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# Low NO<sub>x</sub>/SO<sub>x</sub> Burner Retrofit for Utility Cyclone Boilers

Quarterly Technical Progress Report  
June - September, 1990

Reference Cooperative Agreement

~~DE-FC21-90PC00001~~

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# **Low NO<sub>x</sub>/SO<sub>x</sub> Burner Retrofit for Utility Cyclone Boilers**

**Quarterly Technical Progress Report  
June - September, 1990**

**Reference Cooperative Agreement  
DE-FC22-90PC89661**

**Patents Cleared by Chicago  
on July 11, 1991**

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## **1.0 INTRODUCTION**

### **1.1 PURPOSE OF THIS REPORT**

This is the first of a series of Technical Progress Reports to be issued to the U.S. Department of Energy and other Funding Parties in accordance with the requirements of the Cooperative Agreement for this project, (DOE Instrument Number DE-FC22-90PC89661).

The Technical Progress Report is defined in Attachment 4 to the Federal Reporting Requirements Checklist which forms part of the Cooperative Agreement, as a summary of the work performed during a specific reporting period, including the technical and scientific results (both positive and negative) of that period. A draft Technical Progress Report must be submitted to the DOE for review at the end of each quarter.

This report covers the period which commenced with the signing of the Cooperative Agreement between TransAlta and the DOE on June 14 and ended on September 30, 1990. However, a significant amount of conceptual design, preliminary engineering and preparation for procurement of long-lead equipment was carried out prior to the signing of the Cooperative Agreement and on-site mobilization also commenced before that date. A description of the pre-award activities has therefore been included in this report to provide a complete and chronologically accurate record of the development of the project to date.

### **1.2 SUMMARY OF REPORT CONTENTS**

Section 1.0 is of a purely introductory nature. The purpose of the report is defined and is followed by an outline of the report contents. The development of the project is then generally discussed in terms of its technological background, the applicability of the technology to retrofits of existing plants, feasibility studies, the selection of a host site for demonstration of the retrofit and the initiation of design and construction. Progress to date in conceptual design, preliminary engineering,

procurement, site mobilization, construction and installation is briefly summarized.

Section 2.0 documents the work carried out prior to the signing of the Cooperative Agreement. This included conceptual design, the development of design criteria and preliminary engineering for installation of the retrofit, preparation of environmental reports and permit applications, identification of critical materials and equipment which required long-term procurement, determination of interface requirements with the existing plant, assessment of deficiencies in the existing equipment and remedial measures required to correct them, preparation of the Demonstration Test Plan and the commencement of site mobilization.

Section 3.0 addresses work performed subsequent to the signing of the Cooperative Agreement during the period from June 15 to September 30, 1990. During this time, preliminary engineering, LNS Burner and boiler engineering and design and procurement of major equipment continued and on-site construction commenced. Most of the emphasis was on inspection of the boiler/site and preparations for the Baseline Test. This test would provide calibration of Unit No. 1 for later comparison with the retrofit.

Section 4.0 summarizes technical work planned for the next reporting period.

### **1.3 OVERVIEW OF THE PROJECT**

The objective of this project is to demonstrate the LNS Burner as retrofitted to the host cyclone boiler for effective low-cost control of NO<sub>x</sub> and SO<sub>x</sub> emissions while firing a bituminous coal.

The LNS Burner employs a simple, innovative combustion process to burn pulverized coal at high temperatures and in the process, provides effective, low-cost control of sulfur dioxide (SO<sub>2</sub>) and nitrous oxides



(NO<sub>x</sub>) emissions. The coal ash contains a sulfur and is removed in the form of molten slag and flyash.

Cyclone-fired boiler units are used for steam generation and comprise 9% of the existing U.S. electrical power plants. They are typically older units firing high-sulfur bituminous coals at very high temperatures which results in very high NO<sub>x</sub> and SO<sub>x</sub> emissions. The addition of conventional emission control equipment, such as wet scrubbers, to these older cyclone units in order to meet current and future environmental regulations is generally not economic. Further, the units are generally not compatible with low sulfur coal switching for SO<sub>2</sub> control or selective catalytic reduction technologies for NO<sub>x</sub> control.

Because the LNS Burner operates at the same very high temperatures as a typical cyclone boiler and produces a similar slag product, it may offer a viable retrofit option for cyclone boiler emission control. This was confirmed by the Cyclone Boiler Retrofit Feasibility Study carried out by TransAlta, and an Operating Committee formed of cyclone boiler owners in 1989. The study analyzed the population of existing cyclone boilers in the United States to establish the characteristics of a generic cyclone boiler. An existing utility cyclone boiler, which matched as closely as possible the criteria for a 500 MW generic unit, was then selected for the evaluation of the cost and performance study. It was concluded that the LNS Burner retrofit would be a cost-effective option for control of cyclone boiler emissions. The Operating Committee strongly encouraged a retrofit demonstration. Therefore, an LNS Burner demonstration proposal was submitted to the DOE Round II CCT Program.

A full-scale demonstration of the LNS Burner retrofit was selected in October, 1988 as part of the DOE's Clean Coal Technology Program Round II. The Marion generating plant, which is located on the Lake of Egypt near Marion, Illinois and is operated by Southern Illinois Power Cooperative, (SIPC), was selected as the host site for this demonstration. Unit No. 1, which has a cyclone boiler rated at 33 MW and is used for peak

load conditions, was chosen for the LNS Burner retrofit. A side sectional view of Marion Unit 1 prior to retrofit is shown in Figure 1.

A considerable amount of conceptual design work was carried out prior to the signing of the Agreement. The project was underway by October, 1989 with information for the Environmental Assessment. Preliminary engineering commenced in January 1990, construction mobilization started in May, 1990 and the Project Kick-off Meeting was held on June 13, 1990. The Cooperative Agreement was signed on June 14, 1990 between DOE and TransAlta Resources Investment Corporation.

For the reporting period, June to September, engineering work continued on development of a thermal model and mechanical layout for the LNS Burner, burner/boiler modelling and slag screen design. Design and procurement for balance-of-plant foundations, structures, mechanical and electrical equipment, piping and instrumentation and controls continued. Detail inspections were made of the boiler/site. Test modifications were made to Unit 1 boiler in readiness for the retrofit. All work relating to preparation for the Baseline Test was completed and the Test Plan was issued for review and released for Baseline Testing.

## **2.0 WORK DONE PRIOR TO SIGNING COOPERATIVE AGREEMENT**

### **2.1 ESTABLISHMENT OF DESIGN CRITERIA REQUIREMENTS**

Significant technical work was accomplished before the signing of the Cooperative Agreement. The proprietary report submitted to the Cyclone Retrofit Feasibility Operation Committee entitled "Cyclone Boiler Retrofit Feasibility Study with the Low NO<sub>x</sub>/SO<sub>x</sub> Burner, CYC20501P, IssueA", dated April, 1989, served as the basis for TransAlta's work.

The design criteria and requirements presented in the feasibility study were reviewed. The site specific requirements were updated, the design fuel analysis was updated based on current coal used on site and standards, such as NFPA 85F were reviewed and applied to the ongoing fuel proprietary design task. The Marion Unit 1 operating requirements were reviewed with the SIPC to incorporate all necessary design and operating criteria and requirements into the Project.

The material balance used in the PON submission was updated to use the Project design coal and to better reflect boiler and plant operating conditions, boiler efficiencies were updated, the coal cyclone separator efficiencies were updated and boiler excess air levels were reviewed. The proprietary Process Flow Diagram was updated and stream flows were revised as necessary. A non-proprietary flow schematic will be developed in the next reporting period and will be issued to the Funding Parties.

The design coal was reviewed to determine a basis which reflects normal variations. The design coal was determined from data obtained from about 40 analyses taken from January 1989 through July 1989. The design and feasibility coal ultimate analyses are compared in the table below.

Component	Feasibility Coal	Design Basis Coal
C, %	60.2	59
H, %	3.81	3.75
O, %	5.47	6.27
N, %	0.98	1.35
S, %	3.18	3.2
Ash, %	17	15.73
Moisture, %	9.2	10.7
Cl, %	0.16	---
Total, %	100	100
HHV, Btu/lb	10,864	10,553

The estimated retrofitted boiler efficiency data was not modified as review of boiler performance and equipment performance is planned after completion of the Baseline Test. The material balance will be updated if necessary. The estimated retrofitted boiler efficiency of 88.05% using the LNS Burner is not expected to change over that presented in the feasibility study. The boiler efficiency comparison between the current cyclone boiler and the estimated efficiency after the retrofit are shown in the table below. The values for the major unit input and output streams are also indicated.

Marion Unit 1	Original Design	LNS Burner
Steam Flow, lb/h	335,000	335,000
Coal Flow, lb/h	37,000	38,074
Limestone, lb/h	0	6,889
Other Additive, lb/hr	0	1,341
Total Combustion Air, lb/h	331,500	341,160
Boiler Excess Air, %	16	16
Slag Collected, lb/h	3,780	9,138
Fly Ash Collected, lb/h	2,440	2,245
Stack Fly Ash Emissions lb/h	80	40
Boiler Efficiency (net), %	88.45	88.05

Control philosophy and requirements were reviewed with all Project Team Members, including cyclone boiler consultants and operators. Initial

information as shown in the feasibility study on incorporating the LNS Burner into Marion Unit 1 was reassessed. An initial review of existing plant operating procedures and policies was started. The development of process logic will be an ongoing task through the completion of engineering.

Work was done in identifying outline dimensions of major equipment. Space was at a premium for this retrofit. Design requirements for not-to-exceed dimensions were established for key equipment items, including the LNS Burner.

#### **2.1.1 Fuel Preparation Building**

The size and configuration of the fuel preparation building are dictated to a large extent by space limitations at the site and the requirements for interfaces with the coal, limestone and additive storage and handling equipment. The building is located to the east of Unit No. 1 because it is required to be as close as possible to the Unit 1 boiler front and sited so as to avoid obstruction of existing driveways and access to existing plant maintenance bays. A general arrangement of the building structure is shown in Figure 2.

Basic civil, structural and architectural design concepts for the building and its foundations were developed from the relevant codes, standards and other appropriate regulatory and reference documents. A list of the principal design codes and standards used is given in Appendix A.

Initially, the design criteria specified that the structure and foundations would be designed in accordance with BOCA National Building Code requirements for Seismic Zone 2, which is consistent with the design of the existing plant. However, because of the close proximity of the site to the location of the New Madrid fault, Southern Illinois Power Cooperative subsequently requested that the design be upgraded to conform to Seismic Zone 3 requirements. The increase in ground acceleration associated with

this design change has a significant impact on the design and construction of the building. Details of these changes will be available in the next reporting period.

The existing plant stair tower adjacent to the west side of the new fuel preparation building has been used to provide personnel access to all floors above ground level at minimal cost and space requirement. Equipment access with monorails has been provided on the ground floor and at the feeder and silo floors for installation, maintenance or removal of equipment.

The Fuel Preparation Building is fully enclosed and insulated to provide weather protection for equipment and provide a safe operating environment for operating staff. Building exterior colours were selected to match the existing structures at the plant.

#### **2.1.2 Mechanical Systems and Equipment**

Design criteria and process design requirements were established for all mechanical systems and facilities required to support the LNS Burner, including the retrofit of existing plant equipment.

All new mechanical equipment required to support the LNS Burners is located in the fuel preparation building, except for a new coal conveyor which will receive coal from the existing plant coal feeders and transport it through the Unit No. 1 boiler siding to the fuel preparation building. The arrangement of equipment is shown in Figure 3 and 4, Partial Plan and Section.

##### **a) Materials Storage**

New silos will be provided for the storage of limestone (3118 ft<sup>3</sup>) and fuel additive (750 ft<sup>3</sup>) inside the fuel preparation building. These new silos are sized for 45 hours and 73 hours of full load operation respectively. The upper sections of the silos are cylindrical in shape and fabricated from mild steel. The lower sections are conical with

sides sloping at 70° to the horizontal to ensure the flow of wet material and are fabricated from stainless steel to reduce friction and prevent corrosion.

Bulk storage for four days supply of limestone and fuel additive will be located approximately 100 feet south of the Unit No. 1 stack and will be sited to avoid obstruction to plant maintenance and laydown areas. This location was chosen to ensure that the silos could be filled with materials from the bulk storage stockpile within a maximum period of one hour.

The limestone bulk storage stockpile will not be covered because the graded limestone used by SIPC at the plant is known to flow freely in all weather condition. The fuel additive stockpile will be covered with tarpaulins to prevent excessive absorption of rainwater.

Loading of materials from the stockpiles will be carried out by the existing rubber tired loaders used at the plant.

Coal will be stored in the existing coal bunkers at the plant because preliminary studies showed that a coal conveyor from the existing plant storage would be less expensive than new bunkers and feeders. It was also considered that maximum utilization of the existing plant fuel feed would assist extrapolation of the retrofit design to fit other existing plants.

b) Materials Handling

The original design concept was based on the use of pulverized limestone delivered directly to the new storage silos. A subsequent design study confirmed a change to crushed limestone to take advantage of its availability at the site, at a considerable saving in cost (\$6/ton versus \$30/ton), where it is used for the Unit No. 4 scrubber. Additional loading equipment, including a bucket elevator rated at 144 tons/hour and loading hopper of 240 ft<sup>3</sup> capacity located at grade level are required to handle this material.

The existing SIPC coal handling system will be used, with the addition of a covered, explosion-proof conveyor to intercept coal downstream of the existing coal feeders and transport it to the fuel preparation building. It was originally planned to use the existing coal feeders without modification and a drag chain conveyor to transfer coal from the existing feeders to the pulverizer. The drag chain conveyor was later replaced by a Stock Equipment covered belt type conveyor of 25 tons/hour capacity meeting NFPA-85F requirements for explosion-proof design, which is expected to operate more reliably with abrasive coals. Additional space requirements for the new explosion-proof belt conveyor and the geometry of the discharge chute at the pulverizer necessitated the raising and rotation of the existing feeders in Unit No. 1 to fit the new arrangement. The coal handling arrangement is shown in Figure 5.

Coal, limestone and additive will be fed to the "Atrita" pulverizer where the materials will be thoroughly mixed and pulverized to a grading of 70% passing a 200 size mesh. The pulverizer is sized to handle the full design coal flow plus limestone and additive of 23 tons/hour. At full load, the pulverizer has a reserve capacity of 3 percent.

The existing coal bunkers and the new silos for limestone and fuel additive will be fitted with air cannons to clear blockages in material flow.

c) Coal Piping Layout and Materials

Piping runs will follow the shortest and most direct routes to minimize pressure drops in the system. All feeders, chutes and piping from the pulverizer to the LNS Burner, including the cyclone separator, will be designed for an internal pressure of 50 psig in accordance with NFPA-85F requirements. The general layout of coal piping from cyclones to burners is shown in Figures 6 and 7.



Coal and fuel piping to the LNS Burners will be of wear-resistant material, or will incorporate provision for rotation of the pipe sections to equalize wear, and shall be sized to prevent settling of the coal in the pipe.

Pipe materials for the LNS Burner and fuel systems will be carbon steel. Materials for burner support auxiliary systems shall match those of the existing plant systems.

d) Fuel Oil System

The LNS Burner ignitor oil guns will be supplied from the existing fuel oil system, but the system storage and pumping capacities will be upgraded as necessary to accommodate the increased ignitor fuel requirements.

e) Heating, Ventilating and Air Conditioning

The fuel preparation building shall be provided with a ventilation system to maintain a bulk average temperature of 100°F in summer with an outside design temperature of 90°F. It is expected that ventilation will also be required even in winter due to the high motor heat loads.

No building heating is provided due to the high equipment heat loads during normal operation. Freeze protection will not be required during shutdowns, since there are no fluid systems within the building to freeze. The fire system is an air-charged dry pipe system.

f) Fire Protection

Fire protection for the fuel preparation building will be provided by a dry pipe riser system with hose racks on the ground and feeder floors. All areas of the building will be accessible with a 75 foot fire hose and automatic filling of the system will be initiated by opening any hose valve. Water will also be available from two yard hydrants outside the building.

The fire protection system will be designed in accordance with BOCA requirements for Group F-1 Moderate Hazard Factory and Industrial Use and the applicable NFPA codes.

g) Instrument and Service Air

Instrument air requirements will be minimal and will be supplied from the existing common instrument air system.

Service air will be supplied through the existing common service air system. SIPC is upgrading the central plant system by the installation of higher capacity centrifugal compressors and a larger distribution header.

h) Dust Collection

Dust collection for the limestone and fuel additive handling system will be by means of a power operated bag filter installed on the limestone silo which will draw dust-laden air from the entire system. The filter will be self-cleaning and fines will be returned to the limestone silo.

Dusting in the coal system will be controlled by the flow of low pressure seal air through the coal conveyor to the pulverizer.

### 2.1.3 Electrical Systems

Design criteria were developed for the new 2.4 kW switchgear, 480 volt load center and motor control center, raceway and conduit, motors, lighting, cable and the removal, dismantling or disconnection of existing equipment. Applicable sections of Electrical Standards were used as design requirements for the electrical equipment to be purchased, as listed in Appendix A.

Load studies confirmed that the capacity of the existing Unit No. 1 auxiliary transformer is 3,750 kVA. The running load for Unit No. 1 was

determined to be 3,450 kVA with a spare capacity of 300 kVA. Additional load requirements for the retrofit equipment were calculated to be approximately 600 kW which will need to be taken from the station 2.4 kVA system. This will require the addition of new switchgear and a new 480 volt load center. The existing load center will also need extensive modifications because of retrofit requirements for new equipment loads.

The new switchgear will service the Unit No. 1 circulating pump, which will be relocated from the existing Unit No. 1 bus. The new coal pulverizer required for the LNS Burner retrofit will receive power from the existing 2.4 kW power supply for Unit No. 1. Transient load studies will be carried out at the detailed engineering stage to ensure that the system is fully coordinated.

The existing motor control center at the front of the boiler will be surveyed to determine which panel sections and equipment can be retained or relocated. Those which cannot be relocated on the existing panel sections will be removed and mounted on the new motor control center. This will be placed adjacent to the existing motor control center to avoid interference with the new LNS Burners.

#### **2.1.4 Controls and Instrumentation**

The control system and equipment will be designed in accordance with industry I&C design codes and standards as listed in Appendix A.

Control systems will be provided for steady state operation of the retrofitted unit in the main control room. The operator will also be operating other units at the same time when not in the start-up or test mode. Design criteria for start-up and testing will consider one dedicated operator in the control room and one dedicated operator outside the control room.

System design will permit operation of the unit reduced loads with either one or two burners. Actuator design will be pneumatic, signal design will be electric and power supply will be AC.

The LNS Burner will require multiple control loops for burner operation such as coal and air flow, burner temperature combustion control, in addition to those required for the existing balance of plant equipment. A status board will also be required, together with several switches for operation of auxiliary equipment such as blowers and feeders as there is not sufficient space for these items on the existing main control panel.

The combustion control design criteria for the existing plant will be used as the basis for establishing interface requirements between the LNS Burner controls and balance of plant equipment. New transmitters will be provide for main steam pressure and flow and forced draft fan pressure.

Existing plant equipment to be retained includes the forced fan control drive (modified for constant pressure operation), feedwater controls, cyclone air flow transmitters and local air devices. Secondary air shut-off damper drives will be retained in place, but are not required for operation.

A signal will be provided from the burner control system to the existing coal feeder control, but feedback will not be required. Coal feed indication will be retained in the control room and all other existing plant combustion control equipment will be disconnected from service and left in place or removed for storage.

## **2.2 PROCESS DESIGN**

Process design work consisted of updating the material and energy balances to use design coal and to reassess the interface between the boiler, pulverizer and LNS Burner. The pulverizer sweep air is used to dry and to convey coal from the pulverizer to the coal separator cyclone. From the

cyclone, this sweep air serves as final overfire air to the boiler. Work was done on establishing the operating envelope of the pulverizer and assessing the effects of the associated sweep air requirements on the boiler excess air demand. A study indicated that a small 8-inch bypass line would allow better flexibility in matching boiler excess air requirements to pulverizer demand. Boiler excess air turndown is expected to be at levels as low as 14% instead of the normal 16%.

Differences between the feasibility process design and the current design were minor and did not significantly impact the original basis presented in the feasibility study.

### **2.3 LNS BURNER MECHANICAL DESIGN**

Work was done in updating the feasibility design. Fundamental information developed from the Heavy Oil Recovery project was incorporated and used to reassess the design requirements for the LNS Burners. Thermal design requirements, refractory selection and support, coal injector design issues, design requirements for the cooling annulus and special features design and selection were incorporated from the previous HOR work. Effort was focused on identifying an outer, not-to-exceed, envelope which could be used by the other Project Team Members to update plant general arrangement drawings, plan and elevation drawings made of the boiler front and reassess early boiler modification feasibility work. This work helped to identify and adapt to numerous constraints.

