PENNSTATE

COAL -WATER SLURRY FUEL COMBUSTION TESTING IN AN OIL-FIRED INDUSTRIAL BOILER

Semiannual Technical Progress Report
for the Period 08/15/1994 to 02/15/1995

By

Bruce G. Miller, Co-Principal Investigator
Alan W. Scaroni, Project Manager

May 12, 1995

Work Performed Under Cooperative Agreement Number DE-FC22-89PC88697

For
U.S. Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940

By
Energy and Fuels Research Center
The Pennsylvania State University
C211 Coal Utilization Laboratory
University Park, Pennsylvania 16802

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DISCLAIMER

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EXECUTIVE SUMMARY

The Pennsylvania State University is conducting a coal-water slurry fuel (CWSF) program for the United States Department of Energy (DOE) and the Commonwealth of Pennsylvania with the objective of determining the viability of firing CWSF in an industrial boiler designed for heavy fuel oil. Penn State and DOE have entered into a cooperative agreement to determine if CWSFs prepared from cleaned coal (containing approximately 3.5 wt.% ash and 0.9 wt.% sulfur) can be burned effectively in a heavy fuel oil-designed industrial boiler without adverse impact on boiler rating, maintainability, reliability, and availability.

The project will also provide information to help in the design of new systems specifically configured to fire these clean coal-based fuels. The project consists of four phases: (1) design, permitting, and test planning, (2) construction and start up, (3) demonstration and evaluation (1,000-hour demonstration), and (4) expanded demonstration and evaluation (installing a CWSF preparation circuit, conducting an additional 1,000 hours of testing, and installing an advanced flue gas treatment system). The boiler testing and evaluation will determine if the CWSF combustion characteristics, heat release rate, fouling and slagging behavior, corrosion and erosion tendencies, and fuel transport, storage, and handling characteristics can be accommodated in a boiler system designed to fire heavy fuel oil. In addition, the proof-of-concept demonstration will generate data to determine how the properties of a CWSF and its parent coal affect boiler performance. The economic factors associated with retrofitting boilers will also be evaluated.

The first three phases (i.e., the first demonstration) have been completed and the combustion performance of the burner that was provided with the boiler did not meet performance goals. Consequently, the first demonstration has been concluded at 500 hours. The second demonstration (Phase IV) will be conducted after a proven CWSF-designed burner is installed on the boiler.

Prior to the second demonstration, a CWSF preparation circuit was constructed to provide flexibility in CWSF production. The circuit was completed during this reporting period. An additional activity was to interact with vendors and engineering firms prior to selecting the pollution control systems to be installed on the boiler.

1.0 INTRODUCTION

The Pennsylvania State University is conducting a coal-water slurry fuel (CWSF) program for the United States Department of Energy (DOE) and the Commonwealth of Pennsylvania with the objective of determining the viability of firing CWSF in an industrial boiler designed for heavy fuel oil. Penn State and DOE have entered into a cooperative agreement to determine if CWSFs prepared from cleaned coal (containing approximately 3.5 wt.% ash and 0.9 wt.% sulfur) can be burned effectively in a heavy fuel oil-designed industrial boiler without adverse impact on boiler rating, maintainability, reliability, and availability. The project will also provide information to help in the design of new systems specifically configured to fire these clean coal-based fuels.

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The project consists of four phases as previously mentioned. Following is an outline of the project tasks that comprise the four phases:

Phase I: Design, Permitting, and Test Planning
- Task 1. Design
- Task 2. Permitting
- Task 3. Test Planning

Phase II: Construction and Start Up
- Task 1. Host Site Readiness/Boiler Retrofit
- Task 2. CWSF Preparation
- Task 3. Boiler Performance Prediction
- Task 4. Shakedown Testing

Phase III: Demonstration and Evaluation
- Task 1. Test Burn
  - Subtask 1.a. CWSF combustion performance
  - Subtask 1.b. Slagging/fouling propensity; corrosion characteristics
  - Subtask 1.c. Erosion characteristics
  - Subtask 1.d. Fuel transport, storage, and handling characteristics
- Task 2. Evaluation of Retrofit Economics

