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FULL-SCALE UTILITY BOILER TEST WITH SOLVENT REFINED COAL (SRC)

INTERIM REPORT

Richard D. McRanie
April 1978

Work Performed Under Contract EX-76-C-01-2222

SOUTHERN COMPANY SERVICES, INC.
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BIRMINGHAM, ALABAMA 35202

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Carrying out a project with the scope of the Solvent Refined Coal Burn Test and producing adequate documentation to define and describe the entire effort required the skills and patience of a number of dedicated individuals and the resources of several organizations. From inception to conclusion, the success of the solvent refined coal project has been wholly dependent upon those participating, and it is the intent here to give recognition to their contributions.

Foremost among these must be the staff of the Research and Development Department of Southern Company Services, Incorporated under the leadership of Dr. W. B. Harrison and Mr. S. R. Hart, Jr. Management of the burn test project was carried out by Mr. R. D. McRanie, assisted by Mr. R. P. Gehri. Other department staff members and their respective responsibilities included: Dr. C. E. Hickman, pulverizer, vibration and power; Mr. W. A. Harrison, pulverizers; Dr. S. P. Ellis and Mr. R. J. Clarkson, Jr., chemical analysis; Dr. D. M. Boylan and Mr. F. W. Meredith, boiler efficiency; and Mr. J. H. Eastis and Mr. M. T. Newton, vibration and general technical assistance.

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The team of subcontractors and other organizations supporting various phases of the test consisted of the Babcock & Wilcox Company, York Research Corporation, Electric Power Research Institute, Bechtel Corporation, Hittman Associates, Southern Research Institute, and Oxford Construction Company. Interlock Film Studios produced the motion picture documenting the overall project. Mr. J. A. Vezeau of the Southern Company Services Public Relations Department provided assistance in connection with production of the film.

Reporting requirements throughout the burn test program were satisfied by Mr. R. T. Oedamer of the Southern Company Services Engineering Services Department. Illustration and stenographic support of these efforts was provided by Mr. K. R. Riner and Mrs. R. A. Wells, respectively.

EXECUTIVE SUMMARY

Southern Company Services, Incorporated (SCS), the engineering and research affiliate of The Southern Company, recently completed a landmark study of the shipping, handling, and burning characteristics of a new, clean burning fuel called solvent refined coal (SRC). This three-phase effort, performed under a contract with the United States Department of Energy, culminated in an 18-day burn test in the Unit 1 boiler of Georgia Power Company's Plant Mitchell near Albany, Georgia. The SRC burn test, which has been termed an historic experiment, was an unqualified success and a significant milestone in the overall objective of qualifying coal-derived fuels for a variety of future energy needs. This assessment is fully supported by the flawless performance of the 22.5 megawatt unit at Plant Mitchell and the test data that revealed SRC to be so nearly pollution-free that it clearly surpasses current Environmental Protection Agency (EPA) standards.

Beginning in late 1975, approximately 3000 tons of SRC, manufactured from approximately 3.9-percent sulfur coal at a Pittsburg & Midway Coal Company pilot plant in Tacoma, Washington, were successfully shipped in open coal cars to the Plant Mitchell test site. Blowing losses experienced with early shipments were subsequently minimized with a commerically available liquid latex spray coating applied to the top of each car prior to shipment. Dust created during unloading operations was easily suppressed through the application of a wetting agent solution. No subsequent problems with dust were encountered, and the SRC was routinely handled by the conventional fuel conveying and storage systems at Plant Mitchell.

During Phase I, the existing circular burners on Unit 1 were used to burn coal. For Phases II and III of the burn test, water cooled dual register burners developed especially for the Plant Mitchell test by Babcock & Wilcox (B&W) were installed. These burners performed adequately while burning coal during Phase II, and delivered excellent performance during Phase III using SRC as fuel.

To accommodate SRC, the B&W E-35 pulverizers were modified only to the extent of using ambient primary air, reducing ball spring pressure, and installing variable speed feeder motors. These minor modifications were particularly successful, since no problems with pulverizing SRC were encountered under a variety of operating conditions. While testing with SRC, the pulverizers typically consumed 25-percent less power, ground finer, and exhibited 25-percent greater capacity than when grinding coal.

Boiler efficiency measurements performed throughout all phases of the burn test indicated that efficiency at full load was essentially the same when burning either SRC or coal. An added advantage, from an operating standpoint, was that the boiler stayed much cleaner with SRC than with coal, eliminating the need for deslagging the burner front or the use of soot blowers during the entire 18-day burn test.

Emissions tests were conducted throughout the burn test using EPA and ASME procedures for particulates, SO_2, and NO_x. Also continuous monitors analyzed flue gas for opacity, SO_2, NO_x, CO, CO_2, and O_2. Particulate concentrations leaving the primary precipitator were higher than EPA standards; however, this is attributed to the obsolete design of this precipitator which was installed in 1946. Since the unit is equipped with a secondary precipitator of modern design, additional tests were conducted which yielded concentrations in compliance with EPA standards by a wide margin. The air quality measurements indicated that SRC SO_2 emissions were more than 20 percent under maximum EPA limits and that NO_x requirements were met by a comfortable margin of 40 percent. Typical SRC emissions and current EPA requirements (in lb/10^6 Btu) are shown in the table below.

	EPA Requirements	SRC
SO_2	1.2	1.0
NO_x	0.7	0.45
Particulates	0.1	0.04

The quantity of flyash generated while burning SRC was nominally 7 to 10 times less than when firing coal, and bottom ash was virtually nonexistent with no accumulation of ash in any boiler section. This overall low ash loading and the nonabrasive characteristic of SRC ash will significantly reduce such problems as tube cutting and boiler deslagging and will generally reduce maintenance on all ash handling facilities. These advantages, coupled with the ease of pulverization and the exceptional boiler cleanliness, take on a distinct importance in the overall improvement of boiler and auxiliary equipment availability and reliability.

The notable results achieved from the Plant Mitchell burn test have generated much enthusiasm within the Southern electric system for the use of SRC as a boiler fuel. Scientific and statistical data from the project proved that the technical performance of SRC was excellent and that the fuel offers a viable option for making effective use of the nation's large coal deposits. The ease of modifications and enhanced reliability of the boiler and associated equipment make SRC an attractive alternative for existing coal-fired plants when compared with scrubber installations at many times the cost of an SRC conversion. The use of SRC can also eliminate the need for scrubbers on new power plants, leading to greater overall plant reliability and reduced capital requirements.

The successful conclusion of the solvent refined coal burn test represents a large step in the continuing efforts by the Southern electric system to bring this clean coal process out of the laboratory and into the generating plant. When compared to the alternative approaches to meeting electric energy needs in environmentally acceptable ways, the SRC technology seems clearly in the forefront by any consideration. It is clean, uncomplicated in application, and promises to make greater use of the nation's vast coal resources. It now remains to take the necessary steps to ensure the future of SRC by building a demonstration unit capable of direct expansion to a full commercial solvent refined coal facility.

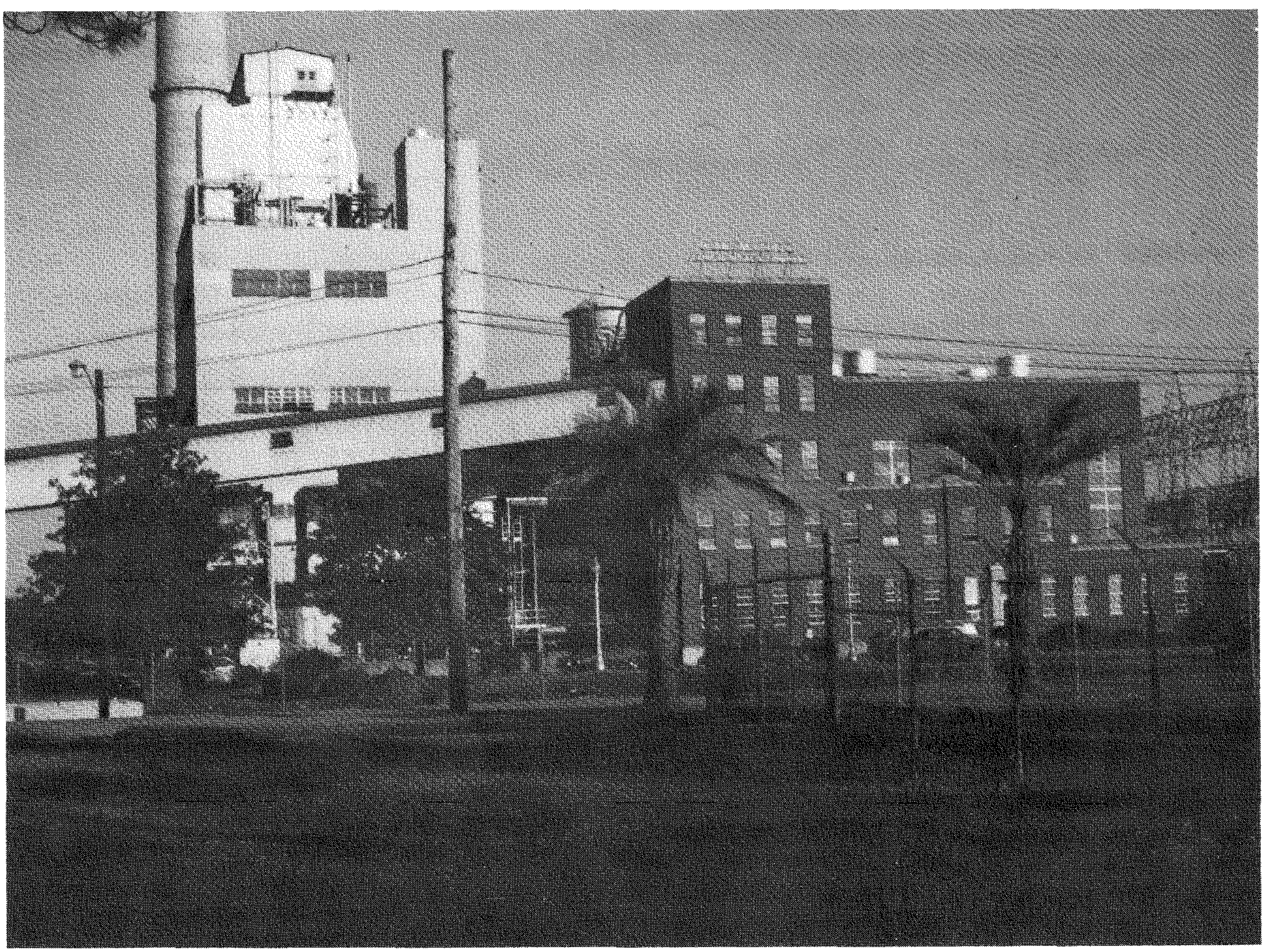


TABLE OF CONTENTS

INTRODUCTION

In the United States today the principal sources of energy for the generation of electricity are water, nuclear fuels, and the fossil fuels – gas, oil, and coal. A careful consideration of these resources must take into account not only the growing shortage of domestic oil and natural gas but also the uncertainties concerning the future of foreign oil and its negative impact on both national security and the national economy. Although the role of nuclear power is expanding as a source of energy, it is compromised by tediously slow licensing and construction procedures. Only a relatively small contribution can be made by other energy resources to national energy needs in the next two decades.