The LNS Burner for this retrofit is formed by two sections; the existing cyclone furnace barrel with an extension of the end of the cyclone furnace barrel. Due to the configuration of the cyclone furnaces for Marion Unit 1, the end of the cyclone furnace is very close to the level of the main turbine operating floor. The estimated diameter of the extended portion of the LNS Burner interfered with the deck. Work was done in assessing the impact of either decreasing the burner diameter, removing a portion of the concrete floor, or inclining the extended portion to miss the floor. Studies indicated that if the extended portion could be offset from the cyclone furnace and tilted about 15 degrees, the interference could be eliminated.

The general arrangement of the LNS Burner installation for this retrofit is shown in Figure 8. See Section 3.2 for information on the status of current LNS Burner design work.

Initial LNS Burner and boiler interfaces and the interaction of the burner gases and overfire air within the boiler cross-section were established. Further discussion on the boiler mixing will be presented later in the report.

The slag screen is an integral portion of the burner-boiler interface. The screen is at the exit of the cyclone furnace and it is designed to capture molten slag droplets from the exiting LNS Burner gases. The initial design of the slag screen has been reviewed to better understand the interactions between thermal design requirements, mechanical design requirements and the desired process conditions. A further discussion of the slag screen design will be done in the next reporting period, as presented later in this report.

## **2.4 SELECTION OF EQUIPMENT FOR SOLIDS FLOW SPLITTING**

The pulverized coal, limestone and additive are pneumatically conveyed from the bottom of the coal separator cyclone to the two LNS Burners through two sets of flow splitters. The required split is one to twelve, with six coal pipes to feed each of the two LNS Burners. Riley Stoker uses a standard design "Riffle Box" which works well for them in other installations. The riffle box splitter uses mechanical fingers to split the incoming flow stream into two outlets. The standard riffle box design cannot be easily modified to use more than two outlets, so a design was developed which would take the flow from each riffle box and divide that flow into six outlets. This splitter is based on designs used in the coal and steel industries. The splitter chosen is orientated vertically with flow entering the bottom and leaving from the top. This one-to-six splitter design is similar to that successfully used for TransAlta's Heavy Oil Recovery test facility, which has one to three split. The Marion splitter is placed in a long vertical section of pipe designed to eliminate any non-uniform flow of solids.

The flow enters through an expanding inlet where the velocity of the gas and solids is reduced to ensure that the solids are uniformly distributed over the internal cross-section. The outlet pipes are located in a contracting cone to increase their velocity before they enter the coal conveying pipes to reduce the contraction losses at the outlet. The split of the solids is expected to be within the allowable limits of 10%.

## **2.5 PULVERIZER SYSTEM SELECTION**

Selection of the pulverizer type required for the project evolved from the project decision to meter and deliver process feedstock (coal, limestone, and additive) directly to a common pulverizer for mixing and grinding, rather than metering and mixing separately, previously pulverized streams for delivery to the combustor.

To promote good product mixing, avoid any product segregation and minimize the impact of different feed material physical characteristics on grinding efficiency, a high speed impactor-type pulverizer was specified. The "Atrita" pulverizer manufactured by Riley Stoker Corporation met the above specifications and was selected for the project. A side section of the pulverizer is shown in Figure 9.

The amount of pulverizer carrier air flow was dictated by the air temperature level achievable from Marion Station #1 boiler's air heater and amount of remaining moisture required in the pulverized product. Because the required pulverizer carrier air flow exceeds that required for coal delivery to the combustor, an indirect firing system was used in which a high-efficiency cyclone separator removes all pulverizer carrier air (which in turn becomes boiler overfire air) and collects pulverized product for rotary valve injection into a separate metered air flow combustor coal delivery stream. This latter circuit contains a booster transport blower, two, two-way riffle distributors, two sets of tight shut-off valves (NFPA requirement) and two, six-way fuel splitters.

## **2.6 HOST SITE CHARACTERIZATION**

The objectives of the host site characterization were to determine the as found condition of the host unit, determine its capability to support pre-modification testing, and to identify any key site considerations that would need to be addressed in the design of the project. The as found condition of the unit was determined through a detailed plant inspection. Site considerations were identified during the preparation of project design criteria. The following sections in 2.6 explain these items.

### **2.6.1 Boiler and Plant Conditions**

Prior to pre-modification testing, Marion Unit 1 was reviewed for operational readiness in the January to June, 1990 timeframe. Plant equipment and records were reviewed to verify the completeness of the Project Demonstration Program. The following specific areas were reviewed:

- a) Equipment operational capability to support pre-modification testing requirements.
- b) Adequacy of Material Performance Plan.
- c) Plant instrumentation operability to satisfy equipment performance plan requirements.
- d) Existing plant configuration for air quality instrument installation.

The review of the plant included examination of the following equipment and plant records:

- Boiler Pressure Part External Surfaces and Refractory
- Boiler Pressure Part Internal Surfaces
- Boiler Casing and Enclosures
- Draft Fans and Air Heater
- Air and Gas Ductwork
- Dust Collection System



- Slag Systems
- Control Devices and Instrumentation
- Electrical 2100V Switchgear
- 480V Power
- Control Room Space
- Balance-of-Plant Systems, Service Air and Water Fire Systems  
Steam, HVAC, Condensate
- New Equipment
- Traffic Patterns
- Review of Operational and Maintenance History
- Review of previous Bechtel study for SIPC regarding unit  
availability improvements

## **2.6.2 Deficiencies and Remedial Measures Required**

The operational readiness inspection for the project was completed in the January to June, 1990 time frame. The major plant deficiencies noted are summarized below, along with remedial measures required to bring the unit operational capability up to standard.

### **a) Boiler and Auxiliaries - Boiler Casing Leaks**

This has been a continuous historical problem which has resulted in severe bulging and deformation of the casing in a number of areas. The flue gas leaks and subsequent casing damage due to overheating were caused by failures in the refractory used to seal the convection pass tangent waterwall tubes. The failure of the refractory can result from improper installation, unit cycling and/or a combination of both. Refractory failure allows localized overheating of the boiler casing and its ultimate failure.

Known casing leaks had previously been repaired by SIPC during the November - December 1988 unit outage. Additional boiler casing, ducting and refractory inspection will be accomplished prior to post-modification testing to determine the extent of modifications required for long-term operation.

b) Chelate Cleaning

The boiler was acid (chelate) cleaned in December of 1988. This was the first time the boiler had been acid cleaned since 1973. A few tube leaks occurred as a result of the acid cleaning which would indicate that some degree of waterside corrosion exists. All leaks were repaired. No further remedial action is required at this time.

c) Boiler Tubes

During the November-December 1988 overhaul outage, the boiler furnace floor tubes were ultrasonically tested to determine wall thickness. As a result of this activity and a visual inspection throughout the boiler, a total of 31 furnace floor and 28 boiler roof tubes were repaired. The furnace floor tube repairs were necessitated because their wall thickness was determined to be less than the ASME minimum allowed thickness. Nothing could be found to indicate that an analysis was performed to determine if the tube wastage was due to fireside abrasion/erosion/corrosion or water side corrosion or both. The boiler was discovered to have been operated for at least the last 15 years without installation of the lower furnace section refractory as called for on the boiler erection drawings. This would support the assumption that the majority of tube metal wastage was the result of fireside abrasion/erosion/corrosion.

All boiler tubes in the lower furnace area will be included in the material monitoring program to be conducted before and after operation of the retrofit in addition to selected tubes in the superheater and convection pass generating tubes section.

d) Air Preheater

In November 1988 a vendor representative made an inspection of the regenerative air heater. The following performance related problems and recommended corrective measures to be taken were identified.

- The cold end basket elements are in bad condition and should be replaced.
- Four hot end axial seals are missing and should be replaced.
- All cold end radial seals are bad and should be replaced.

Prior to major replacement of air heater components, a pre-baseline test was planned to determine the performance of the as found air preheater and to ensure successful completion of the Baseline Test. This test was subsequently completed as outlined in Section 3.5. The air preheater will be inspected in detail as part of the Material Monitoring Inspection prior to the Demonstration Testing of the project.

e) Electrostatic Precipitator

The electrostatic precipitator (ESP) was not inspected during the operational readiness inspection, but the ESP will be inspected prior to pre-modification testing to photograph and document the as-found condition as outlined in the Materials Performance Plan.

f) Performance/Demonstration Test Instrumentation

A survey of the unit instrumentation was conducted and it was determined that all instrumentation required for the demonstration program, with the exception of stack monitoring instruments, is available. All data is transmitted to benchboard quality indicating and recording devices in the control room with the exception of coal flow. Since the unit was not in service, it could not be determined if the instrumentation was functional.

A field startup instrument engineer will be assigned to the project prior to the pre-modification performance test to provide technical direction and assist in the checkout, refurbishment, and calibration of all unit instrumentation.

The existing plant instrumentation which will require checkout, refurbishment (if necessary) and calibration prior to premodification testing has been identified.

g) Ductwork and Furnace Access for Isokinetic Dust Sampling and Gas Temperature Traverses

All flue gas dust sample points required for the demonstration program were available. Some, if not all, sampling piping connections to the boiler casing were found to be in poor condition, e.g., plugged, holes corroded through, and threaded ends rusted away.

Sampling piping connections in poor condition will have to be repaired or replaced. All gas sample point piping connection replacement/repair will be included in a separate work package and will be completed prior to pre-modification testing.

Access to the boiler furnace for furnace temperature probe(s) traverses to obtain temperature profiles during the demonstration program can be gained at two furnace elevations. One penetration, which was included in the original boiler design, is located in a side wall in the area of the cyclones and is currently capped. One or both existing furnace inspection ports, which are located approximately 3/4 of the way up the front wall, can also be utilized.

The fabrication, supply and installation of a water cooled, manually operated probe or probes, aspirating air devices and probe supporting devices will be included in the project work scope. Aspirating air and probe cooling water supplies will be provided.

h) Stack Emissions Monitoring

There is no Unit 1 stack access for emissions monitoring.

The required platform(s), platform access and stack penetrations on and in the Unit 1 stack respectively will be

engineered and installed. All auxiliary services required by the instrumentation, e.g., instrument air, power, cooling water, will also be provided.

i) Slag and Ash Sampling

The bottom ash system is common to all four Marion units. Operation is manual with ash sluiced sequentially from all operating units. Each slag tank is emptied approximately once per shift. There is no reliable method to measure slag quantity at the slag tank. Therefore, slag must be captured at the ash pond during the performance tests to determine the quantity produced.

Operation of the flyash system is similar to the bottom ash system, and quantities will be determined in the same manner.

Flyash samples, for chemical analysis, will be collected from the Multi-Clone hoppers, and the precipitator hoppers, and mixed to obtain a uniform sample.

A collection box will be designed and constructed for this purpose. During a period of 1-2 hours the flyash, and then slag, will be sluiced continuously and the quantity of each will be measured.

j) Turbine-Generator and Unit Auxiliary Systems and Equipment

The No. 1 turbine-generator unit, which underwent a major overhaul during March-April of 1986, has been highly reliable throughout the life of the plant.

Historically, the unit auxiliary systems and equipment have been reliable. The redundancy of equipment will provide maximum assurance of reliability during the demonstration program.

### **2.6.3 Site Considerations**

The fuel preparation building housing the pulverizer and other fuel treatment and transfer equipment shall be located as close as possible to the boiler front. Existing access and driveways to plant maintenance bays shall not be obstructed.

Bulk storage of limestone and fuel additive shall not obstruct existing plant maintenance and laydown space. Material transfer during loading the silos shall not take longer than 1 hour to prevent blockage of plant roadways.

The Marion site Soils Report was reviewed to determine conceptual foundation requirements of the fuel preparation building design.

Existing borings obtained from SIPC in the area of the new fuel preparation building indicated that the natural soil would probably provide suitable foundation bearing material. The actual conditions as they actually existed were not known, particularly regarding backfill for adjacent buildings and previous structures. It was assumed that, based on verbal information received from SIPC, the area was returned to the original condition after construction and demolition of the unloading facility. This was confirmed prior to completion of the foundation.

Two new test (2) borings, each to a 30-foot depth, were drilled to confirm the validity of the previous soils report data. The results confirmed the previous Soils Report data.

## **2.7 IDENTIFICATION OF LONG LEAD EQUIPMENT**

Significant work was done in the identification of long-lead equipment and materials. The Project schedule was updated early in 1990 and was used as a basis to carefully identify those items of equipment and materials which had significantly long enough lead times as to require commitment by TransAlta to procure these items prior to signing the Cooperative Agreement. Each of the Project Team Members reviewed their scope of supply and identified those items which required significant lead times. Engineering and design work that was necessary to specify equipment and materials was identified to DOE and requests were made to start the process of obtaining this equipment.

Contracts were made by procurement departments to review the lead times. Technical specifications were prepared and long-lead items were submitted for formal, competitive bids from suppliers. Bid evaluations were made in accordance with respective Project Team Member internal company standards and were based on availability, technical specification and price. After these items were reviewed, requests to commit to long-lead items on long-lead procurement were submitted to, and approved by, the DOE.

### **2.7.1 Pulverizer and Mechanical Equipment**

The pulverizer was the first major piece of equipment to be acquired. Riley Stoker identified its lead time as in excess of nine months as the pulverizer has a number of specialized forgings. A specification was written for this item. A letter was written to the DOE for approval to commitment for this item. Approval was granted and fabrication was started. Commitments for other items, such as the coal separator cyclone and weigh belt feeders were also made in the Spring/Summer of 1990.

### **2.7.2 Structural Steel**

Structural steel was to be placed on order immediately after signing of the Cooperative Agreement to meet the Project Schedule. The structural steel engineering and drawings were completed sufficiently in the reporting period to permit quotations to be solicited.

### **2.7.3 Electrical System Long Lead Items**

Electrical equipment delivery lead times were dependent upon placement of purchase orders shortly after the Cooperative Agreement is to be signed. Conceptual engineering relating to motor control center and switchgear requirements was accomplished prior to this to ensure construction need dates are met in the Project Schedule.

A purchase order was placed to General Electric for a 2.4 kV switchgear extension consisting of one switchgear cubicle fully compatible with the General Electric equipment presently installed on Marion Unit 1.

The switchgear will service the No. 1 circulating water pump currently powered from the Unit 1 switchgear. The existing Unit 1 switchgear will be used for the new coal pulverizer which is required for the LNS Burner Retrofit. The re-arrangement of switchgear is required to integrate the new plant loads with their appropriate unit switchgear.

It is also required to place a purchase order for one manually operated 480V load center breaker and cubicle suitable for addition on to the existing General Electric Load Center. The breaker will supply power to electrical equipment required for the retrofit.

### **2.7.4 Pre-Modification Testing Requirements**

Subcontract packages for stack modifications, air quality instrumentation, and air quality equipment were completed due to delivery



lead times in order to meet the pre-modification test requirements of the Project Schedule.

## **2.8 REVIEW OF WORK SUPPORTING NEPA AND APPLICATION FOR PERMITS**

During pre-award meetings, the DOE pointed out that they required a Draft Environmental Information Volume (EIV) and Environmental Monitoring Plan Outline (EMPO) in order to complete their environmental assessment of the cyclone boiler retrofit project. After approval, the EMPO will be developed into the Environmental Monitoring Plan (EMP).

Preparation of the draft EIV began in January 1989. Background information on existing environmental conditions in the site area was collected from State agencies, (including the Air Pollution Control and Water Pollution Control divisions of the Illinois Environmental Protection Agency (IEPA), the Department of Conservation and the State Water Survey), the U.S. Fish and Wildlife Service, Marion Chamber of Commerce and Southern Illinois Power Cooperative (SIPC). Information on existing operating conditions at Marion Power Station was also supplied by SIPC. Technical data for the LNS Burner was reviewed and evaluated to assess environmental impacts due to the LNS Burner project. The draft EIV, which incorporated this information, was submitted to the DOE in April, 1989.

Comments on the draft EIV were received from the DOE in May, 1989, with a request for the inclusion of "before and after" comparisons of discharges from the plant and additional information on the proprietary additive and existing conditions at the site. This information was supplied to the DOE in June, 1989.

The EMPO was prepared concurrently with the draft EIV. Information developed for the draft EIV was used to assess which aspects of the project should be monitored. The EMPO outlined the monitoring of flue gas, wastewater and solid waste that would be necessary to

characterize the environmental impacts of the project and support future commercial use of the technology.

## **2.9 MOBILIZATION OF ON-SITE CONSTRUCTION**

Construction forces mobilized on-site prior to signing the Cooperative Agreement in order to establish services and construction equipment necessary to perform construction activities relating to the Baseline Test in accordance with the Milestone Schedule. These construction activities consisted of modifications to the Marion Unit #1 Stack (access platforms for test instrumentation), installation of Emissions Monitoring Equipment and modification to the boiler and ductwork to provide the necessary test ports for the Baseline Test. Purchase and rental of construction equipment and services such as mobile crane, office trailers, site vehicles and welding machines and small tools and consumables was undertaken.

Site Operational Readiness Inspections were initiated to determine maintenance requirements necessary to assure successful completion of Baseline Testing (discussed in 2.7.2).

Several issues relating to site mobilization required special consideration during site mobilization planning. Marion Unit 1 was designed and constructed over thirty years ago to those codes and standards in effect at the time. Plant retrofit and maintenance of the existing plant will require construction activity that will address and implement old and new standards. These criteria, combined with the present day physical aspects of the plant and restoration requirements, were integrated into detailed site planning activity. Key construction and start-up personnel were assigned to engineering planning activities prior to mobilizing at the site.

Criteria relating to demolition and storage of existing plant equipment required for restoration were developed. All equipment which has to be removed or dismantled will be stored for future reinstatement. Equipment which is disconnected will be clearly tagged for future

reconnection. An equipment list will be prepared and plant drawings marked up to identify all such equipment.

All equipment, electrical connections and electrical cables dismantled for the retrofit will be left in place with loose ends terminated and tagged.

Safety and plant inspection methods were established for implementation. Criteria for plant walkdowns and inspections were developed in order to establish the as-built and operational status of equipment. These conditions are necessary to avoid interferences during construction and permit the most cost effective construction of the retrofitted plant.

Construction laydown areas were established with the operating utility so as not to interfere with plant operations and maintenance activities ongoing at the site. Detailed planning required that areas where foundation work was intended be investigated for all past construction activity. Access requirements and preconstruction activities were established.

The new Fuel Preparation Building as described in section 2.1.1 of this report was to be located in an area that previously was occupied by a storage building. Construction planning required that this be taken into consideration and provisions made to assure old foundations would not affect new construction. The lack of valid information from original construction of the plant required that soil borings be made prior to design of the building foundation.

## **2.10 DEMONSTRATION TEST PLAN**

The Demonstration Test Plan was prepared to document the tests required to meet the Project objectives of the Statement of Work in the Program Management Plan. This document specifies the methods and management of the data issuing from the Project. The Demonstration Test

Plan identifies the sequence of activity and the data to be collected from the Host Unit. Information will also be collected through a materials monitoring program to assess the long-term durability, operability, and reliability of the LNS Burner. This information will assist in determining the commercial retrofit potential of the LNS Burner for utility cyclone boilers.

Comments on the Demonstration Test Plan were received from DOE in August 1990 and similar suggestions were received from EPRI and other funding parties. Because the Baseline Test was scheduled for early October, 1990, work concentrated on finalization of the test plan for the Baseline Test, into which all comments on the Demonstration Test Plan were incorporated. Specific test details and a test matrix were included and the material monitoring specifications were completely rewritten to incorporate suggestions for a material sampling procedure and to provide for a material and sulfur balance. EPRI was kept informed of the test plan development and the EPRI project manager assisted in its review.

The Demonstration Test Plan will be finalized when engineering design has been completed.

The overall project objectives, as listed on page 1 of the Cooperative Agreement, are to:

1. Construct a full scale retrofit of a utility cyclone boiler using the technology.
2. Evaluate the long term durability, operability and reliability of the LNS Burner in a utility operating environment.
3. Demonstrate the LNS Burner's control of SO<sub>2</sub> emissions against a criterion of 70% or greater SO<sub>x</sub> when burning high sulfur midwestern bituminous coals, with a project goal of meeting New Source Performance Standards (NSPS) of 90% SO<sub>2</sub> reduction.

4. Demonstrate the LNS Burner's control of NO<sub>x</sub> emissions with a Project goal of NO<sub>x</sub> emissions less than 0.2 lb/MBtu (or 150 ppm) when burning high-sulfur midwestern bituminous coals.
5. Demonstrate the LNS Burner's effect on cyclone boiler full load heat rate.

