LOVETT GENERATING STATION

UNIT 3

SLAGGING COAL COMBUSTOR DEMONSTRATION PROJECT

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Orange and Rockland Utilities, Inc.
August 1989

Lovett Generating Station

Unit 3

Slagging Coal Combustor Demonstration Project

ABSTRACT

In the light of many proposed new laws from the federal and state levels concerning acid rain and control of sulfur dioxide and nitrogen oxides, Orange and Rockland Utilities, Inc. recognized the importance of developing new technologies which provide an economical method of reducing emissions. The Company entered into agreements with TRW, Inc. and Stone and Webster Engineering Corporation in 1986 and submitted a proposal to the United States Department of Energy in response to the Clean Coal Technologies Program Opportunity Notice, Phase I. The primary objective of the project is to demonstrate how rapidly and effectively TRW's slagging coal combustor technology can be applied to utility boilers.

Called the Slagging Coal Combustor Demonstration Project, the plan calls for the retrofit of Lovett Generating Station Unit 3 with four (4) 180 million btu per hour slagging combustors. This site is ideal for the demonstration because the unit uses multiple burners and already has coal handling facilities and equipment. The atmospheric emissions predicted for the demonstration project are the same stringent levels that are now required for low sulfur oil fired operations.

In October 1988, TRW, Inc. signed a contract with the United States Department of Energy for the project to proceed. Engineering design and permitting began October 11, 1988 and is scheduled to be completed January 1, 1990. The second project phase is construction, start-up and shakedown which will take approximately 15 months, or until April, 1991. Phase III which is operations, testing, data collection and reporting is scheduled to be from April 1991 through December 1991. At the conclusion of the demonstration project, Orange and Rockland will make a decision based on the results to either continue operations or to remove the combustors.

The demonstration project is to confirm the anticipated performance values for this technology as applied to utility boilers. Combustion performance, boiler and thermal cycle efficiency, combustor system cooling water requirements, operating reliability and availability data, limestone stoichiometry, furnace sulfur dioxide and nitrogen oxides reduction levels, excess air levels leaving the furnace, and necessary modifications to the boiler to accomplish this retrofit will be key information needed to properly assess the technical and economic aspects of this demonstration and the future marketability of the technology.

If successful this technology will provide an economical method of reducing sulfur dioxide and nitrogen oxides from existing coal plants and retrofitting oil burning plants to coal without increasing emissions or any derating.

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INTRODUCTION

Environmentally, one of the greatest issues facing the electric utility industry is Acid Rain and the control of emissions that lead to its formation. Orange and Rockland recognized the importance of developing new technologies which provide economical methods of reducing such emissions from existing coal fired plants and also allow for the retrofit of existing oil fired plants to coal to reduce our dependence on foreign oil through the combustion of domestic coals. In view of this need, Orange and Rockland entered into an agreement with TRW, Inc. and others to demonstrate that TRW's entrained, coal fired, slagging combustion system (SCS) can be rapidly and effectively retrofitted to a utility boiler. This demonstration project was initiated in response to the United States Department of Energy's Clean Coal Technologies Program Opportunity Notice, Phase I.

The TRW system has been successfully demonstrated on a 40 million btu per hour (mmbtu/hr) industrial coal fired boiler in Cleveland, Ohio. However, most utilities require a retrofit demonstration be conducted on a utility size boiler, as well as successful performance in the industrial market, before a system can be accepted for retrofitting base loaded units. Such a demonstration requires substantial funds and therefore requires cost shared participation.

Orange and Rockland (O&R), TRW,Inc., Stone and Webster Engineering Corporation (SWEC), United States Department of Energy (USDOE), Electric Power Research Institute (EPRI), Empire State Electric Energy Research Corporation (ESEERCO), New York State Energy R&D Administration (NYSERDA), State of Ohio, and Industrial Mining Company have joined together to form such a group and are proceeding to conduct the first utility size demonstration.

The retrofit will consist of installing a total of four (4) TRW slagging combustor systems (SCS) on the side walls of the existing boiler; modifying the existing coal feed system to TRW's indirect coal feed system requirements; making modifications to the existing boiler pressure parts and ductwork; adding a baghouse and associated ductwork for particulate emissions control and fully integrating the SCS into the existing steam cycle in an efficient manner consistent with required plant operating flexibility.

An important aspect of this project is the test program to demonstrate the ability of the TRW combustor system to meet both New York SIP and NSPS emission requirements. Both low sulfur (0.7%) and medium sulfur (2.5%) coal will be tested, requiring different levels of sulfur removal to reach the required emissions. Two tests will be conducted. The first will consist of injecting limestone into the discharge gases from the combustor. Variations of limestone feed injection nozzle designs, flow velocities and carrier air ratios would be tried to maximize sulfur capture. In the second set of tests, the optimal sorbent injection scheme previously determined will be supplemented with recycle material. Solids collected in the baghouse will be processed and reinjected into the combustor discharge gases, along with the fresh limestone.

Orange and Rockland, SWEC and TRW will work with a boiler supplier to make the necessary modifications to the boiler and its auxiliaries to fully integrate the new combustion systems into the original plant design. TRW is responsible for the design and procurement of the combustors, limestone feed system, coal feed system and associated controls. O&R is responsible for plant preparation and operations. SWEC is responsible for the system design for the balance of plant associated with the project and installation for all the equipment.

Engineering design and permitting began in October 1988 and is to continue for 15 months, until January 1990. Construction, startup and shakedown is scheduled to begin in January 1990 and continue for 15 months until April 1991. At that time Phase III of the project is to commence. Phase III involves, operations, testing, data collection and reporting. This last phase is scheduled to conclude in December 1991. The project cost is $49 million, with USDOE contributing $23.5 million, TRW $6.7 million, O&R $6.0 million and the other cost share participants contributing the remaining $12.8 million.

At the end of the program Orange and Rockland will make a decision based upon the results that if successful, the combustors will remain in operation and become one of our base loaded units. If not successful the unit will be converted back to its present day operation of burning either natural gas or fuel oil. The modifications associated with the project will enable the unit to burn fuel oil or natural gas, if necessary, during and after the demonstration phase.

PROJECT DESCRIPTION

TRW's slagging combustor system (SCS) is a technology that can be used to replace gas or oil firing, or to permit coal fired units to maintain or reduce emissions. At Lovett Generating Station Unit No. 3, the SCS will demonstrate the ability to burn coal having a range of sulfur contents (from 0.7 to 2.5%) and meet New Source Performance Standards (NSPS) and New York SIP emission requirements for particulates, sulfur dioxide and nitrogen oxides.

The SCS removes approximately 85% of the ash from the combustion process as a molten slag prior to introducing the combustion gases into the existing furnace. Removing these solids upstream of the existing furnace greatly reduces fouling and erosion problems, permitting boiler heat absorption designs similar to those for oil or gas fired units.

The SCS utilizes a multi-staged combustion process, with the first stage taking place in the combustor at sub-stoichiometric conditions to limit the formation of nitrogen oxides. Combustion is completed in the existing furnace.

Particulates (flyash) that do enter the boiler are removed in a baghouse to meet emission requirements. Sulfur dioxide emissions are controlled by injecting a calcium based sorbent into the combustion gases, in the existing furnace.

Calcium is also collected in the baghouse in the form of reactive lime which, coupled with a low level of flyash, produces an excellent product to recycle. Recycle permits a reduction in the amount of fresh limestone required for a given sulfur reduction rate.

The boiler is a balanced draft CE furnace designed for main steam conditions of 1850 psig and 1050 F at the high pressure superheater outlet and 430 psig and 1000 F at the single stage reheater outlet. The unit was originally designed to burn coal, corner fired at four elevations with Raymond pulverizers and preheated combustion air utilizing a two pass tubular air heater system. Since the unit has been operated only on oil or natural gas since the enactment of stringent air quality control standards in the early 1970's, the boiler is equipped only with a multiple cyclone type dust collector for particulate control before the flue gases are discharged to the stack through the induced draft fan system. The unit is top supported, of tangent tube wall construction, and is totally enclosed in the power house building.

The power plant modifications will be made primarily within the power house enclosure itself with the exception of the new baghouse system required to meet new source performance standards for particulate emissions.

PRINCIPAL MODIFICATIONS

The principal modifications at Lovett will include furnace pressure part modifications to accommodate the four TRW slagging combustion systems, the addition of a new baghouse for particulate control, external ductwork, boiler heating surface and thermal cycle modifications to fully integrate the additional heat absorption of the TRW combustors, modifications to the coal pulverizer systems to accommodate TRW's indirect pulverized coal dense phase feed systems, and installation of the new limestone injection system and the waste recycle/reinjection system. As part of the modifications, there will be some asbestos abatement resulting from insulation required to be removed from the boiler and other systems.