It appears, therefore, in the national interest to meet as many energy needs as possible with the nation's most abundant fossil energy resource – coal. To do so, ways must be found to satisfy the environmental regulations which limit the emissions of particulate matter, sulfur dioxide, and oxides of nitrogen from coal burning plants. Because of these environmental regulations, much of the coal currently available to electric utilities contains sulfur and ash at levels rendering it unacceptable as a boiler fuel without further treatment of either the coal or combustion gas stream.

Clearly, major pollution abatement efforts are necessary. It is in this context that Southern Company Services, Inc. (SCS) has undertaken development of the process of solvent refining of coal in order to address the question of how best to comply with environmental regulations while using coal as the principal energy resource for generation of electricity.

Southern Company Services, Inc. is affiliated with and provides engineering and other services to Alabama Power Company, Georgia Power Company, Gulf Power Company, and Mississippi Power Company, which together form The Southern Company. The presently installed generating capacity of The Southern Company is nearly 22,000 megawatts, and in 1977 about 32 million tons of coal were burned in the system, with a projected increase to approximately 50 million tons by 1985 if trends continue.

With this continuing corporate commitment to coal burning, the search for technology to enable compliance with environmental regulations is an urgent corporate goal which coincides with the national interest. Since 1969, The Southern Company has attempted to enlist interest in the solvent refining process wherever possible, and through these efforts has become well known in the electric utility industry as the leading advocate for the commercialization of solvent refined coal (SRC).

The availability of SRC in commercial quantities for generation of electricity could lead to a number of important advantages. Standardized power plant designs would be feasible, where now each design depends to some extent on the specific expected coal supply. Smaller boilers and smaller fuel storage and handling facilities might be possible, due mainly to the higher heating value of SRC compared with raw coal. Fuel transportation costs should be reduced. Ash and sludge handling and storage facilities should be drastically reduced or eliminated, and finally, the plant fueled with SRC is expected to experience higher availability and lower maintenance than a raw coal-fired plant.

Responding to an RFP issued in October 1975 by the former United States Energy Research and Development Administration, now the United States Department of Energy (DOE), Southern Company Services offered to undertake the responsibility to receive, store, and test burn approximately 3,000 tons of solvent refined coal in a small utility boiler. In anticipation of this work, the Electric Power Research Institute (EPRI) had supported several laboratory and pilot studies to evaluate handling, pulverizing, and burning properties of SRC. Based on the results of these studies, SRC was shown to have desirable properties as a utility fuel. A full-scale combustion program would greatly expand the scope of these pilot tests. Not only would the handling and storage characteristics of SRC be determined, but also detailed boiler modifications could be evaluated. During burning, careful observations and evaluations of boiler performance would be made, and rigorous measurements of emissions would assess SRC's ability to comply with existing EPA standards.

In July 1976, the U. S. Department of Energy awarded Southern Company Services a contract to carry out the proposed effort, the principal objective of which would be to demonstrate the advantages of SRC as a boiler fuel. Attainment of this objective would show that a commercial boiler and its auxiliary equipment could be modified to accommodate SRC, and that the use of this fuel would offer a means for pollution abatement at existing coal-fired generating plants as well as an alternative to flue-gas processing (desulfurization) for planned coal-fired units. On a broader scale, attainment of the project goals could be regarded as a significant milestone in the overall objective of qualifying coal-derived fuels for a variety of energy needs.

In the Southern electric system the affiliated companies of The Southern Company operate 80 different fossil-fired boiler units, ranging in size from 22.5 to 880 megawatts each. From these facilities, a 22.5-megawatt unit operated by Georgia Power Company at Plant Mitchell near Albany, Georgia was selected for the burn test. Although this unit is one of the smallest in The Southern Company system, it was deemed desirable because of the limited quantity of SRC available for the test. Selection of this unit enabled maximum operating experience at the lowest possible cost, yet at a scale sufficient for meaningful application of the results to larger units.

Unit 1 at Plant Mitchell consists of a pulverized coal-fired Babcock & Wilcox (B&W) F-type boiler and a General Electric (GE) turbine generator rated at 22.5 MW. The boiler is unusual, in comparison with a modern utility design, in that it has a horizontal, multi-turn gas pass, as shown in Figure 1. The superheater in this boiler is convective only. Normal steam pressure is 900 psi, and steam temperature is 900°F.

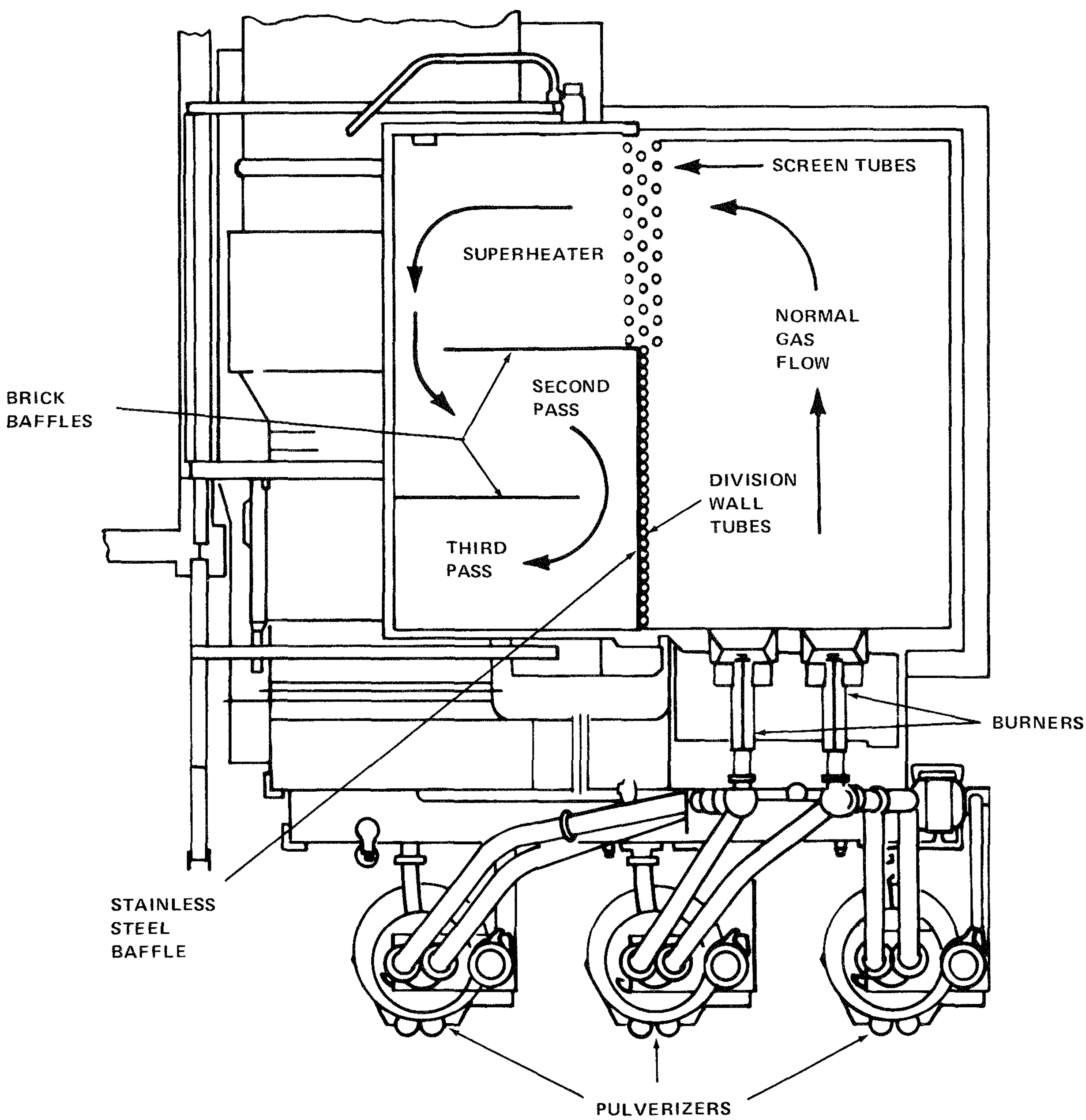


FIGURE 1

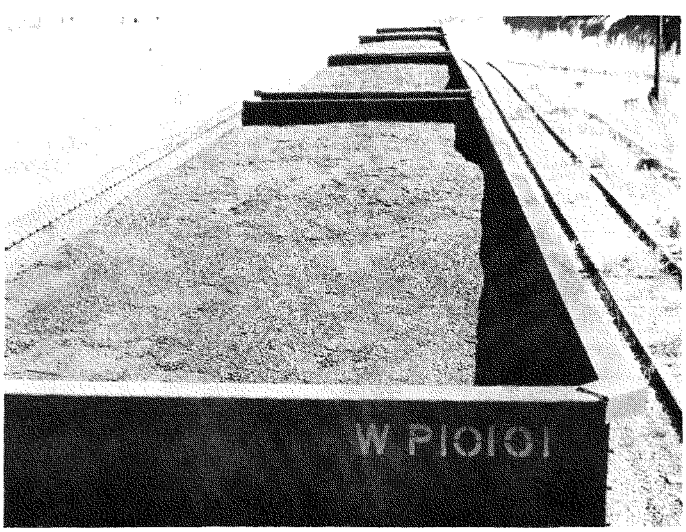
UNIT 1 BOILER

Plans called for the burn test to be conducted in three phases. Phase I was to operate and test the boiler under normal conditions firing coal. For Phase II, new burners and pulverizer feeders were installed, and the boiler was

tested again firing coal. During Phase III, when SRC was fired, hot air to the pulverizers was closed off, pulverizer spring pressure was reduced, and the boiler was tested for a third time.

FUEL HANDLING

Beginning in November 1975 and continuing through 1976, approximately 3000 tons of SRC were shipped via standard hopper bottom rail cars from Tacoma, Washington to Plant Mitchell at Albany, Georgia. Eight shipments totaling 41 rail cars were made, ranging in size from 1 car up to 11 cars. A typical shipment of the SRC material produced at Tacoma is shown below. The flake product had a nominal size of 1/8 to 1/4 inch.