Task 3. Project Report

Phase IV: Advanced System Tests

Task 1. Procure and Install Burner and Superheater

Task 2. Construction of a CWSF Preparation Facility

Task 3. Installation of an Advanced Flue Gas Treatment System

Task 4. 1,000-Hour Test

Task 5. Final Report

Penn State began a coal-water slurry fuel (CWSF) research and development program in 1984 with the ultimate goal of facilitating the replacement of petroleum-based fuels with coal-based fuels in fuel oil-fired (designed) boilers. The Pennsylvania legislature appropriated funds in 1984 for the construction of a demonstration CWSF boiler with a capacity of approximately 15,000 lb steam/h at 300 psig on the University Park campus of Penn State. The project goal was to conduct a demonstration of the use of CWSF derived from Pennsylvania coal. The boiler performance was required to be environmentally acceptable and the testing was to evaluate the effect on boiler performance of long-term firing with CWSF. From a commercialization viewpoint, it was considered necessary to demonstrate at the industrial scale the technical feasibility of retrofitting existing fuel oil-fired units to burn CWSF, particularly in the commercial and light-industrial sectors. State funding was also provided for the installation of a 1,000 lb steam/h (nominally rated) Cleaver-Brooks A-frame watertube research boiler (Kinneman et al., 1988) to investigate: the effect of boiler operating parameters on combustion performance (Miller et al., 1988); automation of the firing of CWSF, particularly with respect to start up and shutdown procedures but also for optimizing boiler performance (Wincek et al., 1989); testing candidate CWSFs (Miller et al., 1991); and providing the necessary research support and operator training prior to start up of the demonstration unit. The CWSF demonstration program is being conducted on the 15,000 lb steam/h demonstration boiler.

The approach used in the program was as follows:

1. Install a natural gas/fuel oil-designed package boiler and generate baseline data firing natural gas.
2. Shake down the system with CWSF and begin the first 1,000 hours of testing using the burner/atomizer system provided with the boiler. The first 1,000-hour demonstration was to consist of boiler optimization testing and combustion performance evaluation using CWSF preheat, a range of atomizing air pressures (up to 200 psig as compared to the 100 psig boiler manufacturer design pressure), and using steam as the atomizing medium.
3. If the combustion performance was not acceptable based on the combustion efficiency obtained and the level of gas support necessary to obtain flame stabilization, then low-

cost modifications were to be implemented, such as installing a quarl and testing alternative atomizers.

4. If acceptable combustion performance was not obtained with the low-cost modifications, then the first demonstration was to be terminated and the burner system replaced with one designed specifically for CWSF.
5. In addition to the CWSF burner, a superheater tube and advanced flue gas cleanup system were to be installed for the second 1,000-hour demonstration.

The first three steps (i.e., the first demonstration) have been completed and the combustion performance of the burner that was provided with the boiler did not meet the targeted performance goals. Consequently, the first demonstration (Phases I-III) has been concluded at 500 hours and the results have been presented elsewhere (Miller et al., 1993). The second demonstration (Phase IV) will be conducted after a burner designed specifically for CWSF is installed on the boiler.

The status of Phases I through III and a summary of Phase IV is presented in Sections 2.0 through 5.0, respectively. Activities planned for the next semiannual period are given in Section 6.0. References are contained in Section 7.0 and acknowledgments are given in Section 8.0.

2.0 PHASE I: DESIGN, PERMITTING, AND TEST PLANNING

Phase I was completed on February 15, 1993 and the results have been presented previously (Miller et al., 1994b).

3.0 PHASE II: CONSTRUCTION AND START UP

Phase II was completed on October 10, 1992 and the results have been presented previously (Miller et al., 1994b).

4.0 PHASE III: DEMONSTRATION AND EVALUATION

Phase III work was completed on June 21, 1993 and the results have been presented previously (Miller et al., 1994b). Drafts of a project report covering the first three phases were submitted to DOE on June 21, 1993 and August 15, 1994.

5.0 PHASE IV: ADVANCED SYSTEM TESTS

The milestone schedule for Phase IV is shown in Figure 1, and Table 1 contains the milestone description for the entire project.