Molten slag from the four combustors will drop into slag tanks. A clinker grinder at the tanks bottom will reduce the slag to a size that can be handled with the existing sluice system. A water jet will transport the slag to the existing bottom ash handling system. This system is a closed loop system with no discharges. Additionally, the slag removal system includes an overflow tank, and a pump to maintain level in the slag tank.

A new baghouse will be installed atop of Lovett in place of an existing outdated electrostatic precipitator. This baghouse will be exhausted through an existing stack to minimize ductwork. The location of these items is dictated by the present arrangement of Lovett Generating Station.

Flyash and spent limestone will be picked up from the baghouse and moved by a vacuum type pneumatic flyash system. The flyash system will include a vacuum blower, a receiver filter, discharge valve assemblies, piping, wearback elbows, couplings, instrumentation, and provisions for integration with the units distributed control instrumentation system.

TRW SLAGGING COAL COMBUSTOR - BASIS OF DESIGN

TRW has fabricated six different combustors and performed over one thousand tests leading to the final design of the commercial unit in place at Cleveland since development of this system began in 1975.

The slagging combustor system consists of a slagging stage which is designed as a water-cooled cylinder with tangential air inlet, a dense phase feed system designed to deliver pulverized coal to the combustor, a coal fired precombustor and associated controls which complete the system. The system has been tested on a wide range of coals and is inherently tolerant of coals with widely varying properties.
The staged nature of the combustion process allows these fuels to be burned with carbon conversion efficiencies in excess of 99 percent while producing nitrogen oxides levels which meet current emission standards. By adding sorbents at the appropriate combustion stages, sulfur dioxide removals of 50 to 90 percent have been demonstrated at Ca/S ratios of 3:1 for coals with sulfur contents ranging from 0.60 to 2.1 percent. The compact design of the system makes its application feasible for a variety of equipment ranging from new steam generation equipment to the retrofit of furnaces originally designed for coal, residual oil or natural gas.

ENTRAINED COMBUSTION SYSTEM

The complete system consists of a small coal hopper with integral dense phase feed components,the combustor which contains a compact slagging stage and a precombustor for boosting inlet air temperature, a slag recovery device, a short connecting duct and associated controls. The system is integrated with conventional coal and ash handling systems and attached or retrofitted to new or existing boilers.

The dense phase feed system includes a coal hopper which receives standard pulverized coal (70 percent through 200 mesh) from a conventional mill. Coal level in the tank is maintained by closed loop control of the pulverization system. This assures a sufficient supply of coal for the combustor injector. A flow measurement and fluidizing system maintains a controlled steady, dense phase fuel at a 10 to 1 weight ratio of coal-to-fluidizing gas. Turn down ratios of 3 to 1 can be achieved by reducing combustion air flow and coal flow simultaneously.

The main slagging system, as installed in Cleveland, consists of an insulated water cooled cylinder which receives preheated air from the coal fired precombustor and pulverized coal from the dense phase feed system. The unit is constructed of mild steel tubing in a fashion similar to typical boiler waterwall construction. Cooling water which is routed to each of the critical components via separate circuits is supplied through a single supply and discharge flange. Internally, the slagging stage is provided with a slag control baffle and welded studs to ensure uniform slag deposition.

The slag layer uniformly covers the combustor wall to a depth of 10 to 19 mm and has the appearance of a black glassy material. It acts as an efficient thermal and hot gas barrier.

A precombustor is attached to the tangential air inlet of the slagging stage. It is fired with coal and is used to boost the air inlet temperatures to the value desired for optimum combustor performance. Coal is fed to the precombustor from the same dense phase feed system used to supply the slagging stage.

A short duct connects the exit of the combustor to the secondary burner at the boiler front. This burner allows combustion air to be mixed with the hot combustor gases exiting the duct. Combustion of the unburned gases is completed in the furnace. All solid carbon (99.5 percent) is combusted within the burner.

COMBUSTOR'S PRINCIPLES OF OPERATION

The heart of the system, the main slagging stage, consists of a water cooled cylinder with a tangential air inlet and slag control baffle. The air inlet and baffle combination promote appropriate mixing and combustion reactions and internal slag flow patterns.

Pulverized coal (70 percent through 200 mesh) is transported in a dense phase fluidized condition to the injector located on axis in the head of the combustor. The coal is injected conically into the combustor, entrained by the swirling air flows and burned sub-stoichiometrically.

Ash contained in the coal is converted to drops of molten slag and impinges on the water cooled walls as a result of centrifugation from the swirling gas flow. At equilibrium, reached within a few minutes of initial start-up, the slag is solid at the wall and liquid on the side facing the combustion gases.

Once on the wall, the molten slag is driven to the baffle by a combination of aerodynamic and gravity forces. It is constrained by the baffle to flow through a key slot and into the slag tap located just after the baffle. The molten slag stream then drops into the slag recovery device. On shut-down the slag layer remains affixed to the combustor wall.

The TRW combustor design is based on two separate combustion stages: one in the combustor; and, the second in the existing steam generator furnace. Multi-staged combustion technology has been used since the 1970's to minimize the production of nitrogen oxides.

The slagging combustor is operated in a sub-stoichiometric atmosphere (equivalence ratio of 0.7 to 0.9 stoichiometry). In this atmosphere of oxygen deficiency, the conversion of nitrogen oxides is controlled while the hot gas is rich in carbon monoxide and hydrogen.

The first stage combustion temperature and heat flux are sufficient to achieve liquid slag flow conditions, but the sub-stoichiometric atmosphere precludes high nitrogen oxides formation.

The hot gas is then introduced into the steam generator furnace where the second stage of combustion occurs as secondary air is added in the furnace. The secondary combustion phase takes place at temperatures low enough to preclude formation of significant quantities of nitrogen oxides.

PROJECT PLANNING AND DESIGN

Conceptual engineering began in October 1988 with the layout of the combustors and other equipment in sufficient detail to support preparation of licensing applications and environmental reports. The Environmental Information Report was filed with USDOE in December 1988 and licensing applications and Draft Environmental Impact Statement were filed with the New York State Department of Environmental Conservation on April 28, 1989. Preliminary engineering involved the detail sizing, layout, development of the control philosophy and economic studies of the combustors, baghouse and associated equipment.

During this period all parties aggressively pursued every means possible to ensure that this project would be the most economical and viable facility which incorporated up to date designs. To this end consultants were retained to assist and optimize the combustors integration. This work included:

- two scaled to size plastic models were constructed to determine the air flow patterns within the boiler from different configurations of combustor locations.
- modeling of boiler to predict changes in performance caused by the installation of the four combustors.
- continued testing at Cleveland facility to optimize sulfur dioxide reduction
- installation and testing of recycle/reinjection system at Cleveland facility.

Results of these test have been incorporated during the preliminary engineering phase of the project. The final combustor location with two on each side wall, at staggered elevations was shown to best duplicate the flows in a Combustion Engineering tangentially fired boiler. Also a computer model of the combustor was used in conjunction with balance of plant analyses to determine the overall effect caused the addition of the combustors on the unit's output, heat rate and performance .

Detail engineering design of the majority of various design packages transitioned from the preliminary engineering phase during the summer of 1989. Engineering activities presently ongoing include detail design of civil/structural requirements, mechanical and electrical systems, instrumentation and controls, baghouse, flyash handling and coal handling systems.

Throughout the project design, the concept of constructability is being incorporated as an integral part of the process. Construction management personnel have been involved since the early planning phase and remain close to the design engineers as the functions of design proceed to completion. Additionally the unit has been entirely three dimensionally modeled to aid in equipment layout, construction scheduling, identifying interferences with existing equipment and preparation of detail drawings. It is believed that such deliberate attention to an appropriately integrated construction/engineering design interface will result in an economical retrofit with minimum construction delays.

THERMAL CYCLE INTEGRATION

Integration of the combustors with the existing thermal cycle has been one of the projects highest priorities. Many scenarios were investigated to determine those most thermodynamically feasible within the constraints of the design conditions of both the combustor and existing equipment. Eight (8) alternatives were investigated. These scenarios ranged from "indirect" integration in which a closed combustor cooling system transfers heat to the feedwater cycle via a new heat exchanger to "direct" integration in which feedwater is circulated directly through the combustor. Additional alternatives included the utilization of flash tanks in which the combustor cooling water would be flashed to various levels to be utilized either in the cycle or the plant.

It was determined that direct integration was the most appropriate for this demonstration, because it minimizes both operational and physical modification to the existing plant, especially the boiler and turbine. The direct integration physically ties the boiler feedwater system and the combustor cooling water system. The main advantages of such a coupling are:

- Combustor cooling water flows are varied throughout the entire load range.
- Boiler drum level control will be affected only by boiler load and not directly by combustor cooling requirements.

These parameters are most important in alleviating potential operating and control problems. The advantages of coupling the feedwater and cooling water circuits and costs were the determining factors in selecting the direct integration scenario.