Some of the flake SRC in the early shipments from Tacoma tended to blow off the rail cars while in transit. This problem was investigated, and the most successful solution proved to be the application of a liquid latex top coat to the SRC after the rail cars were loaded. This coating hardened into a flexible, but adhesive, layer of SRC covering the car.

SRC was found to break up during handling and shipment, creating considerable dust during unloading at Plant Mitchell. This problem was successfully controlled through the use of a dust suppression spray system which applied a wetting agent solution to the SRC during unloading operations.

Several carloads of a large chunk (6 to 12 inch) SRC product were also prepared and shipped to Plant Mitchell by Pittsburg & Midway (P & M). This product had better shipping characteristics, with less dust being created during unloading than with the normal flake product.

The SRC was off-loaded and stored on reinforced plastic sheeting to protect it from soil contamination. Although exposed to the weather, no physical degradation of the product was noted in 1 year of storage. Because of heavy rains, there was some erosion of the storage pile in the areas where the flake product was stored; however, this erosion did not occur in the larger chunk product storage areas.

For the burn test, the SRC was transported by dump truck to the track hopper, where it was conveyed to the in-plant storage bunkers by the normal fuel handling conveyors. No wetting agent was applied, no equipment modifications were required, and there were no problems with dust, bunker filling, storage, or feed of the SRC.

In summary, the test demonstrated that SRC can be shipped in standard, open coal cars, and that blowing losses can be minimized by the application of a commercially available spray prior to shipment. The product is easily handled by conventional fuel conveying and storage systems if some provision is made for dust control, probably through a combination of spray and ventilation techniques.

BURNERS

For Phase I, the circular burners originally designed for Unit 1 were to be used to burn coal. However, B&W investigations had shown that different burners would be required to burn SRC with acceptable efficiency and to solve potential problems such as high NO_x emissions and coal nozzle pluggage.

Under a contract with EPRI, the B&W dual register burner design was modified, and burners were developed especially for the Plant Mitchell test. These modified burners, used during Phase II and Phase III of the burn test differed in two respects from the normal B&W dual register burner. First, to accommodate the fuel requirements of the 22.5-MW boiler, the capacity of each burner had to be about one-half that of the smallest standard B&W dual register burner. Second, to eliminate SRC melting and subsequent plugging of the burner nozzle, the nozzle had to be water cooled. Figure 2 details the final design of the burners used in the test. Six of these burners were used for the Plant Mitchell tests.

The dual register burner was developed by B&W primarily as a low NO_x burner. It has no mechanical fuel spreader, and the mixing of fuel and air is controlled by varying the split on the secondary air between the inner and outer registers and the amount of spin on the inner register air.

B&W had demonstrated that clockwise spin of the secondary air was the preferred mode of operation for the burners. However, to achieve optimum clockwise spin, it was necessary to modify the spin vanes. It was also noted that the secondary air register doors were not closing tightly, which in effect allowed secondary air leaks into the furnace when one or more burners were out of service. Because of time constraints, it was decided not to modify the doors.

Since river water was used as cooling water for the burners, it was necessary to install 60 mesh screen filters on this water supply. Water flow at 10–15 gpm/burner was maintained at all times regardless of whether or not a burner was in service. The water cooling was particularly successful since there was never any significant accumulation of SRC on the burner nozzles.

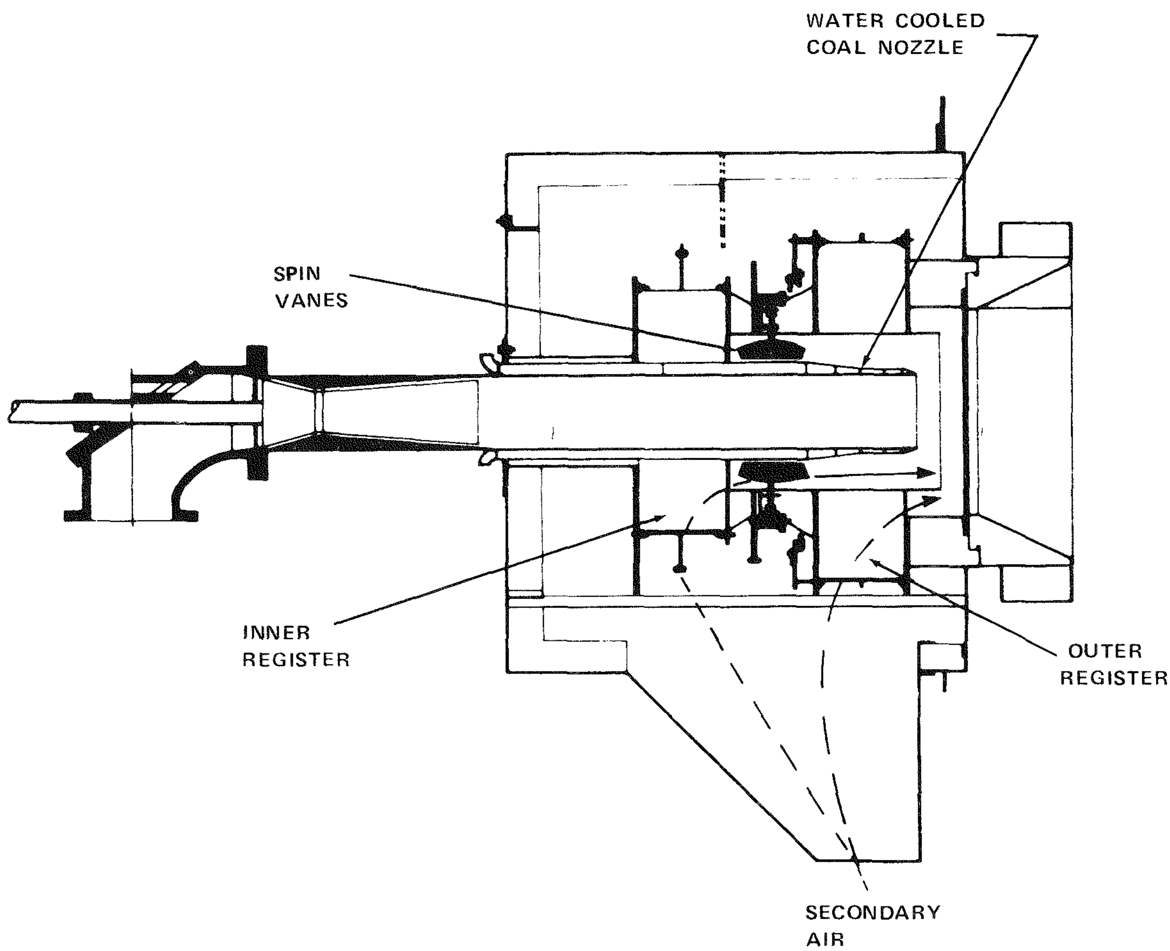


FIGURE 2
DUAL REGISTER BURNER MODIFIED FOR SOLVENT REFINED COAL

The burner nozzles were designed for cold primary air operation with SRC, whereas for the Phase II tests, with coal, hot air was used. This resulted in excessive velocity of the primary air and coal stream as it entered the furnace. For this reason, operation of the burners when firing coal during Phase II was, at best, marginal. At times the flame was unstable and adjustments to the burner registers were critical. It was difficult to flare the flame enough to keep the fire off the back wall of the furnace. As a result, extra care had to be taken to prevent the occurrence of hot spots on the back wall of the furnace.

When firing SRC, the operating characteristics of the dual register burners were good. Because of the high volatile content of SRC, flame stability was exceptional. As a matter of fact, it was difficult to cause the fire to become unstable.

To achieve maximum efficiency with minimum excess air, burner adjustments were made using a combination of opacity and CO readings and visual observations. When the SRC flame was adjusted to a short, bushy, high intensity flame, efficiency decreased dramatically. The best flame was a long, stringy, lazy flame which just barely licked the rear wall of the furnace. This observation was consistent with fuel burnout tests conducted at B&W, and verified that SRC requires maximum flame residence time to achieve complete burnout.

Due to windbox design, there was an imbalance in the secondary air to the burners which caused problems during all phases of the burn test. This imbalance problem was particularly evident during Phases II and III when the dual register burners were used because these burners depend upon secondary air differential pressure to ensure adequate fuel-air mixing.

Two of the six burners would not produce a good flame, especially under medium load conditions. The fire would become smoky at times, and the opacity and CO readings would fluctuate. There is no confirmed explanation, other than poor secondary air distribution on those two burners, to account for these anomalies. The effect of this imbalance problem was manifested by a decrease in medium load combustion efficiencies.

The performance of the modified dual register burners during Phase III was excellent. This was true in spite of the difficulties encountered with the spin vanes, the register doors, and poor secondary air-fuel distribution.

PULVERIZER PERFORMANCE

Prior to the burn test, laboratory studies and preliminary grinding tests in a B&W E-21 pulverizer identified several potential problems associated with pulverizing SRC in a ball and race type coal pulverizer. For example, an EPRI study (Research Project 1235–4) conducted by B&W noted the following problems when attempting to pulverize SRC:

- Uncontrolled feed rate.
- Excessive energy requirements.
- Agglomeration of SRC on pulverizer internals.
- Ball sliding and excessive rolling resistance.

With these potential problems in mind, modifications were made to the E-35 pulverizers prior to feeding SRC. Variable speed feeders were installed, and the pulverizer control system was modified such that the fuel feed rate to the pulverizer varied directly with primary air flow. The result of these modifications was that no feed control problems occurred during the test. Based on the E-21 grinding test, a ball loading of 500 lb/ball was used during the SRC burn phase as compared to the 1300 lb/ball force used to pulverize coal. B&W had observed a significant reduction in grinding power requirements with only a slight reduction in product fineness with the reduced ball loading.

SRC will become soft at normal coal pulverization temperatures of 150°F, so it was necessary to disconnect the hot air supply to the pulverizers prior to Phase III testing. This was accomplished by removing and blanking off the hot and cold air mixing tees before the primary air fans. The primary air fans were then using ambient air.

Pulverizer parameters such as product fineness, energy requirements, vibration accelerations, and depth of SRC bed were investigated for various pulverizer modifications and operating conditions.

The pulverizer modifications were particularly successful in that no problems with pulverizing SRC were encountered. The pulverizers were operated under many conditions related to fuel-air ratio, fuel bed depth, and ball loading. No problems could be induced even under conditions that were expected to cause trouble. Pulverizer capacity while grinding SRC was easily equivalent to coal on a weight basis and far exceeded coal on a Btu basis.

It should be pointed out that some of the conclusions drawn in the following sections differ from those presented in the aforementioned EPRI study, probably as a result of the larger pulverizers used in the SRC burn test.