5.1 Task 1. Procurement and Installation of a Burner and Superheater

A low-NO_x burner was procured from Energy and Environmental Research Corporation (in conjunction with another program (Cooperative Agreement No. DE-FC22-92PC92162), that was designed to fire natural gas and CWSF or dry, micronized coal. Details of the burner were given in the previous semiannual report (Miller et al., 1994a). Currently, the burner is being operated in a dry, micronized coal mode for another program (Cooperative Agreement No. DE-FC22-92PC92162). The CWSF atomizer will be installed prior to the Phase IV testing which will be conducted from December 1, 1995 to June 1, 1996.

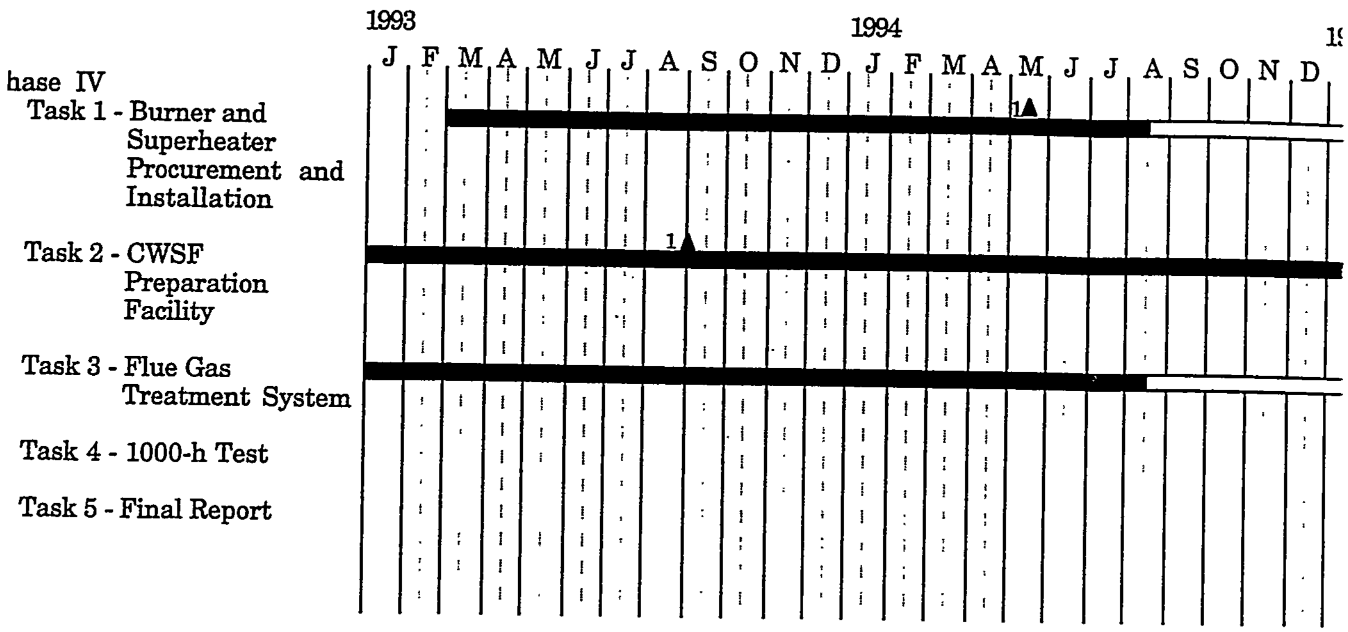
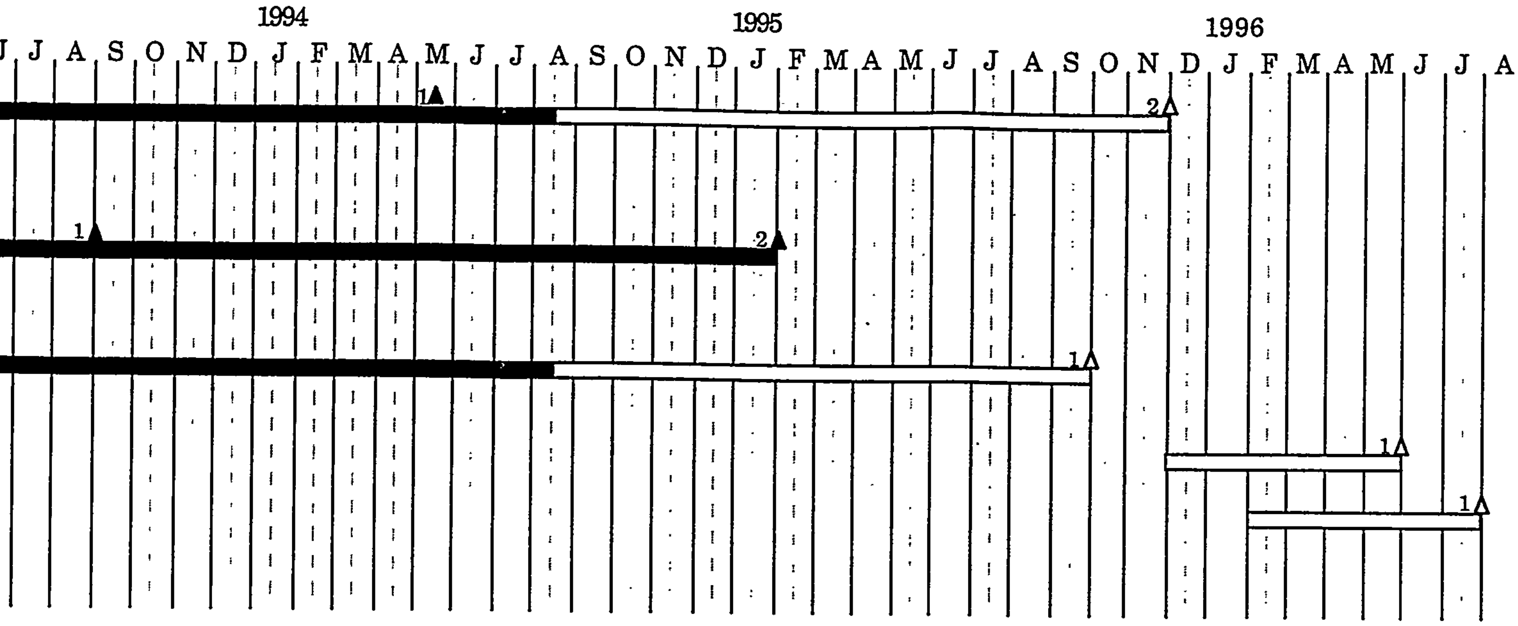