ENVIRONMENTAL IMPACTS

From the outset, environmental protection was established as a high priority. In 1988, Orange and Rockland initiated discussions with various Federal, State and local agencies exercising regulatory oversight of the project. This process identified the environmental issues that needed to be addressed for this project. This included such topics as: emissions and air quality impacts, acidic deposition, noise generated by coal handling facilities, disposal of the flyash/ limestone by-product, use of water resources and aesthetic impacts.

In designing this project, Orange and Rockland committed itself to minimize the environmental impacts of this project and to maintain and preserve the local environment.

This project will not result in any significant increase of any air pollutants, thermal discharges, wastewater discharges or noise pollution.

Effects on Air Quality

Emission rates for sulfur dioxide, oxides of nitrogen and particulate matter will either remain the same or decrease as a result of this project. Therefore, there will be no adverse air quality impacts resulting from this project and no contraventions of National Ambient Air Quality Standards.

Effects on Water Quality and the Aquatic Ecosystem

Liquid waste effluents discharged to the Hudson River caused by operation of the combustors will meet all applicable water quality standards. Because the proposed project will be connected to the existing plant's overall wastewater collection and treatment system and results in no new discharges, the project has no adverse impact upon water quality.

Effects on Land and the Terrestrial Ecosystem

The project will not have a significant impact on local land use. Facility modifications will be constructed solely on land that has been already utilized for construction and operation of the existing station. Solid waste disposal in the Coal Ash Management Facility will be entirely on land previously utilized for ash disposal. Therefore, operations of the plant and solid waste disposal area has no new impacts on the terrestrial ecology of the area.

Impacts on Solid Waste

The additional solid waste production due to the program is a small quantity of flyash/limestone mixture and slag. Because of the relatively small quantities to be produced compared to that already produced at Lovett, no significant adverse impact is expected.

Noise

Construction activities will increase the noise levels in the vicinity of the station during daylight hours. The residents closest to the station may be temporarily aware of the construction traffic related to worker transportation and delivery of materials. All other construction activities are not expected to disturb the community. Noise levels from increased plant operation of the coal handling equipment or the baghouse will not have a significant impact on the community.

Visual Impacts

The baghouse and associated ductwork will be located on top of Unit 4 in place of the existing precipitator. These will be designed not to exceed the maximum height of the existing structure. This change is not expected to produce significant disturbance to the existing Hudson River visual corridor. The new equipment will be provided appropriate architectural treatment to reduce glare, be homogeneous with the site architecture and be sympathetic to existing site aesthetics.

Presently, the New York State Department of Environmental Conservation is in the process of review our applications and a favorable decision is expected during the fall of 1989.

TEST PROGRAM

One important purpose of the test program is to demonstrate the ability of the TRW combustor system to meet both New York SIP and NSPS emission requirements. These are:

	N.Y.S.I.P. for Coal/Oil-Fired	NSPS for Coal-Fired Boilers	Proposed Emissions
TSP	0.03 lb/mmbtu	0.03 lb/mmbtu	0.03 lb/mmbtu
NOx	0.7/0.3 lb/mmbtu	0.6 lb/mmbtu (bituminous) 0.5 lb/mmbtu (sub-bituminous)	0.27 lb/mmbtu
SOx	0.4 lb/mmbtu	1.2 lb/mmbtu Plus 90% Reduction	0.4 lb/mmbtu

Two coals will be tested: One coal will be low sulfur (0.7%) West Virginia/Kentucky bituminous coal from the Stone and Rawl Mines. The second coal will be medium sulfur (2.5%) bituminous coal from Ohio.

With a 0.7% sulfur coal, it would be necessary to remove 60% of the sulfur to achieve the emission goal of 0.4 pounds of sulfur dioxide per mmbtu. Two tests would be conducted; the first would consist of injecting limestone into the gases as discharged from the combustor. Calcination of the limestone will occur first, followed by reaction of the lime (CaO) with the sulfur dioxide in the flue gases. Variation of limestone feed, injection nozzle designs, flow velocities and carrier air ratios will be tried to maximize sulfur capture. In the second set of tests, the optimal sorbent injection scheme previously determined will be supplemented with recycle material. Solids collected in the baghouse will be processed and reinjected into the combustor discharge gases, along with the fresh limestone.

It has been determined, by testing, that calcination in the limestone injection schemes previously described is extremely effective. A majority of the calcium collected in the baghouse is in the form of reactive lime. This, coupled with the low level of ash (resulting from the fact that 80 to 90% of the original ash is removed as slag), produces an excellent product for recycle.

The purpose of the recycle is to increase the effective Ca/S ratio within the furnace and thus permit a reduction in the amount of fresh limestone required for a given sulfur reduction rate.

A similar series of tests will be run with the medium sulfur coal. In this case, 90% sulfur removal will be required to reach the 0.4 pounds of sulfur dioxide per mmbtu goal. Previous testing suggests this level is feasible with the solids recycle scheme.

Performance Characteristics

Data will be collected over the test period to demonstrate the performance values of the combustor on the boiler. Operating data such as pressures, temperatures, combustor stoichiometry ratios, flow velocities and slag conditions will be monitored to assess the combustor operation. Equipment operation and maintenance records will be kept and reviewed to evaluate the reliability and availability of the systems. Combustor cooling water requirements will be monitored as well as other equipment integrated into the thermal cycle. The unit's output, heat rate and performance at various loads will be tested and analyzed, as well as the combustors ability to follow load on economic dispatch.

All the factors will be reviewed to determine the technical and economic feasibility of retrofitting units with TRW's SCS system. These will be factors considered in Orange and Rockland's decision to continue use of the combustors or return the unit back to its original mode of natural gas and fuel oil operations after the demonstration project is completed.

PROJECT SUMMARY

PROJECT TITLE:	ADVANCED SLAGGING COMBUSTOR UTILITY DEMONSTRATION
PROPOSER:	TRW, Inc.
PROJECT LOCATIONS:	Orange & Rockland Utilities, Inc. Lovett Station, Stony Point, NY TRW's Cleveland Test Site Cleveland, OH
TECHNOLOGY:	Entrained Slagging Combustor with Sorbent Injection (in the boiler)
APPLICATION:	Industrial and Utility Boilers
TYPES OF COAL USED:	Low and Commercially Washed High-Sulfur Bituminous Coal
PRODUCT:	Steam for Electricity
PROJECT SIZE:	69 MWe/4-160 MMBtu/hr (Lovett) 40 MMBtu/hr (Cleveland)

ADVANCED SLAGGING COMBUSTOR UTILITY DEMONSTRATION PROGRAM

PROGRAM GOALS AND OBJECTIVES

DEMONSTRATE THE FOLLOWING:

- SCS TECHNOLOGY CAN BURN COAL IN NEW & EXISTING UTILITY POWER BOILERS

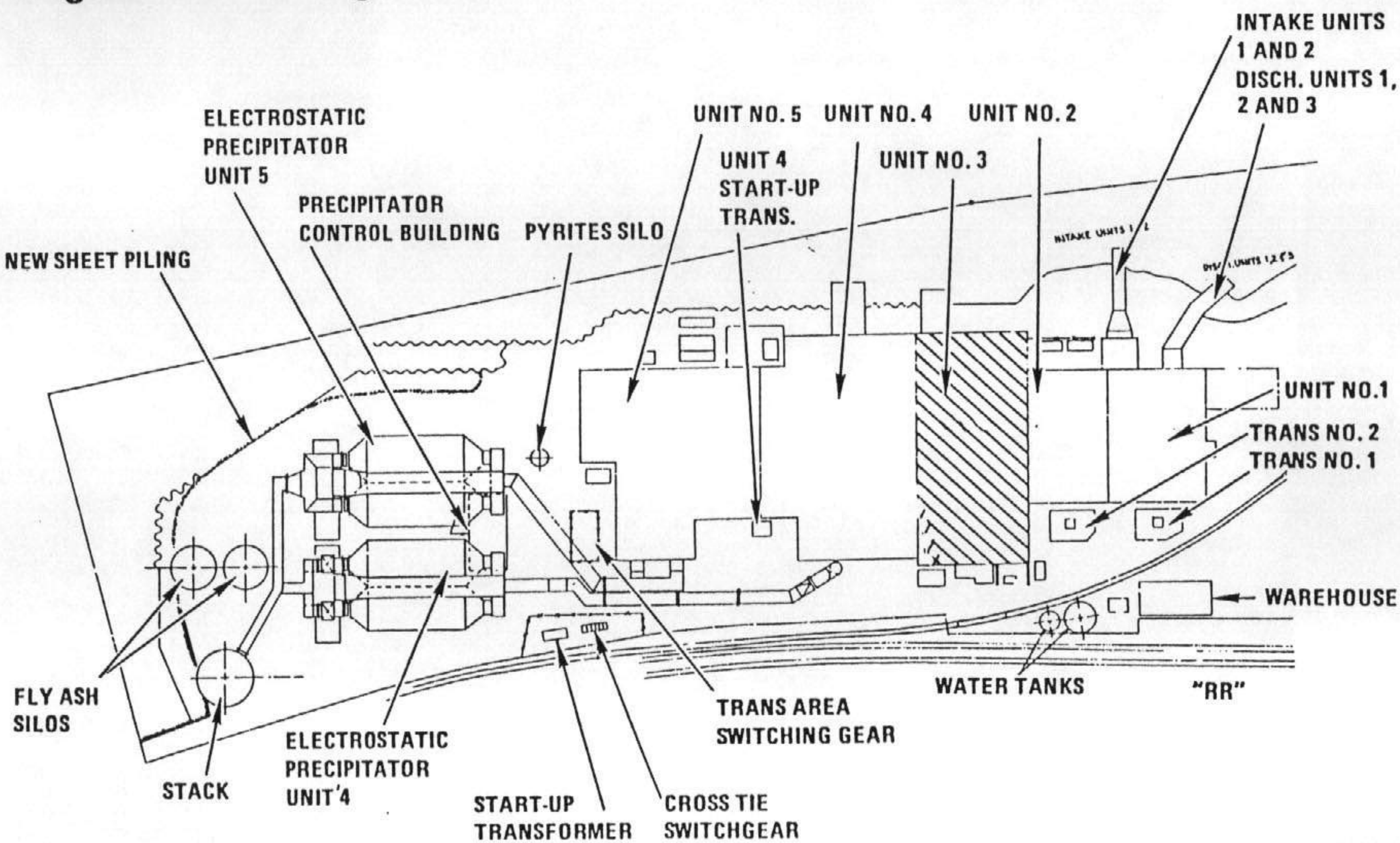
- OIL & GAS FIRED BOILERS CAN BE CONVERTED TO SCS TECHNOLOGY

- SCS TECHNOLOGY CAN MEET APPLICABLE AIR QUALITY STANDARDS

  NEW YORK STATE IMPLEMENTATION PLAN (NYSIP)

  NEW SOURCE PERFORMANCE STANDARDS (NYSPS)

Utility Demonstration Plan
Original Site Arrangement



Orange & Rockland Utilities - Lovett Unit No. 3
Operating Conditions

Power generation	—	69 MW
Steam flow	—	420,000 lb/hr
Superheater		
• Temperature	—	1050°F
• Pressure	—	1850 psig
Reheater		
• Temperature	—	1000°F
• Pressure	—	430 psig
Feedwater temperature	—	552°F

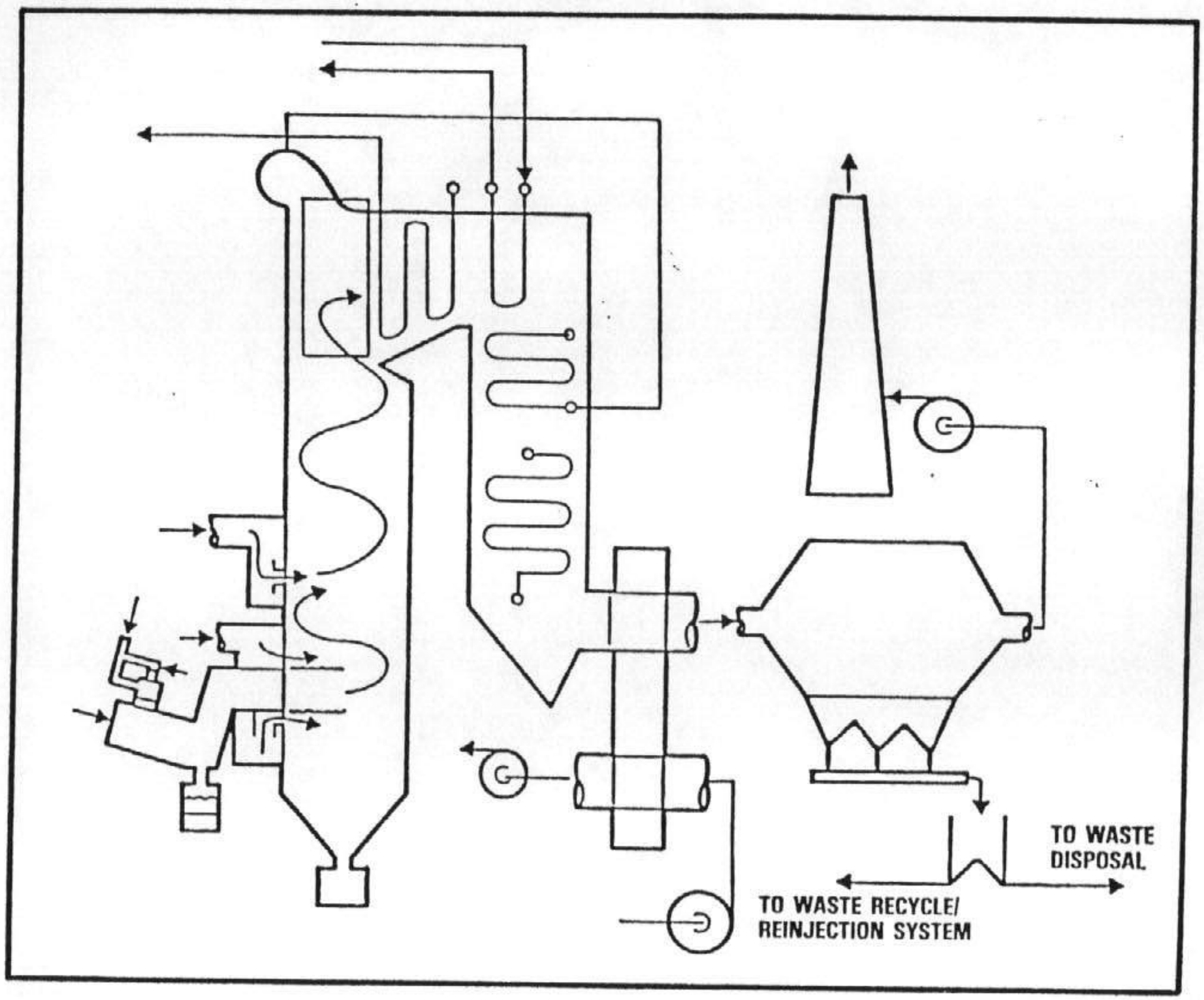
Characteristics of TRW Combustor

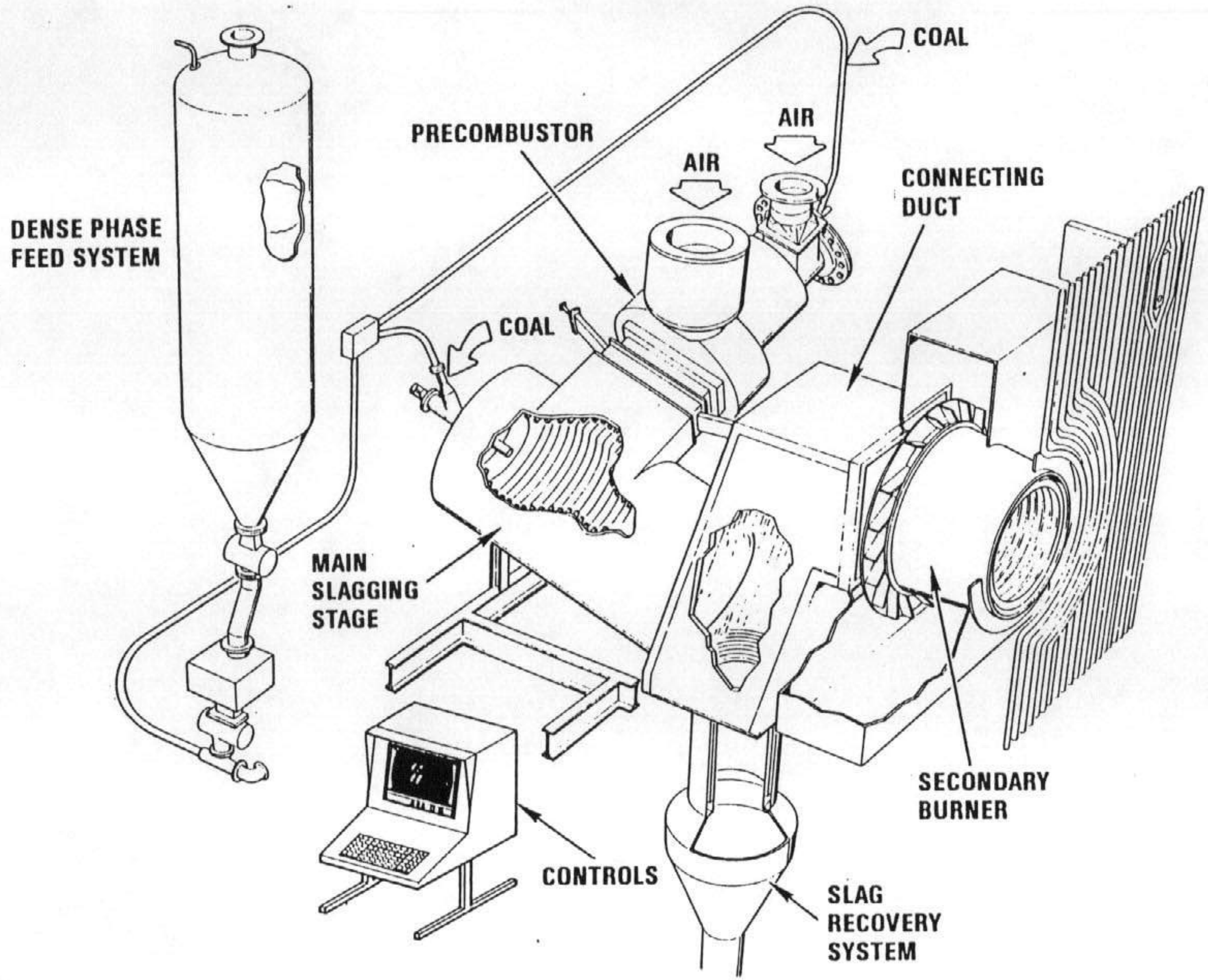
Small Size	3ftD x 5ftL - 6ftD x 9ftL (40 - 160 MMBtu/hr) 1MMBtu/hr-ft^3	Fits Available Space
Simple Configuration	Cylinder, Water Cooled	Low Maintenance
No Refractory Liner	~ 1/2 in. Slag on Wall	Avoids Failure, Downtime
High Slag Removal	80 - 94%	Minimizes Carryover
High Carbon Burnout	> 99.5%	Efficient Combustion
Low NO_x	230 - 450 ppm	Meets Pollution Standards
Reduced SO_x	50 - 90%*	Meets Pollution Standards
Flexible Device	Adjustable Air and Coal Feed	Accommodates Range of Coals and Turndown
Previous Tests	Short Duration	Many Cycles
State of Development	Ready for Field Demos	Industrial Boiler Demo in Progress, Utility Boiler Demo Planned