Product Fineness

Prior to Phase I testing, the major problem with the pulverizers was their inability to produce adequate fineness while grinding coal. Design performance conditions for these mills would be approximately 70 percent of the coal passing 200 mesh. Before modification, typical fineness was 50 percent of the coal passing 200 mesh.

The pulverizer shown in Figure 3 is an E-35 B&W pulverizer with a rotating classifier. These pulverizers are outdated and there is a scarcity of information concerning corrective measures for unsatisfactory performance and proper operating parameters. As a consequence, several weeks were spent modifying the pulverizers to improve fineness. Experimentation with the pulverizers included changing the throat gap, varying ball loadings, and modifying the classifier.

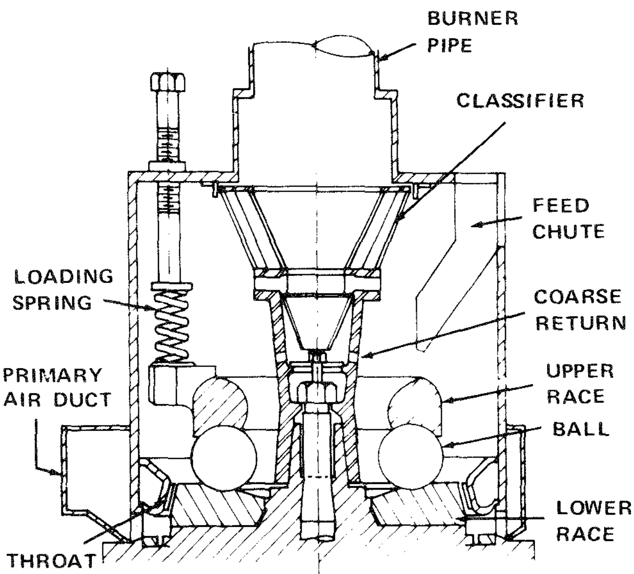


FIGURE 3
B&W E TYPE PULVERIZER

The most important item affecting fineness was determined to be classifier configuration. The final classifier design is shown in Figure 4. With this classifier, the fineness results obtained when pulverizing coal ranged from 58 to 67 percent passing 200 mesh. Although the fineness was not completely to specification, combustion conditions had improved considerably with ash combustibles dropping from approximately 20 percent to approximately 10 percent and therefore it was decided to commence testing.

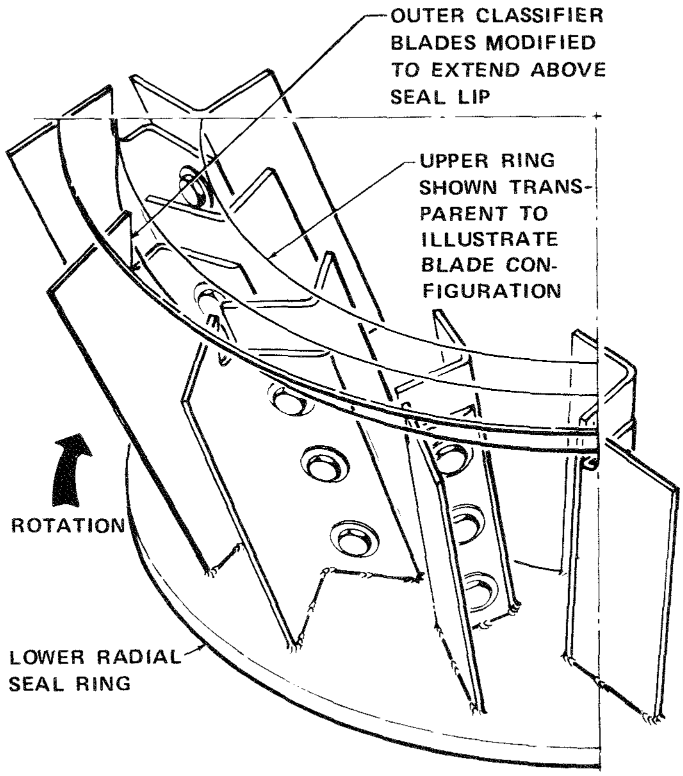


FIGURE 4
MODIFIED CLASSIFIER CONFIGURATION

The product fineness performance of the pulverizers while grinding SRC is shown in Table 1. As expected, the pulverizers produced a finer ground product when pulverizing SRC than with regular coal.

Grinding Energy Requirements

An important parameter in the design of a pulverizer, from the viewpoint of both economics and plant operation, is the energy expended to grind the product as measured either by horsepower input to the shaft or gross pulverizer energy.

Since horsepower input to the pulverizer is proportional to torque and shaft speed, a strain gauge bridge was applied to the input shaft of one mill to measure the input torque, and a photoelectric tachometer was used to determine rotational speed. Table 2 lists both the horsepower and gross pulverizer energy requirements for various combinations of fuel feed rates and load forces on the balls.

Since the heating value of SRC is so much higher than normal coal, a more representative measure of grinding energy requirements can be obtained by expressing the fuel feed rate in 10^6 Btu/hour rather than in lb/hour. Figures 5 and 6 graphically illustrate Table 2 data.

TABLE 1

SRC FINENESS TESTS

Date	Pulverizer	Fuel-Air Ratio	Burner	Pass 200 Mesh (%)	Mill Load (lb/hour)
6–17–77	A	44.1	AA	76.6	5714
6–17–77	C	41.0	CA	86.5	5934
6–17–77	C	41.0	CB	88.3	5934
6–17–77	C	31.2	CB	90.9	7500
6–23–77	A	44.2	AA	80.8	5567
6–23–77	A	44.2	AB	84.2	5567
6–23–77	B	38.4	BA	87.4	6102
6–23–77	B	38.4	BB	81.0	6102
6–23–77	C	40.3	CA	90.0	5806
6–23–77	C	40.3	CB	88.5	5806

TABLE 2

PULVERIZER ENERGY REQUIREMENTS

Date	Fuel Feed Rate SRC (lb/hour)	Fuel Feed Rate Coal (lb/hour)	Pulverizer Ball Loading (lb/ball)	Shaft Horsepower	Gross Pulverizer Energy (kWh/ton)	Gross Pulverizer Energy (kWh/10^6 Btu)
6–21–77	2602		500	42	23.8	0.78
6–21–77	4373		500	45	15.1	0.49
6–21–77	6000		500	51	12.5	0.41
6–21–77	6300		500	51	11.9	0.39
6–21–77	6900		500	51	10.9	0.36
6–21–77	7660		500	45	8.6	0.28
6–27–77	6279		700	56	13.1	0.43
6–27–77	8000		700	50	9.3	0.30
6–27–77	6000		900	56	13.7	0.45
6–27–77	6429		900	59	13.5	0.44
6–27–77	7941		900	62	11.4	0.38
6–30–77		7058	1300	65	13.4	0.52
6–30–77		7414	1300	68	13.3	0.52
6–30–77		8000	1300	70	12.9	0.49

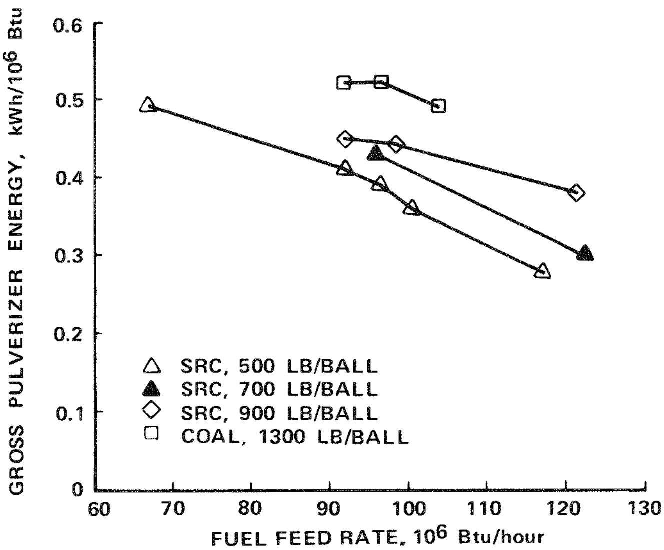


FIGURE 5

GROSS PULVERIZER ENERGY VERSUS FUEL FEED RATE

The grinding power requirements observed in the Plant Mitchell study were opposite the results reported by B&W (EPRI Project 1235–4) using the E-21 pulverizer. In this report B&W stated that the work required to pulverize SRC was greater than that for coal. However, the minimum ball loading for these B&W tests was 1000 lb/ball. In a subsequent report (EPRI Project 1235–5), B&W indicated that the energy required to pulverize SRC with a ball loading of 500 lb/ball was less than that for coal.

In all cases at Plant Mitchell, the grinding power requirements were less for SRC than for coal. At an equal Btu grinding rate of 100 x 10^6 Btu/hour, SRC required 25 percent less energy to grind. At an equal feed rate of 7000 lb/hour, SRC typically required 20 percent less energy to grind. In addition, pulverizer capacity is at least 25 percent greater when grinding SRC than when grinding coal when the capacity is compared on a Btu basis.