Figure 1. PHASE IV MILESTONE SCHEDULE (Second



igure 1. PHASE IV MILESTONE SCHEDULE (Second Demonstration)

Table 1. Milestone Description

Milestone	Description	Planned Completion Date	Actual Milestone Completion Date
Phase I			
Task 1, No. 1	Identify equipment and diagnostic instrumentation	09/15/89	09/15/89
Task 2, No. 1	Review present permit	09/15/89	09/15/89
Task 3, No. 1	Develop CWSF specifications, identify operating procedures, prepare detailed test plan	10/15/89	02/15/93
Phase II			
Task 1, No. 1	Building/boiler construction and installation let for bids	10/18/89	10/18/89
Task 1, No. 2	Building/boiler construction and installation awarded	12/31/89	03/23/90
Task 1, No. 3	Prepare site, install boiler and auxiliary equipment	04/01/91	01/31/92
Task 2, No. 1	Identify coal for CWSF preparation	09/30/90	09/30/90
Task 2, No. 2	Prepare CWSF for demonstration	04/01/91	10/13/92
Task 3, No. 1	Predict boiler performance	06/15/91	02/01/92
Task 4, No. 1	Shakedown boiler and auxiliary equipment	04/31/91	06/30/92
Task 4, No. 2	Generate baseline data on gas	05/31/91	09/30/91
Phase III			
Task 1, No. 1	Perform demonstration		
Subtask 1a, No. 1	300-hour demonstration milestone	07/31/92	07/31/92
Subtask 1a, No. 2	500-hour demonstration milestone	10/31/92	11/13/92
Subtask 1a, No. 3	Redefine CWSF specifications	01/15/93	01/15/93
Subtask 1b, No. 1	Develop deposition and corrosion test plan	10/15/89	10/15/89
Subtask 1b, No. 2	Design suction pyrometer	06/01/90	08/01/90
Subtask 1b, No. 3	Construct suction pyrometer	10/01/90	10/01/90
Subtask 1b, No. 4	Deposition characterization equipment design and specification	01/01/91	02/15/91
Subtask 1b, No. 5	Acquisition of baseline data for spectroscopic analysis of deposits; acquisition of baseline data for corrosion of tubes by ash components	08/31/91	08/15/92
Subtask 1b, No. 6	Coupon testing in boiler	10/31/92	11/13/92
Subtask 1b, No. 7	Complete deposition and corrosion testing	01/15/93	01/15/93
Subtask 1c, No. 1	Develop erosion test plan	10/15/89	10/15/89
Subtask 1c, No. 2	Complete research boiler erosion evaluation	08/01/90	08/01/90
Subtask 1c, No. 3	Full-scale erosion technique decision	10/01/90	10/01/90
Subtask 1c, No. 4	Design probe for full-scale erosion study	01/01/91	02/15/91
Subtask 1c, No. 5	Construct erosion probe	05/01/91	10/15/91
Subtask 1c, No. 6	Complete erosion modeling	01/15/93	06/15/93
Subtask 1d, No. 1	Identify viscometer	10/15/89	10/15/89
Subtask 1d, No. 2	Complete preliminary viscosity and stability tests	08/15/90	09/15/90
Subtask 1d, No. 3	Complete viscosity and stability tests	11/30/92	11/30/92
Task 2, No. 1	Complete economic evaluation	01/15/93	01/15/93
Task 3, No. 1	Complete project report	03/01/93	06/21/93
Phase IV			
Task 1, No. 1	Procure and install burner	04/15/94	05/09/94
Task 1, No. 2	Procure and install superheater	12/01/95	
Task 2, No. 1	Complete construction of Fuel Preparation Facility	08/31/93	08/31/93
Task 2, No. 2	Install and shake down CWSF preparation circuit	01/31/95	01/31/95
Task 3, No. 1	Install flue gas treatment system	10/01/95	
Task 4, No. 1	Complete 1,000-hr test	06/01/96	
Task 5, No. 1	Complete final report	08/01/96	

No work was conducted on the procurement and installation of the superheater this reporting period. The superheater will be installed prior to the Phase IV testing.

5.2 Task 2. Construction of CWSF Preparation Facility

Construction of the CWSF preparation circuit was completed during this reporting period. Figure 2 is a schematic diagram of the CWSF preparation circuit. The installation of the CWSF circuit was conducted in conjunction with another program (Cooperative Agreement No. DE-FC22-92PC92162).

Items that were installed or constructed during this reporting period are listed below:

- Moyno pumps were received and installed;
- Two stainless-steel tanks were received and installed;
- Two mixers for the stainless-steel tanks were received and installed;
- CWSF, water lines, and flush line within the Fuel Preparation Facility were installed;
- Chemical metering pumps and their associated tubing were installed;
- Piping for compressed air and water lines was installed to each major piece of equipment (pumps, tanks, etc.) ;
- The 4' x 8' Centrix ball mill was refurbished. Allis Mineral Systems of York, Pennsylvania fabricated a new main bearing for the ball mill. A new lubrication system, screw feeder, and a 50 hp motor were procured and installed. Installation of these components and controls for the ball mill were conducted by Beitzel Corporation;
- Pneumatic valves for tanks T1, T2, T3, and T4 were installed;
- The sump for the ball mill was fabricated and installed; and
- The rotary drum vacuum filter for cleaning the purge water was installed.

5.3 Task 3. Installation of a Flue Gas Treatment System

It is the objective of Task 3 to install commercial NO_x and SO_2 control systems on the boiler. Vendors and engineering firms were contacted to identify the appropriate emissions control technologies. Appropriate NO_x and SO_2 technologies will be identified, the systems will be designed, and components will be procured during the next reporting period.

5.4 Task 4. 1,000-Hour Test

No work was scheduled or conducted in Task 4.

5.5 Task 5. Final Report

No work was scheduled or conducted in Task 5.

