precipitator-1

0-1 - Outlet to precipitator-1

(1) - ± 2% of total concentration

(2) - ± 10 ppm

(3) - 40 ppm detectable limit

(4) - 0.5 ppm detectable limit

0-3 - Outlet to precipitator-3

SO_x and NO_x values are in ppm

TABLE 5

SRC COMBUSTION TEST - PHASE II, COAL

	Proximate Analysis				SO$_2$, ppm		NO$_x$, ppm
Date	% Sulfur	% Nitrogen	Heating Value, Btu/lb (1)	Load	Grab Sample	Continuous Analyzer	
5/26	0.64	1.38	14935	Low	254	260	110
5/31	1.05	1.81	14723	Low	329	360	110
6/2	NA	NA	NA	Low	174	200	100
5/25	1.09	1.29	14648	Med	413	500	170
5/29	0.62	1.82	14923	Med	209	220	160
5/30	1.15	1.82	14725	Med	403	400	150
5/24	1.34	1.19	14720	Full	NA	745	225
5/27	0.73	1.51	14802	Full	311	330	215
5/28	0.72	1.45	14797	Full	381	330	220
6/5	0.66	1.60	NA	Full	214	200	170
6/6	0.64	1.81	14931	Full	210	180	110

NA - Not Available

(1) Moisture and Ash Free Basis.

TABLE 6

SRC COMBUSTION TEST - PHASE III, SRC

	Proximate Analysis				SO_2, ppm		NO_x, ppm
Date	% Sulfur	% Nitrogen	Heating (1) Value, Btu/lb	Load	Grab Sample	Continuous Analyzer	
6/15	0.70	1.54	15742	Low	198	225	125
6/18	0.74	1.80	NA	Low	216	220	120
6/19	0.66	1.82	15668	Low	218	235	125
6/14	0.72	1.62	15729	Med	248	260	160
6/13	0.73	2.02	15591	Full	371	325	190
6/16	0.73	1.77	15602	Full	410	335	190
6/17	0.72	1.47	15775	Full	404	345	190
6/22	0.70	1.37	15647	Full	400	345	200
6/23	0.64	1.37	15534	Full	395	325	220
6/24	0.66	1.71	15505	Wide Open	449	380	260

NA - Not Available

(1) Moisture and Ash Free Basis

TABLE 7

RUN NUMBER, PRECIPITATOR NUMBER 1

	Run Number, Precipitator Number 1								
Conditions	1	2	3	4	5	6	7	8	9
Coal									
Date	5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1
Load, MW	21	14	6	21	21	14	14	7.5	7.5
Fuel Feed, lb/hr	22,300	15,300	7,400	21,000	20,000	15,000	15,000	9,400	9,700
SO_2 lb/10^6 Btu	2.33	1.86	1.50	1.03	1.06	1.84	1.84	2.38	1.39
NO_x lb/10^6 Btu	0.50	0.45	0.46	0.48	0.51	0.50	0.50	0.52	0.50
SRC									
Date	6/13	6/14	6/15	6/16	6/17	6/18	6/19	6/20	6/21
Load, MW	21	14	7.5	21	21	7.5	7.5	14	14
Fuel Feed, lb/hr	17,500	12,000	7,200	17,800	17,600	7,400	7,400	12,000	12,200
SO_2 lb/10^6 Btu	0.99	1.02	1.21	0.97	1.01	1.05	1.13	1.11	1.04
NO_x lb/10^6 Btu	0.41	0.45	0.48	0.39	0.40	0.41	0.41	0.49	0.45

total carbon in the ash might be the same.

- The total quantity of fly ash produced from SRC combustion is approximately ten percent of that resulting from the coal normally used at this facility.
- The aerodynamic particle size of SRC ash was much smaller than that of coal fly ash. It is estimated that two to five percent of coal fly ash collected in Phase II was less than one micron. Comparably, approximately twenty percent of the SRC fly ash was collected on the filter following the one micron cyclone.

  It should be noted, however, that due to the low density of the SRC ash, particles which should have been collected by the one micron cyclone instead may have passed through the cyclone and collected on the filter. The cyclones in the SASS train were designed to collect particles having the density of coal fly ash, i.e., 1 g/ml. SRC fly ash is approximately one-fifth as dense as coal fly ash. It was observed that, with SRC, the filter had to be changed frequently during each daily test, indicating that after a certain volume of particulate was collected in the cyclone, particles began passing through the 1 micron cyclone or the particulates collected were agitated and suspended in air, finally collecting on the filter.
- The efficiency of precipitator #1 with SRC ash was estimated by the ERDA Sampling Team to be at best twenty percent. The hoppers to the precipitator were checked and no ash had been collected. The low efficiency of the precipitator is probably due to the low resistivity and density of the high carbon fly ash.

  During the latter part of Phase III, when precipitator #1, boiler #2, and precipitator #2 were shut down, the efficiency of collection by precipitator #3 was significantly higher than observed with precipitator #1. Partical loading at the outlet totaled approximately 1 gram. This compares with about 25 grams for a similar full load test at the outlet to precipitator #1. The filter following the cyclones did not have to be changed during tests at the outlet to precipitator #3. Up to five filter changes had been needed during tests at both the inlet and the outlet to precipitator #1.

  There was a visible plume on all SRC combustion tests using precipitator #1. The opacity was estimated at Ringelman 2. However, when only precipitator #3 was functioning, there were no visible emissions. During coal combustion, there was evidence of a plume on occasion. Boiler #2, which was shut down when tests were run around precipitator #3, may be the cause of the visible plume. It was suggested that without boiler #2 flue gas feeding into precipitator #3, the unit, which is oversized, was effective.
- Although approximately equal volumes of ash were collected from both coal and SRC combustion, about 50 percent less fly ash, by weight, was collected during the SRC tests.
- Some dusting was noted during handling of SRC. A front end loader was used to load a dump truck which in turn emptied into the feed hopper. It was difficult to assess accurately the potential magnitude of this problem, since this method of handling is not standard operating procedure at the plant.

Generally, the SASS train performed adequately. On most occasions, representative flue gas samples were collected. There were, however, several problem areas.

- The SASS train equipment proved to be very cumbersome. This problem was aggravated by space limitations.
- An electrical generator had to be rented in order that an adequate supply of electricity (45 amps) was available. Two runs on Phase III were lost when the generator broke down.
- The entire SASS train operation, including preservation of samples and preparation of the equipment for the

next run, required 10 to 12 hours. Three men were required for this labor intensive effort.

- As mentioned earlier, the cyclones were designed to collect particulates with a density comparable to coal fly ash. SRC fly ash, which has one-fifth the density of coal fly ash, may have passed through the cyclones. This may explain why filters had to be changed so frequently. Each time a filter had to be changed, the run had to be stopped, the filter cooled and removed, and the oven reheated. Each filter change required a delay of up to thirty minutes. This may have caused an erroneous particle size distribution since particles may have passed through to the next smaller cyclone or to the filter.
- Because the particulates were extremely light and fine, small amounts of particulate were lost during the subsequent transfer to the plastic sample containers.
- Because of the time constraints, it was impractical to soak the SASS train in 1:1 nitric acid following each run. If this procedure, prescribed in the operator's manual, had been followed, it would have been impossible to both preserve the samples and prepare for the next day's operation.