*Depends on sulfur content of the coal

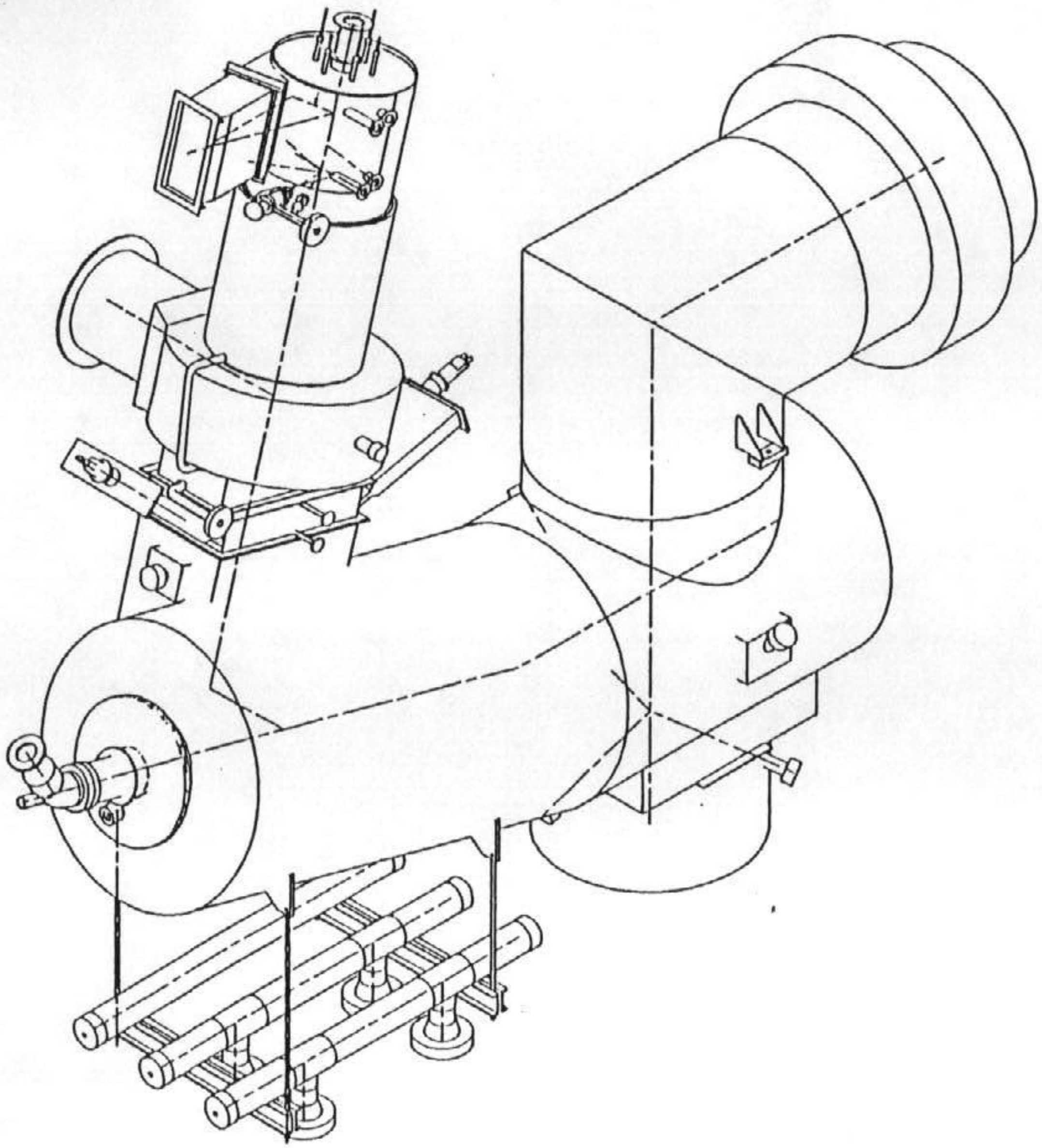
Boiler — Bag House Flow Diagram

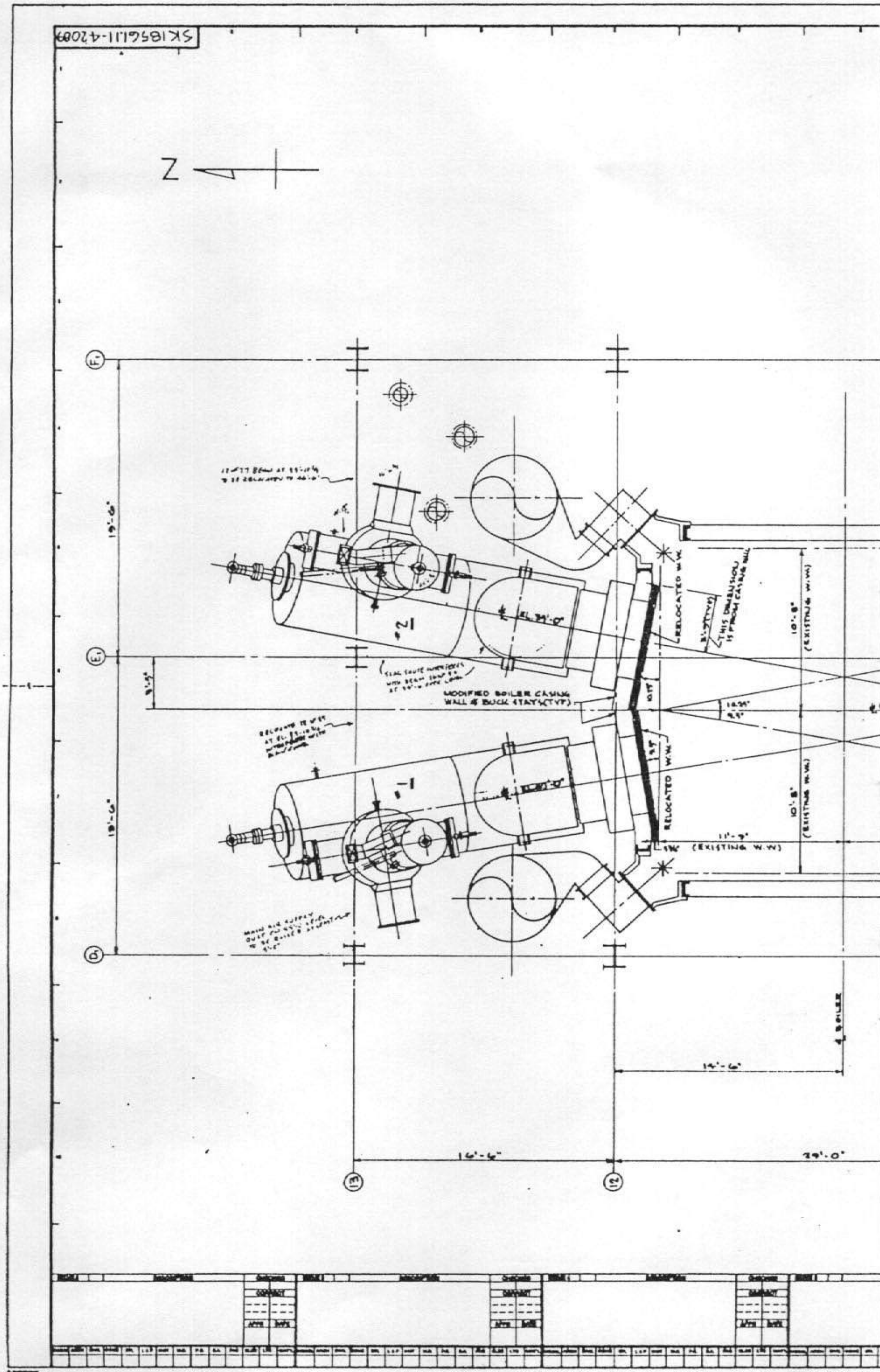
Low Sulfur Coal Conversion Lovett No. 3 Retrofit