As identified in Section 4.0 of the Statement of Work which forms Attachment A to the Cooperative Agreement, the specific Project objectives to be assessed during LNS Burner demonstration operation are:

- Performance and reliability of all system components
- Emissions control capabilities
- Materials performance
- Solid waste characteristics

#### **2.10.1 Equipment Performance**

Prior to the LNS Burner Retrofit installation, the plant will be operated for a period necessary to complete pre-modification testing. Pre-modification testing will measure the baseline performance parameters of the existing as-built plant. The testing will include:

- a) Boiler gross efficiency
- b) Precipitator performance
- c) Air heater performance

Pre-modification testing will be performed under steady state conditions at 50, 75 and 100% load. The data gathered will provide the baseline upon which the operation of the reconfigured plant will be compared. Emissions monitoring equipment will be installed, checked out and calibrated before pre-modification testing begins. Existing plant

instrumentation, supplemented by test instrumentation, will be used to obtain the required test parameter data.

The boiler performance test will be conducted in accordance with ASME PTC 4.1 (abbreviated form). Precipitator and air heater performance will be by correlation of test data with existing performance information.

The heat loss method for efficiency used for the boiler test considers the following losses:

- a) Heat loss due to dry gas
- b) Heat loss due to moisture in the fuel
- c) Heat loss due to H<sub>2</sub>O from combination of H<sub>2</sub>
- d) Heat loss due to combustibles in the refuse (unburned carbon)
- e) Heat loss due to radiation (the manufacturers predicted value will be used provided the boiler insulation condition is acceptable, and/or the value will be determined from the ABMA radiation loss chart)
- f) Heat loss due to sensible heat in slag
- g) Heat loss due to moisture in air
- h) Unaccounted for losses

In calculating the boiler efficiency by the heat loss method, the flue gas temperature leaving the air preheater, corrected for leakage, will be utilized.

A laboratory will be utilized for the analysis of coal and flyash. During the load tests, coal samples will be taken at the coal feeder inlet in accordance with PTC 3.2, Test Code for Solid Fuels and the analysis performed in accordance with ASTM D271. The sample(s) for ultimate analysis taken will be composited and divided into two equal composite samples. One sample will be analyzed by the testing laboratory and the other will be retained as a duplicate until the final results of the test have been reviewed and found acceptable. Separate samples will be obtained for fuel moisture.

Approximately one hour will be allowed to stabilize the unit at steady state load conditions prior to obtaining test data. During the stabilization period and for the duration of the load tests, the boiler continuous blowdown will be valved out of service. Sootblowers will be operated just prior to the stabilization and test period and will then remain idle until the completion of the tests.

Flue gas stack monitoring consists of  $\text{NO}_x$ ,  $\text{SO}_x$ ,  $\text{O}_2$ , and opacity and will be monitored throughout the entire program.  $\text{CO}$ ,  $\text{CO}_2$ , and  $\text{O}_2$  measurements taken from the boiler outlet will be used for performance testing.  $\text{O}_2$ ,  $\text{CO}$  and  $\text{CO}_2$  determine carbon utilization and  $\text{CO}$  and  $\text{O}_2$  normalize  $\text{SO}_2$  and  $\text{NO}_2$ .

Particulate samples will be taken at both the inlet and outlet of the mechanical and electrostatic dust collection system to determine the effect on the existing burner on dust collection system operation. The mechanical and electrostatic precipitator hoppers will be emptied prior to testing and bottom slag will be removed prior to the test. The data provides a baseline to characterized existing plant performance.

Instruments will be calibrated to accuracy and repeatability appropriate to the type of instrument and the intended application, in accordance with good engineering and plant operating practices. Calibration will be appropriate and consistent with the manufactured quality and accuracy of each instrument.

Demonstration testing will be performed under steady state conditions at minimum, intermediate, and rated load. The Demonstration Test period will be 6 months of continuous operation. The units will be operated at 1/2 to 3/4 full power for approximately 3 months and full power for the remainder of the test. It will be operated at reduced load over each weekend.

The tests will measure the general performance of the retrofit plant throughout the 6-month test and will include the determination of the following specific performance tests:

- a) Boiler gross efficiency
- b) Precipitator performance
- c) Air heater performance

The load tests will commence at approximately mid-point of the 6 month period utilizing the same test criteria as the Baseline Test.

The flue gas monitoring of the Environmental Monitoring Plan (EMP) for the LNS Burner Demonstration Project includes stack monitoring of NO<sub>x</sub>, SO<sub>2</sub>, O<sub>2</sub> and opacity over the 6 month test period. Particulate samples will be taken at both the inlet and outlet of the dust removal system as outlined in performance testing to determine the effect of the LNS Burner particulate operation.

The data gathered during the post-modification phase of the project will be used to characterized operation of, and emissions from, the LNS Burners as outlined in pre-modification testing. Particulate and SO<sub>2</sub> emissions and opacity data will be used to confirm that Unit 1 is in compliance with the State of Illinois emission limitations. Specific operating data points will be at minimum, intermediate, and rated.

The emissions monitoring instruments used will be selected to meet the performance specifications of the NSPS regulations. Reference data for emissions will be monitored throughout the duration of the 6 month test period and checked against performance test results.

Data acquisition during the conduct of plant performance testing as well as during the demonstration phase of the program will be obtained from new emissions monitoring instrumentation, and existing plant instrumentation. These devices will be supplemented by portable test instruments and a data acquisition system. Refer to Drawing Data



Acquisition Measurement Drawing M74-BA01 Sheets 1 and 2, for listing of  
plant parameters to be monitored, located in Appendix B.

## **2.10.2 Materials Monitoring Program**

The existing boiler, air heater and dust collection system component materials as well as the retrofitted burner support system components and materials such as cyclones and pulverizers will require inspection to evaluate their behavior in the LNS Burner Combustion process.

Pre-Demonstration and Post Demonstration Monitoring will consist of material inspection and the accumulation of baseline data concerning the as-found condition of boiler pressure part, refractory, ductwork, the dust collection system, and the air heater. The as-found material condition and data will be compared to inspection data accumulated, from the same areas, at the completion of the project demonstration phase. New components and material specific to the LNS Burner will be inspected and evaluated.

Areas of expected abrasion, erosion, and wear, will be documented for post demonstration comparison and evaluation. Partial or complete inspections may be made during a Phase III demonstration period outage(s), should such an outage(s) occur and is of long enough duration to permit inspection.

## **2.10.3 Waste Monitoring**

Slag, flyash and sluice water streams from Unit 1 during the LNS Demonstration testing will be analyzed at rated load. Samples of slag and flyash will be tested under EPA's EP Toxicity Test and for leachability of common anions and cations. Sluice water, from both slag and flyash transport systems, will be sampled to determine the effect of the modified ash on parameters such as pH, total suspended solids and total dissolved solids. The characteristics of the sluice water from the LNS Burner Demonstration Project will be compared to the characteristics of the sluice water from the baseline cyclone burner configuration. The results of the EP Toxicity Test and leachability tests will be used to evaluate the alternatives for handling and disposal of the slag and flyash. Flyash and slag samples

taken as outlined in post-modification performance tests will be analyzed for conformance to requirements outlined in the Environmental Monitoring Plan.

#### **2.10.4 Emissions Control**

Instrumentation for the Marion Unit #1 Emissions Monitoring Program was purchased and installed. This equipment is required by Technical Specifications of the Demonstration Program Plan for the Baseline and Demonstration Performance Test. The instrumentation consists of continuous monitoring devices for O<sub>2</sub>, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> and opacity. Installation of a stack platform, modifications to the stack for the instrument probes, foundation work for the enclosed shelter housing the instrumentation and all grounding and electrical work was completed. The instrumentation was checked out and calibrated satisfactorily.

Addition of sampling ports and related sealing and aspirating air systems to the Unit #1 boiler furnace walls and flue gas ducting were completed to accommodate furnace temperature and flue gas sampling respectively required during performance testing. The modifications were required to permit test probes to be inserted directly into the flue gas streams and furnace streams to determine profiles for the Baseline test to be compared with the retrofitted plant.

### **3.0 TECHNICAL PROGRESS DURING CURRENT REPORTING PERIOD**

#### **3.1 PROCESS DESIGN**

The Process Flow Diagram was reviewed and some minor corrections were made to reflect equipment or systems requirements. The revised non-proprietary process flow diagram is shown in Figure 10. Initial assessment of plant and LNS Burner operating requirements was started. Meetings were held with Marion Unit 1 operators to understand how the unit was operated, to identify startup and shutdown requirements, to identify unit trips and to identify any known unit limitations which could affect the operation of the retrofitted unit. Turndown of the plant was also reviewed by Riley Stoker to identify limits to be placed on the pulverizer and the coal transport system. Riley Stoker identified that the coal conveying system turndown was limited to 80% of design to avoid any potential for solids drop-out in the pneumatic conveying lines. Other turndown limits were also found, but none of them provided any significant impact to the ongoing design efforts.

As part of the review of the operating requirements, initial startup requirements from a cold start to turbine roll were evaluated. Sizing of the LNS Burner startup oil guns was evaluated in context of the overall plant startup requirements. Based on current design requirements, the unit will be started on the LNS Burner oil guns and slowly be brought to temperature and establishment of steam flow. The initial turbine roll at about 4 MW will be on the oil guns. After the turbine stabilizes, coal will be started on the LNS Burners to bring the load up within the 1 MW/m limitation of the turbine.

The review of the unit and LNS Burner operating envelope will continue and will provide significant input into the development of operating procedures. These procedures will be issued in the Startup Plan.

## **3.2 LNS BURNER DESIGN**

Effort during the current reporting period was focused on the development of a burner thermal model, continued development of a mechanical layout and the continuing of burner-boiler flow modeling. The LNS Burner for this retrofit is formed of two sections; the existing cyclone furnace barrel and extension piece protruding from the end of the cyclone furnace barrel. The existing cyclone furnace barrel will remain virtually unchanged. The air ducts and other cyclone-furnace-related changes will be removed. The cyclone furnace barrel will remain water-cooled. The new LNS Burner extension piece will be added to the cyclone barrel consisting of a refractory-lined section, about 16-feet long. This section is externally air-cooled by incoming combustion air flowing through a one-inch thick cooling air annulus from the cyclone end and flowing up to the head end where it enters into the LNS Burner. A schematic of the LNS Burner and its interface with the boiler is shown in Figure 11. Coal with carrier air also enters at the head end.

The thermal design, mechanical layout and burner-boiler flow modeling will be discussed in the following sections.

### **3.2.1 LNS Burner Thermal Analysis**

A thermal model using conventional finite-difference methodology has been developed to evaluate thermal profiles and startup conditions. The model uses a commercially available thermal analyzer program to solve the finite difference equations and to determine the temperature distribution. The model incorporates thermal convection and radiation from the hot gas to the refractory hotface, conduction across and along the refractory material, convection and radiation across the cooling gap, conduction across and along the metal shells, conduction across the outer thermal insulation, convection and radiation from the insulation to the environment and energy transport along the cooling air flow channel. The model handles different material properties, transport properties, process conditions, and physical geometry variables, such as annulus thickness,

refractory thickness, etc. The finite-difference model is currently being hand checked and will be used initially to evaluate refractory thickness requirements and to assess overall process considerations. Early results from the model have shown that the previous selection of about 4-inches of refractory material remains appropriate for the service.

### **3.2.2 Mechanical Design**

The mechanical design activities for the LNS Burner were initially started during the preparation of the feasibility study. These early efforts determined overall length, diameter, refractory thickness and required design features. This effort was continued incorporating design refinements. The diameter and overall length have been finalized, the refractory thickness has been selected and is being checked with the thermal model. The design features are being selected; details, such as thermocouple selection and placement, provisions for flame scanning, observation ports, air manifold design and placement and structural support are being finalized. The design of the coal injector pipes has been finalized and incorporated into the mechanical layout. The fabrication drawings have been started and the development of fabrication details is underway. Fabrication material for the metal shells of the front end has been selected; 310 stainless steel is the material of choice for the demonstration test unit because of its higher tolerance to thermal upsets and transients. The generic type of refractory material has been selected; the specific brand will be finalized later.

### **3.2.3 Burner-Boiler Flow Modeling**

Cyclone furnaces operate with high excess air and at high temperature. The heat release during combustion is very high and as a result the boiler volume is much smaller than would be found in a conventional pc-fired system. The Marion Unit 1 boiler entrance has a small cross-section; about 5-feet depth and about 20-feet in width.

The LNS Burner's operation is fundamentally different than cyclone furnaces. As a result, sulfur is captured and significant  $\text{NO}_x$  reductions is achieved. Because of the small boiler, flow modeling was found to be necessary to establish the location of overfire air ports. Adequate mixing of LNS Burner combustion products with overfire air must be accomplished carefully within this small volume to ensure  $\text{NO}_x$  emission goals can be achieved. The development of a quasi three-dimensional model was started to evaluate mixing of the overfire air introduced into the boiler region. The model uses a commercially available program ("Fluent") to solve continuity, mass, energy and chemical species equations for a given geometry. The initial cases run so far have been concerned with checkout of the model, understanding the relationship of some of the mixing parameters, and the burner-boiler geometrical interactions. Temperature field distributions, oxygen and carbon monoxide concentration fields are being evaluated to determine relative mixing within the boiler cross-section to assure good combustion and temperature conditions at the boiler superheat sections. Preliminary results will be provided in the next reporting period.

#### **3.2.4 Slag Screen Design**

The slag screen uses principles developed during prior work to remove slag droplets from hot LNS Burner gases exiting into the boiler volume. The hot gas with entrained molten slag flows through the old cyclone furnace barrel and impacts the slag screen at the boiler water wall. The slag screen is composed of vertically staggered, refractory-covered, water wall tubes. See Figure 12 for a schematic representation. The slag screen functions by accelerating the combustion gas and entrained molten slag droplets through a gap in the tubes.

Development of a thermal-hydraulic model has been started to determine the slag screen design parameters. The model will use a commercially available thermal analyzer program to solve finite difference equations to evaluate the temperature flow field. The model predicts thermal performance of the slag screen by coupling the hot gas containing

molten slag droplets to the slag screen by convection and radiation. Hydraulic performance, separation efficiency, reentrainment velocity and droplet generation velocity are also calculated by the model. Additional work is planned for the next reporting period on the continued development of this model.

### **3.3 BALANCE OF PLANT DESIGN**

#### **3.3.1 Architectural Design**

Preliminary architectural sketches and layouts of the fuel preparation building were prepared in accordance with the design criteria for use in defining the structural steel framework for the building.

Preliminary floor and roof drawings and elevations were produced showing the locations of all doors and other openings and these were progressively developed into detailed drawings for use in material procurement and construction.

#### **3.3.2 Civil and Structural Design**

A preliminary structural steelwork arrangement was developed from the preliminary architectural layouts and design parameters established. These were progressively revised and updated as vendor equipment information on dimensions and loadings became available.

Design and preparation of detailed drawings was carried out for the structural steelwork and reinforced concrete foundations for the fuel preparation building, structural steelwork and foundations for the bucket elevator and the foundation for the continuous emissions monitoring shelter.

Technical specifications and material requisitions were prepared and issued. Bid evaluations and recommendations were made for award of



purchase orders and contracts. Review of vendor drawings for compliance with technical specifications is in progress.

At SIPC's request, the bucket elevator location changed from the east to the south side of the new FPB to avoid impacting existing maintenance and road accesses. This move also resulted in changes to the conveyor system being used to transport the materials from the bucket elevator to the limestone and additive silos. These changes impacted the structural framing designs and details for the roof and floor plans and the foundation concepts. Significant calculation and drawing revisions were required. Subsequently, material and/or detailing changes were necessary.

During this period, the most significant rework occurred as a result of a request from SIPC to upgrade the designs to conform with BOCA Seismic Zone 3 Criteria due to the site's close proximity to the New Madrid Fault. In accordance with the BOCA Code, all designs had originally been performed for Seismic Zone 2 criteria. Incorporating this request resulted in major calculation and drawing revisions and entailed significant material and detailing changes.

Approximately 15 structural members required replacement with a larger section, 9 additional structural members were added as a result of the increased seismic forces, and approximately 60 dozen minor detailing changes were required to columns, bracing, gusset plates and connection details.

### **3.3.3 Electrical Design**

Load studies were completed of electrical equipment in the Fuel Preparation Building for sizing of the new motor control center and incorporated in design and purchase specifications. This included line drop calculations required for cable sizing. All results were within initial project estimates.

Load studies and voltage drop calculations were completed for the stack monitoring equipment to finalize power center and cable sizing requirements. Grounding, conduit and power and control routing and connection drawings were issued for the equipment.

A review of the existing plant ground grid was completed and determination made of details for expansion of the grid to the new fuel preparation building.

Voltage drop calculations were completed for the feeder lines to the circulating water pump and the new pulverizer. Field walkdowns were completed for the routing of all tray and conduit in the existing buildings to prevent interferences during construction and thereby optimize design and minimize construction costs. Electrical cable tray was completed for all portions of the fuel preparation and boiler buildings. Portions of cable tray and conduit were routed in longer runs through some portions of the lower levels of the boiler building to avoid interferences noted during the field walkdowns.

Electrical single line schematics were developed for all retrofitted electrical equipment. Layout of lighting in the fuel preparation building was completed. Detailed conduit and cable routing were started in the fuel preparation building.

A study was completed to determine the optimum configuration of the existing plant motor control center to be relocated. The equipment interferes with installation of the new burner and support equipment. Results were that only a portion of the equipment must be dismantled and relocated. The portions that would require relocation would have minimum impact on the cost of construction. Design drawings were issued reflecting the configuration change.

Studies were initiated and completed to determine the optimum location of the receiving equipment of the digital control system. Field devices feeding to the equipment originate in the new fuel preparation

building and the existing boiler building. Space was available to locate equipment only in the lower levels of the plant which would have required long cable runs. From this study it was determined that plant space which now functions as a storage and lunch room could be relocated at considerably less expense to the lower levels and the new control equipment placed in the space thus made available. Cable runs were thus significantly reduced and access to the equipment for test and operating personnel greatly improved.

### **3.3.4 Layout and Piping Design**

Equipment layout studies, including associated pipe layout configuration, were completed. Flow diagrams were prepared for material handling systems, and field walkdowns of existing pipe, equipment, and structures were performed to plan out new piping layouts.

A general arrangement drawing was prepared to form a framework for detailing pipe layout and fabrication drawings for both LNS Burner and balance of plant systems.

LNS Burner system coal pipe drawings were reviewed for compliance with the general arrangements and locations of LNS Burner system pipe hangers established.

P&ID's were prepared for the balance of plant service system and sketches prepared for resolving field pipe and equipment constructability problems. Preparation of suggested field routings of balance of plant pipe systems commenced in accordance with the general arrangement drawings.

Updating to finalize the general arrangement drawings, piping composites and equipment layout continued using current system piping drawings and vendor information.

### **3.3.5 Instrumentation and Controls**

A detailed review of Marion Unit 1 control and instrumentation drawings, plant equipment, and maintenance records was completed to determine LNS Burner interface requirements for balance of plant design. Information from the review was integrated into design of the new LNS Burner combustion control system.

Detail design of the balance of plant control functions for the feedwater controls, feedwater recirculation controls, steam desuperheater controls, generator cooling controls, and other minor control loops and design of instrumentation for the materials handling system was completed.

Detailed design for control room layout and integration of the digital control system equipment into a functional system was started and is in progress. Instrumentation and control devices not required for LNS Burner operation or which require modification were identified and demolition requirements were determined.

Demolition requirements for the existing boiler front panel were defined. All equipment that will be required for LNS Burner operation was identified and design requirements for integration of this equipment into the retrofit design were completed.

Maintenance and upgrade requirements for balance of plant local instruments, actuators, auxiliary control devices and installation detail requirements were established.

Field walkdowns were completed to determine maintenance requirements for all balance of plant instruments.

Prepared Instrument Index (equipment list).

Prepared technical requirements for instrument calibration valve maintenance.

Power requirements for all control systems were determined.

### **3.3.6 Distributed Control System**

Work continued during the current reporting period to finalize the control philosophy. Piping and Instrument Drawings (P&IDs) were started that updated the feasibility study design with the current design requirements. Identification of process control requirements continued during this period. The current boiler system is a 1960's vintage and consists of pneumatic controls with some outdated electrical controls. The new control requirements for the LNS Burner and auxiliary systems greatly exceeded the limited capability of this old system. The panel space on the main control panel is very limited as it serves the three existing 33 MW units. Because of space limitations, limited existing system capabilities and the inability to either maintain or upgrade the old instrumentation, a replacement control system is required for the retrofit. A new distributed control system (DCS) has been chosen that will use free-standing control cabinets located away from the plant control room and will use personal computers as control stations. The DCS will incorporate the three control systems required for the retrofit which are combustion controls and auxiliaries, burner flame safety controls, and data acquisition.