One would expect the pulverizer horsepower required to increase as the fuel feed rate increases. Figure 7 indicates that this relationship held true for grinding coal and for grinding SRC with a ball loading of 900 lb/ball. However, when SRC was pulverized with ball loadings of 500 lb/ball and 700 lb/ball, a downward trend in the horsepower requirement was noted for higher fuel feed rates. The reason for this downward trend is unknown, but

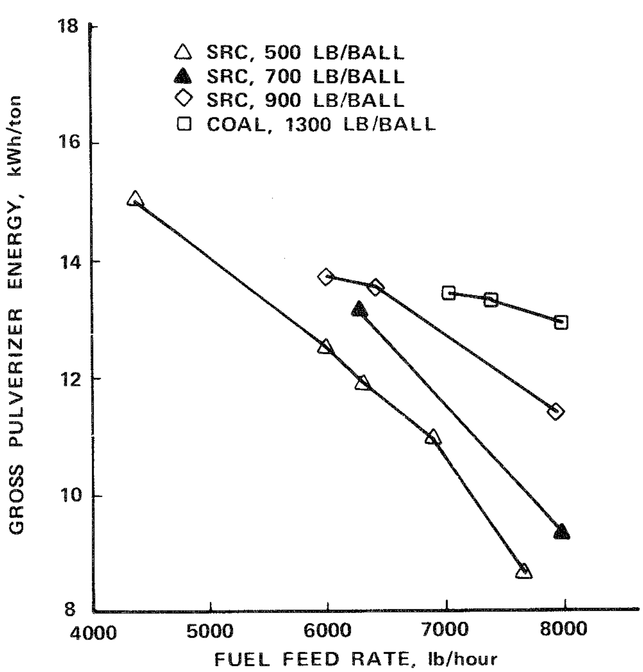


FIGURE 6

GROSS PULVERIZER ENERGY VERSUS FUEL FEED RATE

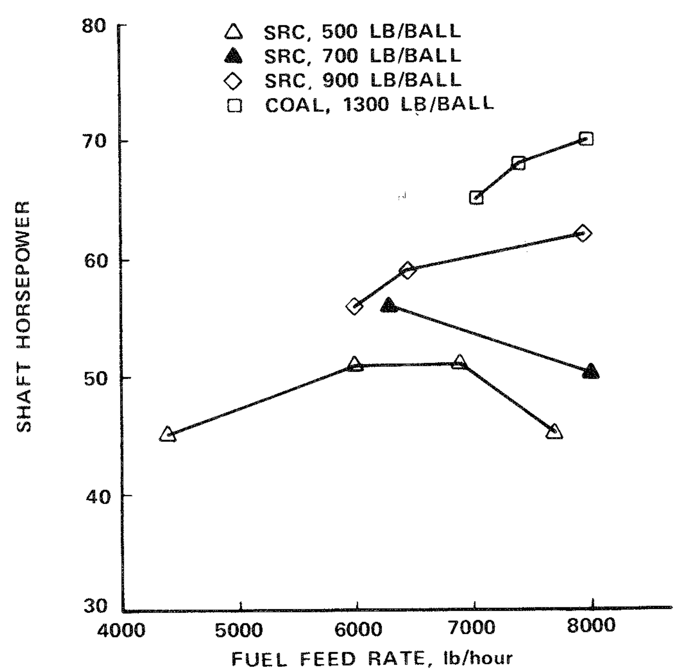


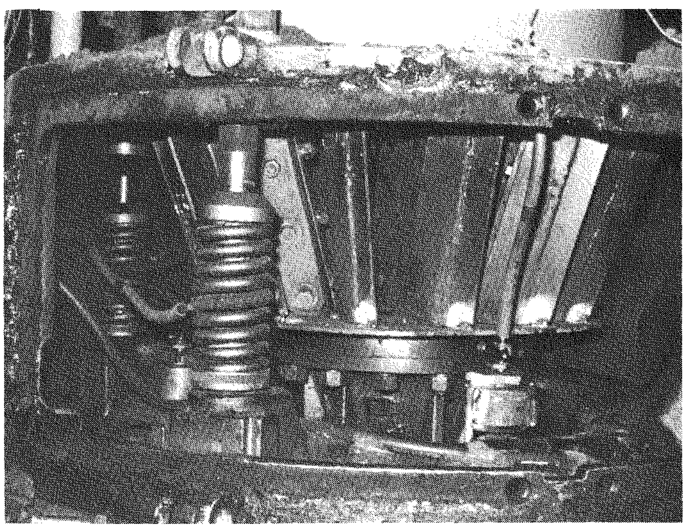
FIGURE 7

SHAFT HORSEPOWER VERSUS FUEL FEED RATE

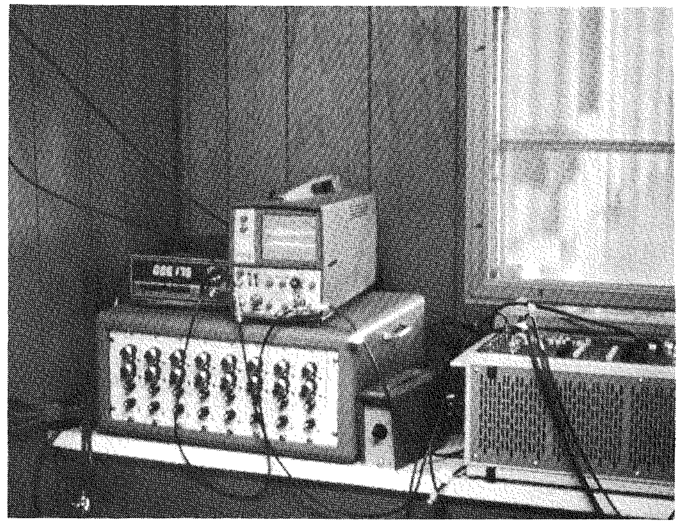
a distinct reduction in vibration acceleration levels was simultaneously observed. A marked reduction in the friction forces within the pulverizer may occur for certain combinations of ball loading and fuel feed rates. As shown in Figures 5 and 6, the 500 lb/ball loading also resulted in a minimum gross pulverizer energy requirement.

Vibration Accelerations and Load Spring Deflections

To observe the real-time operating conditions of the E-35 pulverizers and to detect potential vibration problems or an excessive buildup of SRC deposits within the pulverizers, accelerometers and strain gauges were employed. Accelerometers were mounted on the upper ring and outside casing of the pulverizers, and strain gauges were attached to the load springs of each pulverizer. Outputs from the accelerometers and strain gauges were connected to signal conditioning and data recording equipment.



Typical internal horizontal and vertical acceleration levels are plotted against fuel feed rates for both normal coal and SRC in Figure 8. A linear dependence is shown with acceleration levels decreasing for fuel flow increases for both normal coal and SRC. In addition, acceleration levels measured by the pulverizer internal accelerometers were less when grinding SRC than when grinding coal. For example, at a typical fuel feed rate of 7000 lb/hour the relative average accelerations were 5.4 g and 7.4 g in the horizontal direction and 3.7 g and 4.6 g in the vertical direction for SRC and coal, respectively.



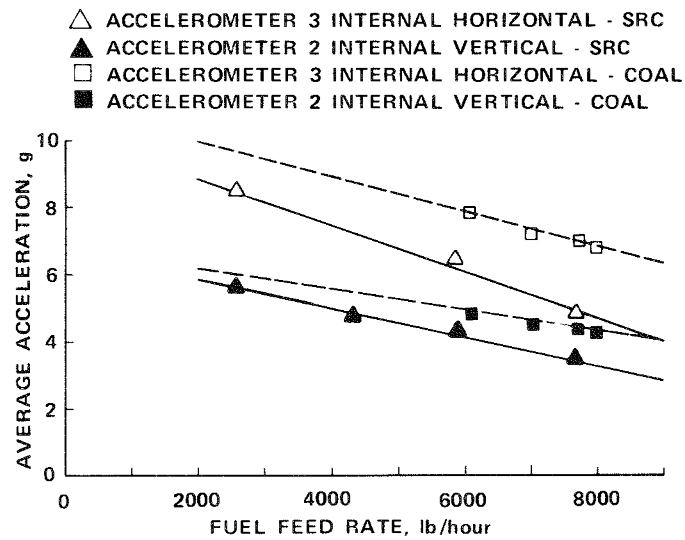


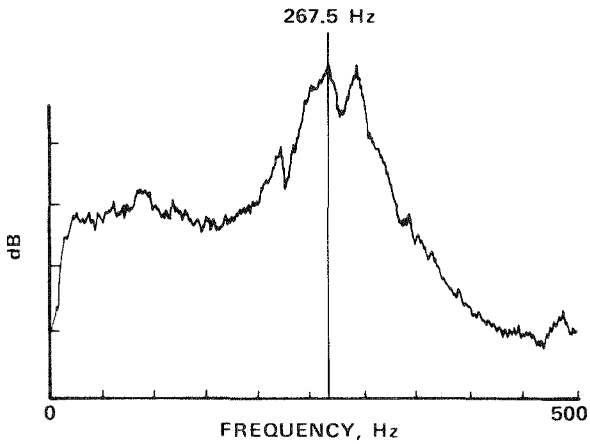
FIGURE 8

PULVERIZER VIBRATION

To determine whether resonances existed which could cause damage to the pulverizer, frequency spectrums shown in Figures 9 and 10 were obtained for coal and SRC operation, respectively. Although peaks occur in the neighborhood of 250 Hz for both coal and SRC, the peaks consist of broad humps rather than sharp spikes, indicating that no damaging resonances were present. Similar observations were made by B&W for the E-21 pulverizer.

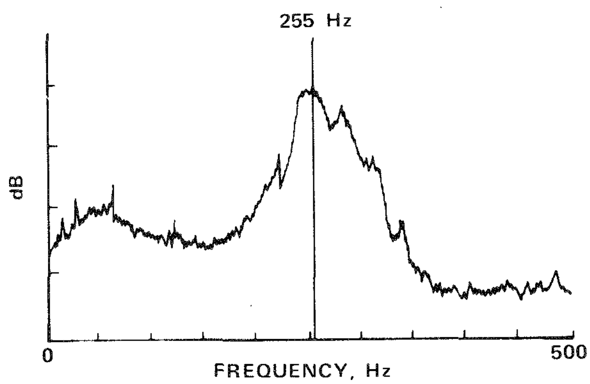
To monitor the level of the coal or SRC bed in the pulverizer and to detect agglomeration on the balls and/or race, springs were instrumented with strain gauges. Difficulties had been encountered at B&W with

SRC caking on the ball and rings in the pulverizer. The internal load of SRC in the pulverizer was varied widely during the Plant Mitchell test, and there were no problems with caking or agglomeration of SRC in the pulverizer. Upon inspection, only a thin coat of SRC was evident on the internal pulverizer parts.



ACCELEROMETER 3 INTERNAL
HORIZONTAL - COAL 1300 LB/BALL

FIGURE 9
ACCELEROMETER FREQUENCY SPECTRUM



ACCELEROMETER 3 INTERNAL
HORIZONTAL - SRC 500 LB/BALL

FIGURE 10
ACCELEROMETER FREQUENCY SPECTRUM

Summary

There were absolutely no problems with pulverizing SRC in the E-35 mills. The mills consumed less power, ground finer, had greater capacity, and ran smoother when pulverizing SRC. No problems could be induced even under increased SRC bed depth or increased ball loading, conditions which had caused problems in B&W's smaller scale work.

BOILER EFFICIENCY

A series of tests was performed in accordance with ASME Power Test Code PTC4.1-1964, Steam Generating Units, to determine the relative effect of SRC compared with coal on the efficiency of the boiler.

Boiler efficiency in these tests was determined by the heat loss method described in the ASME Power Test Code. In the heat loss method, the input energy which is lost in the boiler is determined on a per pound of coal basis and is then related to the heating value of 1 pound of coal. The difference between the percent losses and 100 percent is the boiler efficiency. An advantage of this method is its ability to isolate and compare individual sources of energy loss. This procedure is ideal for these tests in which a comparison of performance of coal and SRC is desired. The method takes into consideration the following ways in which energy is lost from the boiler:

- Dry gas loss – Sensible heat that departs with the expended dry flue gas.
- Moisture loss – Energy lost in vaporizing the moisture in the fuel.
- Hydrogen loss – Burning of hydrogen in the fuel produces water vapor, making some input energy (based on the fuel high heating value) unavailable.
- Unburned combustibles loss – Fuel that passes unburned to be discarded in the ash pond.
- Radiation loss – Thermal radiation from the boiler outer surface.
- Minor losses – Various small losses resulting from humidity of the incoming air, burner cooling water, etc.