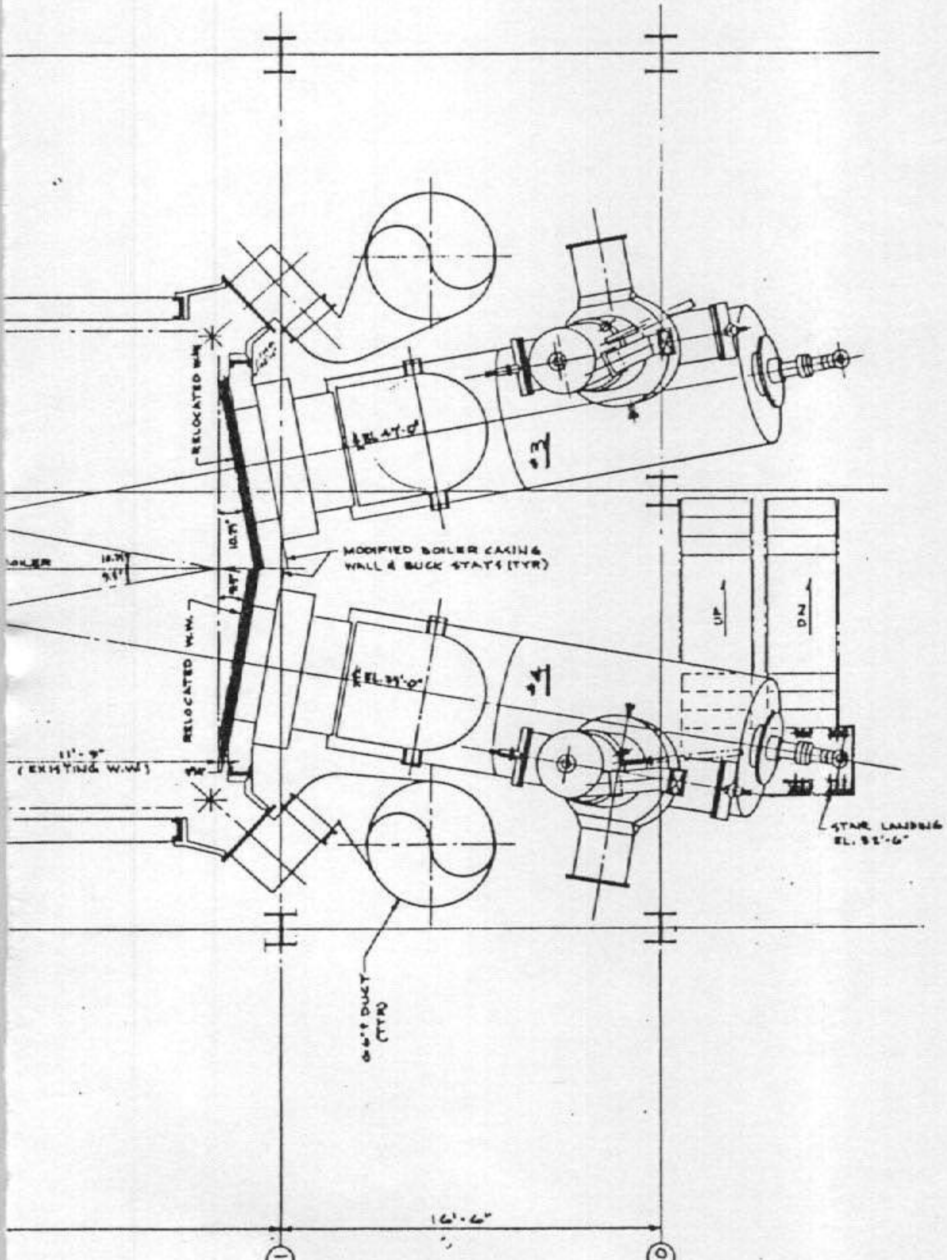

COAL
AIR
AIR
PRECOMBUSTOR
CONNECTING DUCT
DENSE PHASE FEED SYSTEM
COAL
MAIN SLAGGING STAGE
SECONDARY BURNER
CONTROLS
SLAG RECOVERY SYSTEM

M65 Combustor





SK185611-42089
N
MODIFIED BOILER CASING
WALL & BUCK STAYS(TYP)
RELOCATED W.W.
THIS DIMENSION IS FROM CASING WALL
(EXISTING W.W)
10'-8"
19'-6"
14'-6"
24'-0"
11'-9"
#2
#1
EL. 34'-0"



HOLDS

1. SLAG SHUTES
2. TWO LOWER COMBUSTOR ELEVATIONS AT ℄ EL. 55'-0".
3. CONFORMATION OF PRIMARY AIR INLET BARREL MODIFICATION BY TRW FOR COMBUSTORS #1 & #3.
4. LOCATION OF COMBUSTORS ARE PRELIMINARY, FINAL LOCATION WILL BE DETERMINED WHEN BOILER W.W. TUBE LAYOUT, CASING PICTURE WINDOW DETAIL & MAIN COMBUSTOR WINDBOX DETAILS ARE AVAILABLE.
5. FINAL ORIENTATION OF PRIMARY & SECONDARY AIR INLET CONNECTIONS TO BE DETERMINED BY BOOSTER FAN DUCT ARRANGEMENT.