A microprocessor based distributed control system was selected for the following reasons:

There were many common inputs which could be "shared" in a DCS, but would require separate hard wiring to the three separate systems listed above.

There was very limited space available in the control room, and especially on the control board, for operator interface devices and start/stop stations for new major equipment such as the pulverizer, fuel/air blower,

feeders for limestone and additive. The distributed control system provided two CRT based operator interface stations for all of the start/stop and modulating controls. These would fit the space available.

By utilization of the distributed nature of the control system, one cabinet was located at the boiler front resulting in significant savings in wiring costs. Four data highway cables 250 feet long are required rather than hundreds of cables of that length.

One DCS cabinet was located where the previous control cabinet was located utilizing existing wire trays and conduit. The third cabinet was located in available space approximately 50 cable feet away. This avoided the need to enlarge or build a new electrical equipment room.

The nature of a DCS is such that the cost of the system is determined by the input/output count and the operator interface. Once these are purchased "logic" is "free" as far as hardware costs are concerned. This permits the flexibility to make significant changes in the control strategy and implement control improvements as testing provides feedback on the operating characteristics of the process, i.e., as knowledge of the process is gained, the control system can be modified without purchasing additional hardware.

Another key feature of the DCS is the redundant controller approach used in the combustion/boiler control and the burner control systems. In the event of a controller failure, the unit will continue to run safely on automatic control allowing the failed controller to be replaced at a convenient time.

### **3.3.7 Mechanical Design**

Mechanical design requirements were completed for the major components of the Materials Handling System. Piping and Instrument drawings and technical requirements were completed for the bucket elevator, coal limestone and additive storage, screw conveyor system and other related support equipment.

A mechanical equipment list was prepared, equipment weights and electrical loads for all mechanical equipment outlined on the equipment list were determined, and operating requirements for fuel handling equipment prepared. The equipment list is shown in Appendix C.

Fuel Preparation Building equipment heat loads and ventilation requirements were determined. The large amount of heat released by electric motors in the fuel preparation building (725 hp) required the use of power ventilators. Roof ventilators were selected since they were self-contained and reliable, and would more effectively remove the heat that accumulates in the upper levels of the building than wall mounted fans. Each ventilator is equipped with a local adjustable thermostat, and a backdraft damper. Inlet air is admitted near grade level, below the feeder floor, through weather louvers. Each will be provided with manual shutoff dampers which will be manually close in winter as required to maintain room temperature.

Engineering requirements for plant start-up were determined, which indicated that a heat input of 30,000,000 BTU/HR is required for start-up of the LNS Burners. This heat input will be provided by an oil gun/ignitor mounted in the end of the LNS Burner. Each oil burner will be sized for this capacity with 8/1 turndown capability. 150,000 gallons of oil is available on site for all four units. No additional storage capacity will be required. 400 gallons/hr x 24 hours or 9,600 gallons will be required for startup. An air atomization system will be provided for the oil burners in lieu of the existing plant mechanical atomization system.

### **3.3.8 Technical Specifications**

The technical specifications and material requisitions were prepared and finalized from design criteria to satisfy project material, and services requirements for construction and testing of the Cyclone Retrofit Project. These documents together with project drawings constitute the technical requirements of bid and procurement packages for material and services and are listed in Appendix D.

## **3.4 BOILER MODIFICATIONS**

### **3.4.1 System Air Ducting Design and Modifications**

To accommodate the LNS Burner's air entry requirements, while eliminating the existing cyclone burner primary and secondary air duct connections, the following modifications were made to the arrangement of new and existing ducts:

- a) Removal of the cyclone's primary air duct, blockage and sealing of the cyclone's secondary air entrance ducting and removal of the entire section of existing 54" diameter secondary air ducting downstream of the existing air flow measuring venturis.
- b) Interconnection of the LNS Burner air ducting to the new terminus of the 54" diameter secondary air ducting. Each duct section was equipped with a control damper and mass air flow measuring device.

For the over-fire air requirements, new furnace wall ports will be designed and installed in both front and rear walls. The design of these ports will be confirmed with burner and boiler flow modelling as discussed in Section 3.2.3.

From the air heater air side discharge, and FD fan discharge, new hot air and tempering air ducting with control dampers were designed for



both the Atrita pulverizer and transport blower inlet ducting. This inlet ducting was equipped with a flow control damper and air flow measuring device (a mass flow meter for the transport blower; a segmental orifice plate for the less critical Atrita circuit). In this way, control of air flow and temperature could be achieved in both flow circuits. Air ducting arrangement is shown in Figures 13 and 14, and the previous Figure 5.

All ducting will be fabricated from 1/4" carbon steel plate and sized to provide a nominal full load duct velocity of 60 ft/s, thereby achieving a reasonable balance between duct size and system pressure drop.

The existing FD fan flow capability is sufficient for all air flow circuits, however, the FD fan's developed head required a boost from the pulverizer primary air fan for the boiler combustion air circuit and a boost from a separately provided transport blower for the combustor air/fuel feed circuit.

Modifications to the Unit 1 boiler furnace walls and flue gas ducting were completed to accommodate furnace temperature and flue gas sampling ports respectively required during performance testing. The modifications were required to permit test probes to be inserted directly into the flue gas streams and furnace streams to determine temperature and gas analysis profiles for the Baseline Test to be compared with the retrofitted plant.

### **3.5 BASELINE TEST PREPARATION**

All work relating to Baseline test preparation was completed. The Baseline Test Program was finalized after coordination with the DOE and all Funding Parties. All technical specifications, drawings, and procedures for the Baseline test were completed and finalized. This work consisted of the following major documentation:

- Demonstration Program Test Data Acquisition Measurements Drawing

- Boiler Performance Test Specification
- Air Quality and Solid and Waste Water Monitoring
- Boiler Material Monitoring Specification
- Air Pre-Heater Material Monitoring Specification
- Dust Collection Material Monitoring Specification
- Slag Collection Procedure

The Demonstration Program Test Data Acquisition Measurement Drawing outlines the specific data to be taken during the Baseline Test. All data points and expected values of parameters to be measured including responsibility for data collection are outlined. The content of the other documents are described in the Work Done Prior to Signing of The Cooperative Agreement section of this report.

The Boiler Performance Test, Air Quality and Solid Monitoring Specifications were amended to include Material and Sulfur Balance requirements. This required data to be gathered on the boiler system. Major streams flows of coal, air, ash, and flue gas was measured to provide calculation of a material balance. Slag quantities were measured by weighing the material as it discharged from the plant to the collection holding ponds.

The operational performance of the Air Preheater which is critical to the LNS Burner and successful completion of the Baseline Test was tested during normal operation of Marion Unit 1. The equipment performed as designed. Surveys conducted during operation of the unit confirmed that plant instrumentation was performing satisfactorily and that maintenance completed in prior months should assure successful completion of the Baseline Test.

Instrumentation for the Marion Unit 1 Emissions Monitoring Program was purchased and installed. This equipment is required by Technical Specifications of the Demonstration Program Plan for the Baseline and Demonstration Performance Test. The instrumentation consists of continuous monitoring devices for O<sub>2</sub>, CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> and

opacity. Installation of a stack platform, modifications to the stack for the instrument probes, foundation work for the enclosed shelter housing the instrumentation and all grounding and electrical work was completed. The instrumentation was checked out and calibrated satisfactorily

Operational readiness inspections as discussed in the previous reporting period (Section 2.6.2) were completed to determine maintenance requirements and assure availability of Marion Unit 1 for Baseline Testing. The inspections included the boiler and auxiliary systems and instrumentation and control for the non-retrofitted Unit. Performance of equipment vital to the successful completion of the test were corrected. Equipment repairs required included repair of areas of boiler tubing and flue gas duct, air preheater steam coil replacement, replacement of blowdown tanks and other minor mechanical, electrical and instrumentation maintenance. A program was initiated to determine the longer term Marion Unit #1 Maintenance requirements to assure availability for the six month Demonstration Program.

Detail procedures for the Baseline Test were completed and finalized. This included procedures for the Boiler Performance Test, Emissions and Waste Monitoring Program, Slag Catching Program and the Material Monitoring Programs. The contract was awarded for the Emissions and Waste Monitoring Programs. The program requires third party monitoring of stack emissions and solid and water discharge.

Baseline testing, scheduled for July, 1990 was postponed until October, 1990 pending funding approval for expenditures required during testing.

### **3.6 ENVIRONMENTAL SUPPORT**

Fact finding comments on the draft EIV were received from the DOE in June, 1989, regarding floodplains at the site and the status of existing permits. These were responded to in July, 1989.

During a tour of the Marion Power Station by the DOE in July, 1989, discussions were held relating to ash disposal, precipitator performance and wetlands. Further comments were received from the DOE in August, 1989 and a detailed response was submitted in September, 1989.

The final EIV incorporating the results of the above discussions, was submitted in October, 1989.

DOE accepted the EMPO in June, 1989 but requested that further information on the disposition of the proprietary additive and more complete monitoring of flue gas and wastewater be included in the EMP. A response was sent to the DOE in August, 1989 to ensure that the EMP would address these concerns and the EMP was prepared.

In late July, PETC submitted a draft Environmental Assessment for the Project to DOE headquarters.

In September 1990, PETC and their consultant SAIC asked for background information needed to prepare an assessment of long-term impacts of LNS Burner operation if the burners were to be left in the unit after the end of the demonstration including the impact on sluice water pond life. Historical electrical production and coal consumption was obtained for all four units, and forwarded to PETC to respond to the issue of long-term impacts of the technology. A letter was issued to SAIC and PETC stating that SIPC had long term plans for pneumatic transfer of flyash from Unit 1 to the Unit 4 scrubber sluice system which would eliminate the need for flyash sluice water for Unit 1 and extend the life of the ash pond. As part of the monitoring program for the Baseline Test, which is

scheduled for October, 1991, samples of raw sluice water and sluice water from the flyash pond and bottom ash pond will be collected and analyzed.

A permit was issued to Southern Illinois Power Cooperative (SIPC) to construct emission and/or air pollution control equipment consisting of installation of LNS Burners on Marion Unit #1 and the addition of limestone and additive silos and other equipment as described on the application. The permit required that an evaluation of impacts from ash ponds from LNS Burner operation be submitted to the State of Illinois. This was completed and forwarded.

### **3.7 TECHNOLOGY TRANSFER**

A paper entitled "Cyclone Retrofit Demonstration Program with TransAlta's Low NO<sub>x</sub>/SO<sub>x</sub> Burner" will be presented at the Joint Power Generation Conference in Boston, Massachusetts in October, 1990 by William L. Fraser, President of TransAlta Technologies, Inc. and Dr. Gerard G. Elia, Project Manager, U.S. Department of Energy. A copy of the paper is attached as Appendix E to this report.

A similar paper will be presented by Keith Moore, Vice President of TTI, at the French/American Natural Gas and Coal High Performance Technologies Symposium in Chicago, Illinois in November, 1990. The symposium is sponsored by the Gas Research Institute, the Institute of Gas Technology, Southern Illinois University Coal Research Center and the French Trade Commission.

#### **4.0 WORK PLANNED FOR NEXT PERIOD**

The following work is scheduled for execution during the next reporting period from October 1, 1990 to December 31, 1990:

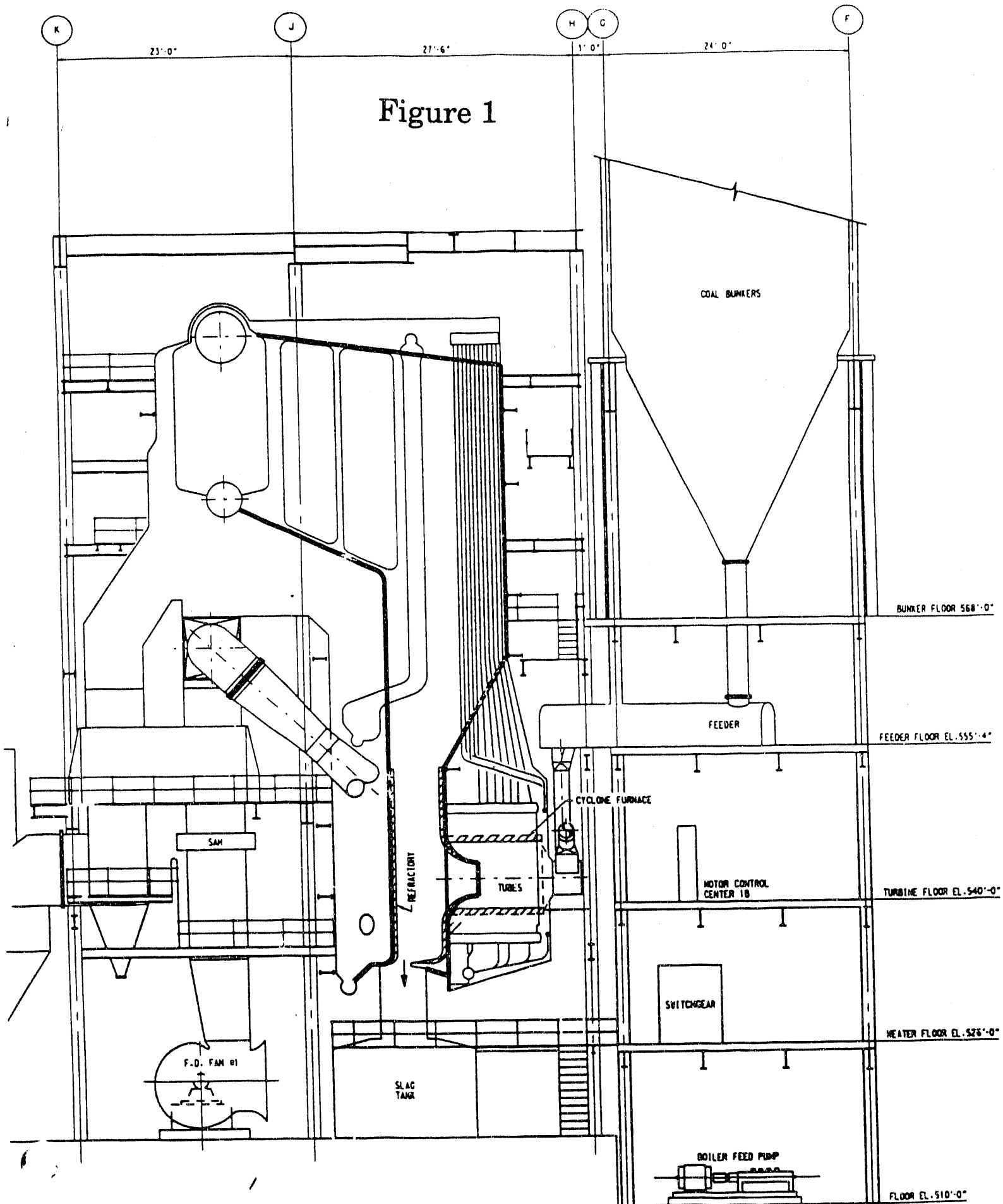
- Finalize the Demonstration Test Plan to include comments and issue to funding parties
- Continue thermal analysis of LNS Burner and finalize design and fabrication details and drawings
- Continue development of LNS Burner - Boiler flow model and establish location of overfire air ports
- Select and finalize design for solids flow splitting equipment
- Continue development of thermal-hydraulic model for the slag screen and finalize slag screen design and fabrication details
- Carry out Baseline Test
- Prepare and submit Baseline Test Report
- Initiate preventative maintenance program
- Complete detailed design and construction of fuel preparation building and structural steelwork for bucket elevator
- Install major equipment such as pulverizer, coal separator cyclones, bucket elevator and feeders
- Detailed study of electrical loads
- Complete design and procurement of microcomputer digital based control system

**FIGURES**

**1 - 14**

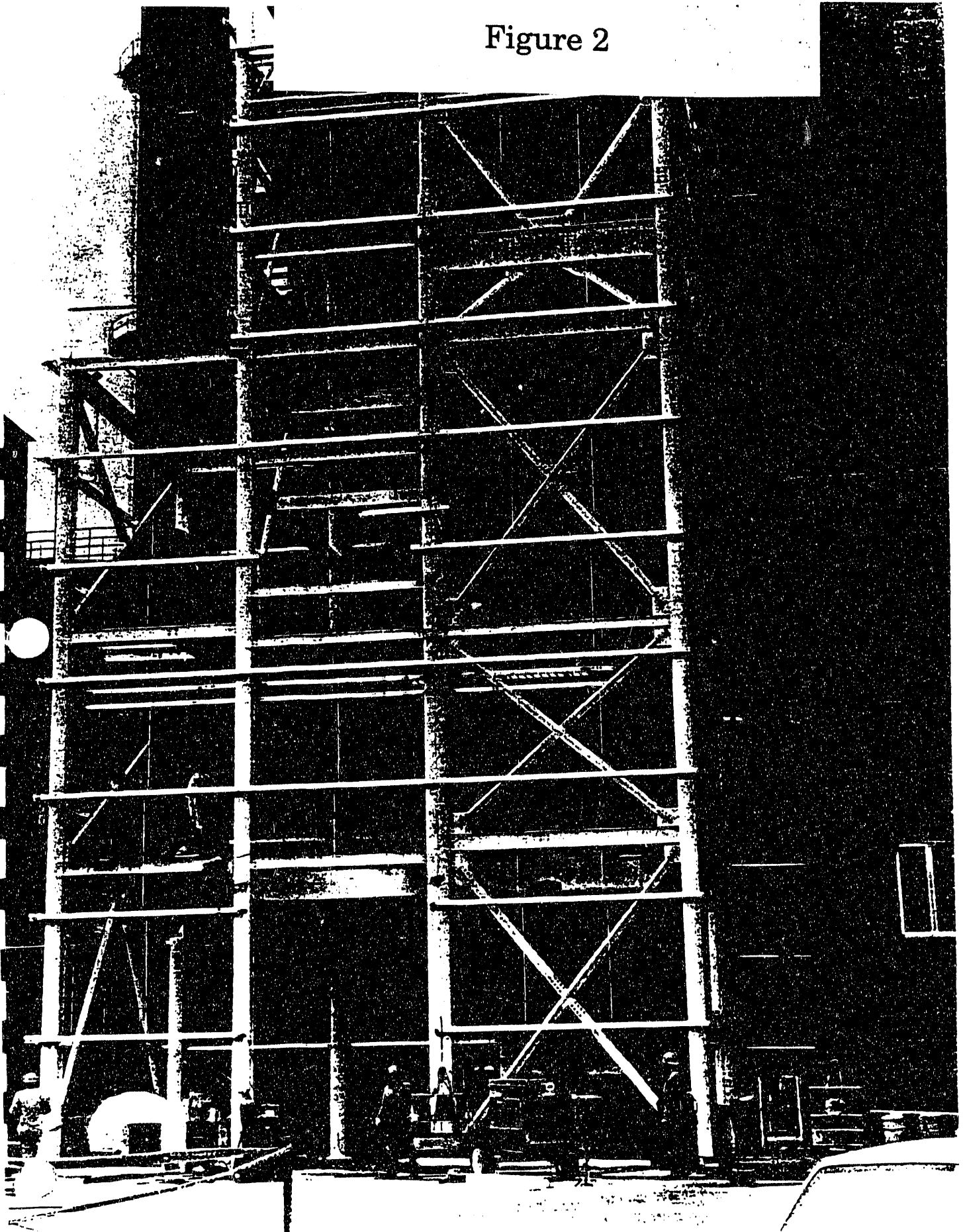


Figure 1



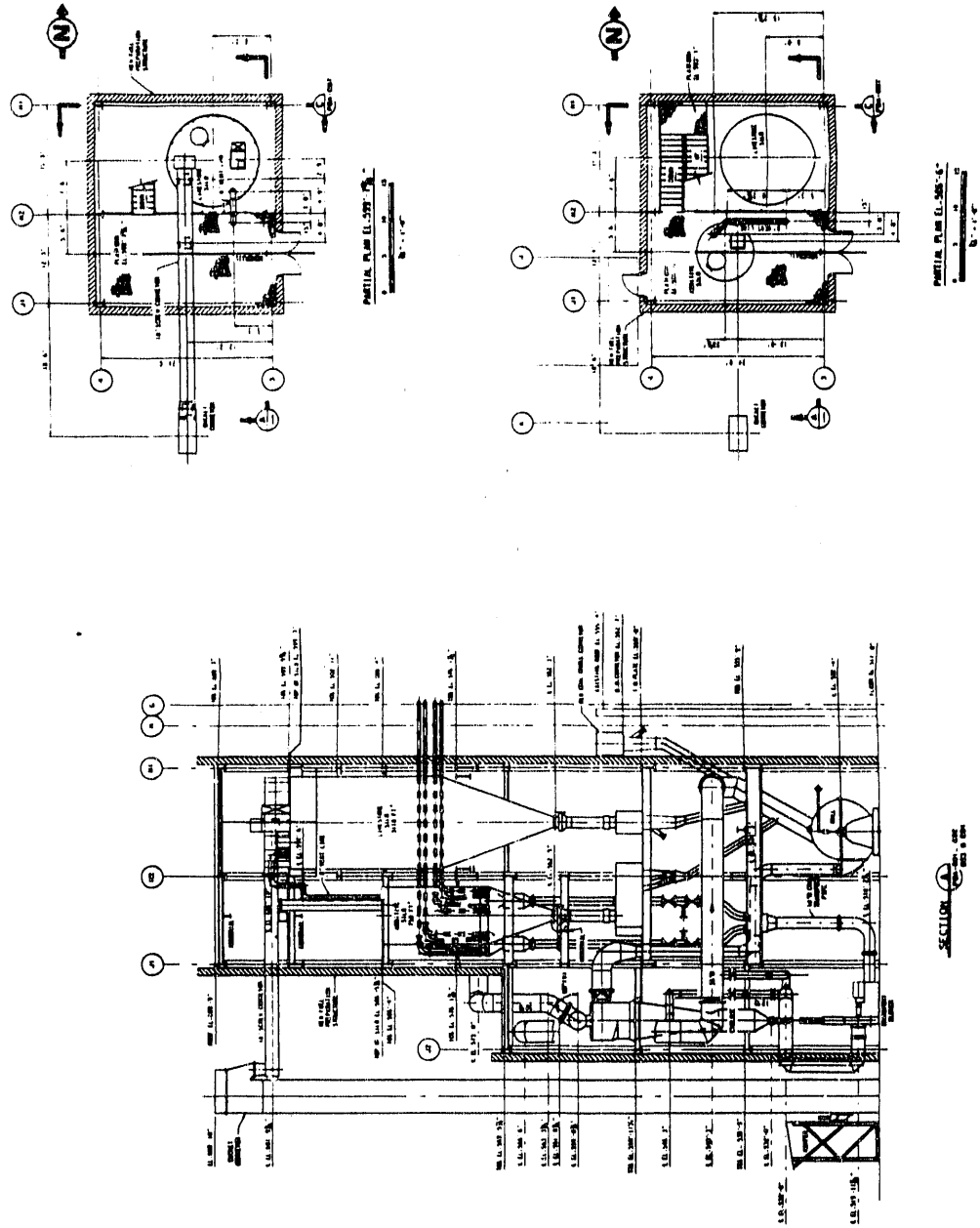
SIPC UNIT #1  
BEFORE RETROFIT

Figure 2



Cyclone Retrofit  
Fuel Preparation Building Steelwork

Figure 3



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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This technical drawing shows a detailed cross-section of a mechanical assembly, possibly a pump or engine component. The drawing is oriented vertically with the main body on the left and a flange or mounting base on the right. Key features include:

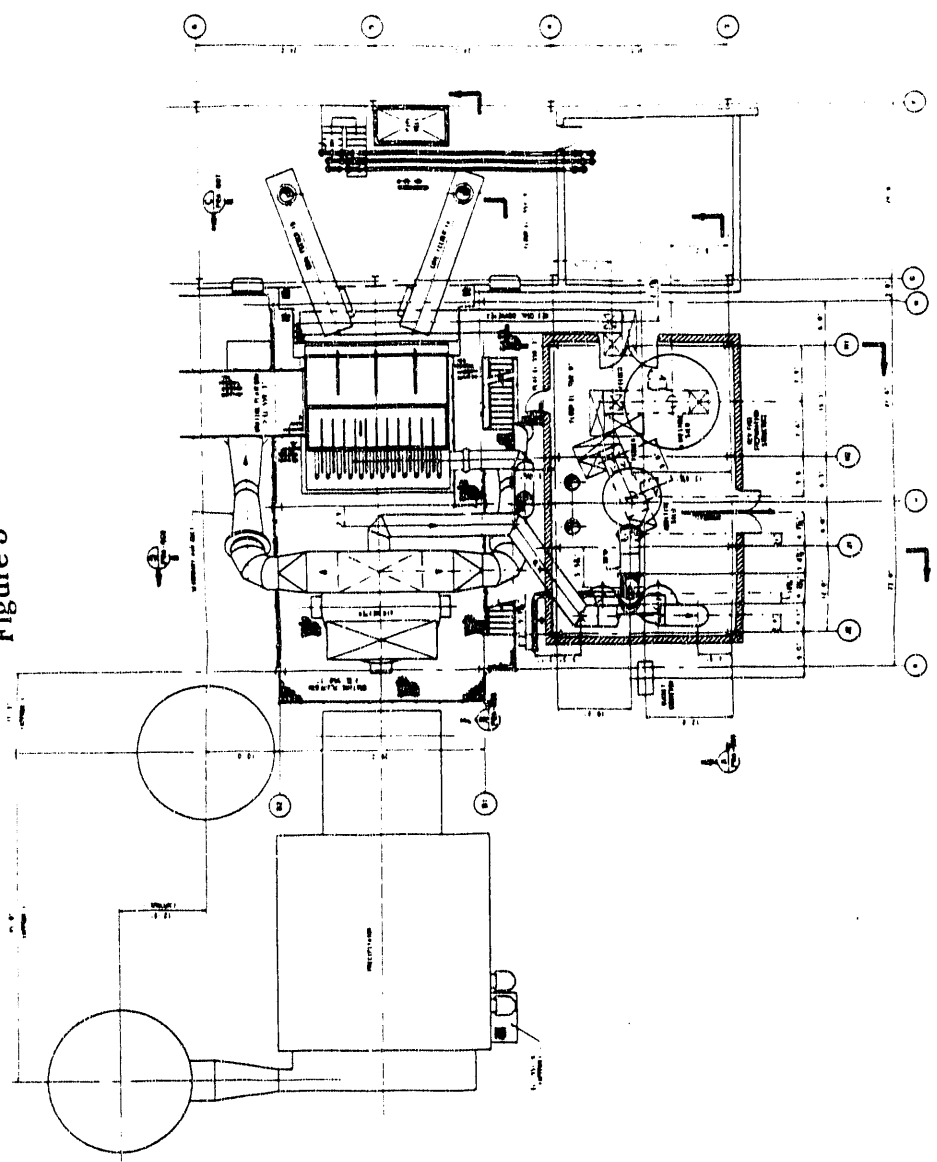
- Top Section:** A large, rectangular component with a central circular opening, labeled with Chinese characters and dimensions.
- Central Section:** A complex arrangement of pipes, valves, and mechanical linkages. A large, curved pipe or duct is prominent on the left side.
- Bottom Section:** A flange or mounting base with multiple bolt holes, labeled with dimensions.
- Labels and Dimensions:** Numerous Chinese characters and numerical dimensions are provided throughout the drawing to specify parts and measurements.

SECTION 10  
PREFACE  
10-1

[illegible]



Figure 5

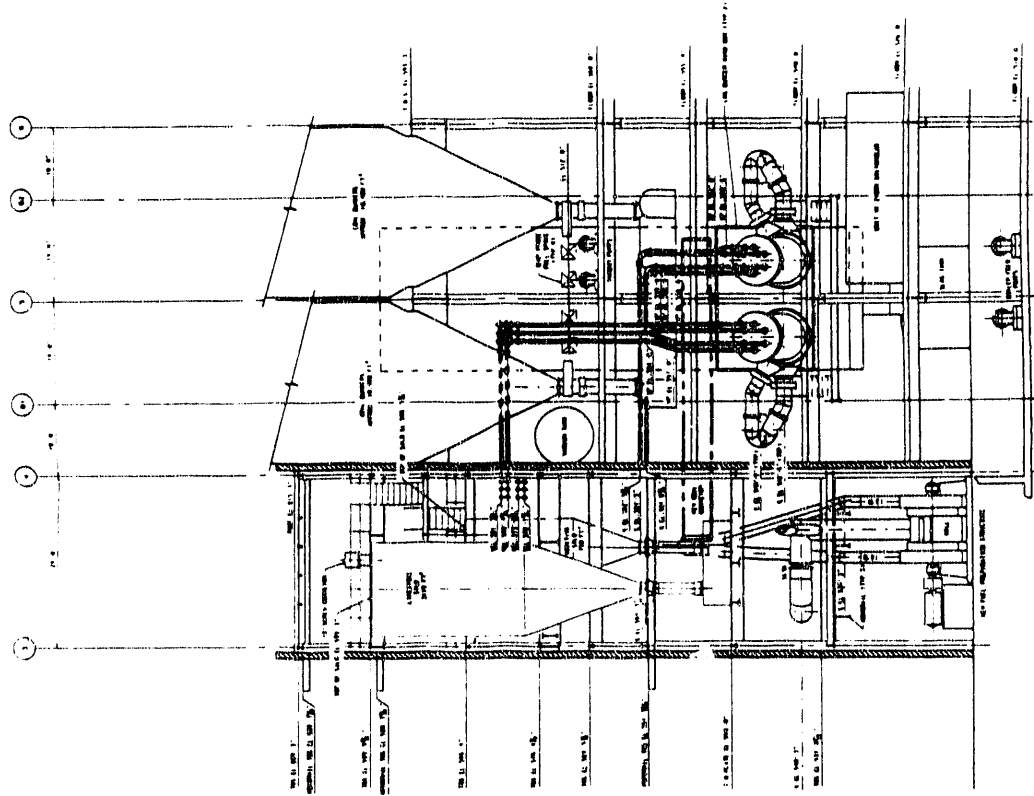


STANDARD FLOOR PLAN EL. 550'-0" & EL. 555'-0" (EAST HALF)

1" = 10'-0"

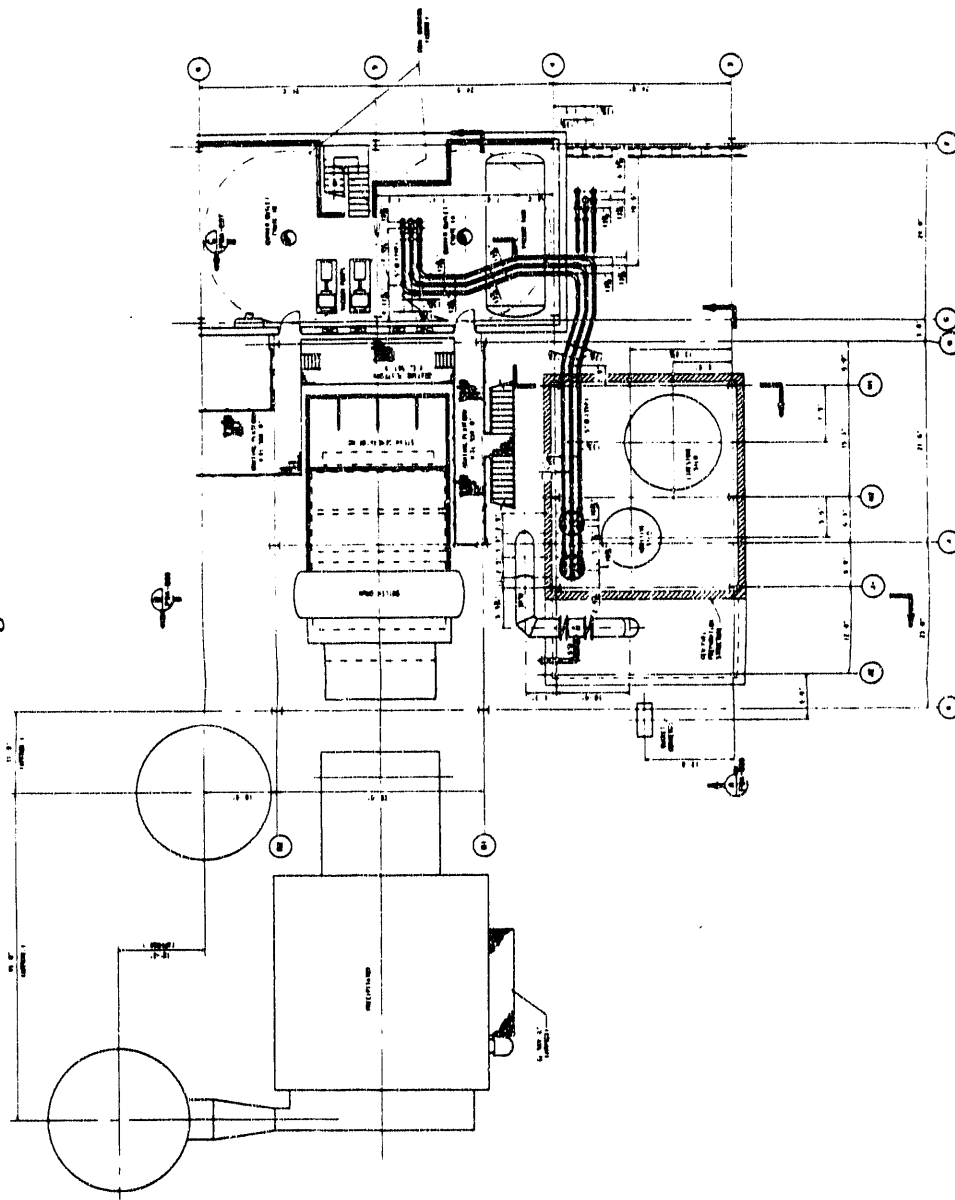
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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Figure 6



SECTION C-C	
TITANIC TECHNOLOGIES	
CUSTOMER: U.S. NAVY	
SOUTHERN ILLINOIS POWER COOP	
DATE	10/1/88
DESIGNED BY	J. J. JONES
CHECKED BY	J. J. JONES
APPROVED BY	J. J. JONES
SCALE	1" = 1'-0"
SHEET NO. 1 OF 1	

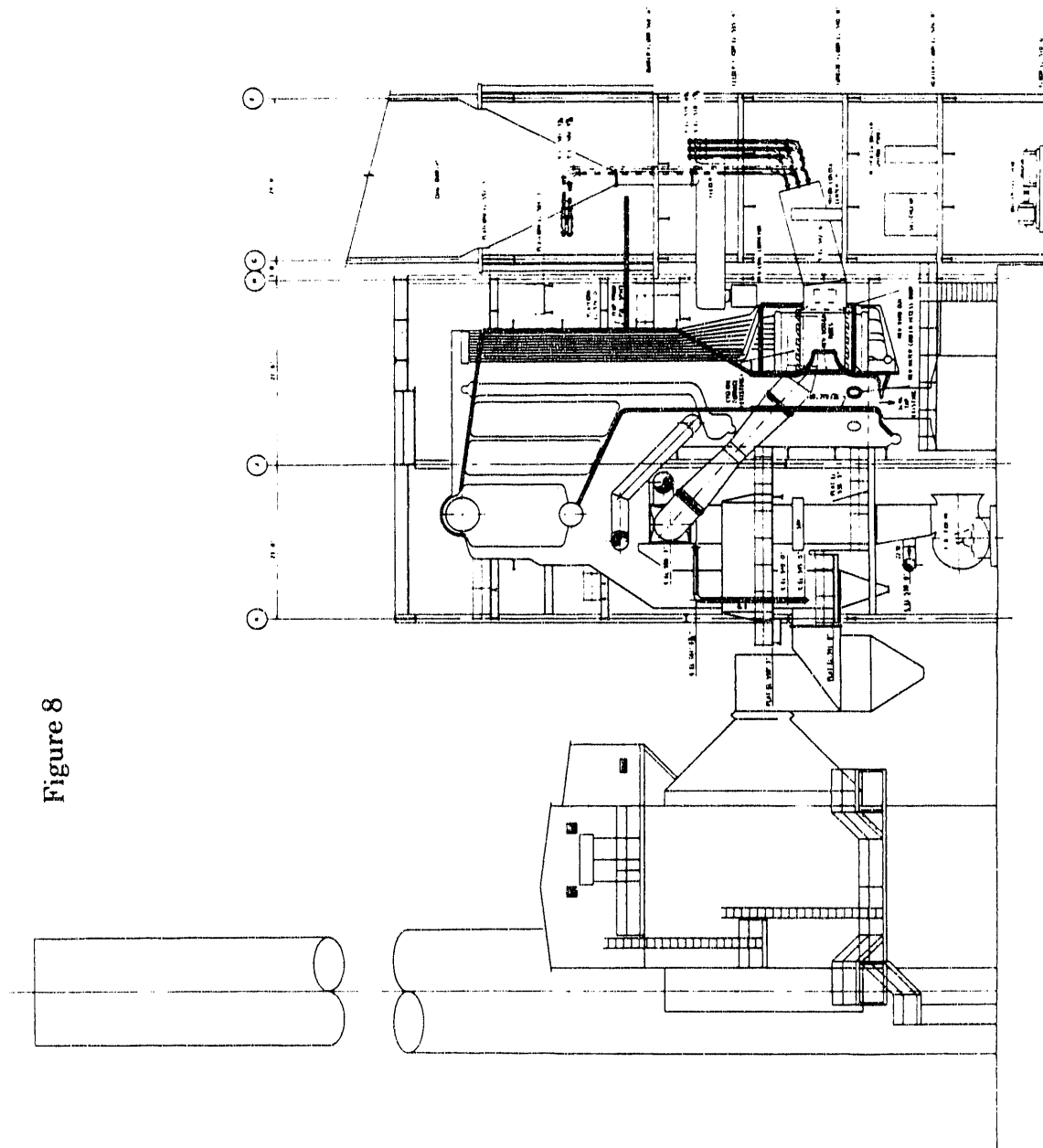
Figure 7



REPRODUCED FROM THE 11-200-27  
 1. 11-200-27  
 2. 11-200-27

TRANSMISSION TECHNOLOGIES	
CYCLOTRON RESEARCH PROJECT	
SOUTHERN ILLINOIS POWER CO.	
FLOOR PLAN	
E1-500-0	
REVISION	
DATE	
BY	
FOR	

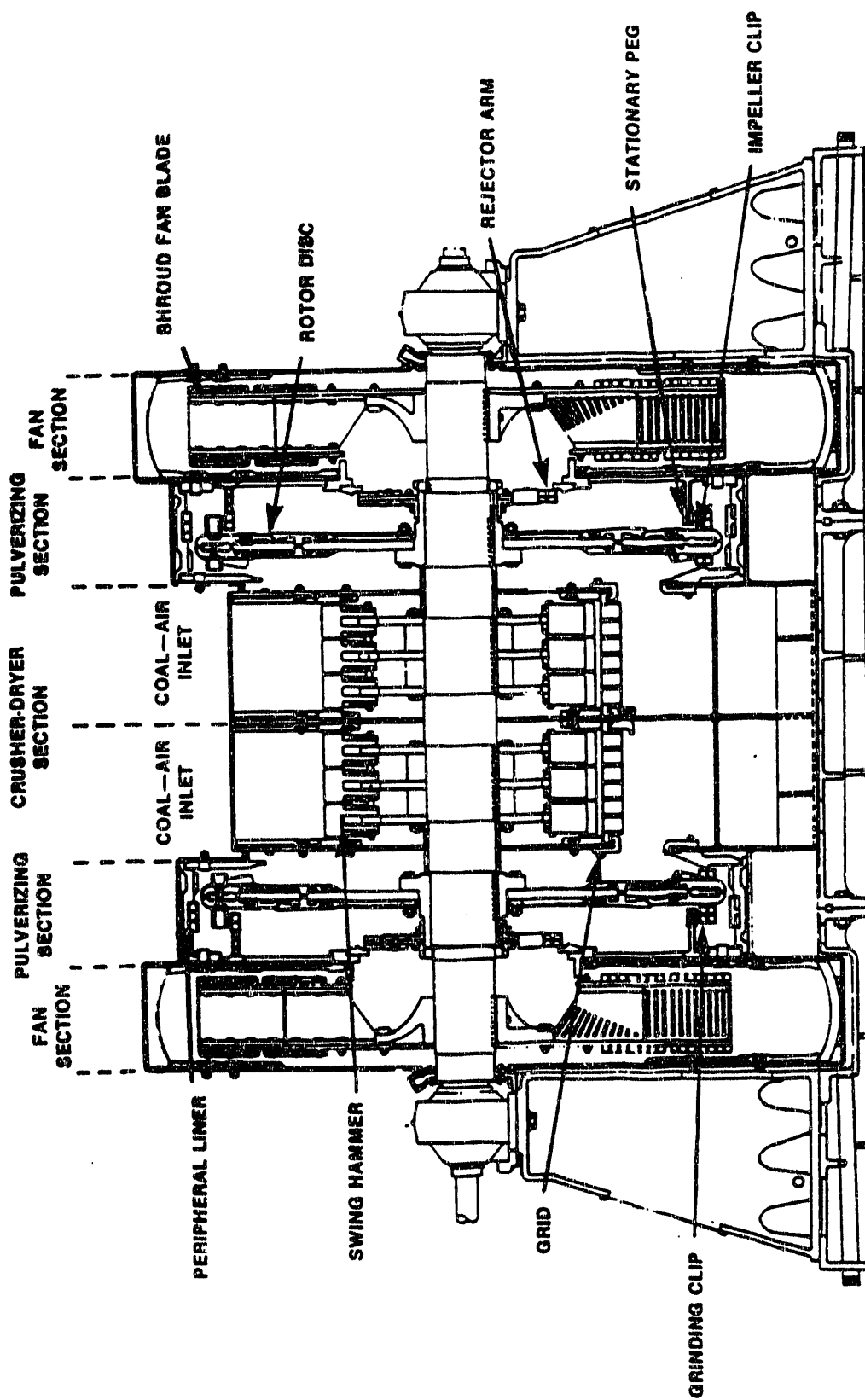
Figure 8



RECEIVED	DATE	TIME	FOR	NO.
TRANSMISSION TECHNOLOGIES				
CYCLONE REFINERY PROJECT				
SOUTHERN ILLINOIS POWER COOP				
SECTION B-B				
1				