For each of the three test phases, efficiency tests were run at unit loads of approximately 7, 14, and 21 MW. Usually two tests, each of 4-hours duration, were conducted at each load.

The boiler performance test results are summarized in Table 3, and represent the actual measured boiler efficiency of the unit for the three phases. However, certain basic test conditions changed between tests which would bias a fair comparison of coal and SRC based on these results. In particular, air heater

TABLE 3

UNADJUSTED BOILER EFFICIENCY RESULTS

	Phase I Tests						Phase II Tests						Phase III Tests							
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	7	8
Load, MW	22.5	22.5	15.3	15.0	7.5	7.3	21.1	21.0	14.1	14.0	6.0	6.0	21.0	21.0	14.0	14.0	7.0	7.0	21.0	21.0
Dry Gas Loss, %	8.2	7.3	7.3	7.6	8.5	7.7	6.8	6.8	7.2	7.7	9.4	8.8	7.3	7.2	8.2	7.7	9.9	10.0	7.0	6.9
Moisture Loss, %	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Hydrogen Loss, %	4.2	4.1	4.2	4.0	4.1	4.1	3.3	3.1	3.4	3.5	3.6	3.6	4.1	4.0	4.0	3.9	4.1	3.9	4.0	3.9
Combustible Loss, %	2.0	2.1	2.6	2.5	5.3	5.4	1.3	1.6	3.1	1.5	3.6	3.1	1.6	1.5	4.3	4.5	3.5	3.5	1.2	2.4
Radiation Loss, %	0.3	0.3	0.6	0.6	1.0	1.0	0.4	0.4	0.6	0.6	1.1	1.1	0.4	0.4	0.7	0.7	1.0	1.0	0.4	0.4
Minor Loss, %	0.2	0.2	0.2	0.2	0.1	0.2	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.3	0.3
Efficiency, %	84.4	85.3	84.4	84.4	80.4	81.0	87.3	87.2	84.9	85.8	81.3	82.4	86.0	86.3	82.2	82.6	80.8	80.9	86.9	85.9

effectiveness varied due to repairs after Phase I. Also, at low loads an apparent flow transition to laminar conditions reduced low load air heater effectiveness. Because the dry gas losses are dependent on the ability of the air heater to recover energy from the flue gas, variation of air heater effectiveness influences the boiler efficiency independently of the fuel.

Another factor which varied between tests was the hydrogen content of the fuel. The Phase II results show especially low hydrogen losses because of the low hydrogen content of the coal. This enhanced the Phase II results. However, the bulk of the hydrogen loss results from reduction of the data using the fuel high heating value (HHV). It is thereby assumed that the final hydrogen combustion product should be condensed to liquid water, and that the latent heat released by the condensation should be available to the boiler. When the hydrogen-derived water exits the system as a vapor, the latent heat would then appear as a loss. Use of the HHV therefore implies that the presence of hydrogen severely degrades the fuel and the boiler performance, which is an erroneous conclusion. This contradiction is avoided through the use of the fuel low heating value (LHV), and thus the final hydrogen combustion product is assumed to be water vapor.

Table 4 presents a summary of the test results adjusted for the effect of air heater variation and based upon the low heating value of the fuel. With the low heating value, the water vapor latent heat is assumed not to be available, and the hydrogen loss now represents the sensible heat carried from the system by the hydrogen - derived water vapor in the flue gas. It is believed that these adjusted results represent a much more reliable basis for comparison of test results because the variability of air heater performance and fuel hydrogen content have been removed from the analysis.

Figure 11 presents a plot of adjusted boiler efficiency as a function of unit load for each test phase, and shows the efficiency at full load to be approximately the same in all phases.

The sharp efficiency drop at medium load in Phase III is the result of a large amount of unburned combustible material. Although combustible loss accuracy problems were encountered due to the sensitivity of the results to small SRC and ash combustible analyses errors, this large medium load combustible loss is apparently real and

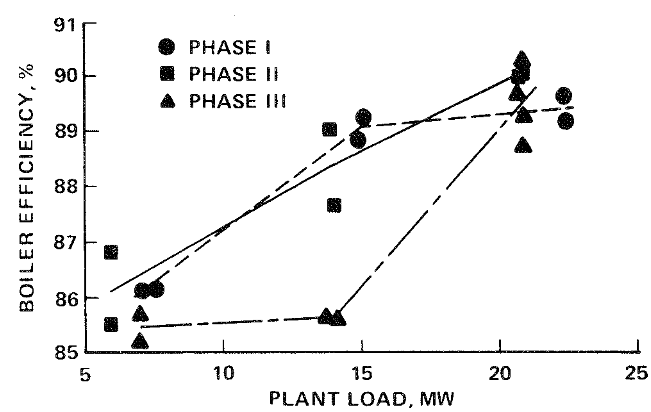


FIGURE 11

BOILER EFFICIENCY VERSUS LOAD (CORRECTED FOR AIR HEATER PERFORMANCE AND BASED ON FUEL LOW HEATING VALUE)

TABLE 4

BOILER EFFICIENCY RESULTS

(Adjusted for Air Heater Variations and Based on Fuel Low Heating Value)

	Phase I Tests						Phase II Tests						Phase III Tests							
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	7	8
Load	22.5	22.5	15.3	15.0	7.5	7.3	21.1	21.0	14.1	14.0	6.0	6.0	21.0	21.0	14.0	14.0	7.0	7.0	21.0	21.0
Dry Gas Loss, %	7.0	6.7	6.4	6.7	6.2*	6.1*	7.1	6.7	7.5	7.7	8.4	7.6	7.7	7.6	8.2	8.1	9.0	8.6	7.5	7.5
Moisture Loss, %	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Hydrogen Loss, %	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Combustible Loss, %	2.1	2.2	2.7	2.6	5.5	5.6	1.3	1.7	3.2	1.5	3.7	3.2	1.7	1.5	4.5	4.7	3.7	3.7	1.2	2.5
Radiation Loss, %	0.4	0.4	0.6	0.6	1.0	1.0	0.4	0.4	0.6	0.6	1.1	1.1	0.4	0.4	0.7	0.7	1.0	1.0	0.4	0.4
Minor Loss, %	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.6	0.5	0.3	0.4
Efficiency, %	89.2	89.5	89.1	88.9	86.2	86.2	90.0	90.0	87.6	89.0	85.5	86.9	89.3	89.6	85.6	85.6	85.2	85.7	90.1	88.7

*Suspected Error in Air Heater Data

is also evidenced by precipitator test results. Similar large losses appear in later medium load SRC tests and seem to be related to boiler operating conditions, including high excess air and difficulty in maintaining satisfactory firing conditions. Flame observations indicated nonoptimum combustion characteristics. The specific causes of these medium load operating problems are believed to be related to low pressure differentials across the burner secondary air registers and a poor distribution of secondary air in the windbox. Both of these conditions would cause poor mixing of the fuel and secondary air.

Dry gas losses were also somewhat higher with SRC than with coal. SRC has a low melting point and, to prevent agglomeration of the fuel in the pulverizers, only ambient primary air was used. This reduced the amount of energy recovered in the air heater, and in general increased the Phase III dry gas losses by a small amount.

With the exception of medium load, excess air was approximately the same in Phases II and III. Excess air in Phase I, however, was significantly lower, which is reflected by the lower Phase I dry gas losses. The increased excess air in Phases II and III is believed to be due to characteristics of the dual register burners coupled with the windbox design.

The losses due to fuel moisture were less with SRC than with coal. SRC is essentially water-free, with only a small amount of surface moisture acquired during storage. When compared with SRC, approximately 0.5 percent more of the input energy was lost with coal due to moisture.

A simplified way of illustrating overall generating unit efficiency is to calculate the gross unit heat conversion at various unit loads. The results of these calculations are shown in Figure 12. Full load heat conversions were essentially the same for all phases, while medium and low load heat conversions were somewhat lower during Phases II and III. These lower values reflect the change to dual register burners and subsequent higher excess air. The variation in overall generating unit performance with load essentially masks the minor variations in boiler performance caused by changes in fuel and burner type.

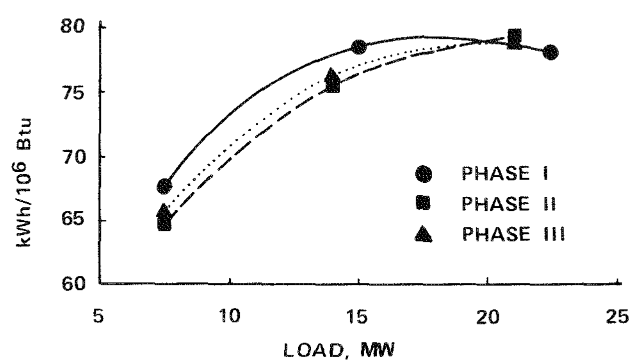


FIGURE 12
HEAT CONVERSION VERSUS LOAD

EMISSIONS

York Research Corporation was contracted to conduct a major portion of the emissions testing work related to the SRC burn test. During each phase of the program, emissions measurements were performed with the boiler operating at full load (22 MW), medium load (14 MW), and low load (7.5 MW). The following measurements were made:

1. Continuous monitoring of opacity, O_2, CO_2, CO, NO_x, and SO_2 in the precipitator outlet flue gas.
2. Manual SO_2 and NO_x tests using EPA Methods 6 and 7, respectively, at selected full load conditions.
3. Particulate loadings at both the inlet and outlet to the primary precipitator by EPA Method 5 and ASME Power Test Code PTC 27.
4. Particle size distributions of the flyash at the inlet and outlet of the precipitator.
5. Percent combustibles in the precipitator inlet flyash.
6. Resistivity of the inlet flyash (performed by Southern Research Institute).

The above tests were performed to document the performance of SRC as a fuel for utility boilers. Table 5 is a compilation of some of the important test results dealing with the environmental acceptability and burning efficiencies of SRC. SRC easily complies with the existing EPA New Source Performance Standards for SO_2 and NO_x, which are 1.2 $lb/10^6$ Btu and 0.7 $lb/10^6$ Btu, respectively.