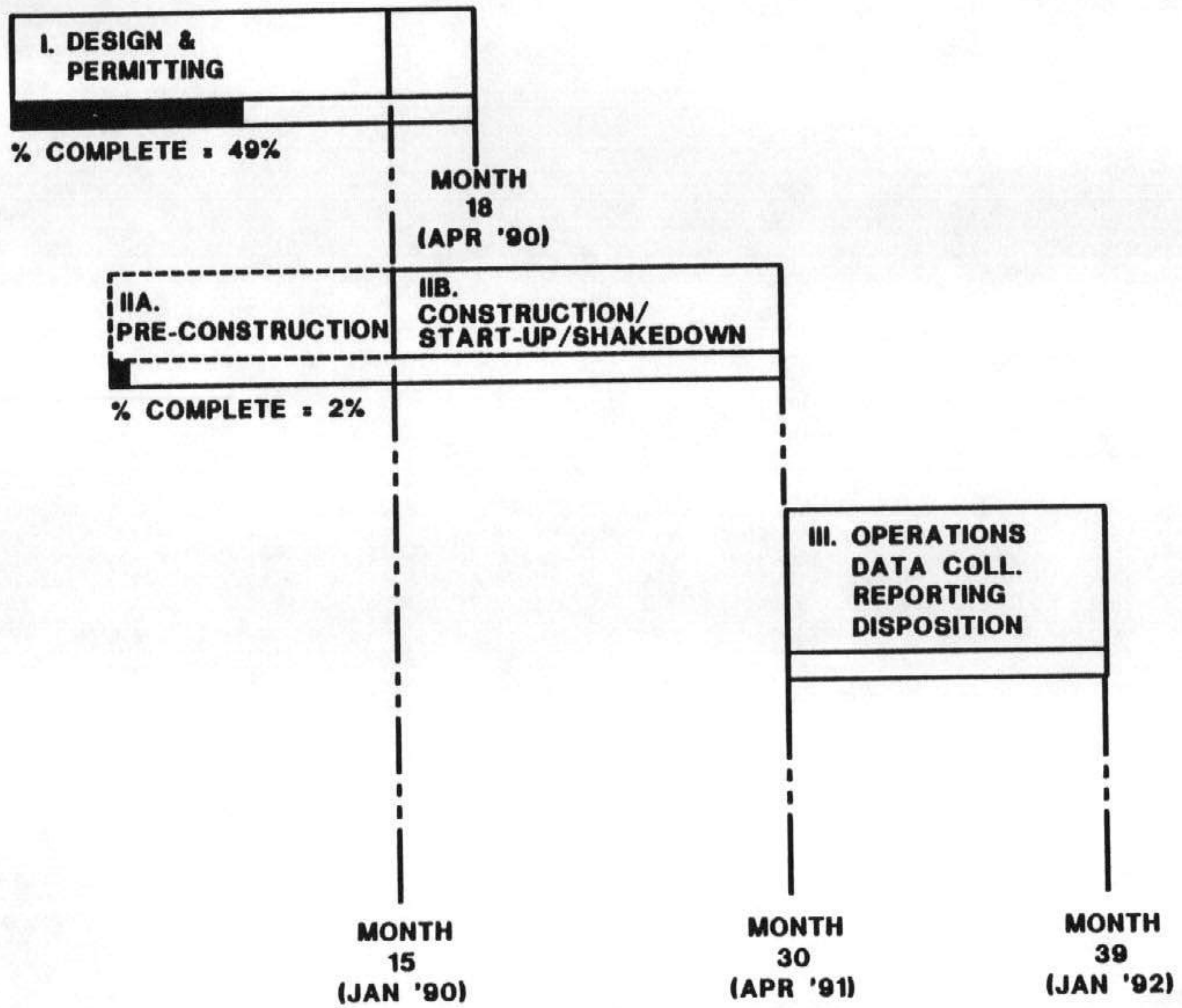
4/20/83
4/24/84
4/26/84

COMBUSTOR LOCATIONS
PLAN - BETWEEN EL. 24'-6" & 55'-0"
TRW COAL COMBUSTOR
UTILITY DEMONSTRATION PROJECT
LOVETT STATION NO. 3
ORANGE & ROCKLAND UTILITIES INC.
STONE & WEBSTER ENGINEERING CORPORATION
NEW YORK, NEW YORK

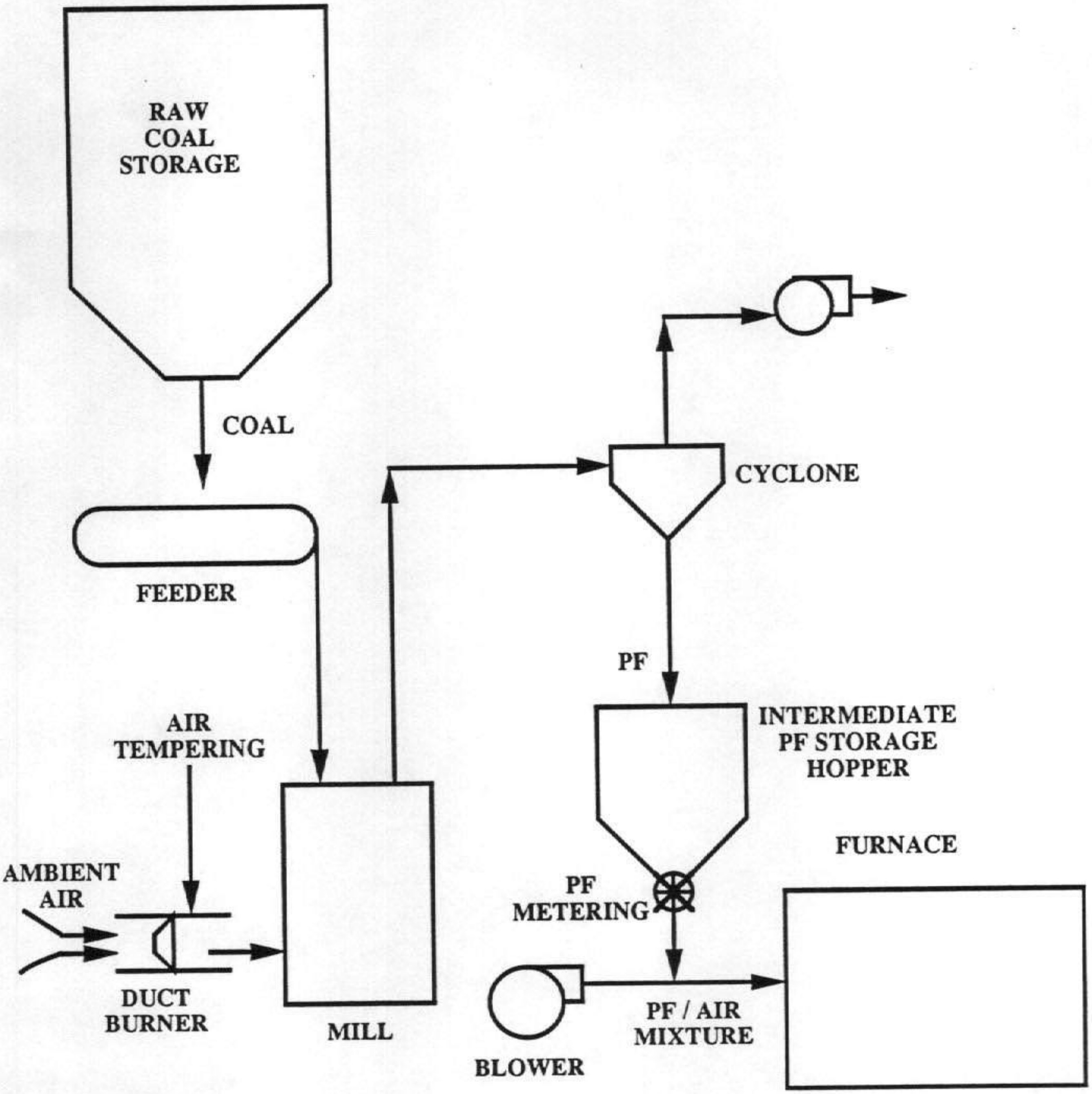
SK-18561.11-42089

ADVANCED SLAGGING COAL COMBUSTOR UTILITY DEMONSTRATION

SCHEDULE OVERVIEW/STATUS
AS OF 6/30/89

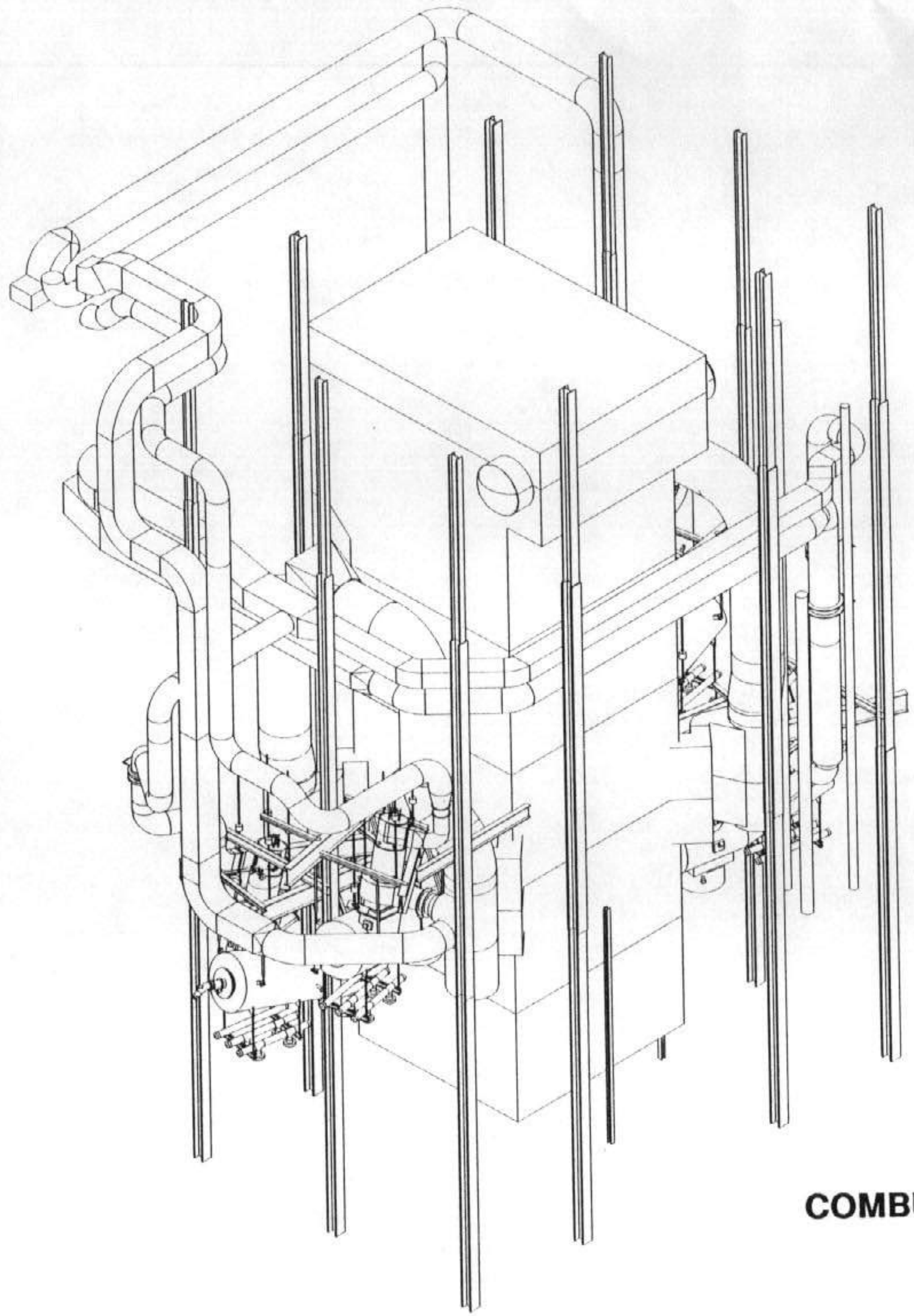


TRWSOS (GB 8/2/89)