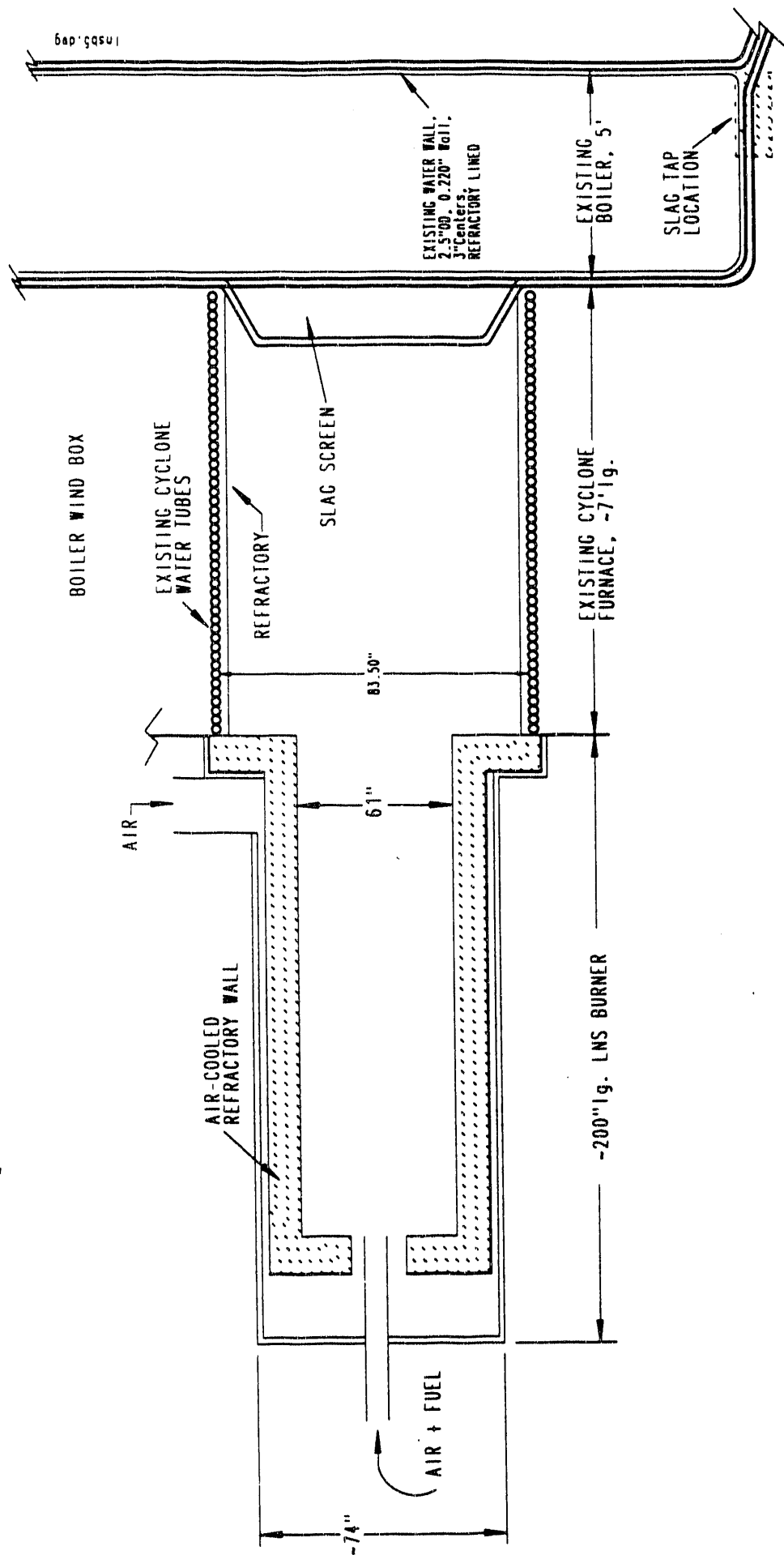
Figure 9



# RILEY ATRITA PULVERIZER—DUPLEX



Figure 11



Elevation View: Schematic of LNS Burner Cyclone Retrofit

Figure 12

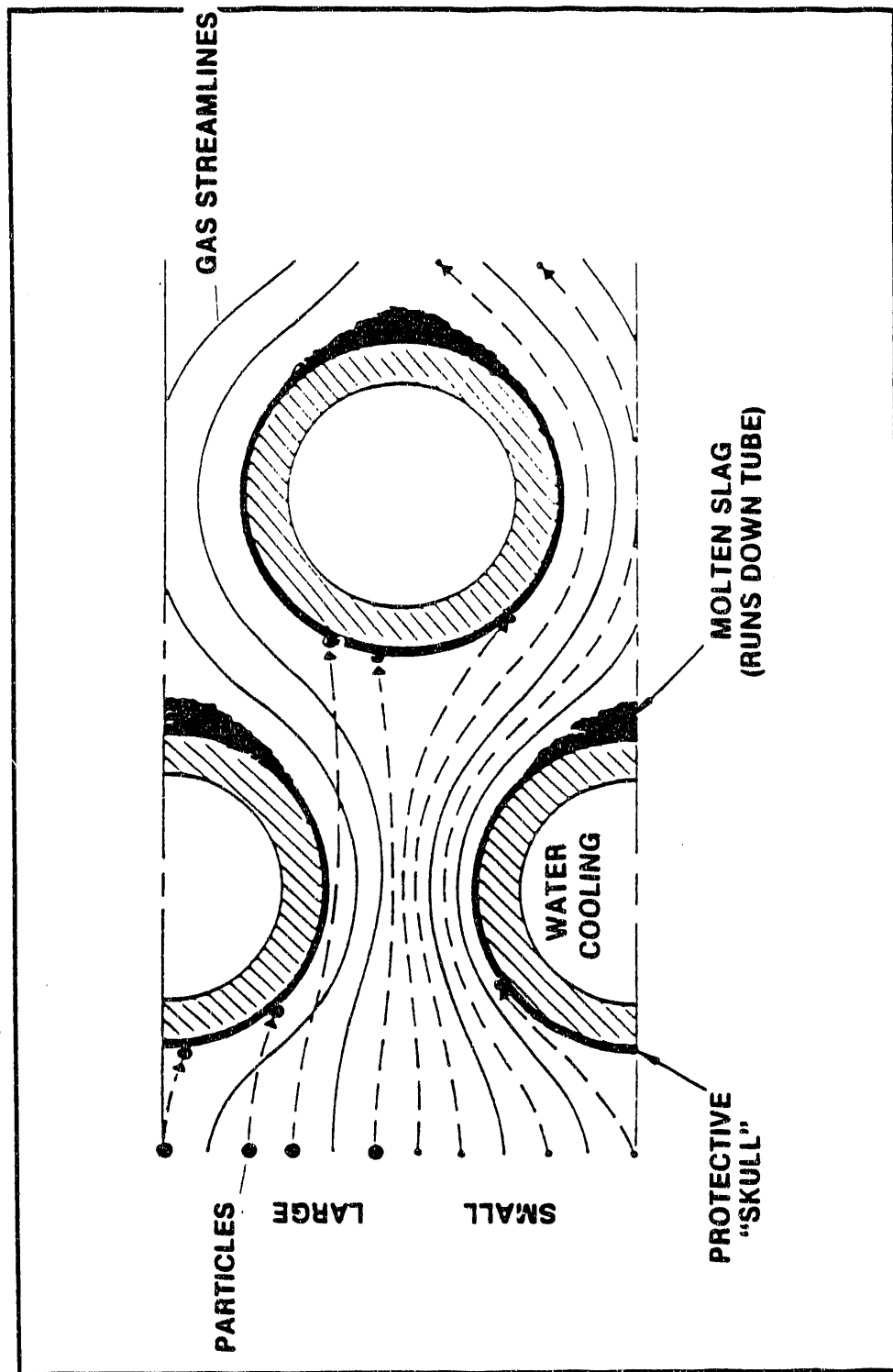
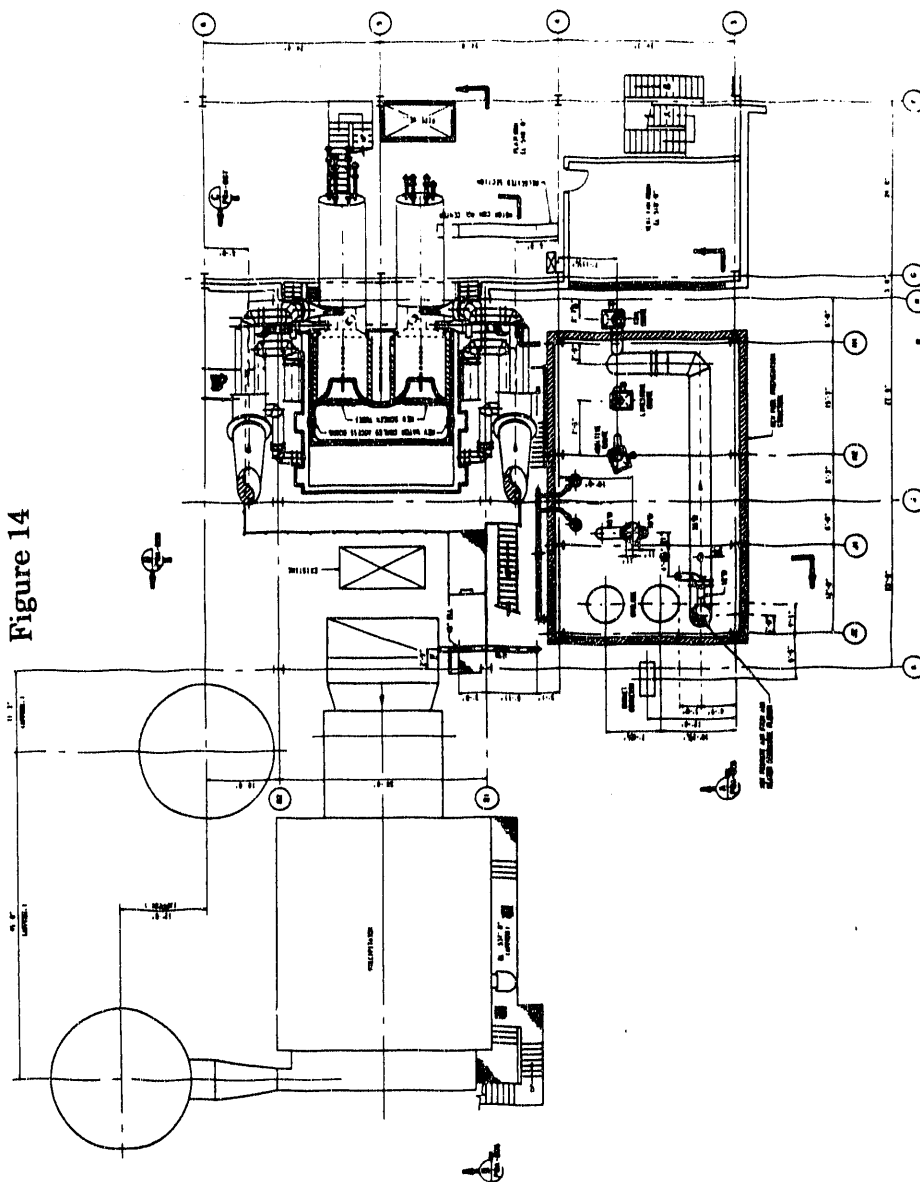


Figure 4-3. Slag Screen Cross Section (Typical)

[illegible]



MEASURE FLAME PLAS EL. 540-0"

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**APPENDIX A**  
**Design Codes and Standards**

## **Appendix A**

### **Design Codes and Standards**

#### **1. Civil, Structural and Architectural Design**

- a) BOCA National Building Code - 1987
- b) American Institute of Steel Construction (AISC)
  - Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, 1978
  - Code of Standard Practice for Steel Buildings and Bridges, 1978
  - Specification for Structural Joints Using ASTM A 325 or A 490 Bolts, 1978
  - Manual of Steel Construction, 8th Edition
- c) American Welding Society (AWS), Structural Welding Code, AWS D1.1 - 1988
- d) American Concrete Institute (ACI), Building Code Requirements for Reinforced Concrete, ACI318-83
- e) American Society for Testing and Materials (ASTM), Applicable standards for the various construction materials specified in the design document
- f) American National Standards Institute (ANSI), Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, ANSI A58.1 - 1982
- g) American Iron and Steel Institute (AISI), Specification for the Design of Cold-Formed Steel Structural Members, Parts 1 and 2, 1977
- h) Occupational Safety and Health Administration (OPSHA), Department of Labor Occupational Safety and Health Standards, Title 29 - Labor, Part 1910
- i) National Fire Protection Association (NFPA), NFPA 24 - 1981
- j) All applicable state and local codes and regulations



- k) Specification 19630-C-010, Reinforced Concrete Work, Latest Revision
- l) Specification 19630-C-011, Structural and Miscellaneous Steel Work, Latest Revision

## **2. Mechanical Codes and Standards**

- a) American National Standards Institute, ANSI, B31.1, Power Piping
- b) National Fire Protection Association, NFPA 85F, Installation and Operation of Pulverized Fuel Systems
- c) Building Officials & Code Administrators, BOCA Building Code, Article 10, Fire Protection

## **3. Electrical Codes and Standards**

Electrical Standards - (Applicable Sections of)

- a) National Electrical Code - NFPA
- b) National Electrical Manufacturers Assoc. - NEMA Standards
- c) ICEA (Cable Construction & Coding)
- d) Underwriters' Laboratories Testing Requirements
- e) IEEE Testing Requirements
- f) IES Lighting Standards

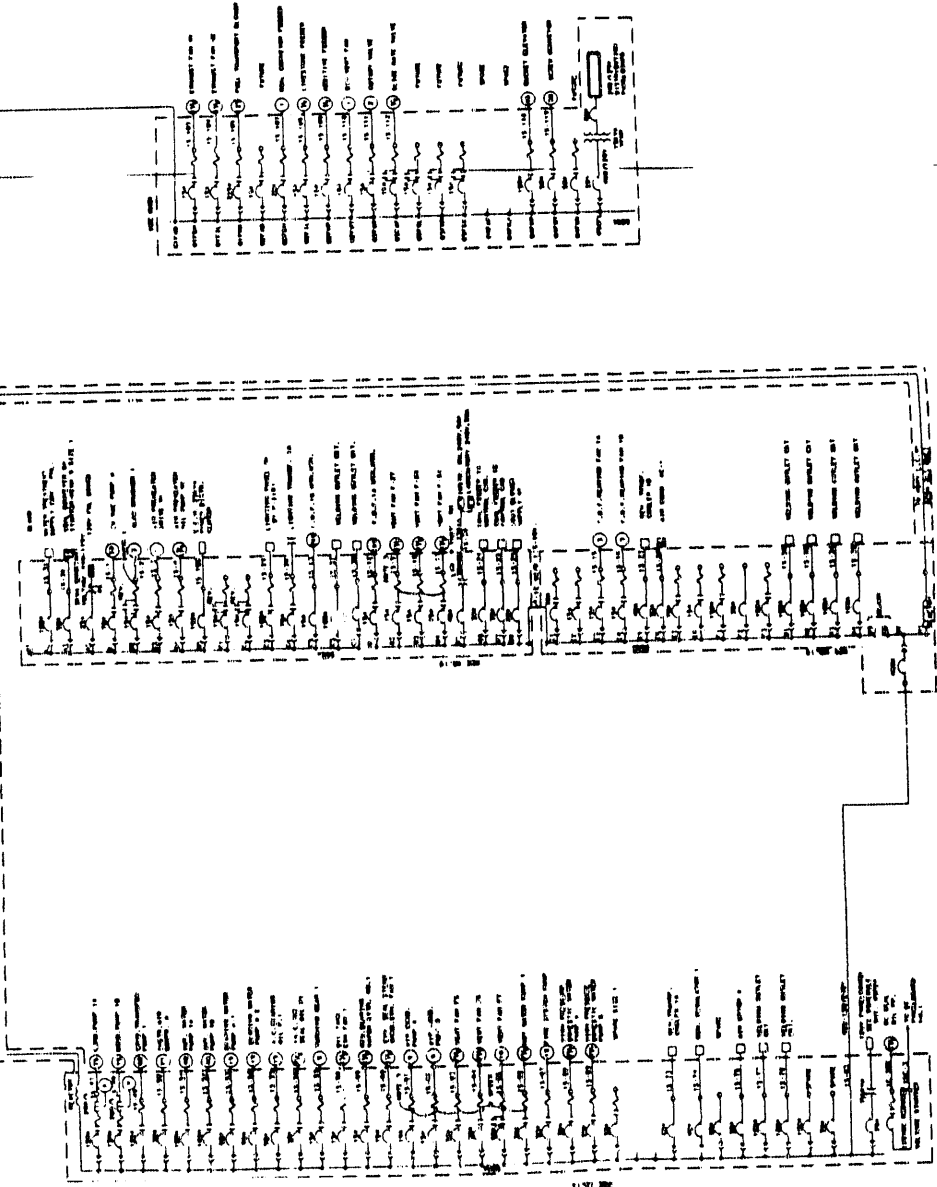
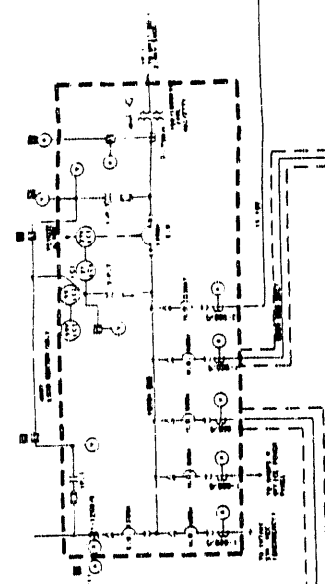
## **4. Control Systems**

I & C Standards - (Applicable Sections of)

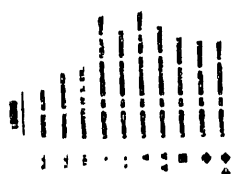
- a) ISA S6.1 Instrumentation Symbols and Identification
- b) ISA S51.1 Process Instrumentation Terminology
- c) SAMA RC22-11 Functional Diagramming of Instrument and Control Systems
- d) NFPA 85F National Fire Protection Assoc. Standard