York Research Corporation's continuous monitoring trailer provided 24-hour a day data on the combustion conditions during all three phases. All six parameters were recorded in continuous fashion on strip chart recorders. The readings were averaged over one-half hour intervals for the entire recording period. All analyzers were calibrated before and after each test period to ensure accuracy. Another method of ensuring analyzer

TABLE 5

OPERATION AND EMISSIONS DATA

	Phase I			Phase II				Phase III			
Load, MW	22.5	15	7.5	21	14	7.5	21*	21	14	7.5	21*
Fuel Rate, lb/hour	23880	16143	9010	20676	14784	9510	20065	17714	12178	7311	17678
Excess O_2, %	4.7	6.0	11.0	4.4	6.2	11.6	4.6	6.0	7.5	11.3	6.2
Particulate Loading In, $lb/10^6$ Btu	9.90	10.84	9.81	7.39	9.09	8.96	4.72	1.04	1.91	1.77	0.96
Particulate Loading Out, $lb/10^6$ Btu	2.30	0.46	0.11	1.66	0.81	0.32	0.07	0.90	1.42	0.93	0.04
Carbon In Ash, %	13.9	14.5	19.5	22.33	20.6	16.9	28.1	77.4	88.7	89.4	74.7
Carbon Efficiency, %	97.70	97.47	97.07	98.00	97.18	97.18	97.87	98.51	96.98	97.07	98.60
SO_2, $lb/10^6$ Btu	1.94	2.15	2.44	1.20	1.57	1.80	0.94	0.95	0.98	1.06	0.93
NO_x, $lb/10^6$ Btu	1.01	0.46	0.89	0.49	0.47	0.49	0.47	0.43	0.45	0.42	0.46
Average Opacity, %	41	18	7	30	22	12	66	32	29	16	40
$kWh/10^6$ Btu	78.05	78.67	67.85	79.30	75.81	64.97	80.22	78.98	76.18	65.77	78.88
Fuel Input SO_2, $lb/10^6$ Btu**		1.96			1.39				0.98		
Emissions SO_2, $lb/10^6$ Btu**		***			1.41				1.00		

*Secondary Precipitator Tests **Average of All Tests ***Equipment Malfunction

accuracy was by comparison of the analyzer data to the manual SO_2 and NO_x tests performed at full load.

Although particulate loadings entering the primary precipitator when burning SRC were 7 to 10 times lower than when burning coal, the particulate concentrations leaving the primary precipitator were higher than EPA standards. However, this precipitator, installed in 1946, does not conform to current precipitator design standards. The design flaws, coupled with the high carbon content of the SRC ash that made the ash resistivity very low, resulted in low collection efficiencies.

Since the unit is equipped with a secondary precipitator of modern design, additional tests were performed using this precipitator. The tests on the secondary precipitator indicate EPA compliance by a wide margin, and show that an adequately designed precipitator will allow SRC to meet existing EPA particulate emission standards.

The particle size distributions were determined by the use of two cascade impactors. The one manufactured by Brink, with a lower sampling rate, was used for the inlet locations. The other, manufactured by Andersen, with a higher sampling rate, was used for the outlet locations. The results of the particle size distributions indicate that the flyash produced from the combustion of SRC contained a larger percentage of fine particles than the flyash produced from the combustion of normal coal.

Tests to determine the resistivity of the inlet flyash were performed by Southern Research Institute using a point-to-plane probe for Phase II and Phase III. During Phase II, the flyash had a resistivity in the order of 1.9×10^{11} ohm – cm. During Phase III, the extremely high carbon content of the ash made any sort of determination of resistivity with the in-situ point plane probe impossible. Further efforts are being made at this time to determine the resistivity of SRC flyash.

CHEMICAL ANALYSIS

Extensive analyses were performed on fuel, ash, and stack gas samples to determine boiler efficiencies and to characterize effluent species produced during combustion. Nominal values of fuel analyses on an as-burned basis in each of the three phases are shown in Table 6.

TABLE 6

COMBINED PROXIMATE AND ULTIMATE FUEL ANALYSES

Parameter	Phase I	Phase II	Phase III
Moisture, %	6.55	5.52	2.21
Carbon, %	67.78	71.34	83.01
Hydrogen, %	4.64	4.52	5.72
Nitrogen, %	1.18	1.44	1.60
Chlorine, %	0.11	0.11	0.09
Sulfur, %	1.16	0.88	0.71
Oxygen (Difference), %	7.57	7.63	6.17
Ash, %	11.18	8.94	0.57
Btu per Pound	12140	12668	15274

The results for each phase were computed by averaging the values obtained from each sample over the entire testing period. All fuel analyses were performed according to ASTM specifications by Commercial Testing and Engineering Company and by the Georgia Power Company Central Fuel Laboratory.

Ash content of SRC as burned during Phase III was 0.57 percent. The average of all shipments as determined by P&M was 0.19 percent. Investigation of this apparent discrepancy determined that the contamination resulted from surface dust and other foreign material. This contamination probably occurred during pit solidification and storage.

Stack gas sampling was conducted by a number of different subcontractors. TRW obtained grab samples

TABLE 7

GASEOUS BOILER EMISSIONS

Date	Conditions	O_2 (%)	CO_2 (%)	N_2 (%)	SO_2 (ppm)	SO_2 (lb/10^6 Btu)	NO_x (lb/10^6 Btu)
			Phase II				
6-1-77	low load	11.6	4.78	78.53	188	1.39	0.47
5-29-77	med load	6.0	7.10	78.71	217	0.95	0.50
5-27-77	full load	4.1	9.78	79.66	319	1.01	0.47
			Phase III				
6-18-77	low load	11.0	6.74	80.02	222	1.09	0.43
6-14-77	med load	7.3	7.57	78.82	255	1.00	0.45
6-16-77	full load	5.6	9.90	80.26	335	0.97	0.40

and performed on-site gas chromatographic analyses for CO, CO_2, SO_2, N_2, O_2 and C_1 -C_6 hydrocarbons during Phases II and III of testing. No C_1 -C_6 hydrocarbons or CO were detected during any test, regardless of load. Also, no polynuclear aromatic compounds were detected. Typical results obtained under optimized operating conditions are shown in Table 7. The last two columns in the table indicate SO_2 and NO_x in pounds per million Btu obtained from continuous analysis of the flue gas by York Research. These analyses were obtained using chemiluminescent and pulsed fluorescent analyzers for NO_x and SO_2, respectively.

TABLE 8

PARTICULATE EMISSIONS

Phase	Primary Precipitator		Secondary Precipitator*
	Inlet	Outlet	Outlet
I	10.0	2.3	--
II	7.0	1.6	0.07
III	1.0	0.9	0.04

All values are in lb/10^6 Btu

*Primary precipitator deenergized during secondary precipitator tests

Particulates were determined by York Research according to EPA Method 5 specifications for sampling and analysis. The results shown in Table 8 are typical values for the particulate loading of the flue gas at the specified sampling points.

ASH DEPOSITION

The ash deposition probe shown in Figure 13 was designed to simulate a furnace water-wall tube or a superheater tube and was employed during all phases of the SRC burn test. Ash adhering to metal surfaces during boiler operation was quantitatively collected by the probe for analysis of physical and chemical characteristics. The sample port was located on the back wall of the furnace, so that the probe penetrated the screen tube section immediately ahead of the superheater.

The probe consisted of a water cooled jacket for support of the deposition section and an air cooling feature to maintain the temperature of the deposition section within a preselected range. The deposition section was composed of twelve 1-inch-long metal rings, with three thermocouples located under the outside surface of the first, sixth, and twelfth rings and connected to a recorder-controller. The middle thermocouple was connected to an air flow control valve with a pressure regulator for temperature control of the probe, which was maintained at 1000 $\pm$ 50°F during all phases of ash collection.

The first trial run disclosed that wind was interfering with collection of ash from the probe, leading to design and construction of a special sample box to serve both as a collection box and a wind screen. During each sampling run, the probe was inserted through the sample box and into the sample port where it remained for the designated duration. Upon completion of each run, the probe was removed from the sample port directly into the box, and while thus shielded, ash adhering to the deposition section of the probe was removed and transported in the sample box to the plant laboratory for weighing. Results of the ash deposition experiment are presented in Table 9.

The data show that the ash deposition rates decrease as the load decreases. The collection rates under full loading conditions for each phase are shown in Figure 14. Since the ash deposition probe has only a limited surface area, the collection rates cannot be expected to be linear over an extended period of time. However, they were linear for the duration of sampling. The most outstanding result is that the deposition rate for Phase III (the actual burning of the SRC) is so much lower than those for Phases I and II when coal was burned. Phase III ash accumulated at less than 0.05 gram per hour, as compared with average accumulation rates of 0.62 gram per hour for Phase I and 1.15 grams per hour for Phase II.

The results of the ash deposition tests confirmed visual observations during the burn test. There was virtually no accumulation of ash in any boiler section.