6.0 NEXT SEMIANNUAL PERIOD ACTIVITIES

During the next reporting period, the following will be completed:

- The CWSF circuit will be shaken down;
- Appropriate NO_x and SO_2 control technologies will be identified; and

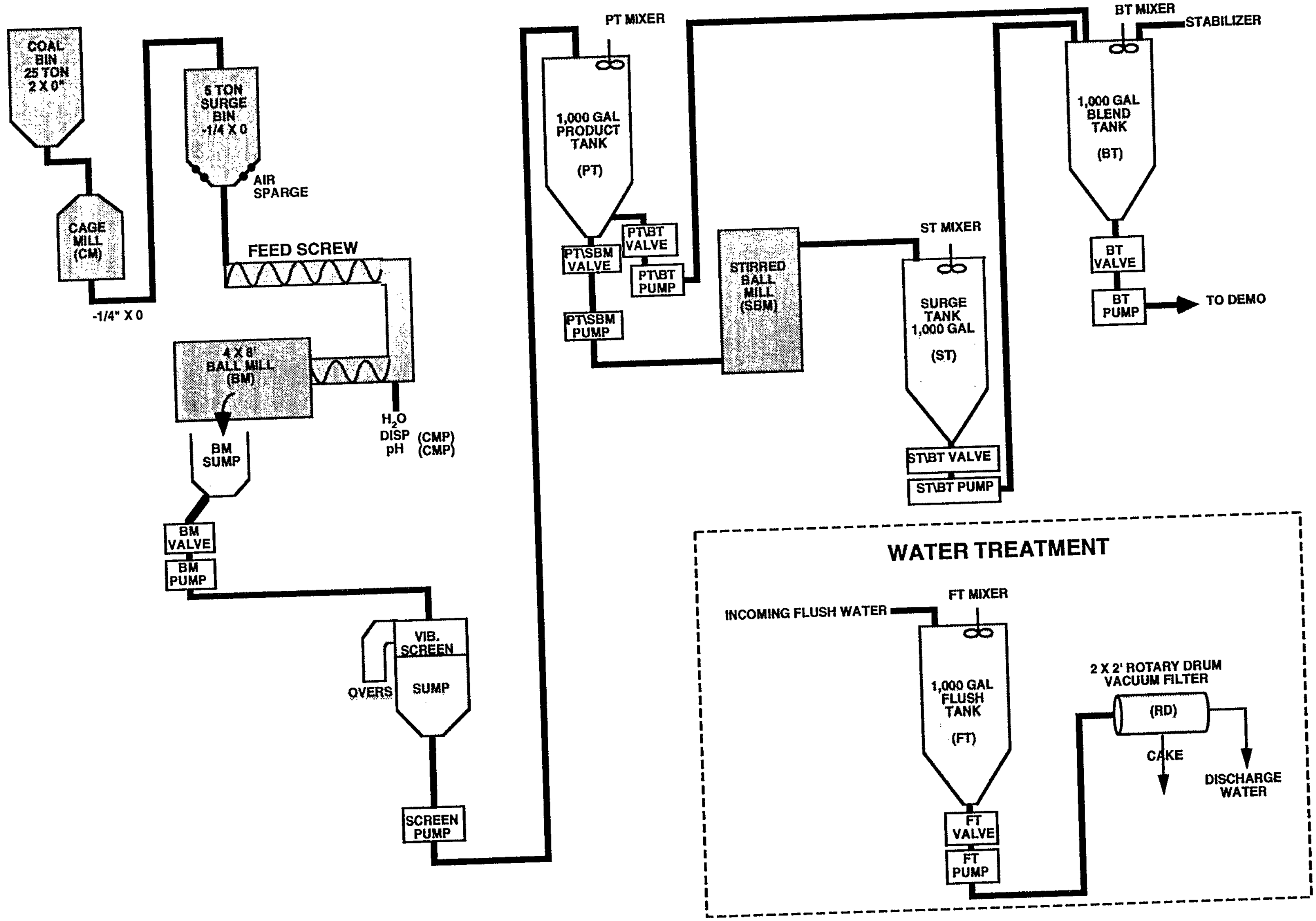


Figure 2. SCHEMATIC DIAGRAM OF THE CWSF PREPARATION CIRCUIT

- The NO_x and SO_2 control systems will be designed and component procurement will begin

7.0 REFERENCES

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