## **APPENDIX B**

### **Demonstration Program Test Data Acquisition Measurements**



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## **APPENDIX C**

### **Equipment List**

MECHANICAL

TRANSAITA EQUIPMENT LIST

2/11/91  
4/4/98

(\*\*ESTIMATED)  
(\*\*assigned by Riley)  
HP SCOPE MFCR SPEC REMARKS

UNIT	SYS	ID_NUMB	DESCRIPTION	QUAN	RATING	drive	T/A	Stock Equip	M-001	HP	SCOPE	MFCR	SPEC	REMARKS
1	JC	B001A.B	combustor	2	200 MBtu/hr			Riley	M-001					
1	JC	H001	coal feed conveyor	1	25 TPH	c/o .33		Riley	M-001					volumetric feeder
1	JC	C001	pulverizer	1	47,600 lbs/hr		600	Riley	M-001					"Atrita" mill
1	JC	F0001	riffle	1	34,186 lb/hr (air)			Riley	M-001					1 X 2 split
1	JC	F0002A.B	flow splitter	2	17,093 lb/hr (air)			Riley	M-001					1 X 6 split
1	JC	F001A.B	cyclone separator	2	71,115 lb/hr (air)			Riley	M-001					(duplex)
1	JC	C001	fuel transport blower	1	34,186 lb/hr (air)		125	Riley	M-001					
1	JC	H004	fuel rotary feeder valve	1	47,600 lbs/hr		2	Riley	M-001					
1	JC	H003	limestone feeder	1	0.55-4.75 TPH	DRV .50 C/O .33		Riley	M-001					
1	JC	H002	additive feeder	1	0.23-1.4 TPH	DRV .50 C/O .33		Riley	M-001					
1	JC	V **	coal/fuel valves (air op)	10*	-			Riley	M-001					4 cyclone, 6 burners
1	JC	V **	fuel sys air dampers (air op)	14*	-			Riley	M-001					
1	JL	Z001	diverter gate valve	1	-		1/3*	Webb	M-002					
1	JL	F001	silco dust collector	1	500 CFM	fan-1 shaker-1/4 (ctrl pwr - 110/60/1*)		Bechtel	M-003					
1	JL	H002	bucket elevator	1	144 TPH		40	Bechtel	M-002					
1	JL	H001	elevator loading hopper	1	240 cu ft			Bechtel	M-002					
1	JL	H003	screw conveyor	1	144 TPH		30	Bechtel	M-002					
1	JL	T001 ABC	LS silo air cannon	3	4.84 cu ft			Bechtel	M-005					
1	JL	T002 AB	additive silo air cannon	2	4.84 cu ft			Bechtel	M-005					
1	JL	T003 ABCDE	east coal bunker air cannon	5	4.84 cu ft			Bechtel	M-005					
1	JL	T004 ABCDE	west coal bunker air cannon	5	4.84 cu ft			Bechtel	M-005					
1	GA	D001	ventilation louvers	4	25 SQFT AREA			Bechtel	A-7					50 sq ft total free area

# TRANSALTA ELECTRICAL EQUIPMENT LIST

UNIT	SYS	ID_NUMB	DESCRIPTION	QUAN	RATING	HP	SCOPE	MFG	SPEC	REMARKS
1	NB	-	breaker, 2400V swgr	1	3PH/1200A	-	Bechtel	GE	E-002	to relocate Cwp si
1	NG	-	breaker, 480V load center	1	3PH/800A	-	Bechtel	GE	E-004	to feed NH01
1	NH	NH01	motor control center, 480V	1	3PH/600A	-	Bechtel	Siemens	E-001	3 sections
1	PP	PP-1	power distrib. center, 480/120V	1	25 KVA	-	Bechtel	West.	E-003	feed to CEH
1	LH	LH01	bucket elevator control panel	1	-	-	Bechtel	Webb	M-002	
1	-	LIT-103/104	silos level indicator panel	2	-	-	Bechtel	Kistler/Morse	J-004	for lime/additive silos
1	-	-	distributed control system consisting of:							
			-engineering work station	1			Riley	Bailey	M-001	
			-PC View-operator work station	2			Riley	Bailey	M-001	
			-printer/plotter	1			Riley	Bailey	M-001	
			-printer	1			Riley	Bailey	M-001	
			-monitor cabinet	1			Riley	Bailey	M-001	
			-burner mgmt cabinet	1			Riley	Bailey	M-001	
			-combustion control cabinet	1						
1	-	-	continuous emissions monitoring system consisting of:							
			-equipment shelter	1			Bechtel	Enviroplan	J-001	CEMOP-281
			-opacity monitoring system	1			Bechtel	Enviroplan	J-001	WEST. 3000
			-oxygen monitoring system	1			Bechtel	Enviroplan	J-001	CEMEX
			-SO2/NOx monitoring system	1			Bechtel	Enviroplan	J-001	ACS 3300/3400
			-CO2 monitoring system	1			Bechtel	Enviroplan	J-001	
			3-pen strip chart recorder	1						

M-010 Incl louver & curb

7

M-001

ILG

Bechtel

2 HP

12,500 CFM

2

ventilation fans

C001 AB

1 GA

Bechtel

1/4\*

7

2\*

unit heaters\*

D002

1 GA

Riley

1/4\*

-

2

ventilation dampers (str op)\*

D003

1 GA



**APPENDIX D**  
**Technical Specification List**

TransAlta Project

Job No. 19630

<u>Document Type</u>	<u>Bechtel Number</u>	<u>Document Title</u>
MR	19630-A-003	Fuel Preparation Building Doors
MR	19630-A-003A	Fuel Preparation Building Doors
MR	19630-A-151	Roof Personnel Hatch
MR	19630-A-154	Aluminum Louvers
MR	19630-C-010	Reinforced Concrete Work
MR	19630-C-011	Structural and Miscellaneous Steel
MR	19630-C-012	Limestone and Fuel Additive Silos
MR	19630-E-003	Dry Type Distribution Power Center
MR	19630-E-004	480 Volt Load Center Breaker
MR	19630-E-005	480 Volt Bus Duct
MR	19630-E-006	Electrical Bulk Commodities
MR	19630-E-007	480 V MCC Bus Tie Breaker
MR	19630-E-008	Electrical Grounding Materials
MR	19630-E-009	Stack Platform Lighting Material
MR	19630-J-003	Stack Monitoring Platform
MR	19630-J-004	Silo Level Indicators and Switches
MR	19630-J-005	Weld Pad Thermocouples
MR	19630-J-007	Tanks For Instrument Calibration
MR	19630-J-009	Instruments
MR	19630-M-002	Bucket Elevator, Loading Hopper, Screw Conveyor
MR	19630-M-004	Silo Dust Collector
MR	19630-M-005	Martin Rig Blaster Air Cannon System
MR	19630-M-010	Roof Ventilator Fans
MR	19630-M-012	Elevator Hopper Winch

TransAlta Project

Job No. 19630

<u>Document Type</u>	<u>Bechtel Number</u>	<u>Document Title</u>
SPC	19630-A-042	Preformed Metal Siding
SPC	19630-A-051	Single Ply Roofing
SPC	19630-C-010	Reinforced Concrete Work
SPC	19630-C-011	Structural and Misc. Steel
SPC	19630-C-012	Limestone and Fuel Additive Silos
SPC	19630-C-1000	Subsurface Investigation & Lab. Testing
SPC	19630-E-001	Motor Control Center
SPC	19630-E-002	2.4kV Metal Clad Switchgear
SPC	19630-J-001	Continuous Emissions Monitoring System
SPC	19630-J-002	Data Logging System
SPC	19630-J-003	Stack Monitoring Platform
SPC	19630-J-006	Bucket Elevator Control Panel
SPC	19630-M-002	Bucket Elevator
SPC	19630-TSC-001	Environmental Monitoring Program
SPC	19630-TSC-002	Instrument Calibration, Testing & Maint.
SPC	19630-TSC-003	Boiler Materials for Monitoring Inspection
SPC	19630-TSC-003A	Boiler Tube Materials Monitoring Inspect.
SPC	19630-TSC-004	Electrostatic Precipitator Materials Monitoring Sys.
SPC	19630-TSC-005	Engineering/Technical/Craft Personnel, Etc.

## TransAlta Project

Job No. 19630

<u>Document Type</u>	<u>Bechtel Number</u>	<u>Document Title</u>
DWG	19630-M74-BA01	Demonstration Program Test Data Acquisition Measurements
DWG	19630-M74-BA02	Demonstration Program Test Data Acquisition Measurements
DWG	19630-SK-M-001	Ground Floor Plans at El. 517'-0
DWG	19630-SK-M-002	Turbine Floor Plan El. 540'-0
DWG	19630-SK-M-005	Partial Plans El. 586'-3 5/16, & Section A-A
DWG	19630-A-001	Architectural Floor Plans El. 517'-0", El. 550'-0"
DWG	19630-A-002	Architectural Roof Plan, Door Schedule & Spec.
DWG	19630-A-003	Architectural Elevations
DWG	19630-A-004	Architectural Elevations
DWG	19630-A-005	Architectural Details and Sections
DWG	19630-C-001	Structural Steel Framing Plan El. 576'-49/16"
DWG	19630-C-002	Structural Steel Framing Plan El. 535'-9", Etc.
DWG	19630-C-003	Structural Steel Framing Els. @ Col. Lines 3 & 4
DWG	19630-C-004	Struct. Steel Framing Els. @ Col. Lines H1 & H2
DWG	19630-C-005	Structural Steel Framing Elevs. at Col. Lines J1 & J2
DWG	19630-C-009	Misc. Steel Platforms and Details
DWG	19630-C-010	Fuel Preparation Building Reinforced Concrete Plan
DWG	19630-C-011	Continuous Emissions Monitoring System

# TransAlta Project

Job No. 19630

<u>Document Type</u>	<u>Bechtel Number</u>	<u>Document Title</u>
DWG	19630-C-012	Bucket Elevator Support Tower Plan, Sec. & Details
DWG	19630-C-013	Bucket Elevator and Inlet Loading Hopper Found.
DWG	19630-C-014	Structural Steel Framing Partial Plans
DWG	19630-C-015	Structural Steel Framing Partial Plans
DWG	19630-C-016	Supplemental Steel Framing Plan Views
DWG	19630-C-017	Supplemental Steel Framing Sections and Details
DWG	19630-C-018	Supplemental Steel Framing Sections and Details
DWG	19630-E-001	Motor Control Center Frame Spec.
DWG	19630-E-002	Modification Drawing Grounding Plan El. 517'0
DWG	19630-E-003	Modification Dwg. Plan El. 526'0" Cable Tray
DWG	19630-E-004	Modification Drawing 480V One-Line Diagram Unit 1
DWG	19630-E-005	Modification Drawing Main One-Line Diagram
DWG	19630-E-010	Cable Tray Layout Turbine Floor El. 540'-0" Unit 1
DWG	19630-E-020	Lighting General Notes and Details Unit 1
DWG	19630-E-021	Lighting Layout Fuel Prep Bldg. Unit 1
DWG	19630-E-022	Lighting Layout Fuel Prep Bldg. Unit 1
DWG	19630-POA-001	Ground Floor Plan @ El. 517'-0", F.P. @ El. 526'0"
DWG	19630-POA-002	Turbine Floor Plan El. 540'-0"

TransAlta Project

Job No. 19630

<u>Document Type</u>	<u>Bechtel Number</u>	<u>Document Title</u>
DWG	19630-POA-003	Feeder Floor Plan @ El. 550'-0" @ El. 555'-4"
DWG	19630-POA-004	Floor Plan @ 568'-0"
DWG	19630-POA-005	Partial Plans El. 568'-5 3/4". 599'-5 13/16"
DWG	19630-POA-006	Fuel Preparation Building Section B-B
DWG	19630-POA-007	Fuel Preparation Building Section C-C
DWG	19630-POA-008	Fuel Preparation Building Section D-D
DWG	19630-SK-E-011	Scope of Work Single Line
DWG	19630-SK-M-001	Ground Floor Plan @ Elv. 517'0" F1 Plan @ Elv. 526'0"
DWG	19630-SK-M-002	Turbine Floor Plan @ Elv. 540'-0" Unit 1
DWG	19630-SK-M-003	Feeder Floor Plan @ Elv. 550'-0" & Elv. 555'4" Unit 1
DWG	19630-SK-M-006	Fuel Preparation Building Section B-B
DWG	19630-SK-M-007	Fuel Preparation Building Section C-C
DWG	19630-SK-M-008	Fuel Preparation Building Section D-D
DWG	19630-SKC-001	Limestone Silo
DWG	19630-SKC-002	Fuel Additive Silo

**APPENDIX E**

**Technology Transfer Paper**

## **Cyclone Retrofit Demonstration Program with TransAlta's Low NO<sub>x</sub>/SO<sub>x</sub> Burner**

By

Gerard G. Elia, Ph.D., P.E.

Project Manager, U.S. Department of Energy  
and

William L. Fraser, P.E.

President, TransAlta Technologies, Inc.

at

1990 Joint Power Generation Conference

Boston, Mass. Oct. 21 - 25, 1990

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*The U.S. Department of Energy, under the Innovative Clean Coal Technology Program, in concert with TransAlta Technologies, Inc., a nonregulated subsidiary of TransAlta Resources Investment Corporation and TransAlta Utilities, in Calgary, Alberta, Canada, will demonstrate the retrofit and operation of the Low NO<sub>x</sub>/SO<sub>x</sub> (LNS) Burner on a 33-MW utility cyclone boiler at Southern Illinois Power Co-operative in Marion, Illinois.*

*The LNS Burner has the potential to control both SO<sub>2</sub> and NO<sub>x</sub> emissions from cyclone boilers at a lower cost than any other known technology. The experience gained from this demonstration program is expected to prove the LNS Burner, thereby providing coal fired boilers a design option for extended life with the ability to meet acid rain environmental legislation.*

### **Introduction**

Operating cyclone-design boilers comprise about 26,000 megawatts (MW) of generating capacity in the United States. The typical cyclone boiler fires a high-sulfur bituminous coal at high temperature, which results in high SO<sub>2</sub> and NO<sub>x</sub> emissions. These boilers are generally older mature units, grandfathered with respect to emission control regulations. The net result is that this relatively small fraction of coal-fired utility generating capacity is responsible for a disproportionate share of total utility boiler emissions.

The U.S. Congress is expected to pass new environmental regulations to control SO<sub>2</sub> and NO<sub>x</sub> from all coal-fired boilers. But it is not economical to fit conventional emission control equipment to the older cyclone units. What is needed, if these units are to be kept in service, is a low-cost retrofit

option. The Low NO<sub>x</sub>/SO<sub>x</sub> (LNS) Burner may be this option.

The LNS Burner's combustion process operates at very high temperatures similar to the cyclone and produces a similar slag product. Furthermore, the LNS Burner demonstrates strong control of both SO<sub>2</sub> and NO<sub>x</sub> emissions during the combustion process. The retrofit costs are in the range of one-half that for wet scrubbers. Therefore, the LNS Burner may offer a low-cost retrofit option for utility cyclone boiler emission control programs and likely extend the economic life of cyclone units.

### **Clean Coal Demonstration Program**

A full-scale demonstration of the LNS Burner retrofit on a cyclone boiler will be conducted under the auspices of the U.S. Department of Energy (DOE) Clean Coal Technology Program. The TransAlta project—Low NO<sub>x</sub>/SO<sub>x</sub> Burner Retrofit for Utility Cyclone Boilers—was selected for



negotiation under the second round solicitation Program Opportunity Notice DE-PS01-88-FE-61530.

The demonstration program is estimated to cost \$16.3 million with a 1992 target date for completion. DOE will manage the project from the Pittsburgh Energy Technology Center (PETC) in Pittsburgh, Pennsylvania. Participants include:

- TransAlta Technologies, Inc. (TransAlta Resources Investment Corporation)
- Illinois Coal Development Board, through the State of Illinois Department of Energy and Natural Resources
- The National Rural Electric Cooperative Association (NRECA), through its Cooperative Research Committee. NRECA will be represented by Associated Electric Cooperative, Inc., of Springfield, Missouri.
- The Electric Power Research Institute, Palo Alto, California.
- Baltimore Gas & Electric, Baltimore, Maryland.
- Central Illinois Public Service Company, Springfield, Illinois.

The project will be conducted at Southern Illinois Power Co-operative's Marion plant on unit 1, a 33-MWe cyclone boiler.

The Clean Coal Technology Program is a jointly funded effort between government and industry to move the most promising advanced coal-based energy technologies from the R&D stage into the commercial marketplace. The Clean Coal effort sponsors projects that are different from DOE's traditional R&D programs. The R&D projects center on relatively long-range, high-risk, high-payoff technologies in which DOE provides most or all of the funding. In contrast, the goal of Clean Coal projects is the demonstration of the commercial feasi-

bility of the most promising advanced coal-based technologies that have already reached the proof-of-concept stage.

The Clean Coal projects are jointly funded endeavors conducted as cooperative agreements between the government and the private sector in which the industrial participant contributes at least 50% of the total cost of the project.

To date, DOE has selected 38 projects under three separate competitive solicitations covering a variety of advanced coal-based technologies. Two more solicitations are planned, with the total program exceeding \$2.5 billion in federal procurement funds. These demonstrations are chosen at a scale large enough to generate appropriate data from design, construction, and operation such that the private sector may judge the commercial potential for the technologies. The Clean Coal Technology Program promises to provide information to the public to demonstrate the technological effectiveness, the commercial viability, and the environmental safety of the advanced coal-based systems. When the Clean Coal Technology Program is completed, the public will have at its disposal a wide range of technical, economic, and operational data to reduce the uncertainties of deploying these technologies in commercial-scale applications.

### Cyclone Boiler Designs

Cyclone-fired boilers are used widely for generating steam, primarily in large electric power plants. Cyclone-fired boilers comprise only 9% of the total coal-fired steam generating capacity in the United States. However, as cyclone boilers are major sources of NO<sub>x</sub>, they contribute nearly 20% of total NO<sub>x</sub> emissions from all coal-fired utility boilers. Three states, Illinois, Missouri, and Indiana, account for nearly half of the total cyclone steaming capacity and one-third of the boilers.<sup>1</sup>

The cyclone furnace tends to maintain a stable flame over wide operating ranges. Once the furnace is lit-off and reaches operating temperature, a flame-out is unlikely. Flame stability is maintained even at low excess air. Units typically operate at a carbon loss of less than 0.1% and can reject a major fraction of the coal ash as a slag product upstream from the boiler. Consequently, combustion efficiencies are very high, and the amount of ash that must be handled by the baghouse or electrostatic precipitator (ESP) is only about 25% of that of pulverized coal (PC) fired units.

Since most cyclone units were built before emission regulations were promulgated, they have been grandfathered with respect to pollution control regulation and very few employ scrubbers for SO<sub>2</sub> control. Baseline emissions from cyclone boilers are summarized in Ref. 1. The emissions of SO<sub>2</sub> reflect the sulfur in the coal being burned, with the highest emissions from high-sulfur bituminous-coal-fired units.

The cyclone generates high NO<sub>x</sub> emissions. The data indicate that at full load none of the cyclone units was able to meet the U.S. NSPS for NO<sub>x</sub> (for bituminous coal, 0.6 pound per million Btu [lb/MBtu]). In general, the cyclone's average full-load NO<sub>x</sub> emissions for bituminous coal is 1.44 lb/MBtu.<sup>1</sup> An ESP is generally used to control particulate emissions.

#### **Project Host Site--Southern Illinois Power Co-operative**

Southern Illinois Power Co-operative (SIPC), located on the 2,300-acre Lake of Egypt near Marion, Illinois, completed its 25<sup>th</sup> year of service in 1988. The Marion plant is SIPC's only generating facility, with a total installed capacity of 272 MW. The plant includes units 1, 2, and 3, each a cy-

clone boiler rated at 33 MW. These units were placed in service in 1963. Unit 4, a 173MW cyclone boiler, was placed in service in 1979. Unit 4 carries the system baseload. Units 1, 2, and 3 are normally on cold standby and are used during higher-load winter and summer peak periods. The 33-MW unit 1 was selected for the retrofit demonstration.

#### **Project Fuel--Marion Station Coal**

The coal currently being fired at SIPC is a blend of high-sulfur (3.5%) bituminous Illinois coal and mining waste material. Coal is supplied from both surface and deep shaft mines year round. The waste material is commonly referred to as "carbon." This material is obtained from old mining operations. It was initially screenings and/or coal washer rejects, which at that time were unprofitable to market. In 1988, approximately 651,000 tons of fuel were delivered at an average cost of \$17.55 a ton.

#### **Project Cyclone Boiler--Marion Station Unit 1**

Unit 1 is a Babcock & Wilcox front-wall-fired cyclone two-drum pressurized-furnace rated at 33 MW similar to that shown in Figure 1. The two cyclone burners, fired with crushed coal, are rated at 200 MBtu/hr each.

The horizontal cyclone burners on Marion unit 1 are about 7 ft in diameter by 9.5 ft long. The cyclone burner walls and reentrant throat are fabricated from water-cooled tubes. The tubes are studded and coated with refractory for protection from the high heat fluxes in this region. Crushed coal is introduced centrally through a burner along with tertiary air and immediately swirled by the incoming tangential primary air input at the head end of the cyclone. Secondary air is introduced downstream tangentially into the cyclone barrel.

<sup>1</sup>*Applicability of NO<sub>x</sub> Combustion Modifications to Cyclone Boilers (Furnaces)*, EPA Report No. EPA-600/7-77-006, Jan 1977.

Combustion occurs primarily along the chamber wall zone in the mixture of slag and coal. The slag formed flows down the chamber wall and passes into the boiler through a key slot that is located in the lower portion of the cyclone boiler back wall. The reentrant throat is designed to minimize slag carryover in the gas stream entering the boiler. Typical slag (bottom ash) rejection rates are about 60%. Maintaining high combustion temperatures is critical to achieving proper slag flow.