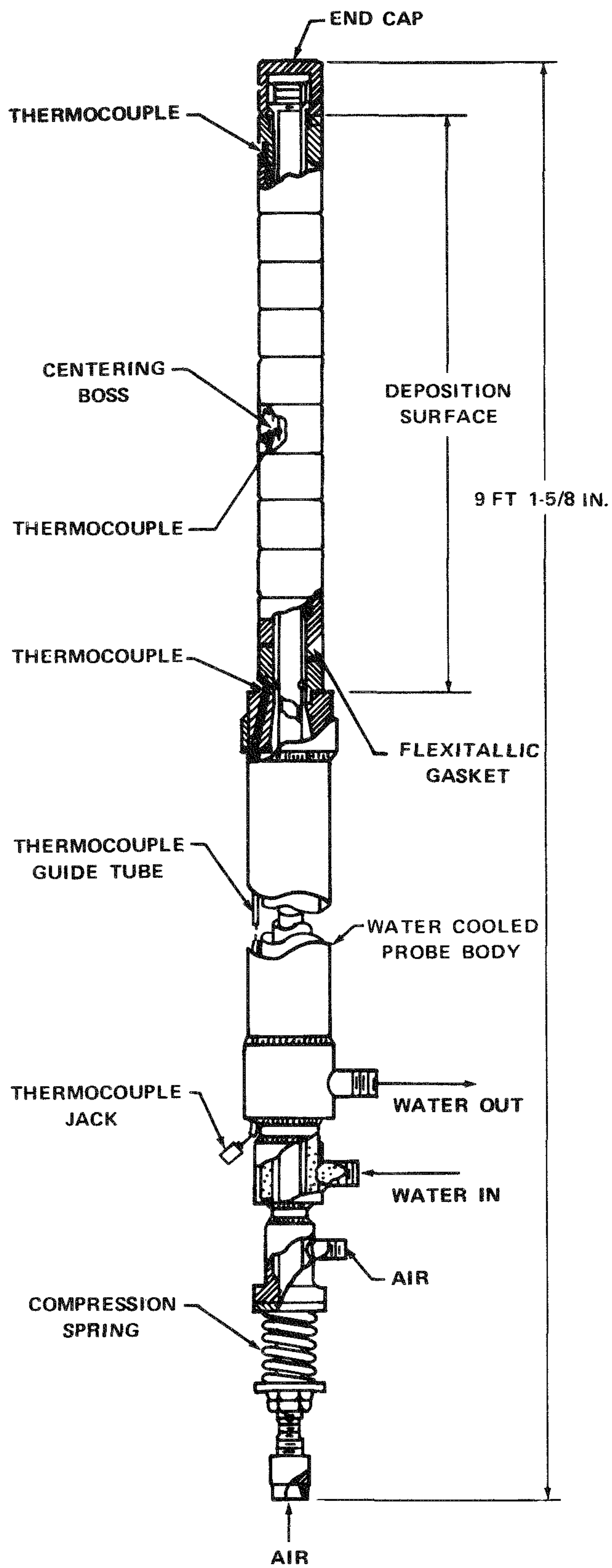


FIGURE 13
ASH DEPOSITION PROBE

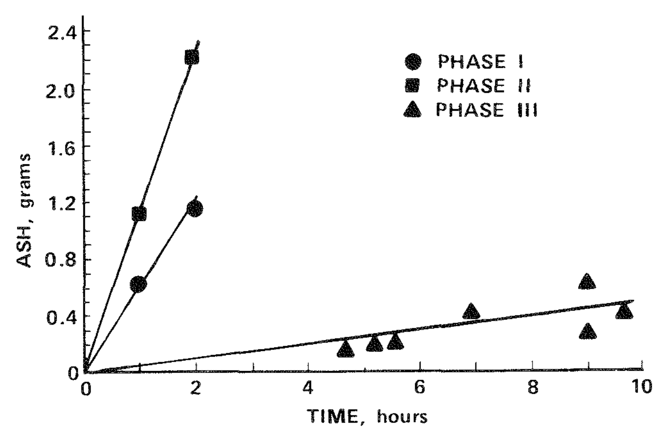


FIGURE 14

ASH DEPOSITION PROBE COLLECTION RATES UNIT AT FULL LOAD

TABLE 9

ASH DEPOSITION RESULTS

Phase	Date	Time	Duration	Loading Conditions	Grams Collected
I	1-25-77	1145–1545	4 hour		
I	3-23-77	950–1150	2 hour	Full	1.2110
I	3-23-77	1315–1415	1 hour	Full	0.6326
I	3-24-77	905–1205	3 hour	Medium	3.6716
I	3-25-77	830–1130	3 hour	Low	3.3335
I	3-25-77	1200–1300	1 hour	Low	1.0003
II	5-24-77	900–1053	1 hour 53 min	Full	2.2157
II	5-25-77	1010–1422	4 hour 12 min	Medium	0.9904
II	5-26-77	830–1140	3 hour 10 min	Low	0.1905
III	6-13-77	1040–1522	4 hour 42 min	Full	0.1318
III	6-14-77	800–1345	5 hour 45 min	Medium	0.1357
III	6-15-77	825–1407	5 hour 42 min	Low	0.0782
III	6-16-77	1025–1602	5 hour 37 min	Full	0.1941
III	6-17-77	800–1655	8 hour 55 min	Full	0.2672
III	6-22-77	723–1700	9 hour 37 min	Full	0.3942
III	6-23-77	640–1535	8 hour 55 min	Full	0.6211
III	6-24-77	800–1455	6 hour 55 min	Full	0.3992
III	6-25-77	725–1240	5 hour 15 min	Full	0.1908

EQUIPMENT RELIABILITY AND AVAILABILITY

The 18-day burn test of SRC demonstrated that power plant equipment will exhibit increased reliability and availability when SRC is used.

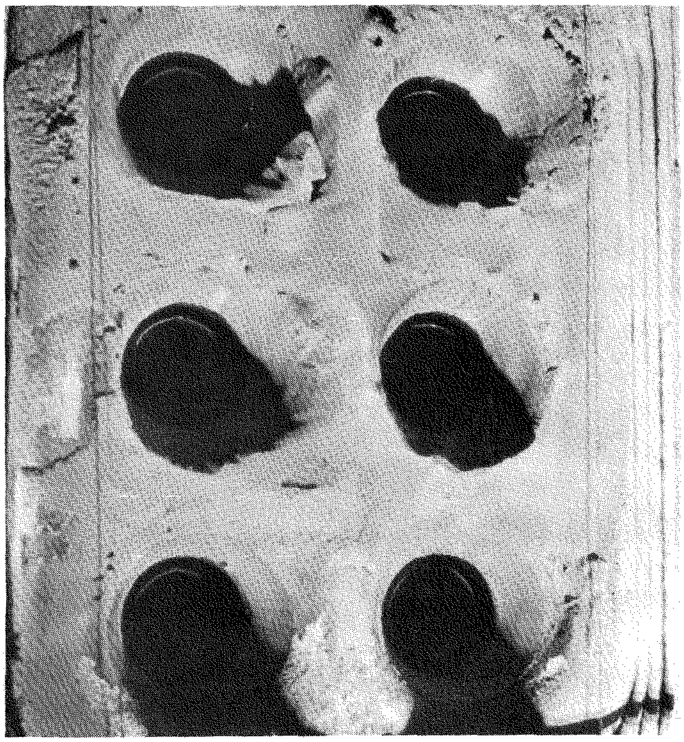
As mentioned earlier, the ball loading of the pulverizers while firing SRC was 500 lb/ball, as opposed to 1300 lb/ball for coal. The lower ball loading pressure combined with the improved grinding characteristics of SRC should decrease wear within the pulverizers.

The quantity of flyash generated when firing SRC was nominally 7 to 10 times less than when firing coal. Bottom ash was virtually nonexistent. During efficiency testing, it was necessary to scrape the bottom of the ash pit in order to collect enough bottom ash sample to fill a quart jar. When firing coal over the same time period (4 hours), the ash pit would be 4 feet deep in bottom ash. The appearance and physical characteristics of the SRC bottom ash are different from normal coal bottom ash. SRC bottom ash looks like black popcorn and is easily crushed between one's fingers, whereas coal bottom ash is dense and hard.

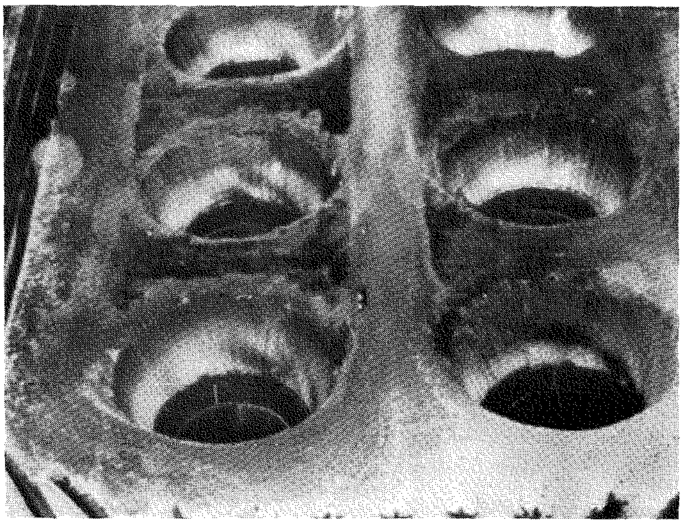
The overall lower ash loading should greatly increase reliability and availability of such equipment as ash sluice pumps, ash lines, clinker grinders, and soot blowers. As a matter of fact, the soot blowers were not used at all during the entire 18-day SRC burn test. Under normal coal firing conditions, soot blowers are used 6–12 times a day. It was also not necessary to deslag the burner front during the entire SRC burn test. When firing coal, this must normally be done at least once a day.

After the burn test was completed, the boiler was inspected for any ash buildup in the superheater sections of the boiler, but none was found. The entire boiler was essentially as clean as it was when the test began.

The low ash loading, easy pulverization, exceptional boiler cleanliness, and nonabrasive characteristics of SRC should greatly improve boiler and auxiliary equipment availability and reliability.



BURNER FRONT AFTER PHASE II TESTING WITH COAL



BURNER FRONT AFTER PHASE III TESTING WITH SRC

CONCLUSIONS

The principal goal of demonstrating solvent refined coal as a desirable boiler fuel was successfully achieved as a result of the burn test at Plant Mitchell. Specific contractural objectives to investigate the transportation, storage and handling, and burning of 3000 tons of SRC were met with only minor modifications to equipment or procedures.

Shipment was accomplished in standard open coal cars, aided by the application of a commercially available spray coating to minimize blowing losses while in transit. SRC was handled by the normal Plant Mitchell fuel conveying and storage equipment, with dust being controlled by the use of a wetting agent during unloading operations. No equipment modifications were required for handling or storage, and no dust problems were encountered during bunker filling, storage, or feed.

The water cooled dual register burners developed especially for the burn test performed well, delivering exceptional flame stability while firing SRC. Installation of these burners was the only necessary modification made to the boiler.

Pulverizer modifications were considered very successful since, under a variety of operating conditions, there were no problems with pulverizing SRC. Results indicate that while grinding SRC the pulverizers consumed 25-percent less power, ground finer, and had a capacity 25-percent greater than when grinding coal.

Boiler efficiency at full load was essentially the same when burning either SRC or coal. The boiler stayed much cleaner with SRC than with coal, totally eliminating the need for soot blowers or deslagging of the burner front during the 18-day burn test. The quantity of SRC flyash was 7 to 10 times less than coal flyash, and there was no ash accumulation in any boiler section. In addition, there was almost no bottom ash accumulation from SRC. SRC ash is characteristically nonabrasive, and coupled with the very low ash loading, will reduce maintenance on the ash handling systems.

Emissions tests, conducted throughout the burn test using EPA and ASME procedures, measured particulates, SO_2, and NO_x. Continuous monitors also analyzed flue gas for opacity, SO_2, NO_x, CO, CO_2, and O_2. Particulates leaving the secondary precipitator yielded concentrations in compliance with current EPA standards by a wide margin. Measurements indicated that SRC SO_2 emissions were more than 20 percent under EPA standards and that NO_x requirements were met by a margin of 40 percent.

The overall results from the Plant Mitchell Solvent Refined Coal Burn Test prove that the performance of SRC as a boiler fuel is exceptional. The fuel is clean, uncomplicated in use, and has characteristics that should substantially improve boiler and auxiliary equipment availability and reliability. And in easily meeting current EPA requirements, solvent refined coal offers a clearly viable alternative to scrubber installations at both new and existing power plants.