The only emissions control criteria are for  $\text{SO}_2$  and particulates; no control requirements are currently imposed for  $\text{NO}_x$ . The present  $\text{SO}_2$  emissions are determined by monitoring the maximum sulfur content in the coal. Actual  $\text{SO}_2$  and  $\text{NO}_x$  emissions from unit 1 are not now measured.

### LNS Burner

The LNS Burner was conceived in 1979 as the result of theoretical combustion work done at Rockwell International. This theory predicted that both the sulfur and the nitrogen compounds formed from burning coal can be projected to be reduced to nearly zero in the combustion step. A series of concept verification tests followed by prototypical burner tests have verified the underlying theory of the LNS Burner. TransAlta Resources Investment Corporation, a non-regulated subsidiary of TransAlta Utilities Corporation located in Calgary, Canada, acquired the LNS Burner from Rockwell in 1986. TransAlta Technologies, Inc., has now been formed to undertake the task of commercializing the technology for the utility industry.

Classed as a slagging combustor, the LNS Burner involves high-temperature fuel-rich combustion for the control of both  $\text{SO}_2$  and  $\text{NO}_x$ . High-sulfur bituminous coal, mixed with limestone, is burned in a refractory-lined air- and water-cooled chamber. Using one-half of the total combustion air, the burner creates a hot fuel-rich gas. During

combustion, the fuel sulfur is captured by the calcium from the limestone and is retained as a solid in the melted coal ash. Nitrogen chemically bound in the coal is converted to harmless molecular nitrogen. All of these operations are carried out in the burner. No solids or other fuels need be injected into the furnace, and no flue gas scrubbing is necessary.

### LNS Burner/Cyclone Retrofit Configuration

The schematic of Figure 2 shows those new components required for the LNS Burner retrofit. Most of the major existing components in the plant will continue to be used, such as the coal bunkers and weigh-belt feeders, the ID fan, and the cyclone boiler. Generally, modifying the cyclone plant to fit the LNS Burner will require only:

- Modifying the cyclone furnace section with the LNS Burner.
- Reworking the coal preparation and conveying system with a coal pulverizer in place of the coal crusher.
- Providing a silo and metering system to add limestone or other additives to the coal.

### LNS Burner Application

In the LNS Burner/cyclone boiler retrofit configuration shown in Figure 3, the LNS Burner will modify the front of the existing cyclone burner. Each LNS Burner is sized for 200 MBtu/hr, firing approximately 8 tons/hr of coal, the same as the existing cyclones. The as-received coal is conveyed from the existing bunkers and mixed with limestone to provide a Ca/S ratio of 2:1. These solids are then fed to the coal pulverizer. The pulverized coal and limestone are then air conveyed to the LNS Burners.

The existing cyclone throat, consisting of studded refractory-coated water-wall tubes,

will be removed. To increase the slag removal efficiency, a new slag screen assembly of staggered tubes, vertically traversing the opening, will be installed. The heat flux on these tubes is expected to be the same as that on the existing cyclone throat tubes. As the slag droplets collect on the screen, the slag drains to the slag tap located in the boiler's insulated lower section. With the high-efficiency LNS Burner slag screen in place of the cyclone throat, an estimate of the new ash load shows that even with the increased quantity of ash, the fly ash load is expected to be lower. The slag quantity for disposal, however, will double.

The clean hot gas exiting the LNS Burner will be burned with final excess air in the boiler to obtain full heat release from the coal. It is in this step that care must be taken to prevent the formation of new thermal  $\text{NO}_x$ .

### LNS Burner Expected Performance

The LNS Burner/Cyclone Retrofit demonstration is expected to provide an  $\text{SO}_2$  reduction of 70% (with 90% as an ultimate goal) and very low  $\text{NO}_x$  emissions (0.2 lb/MBtu). The thermal energy delivered to the boiler by the two 200-MBtu/hr LNS Burners is adequate to generate 335,000 lb/hr of steam with superheat to 905°F at 875 psig.

It is expected that the boiler efficiency will be nearly the same as before the retrofit, only affected by the minor heat loss from the increased quantity of slag. As a result, the gross heat rate will show a small increase. The estimated original and modified boiler performance analysis is presented in Table 1.

### Cost Review

An assessment was made of the engineering, procurement, and construction (EPC) and the operation and maintenance (O&M) costs on a selected 500-MW cyclone boiler. This

unit operated on a medium-sulfur coal. Generally, most application studies indicate that the LNS Burner's cost is a very minor part of the total site-specific retrofit costs. Modifications to the boiler and other auxiliary systems result in the major retrofit costs. For the 500-MW unit, the total retrofit cost was \$130/kW. The O&M cost (primarily for limestone) was \$6.5 million per year. As a further comparison, an additional study was compiled from the Electric Power Research Institute (EPRI) and DOE publications to evaluate a wet limestone scrubber and a selective catalytic reduction (SCR) system for similar emissions control performance. Tables 2 and 3 (assumptions and references) summarize the results.

Also provided in Table 2 are the estimates comparing the LNS Burner and other candidate technologies when applied to a new plant. The EPC and O&M costs for a new 300-MW PC-fired plant built with conventional low  $\text{NO}_x$  burners and no  $\text{SO}_2$  emissions control are listed to provide the base costs. The added costs for emissions control technology and its operation are shown for comparison. Note that these data represent order-of-magnitude costs to evaluate various alternatives. The data neither provide nor are intended to be used to determine the absolute cost of a specific technology. It is clear, however, that the LNS Burner promises a low-cost option for emissions control.

### Conclusions

The key problem for the utility industry is and has been to identify a *cost-effective* emission control technique for coal-fired boilers. There are many emission control processes available, but for the older cyclone plants in particular, the remaining-life economics limits the affordable options, short of decommissioning.

TransAlta's goal is to demonstrate the LNS Burner technology as a viable option for the

cyclone boiler as soon as possible. This aggressive schedule must then continue with larger-scale utility demonstrations, thereby providing a proven, cost-effective emissions control option in the face of pending environmental legislation.

#### **Acknowledgments**

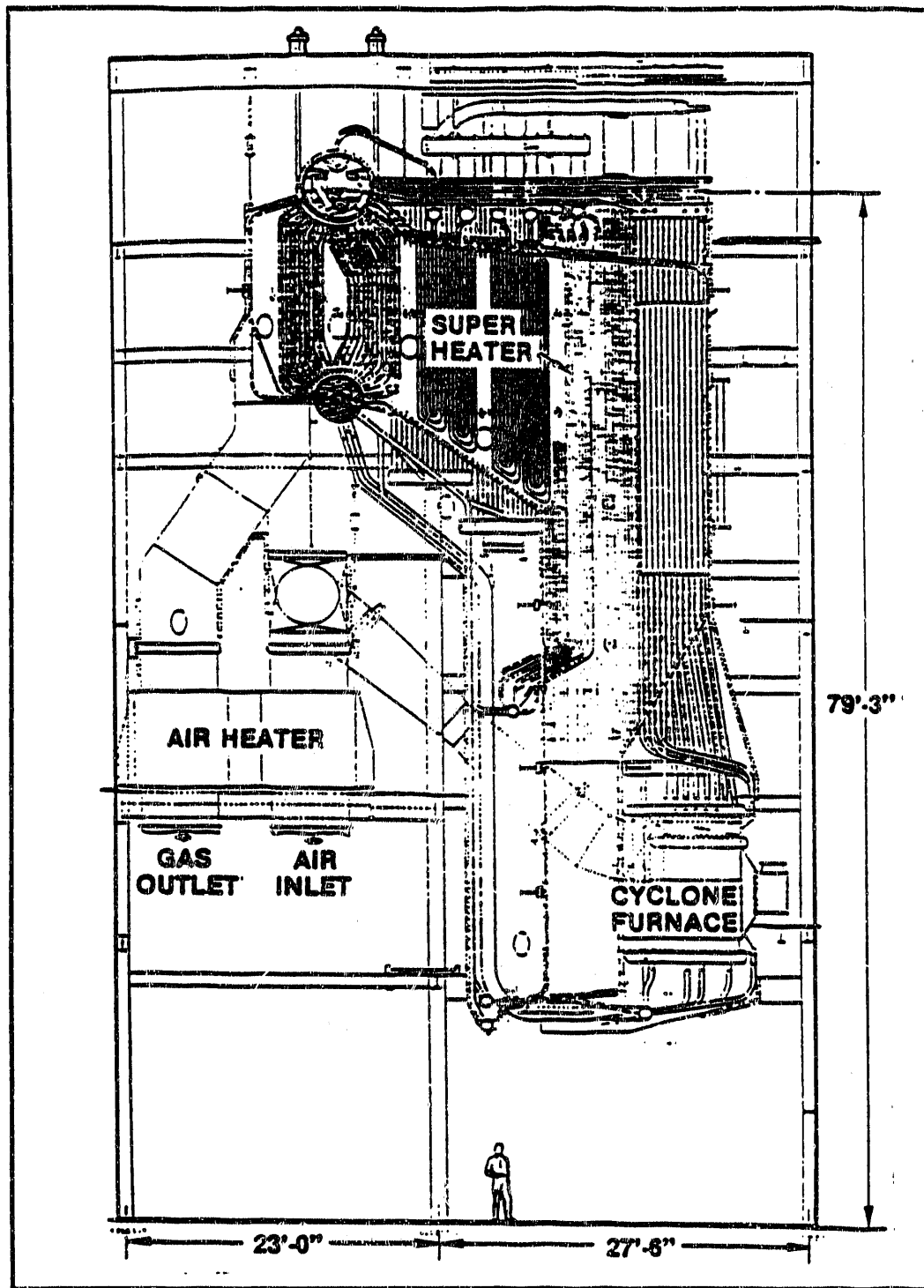
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Wisconsin Power & Light Company  
Electric Power Research Institute.

#### **Disclaimer**

References in this paper to any specific commercial product, process or service is made to facilitate understanding and does not necessarily imply its endorsement or favoring by the United States Department of Energy.



**Figure 1. General View of a Cyclone Boiler and Convection Pass**

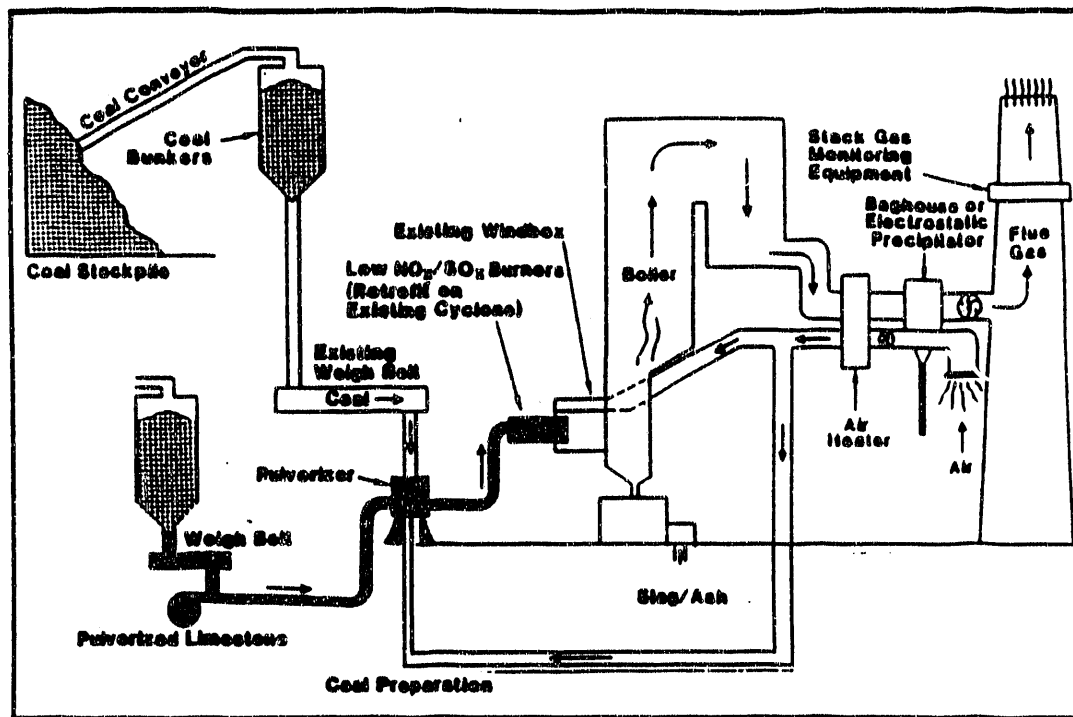


Figure 2. LNS Burner/Cyclone Retrofit Schematic

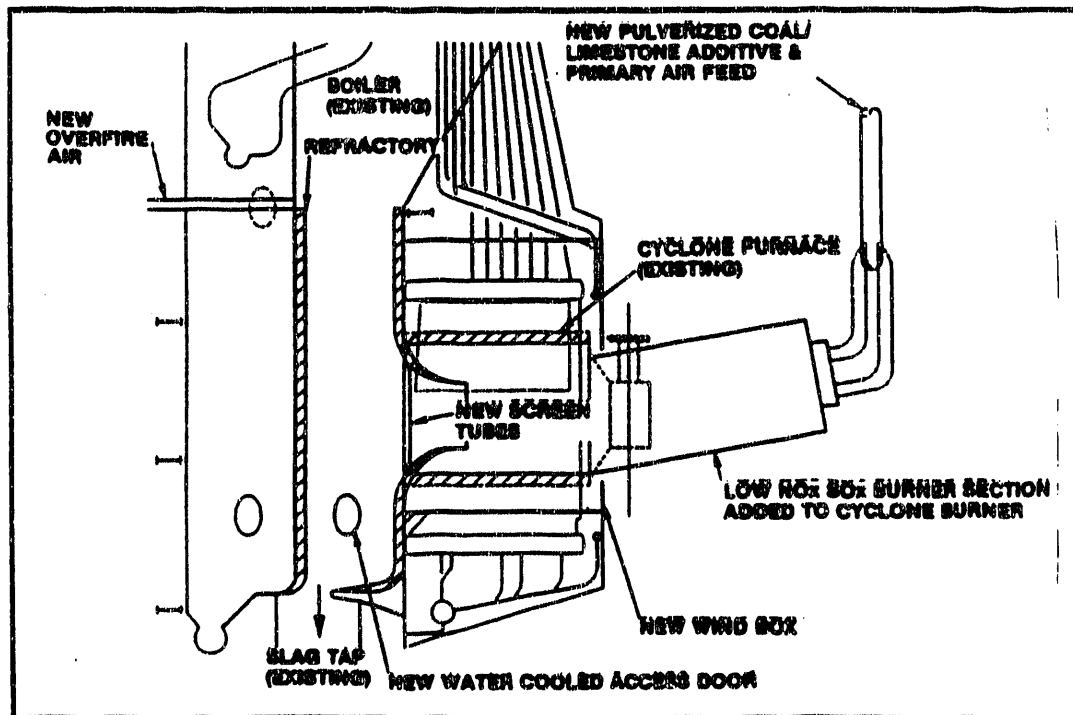


Figure 3. LNS Burner/Cyclone Boiler Retrofit

**Table 1. Estimated Boiler Performance**

<b>Marion Unit 1</b>	<b>Original Design</b>	<b>LNS Burner</b>
Steam flow (lb/hr)	335,000	335,000
Coal Flow (lb/hr)	37,000	36,600
Additive (lb/hr)		
Limestone	0	6350
Other	0	1750
Emissions at the stack (lb/MBtu)		
SO <sub>2</sub>	5.85	1.76
NO <sub>x</sub>	1.35	0.2
Particulates	0.1	0.1
Opacity (%)	<30	<30
Waste Disposal (lb/hr)		
Slag	3760	9420
Fly Ash	2500	2320
Stack Emissions	40	40
Ash tapped as slag (%)	60	80
Boiler efficiency (net)	88.45	88.05



**Table 2. Technology Cost Comparisons<sup>a</sup>**

<b>Technology</b>	<b>Emission Control (%) (SO<sub>x</sub>/NO<sub>x</sub>)</b>	<b>EPC<sup>b</sup> Cost<sup>c</sup> (\$/kW)</b>	<b>O&amp;M Cost<sup>c</sup> (\$10<sup>5</sup>/year)</b>
<b>Cyclone retrofit—500 MW plant</b>			
• Low NO <sub>x</sub> /SO <sub>x</sub> Burner	90/80	130	6.5
• Wet scrubber with SCR <sup>d</sup>	90/80	320	33.2
<b>New 300-MW PC plant (with low NO<sub>x</sub> Burners)</b>	0/50	1150	10.7
<b>Added cost for emissions control</b>			
• PC plant with scrubber	90/50	170	8.2
• PC plant with scrubber and SCR	90/80	320	18.2
• Low NO <sub>x</sub> /SO <sub>x</sub> Burner	90/80	5	2.7
• Fluidized bed with SCR <sup>d</sup>	90/80	175	17.5
• IGCC <sup>e</sup>	90/80	350	16.7

<sup>a</sup>These data have been compiled and factored principally from EPRI and DOE publications. The data represent order-of-magnitude costs that may be useful for comparisons of various alternatives but not for absolute costs of the specific technology.

<sup>b</sup>EPC—engineering, procurement, construction.

<sup>c</sup>Order-of-magnitude costs adjusted to June 1988 dollars.

<sup>d</sup>SCR—selective catalytic reduction (required to achieve 80% NO<sub>x</sub> removal).

<sup>e</sup>IGCC—integrated gasification combined cycle

**Table 3. Assumptions and References Underlying Table 2**

<b>Assumptions</b>	
1.	Capital costs are not site specific. Economic life is taken to be 30 years.
2.	Operating costs are based on EPRI data published in Refs. 2 and 8 and exclude fuel costs. SCR O&M costs include replacing the catalysis bed after 3 years at 2/3 the cost of the original installation and include nominal costs for NH <sub>3</sub> at \$400/MW•year. SCR hazardous waste disposal costs have been excluded. O&M costs also include (1) scrubber power consumption at 2% gross power at \$0.05/kW•hr and (2) IGCC oxygen power consumption at 11.5% gross power at \$0.05/kW•hr.
3.	New plant costs were obtained from Refs. 2 and 3. Costs for AFDC (interest during construction), start-up, inventory, and land costs were backed out of the data so that all costs represented the basic EPC costs. EPRI costs were factored from 200-250 and 500 MW plants to obtain costs for a 300-MW plant. December 1985 EPRI costs were escalated by 2% for 1986, 2% for 1987, and 1% for half of 1988.
4.	Repowering costs are based on DOE information (Ref. 5). The 500-MW unit in the reference has been factored and escalated in the same manner as used for new plant costs.
5.	Retrofit costs are from estimates prepared for TransAlta's DOE clean coal proposal (Ref. 7) and from data in Ref. 4 that have been factored and escalated.
6.	EPRI data basis: <ul style="list-style-type: none"> <li>• Pulverized coal (PC) steam cycle conditions are 2400 psig, 1000°F/1000°F. The steam generator is rated at 2620 psig and 1005°F at the superheater outlet.</li> <li>• Circulating fluidized bed (CFB) steam-cycle conditions are 1990 psig, 1000°F/1000°F. The steam generators are rated at 2400 psig and 1000°F at the superheater outlet. The 300-MWe CFB comprises two 150-MWe combined units, forming one plant.</li> <li>• IGCC design and cost are based on a prototype full-heat-recovery process.</li> </ul>
7.	Low NO <sub>x</sub> /SO <sub>x</sub> Burner costs are assumed to be the same as conventional PC burner costs.
8.	Coal-burning applications use Eastern bituminous coal (3.5% sulfur by weight).
9.	An SCR price of \$150/kW for the PC and cyclone plants was obtained by escalating the high range of the EPRI data (German currency rates) at 10%/year for 2 years. An SCR price of \$75/kW for the fluidized bed plant was obtained by similarly escalating the low range (less NO <sub>x</sub> to be removed) of the EPRI data.
10.	Flue gas desulfurization (FGD) costs are based on Bechtel's CT-121 process and were escalated to present dollars from Ref. 6.
<b>References</b>	
1.	EPRI, <i>ECS Update, Summer 1987</i> , No. 9, Environmental Control System.
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3.	EPRI, <i>Future Power Plants...Choosing among the Many Options</i> , a presentation by Stanley Vejtas, 1 December 1987.
4.	EPRI, <i>Economic Evaluation of FGD Systems</i> , CS-3342, October 1986.
5.	DOE, <i>The role of Repowering in America's Power Generation Future</i> , November 1987.
6.	Bechtel, <i>Flue Gas Desulfurization, The Bechtel CT-121 Process</i> .
7.	Bechtel/TransAlta, submittal to DOE (DE-PS01-88FE61530, Vol. II) and associated estimate.
8.	EPRI projection for a mature IGCC facility, October 1987.

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