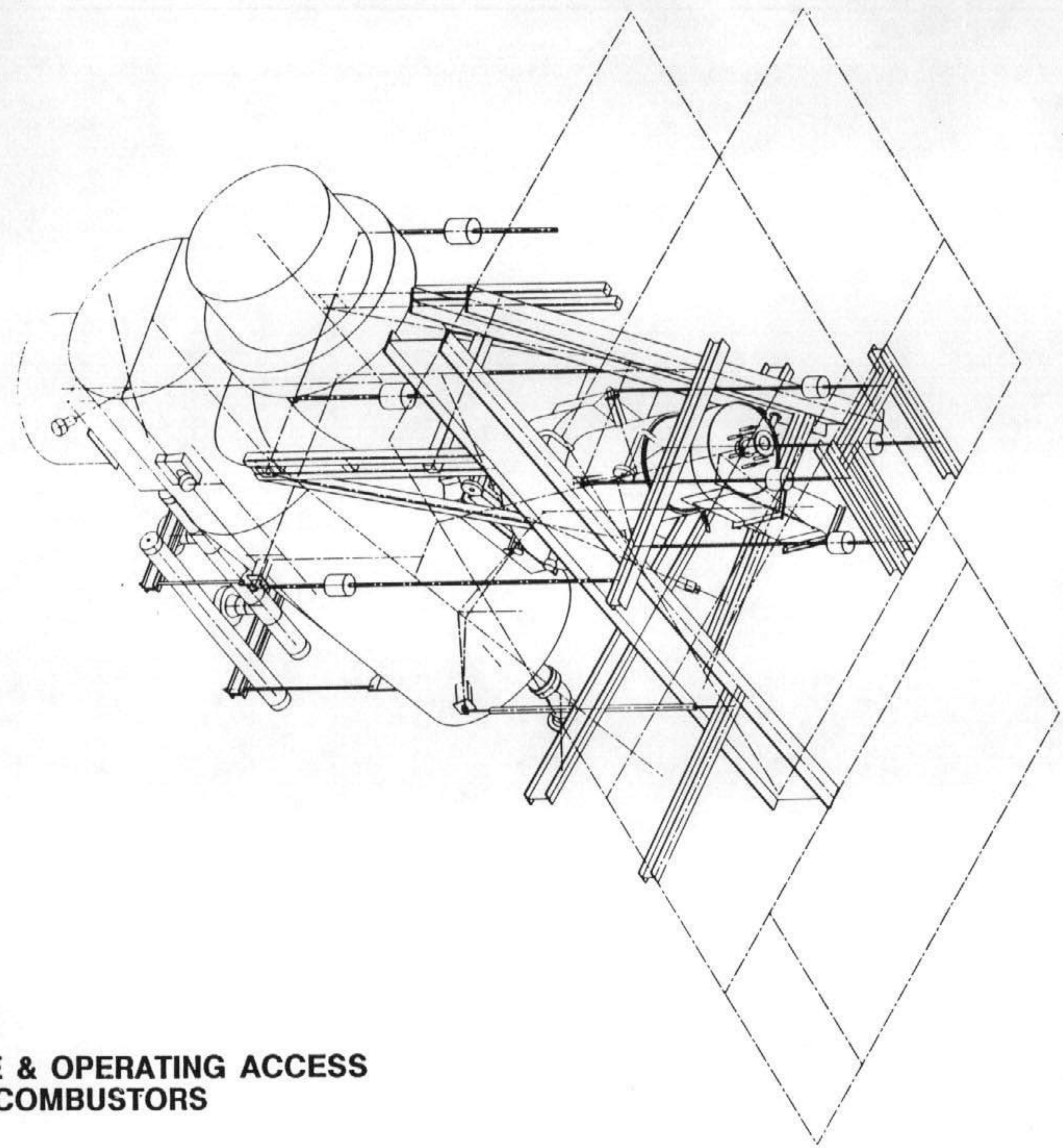


FLOW DIAGRAM OF SEMI-DIRECT-FIRED PF SYSTEM

				SEMI-DIRECT-FIRED PF SYSTEM
ISSUE	DESCRIPTION	PE	DATE	TRW COMBUSTOR DEMONSTRATION LOVETT STATION UNIT 3
STONE & WEBSTER ENGINEERING CORP NEW YORK, NY				DWG NO: 18561 - FSK - 4

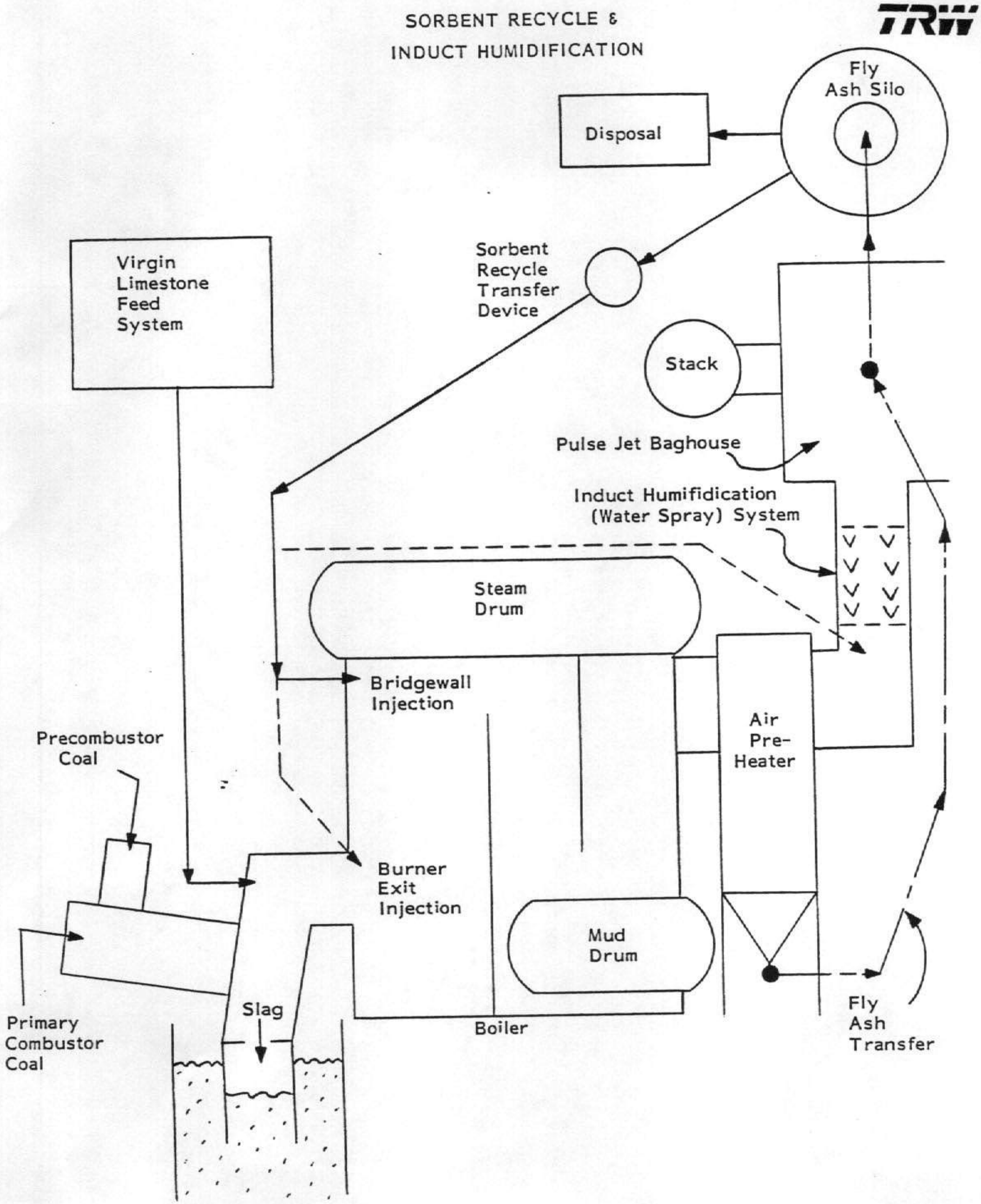


COMBUSTION AIR DUCTS



MAINTENANCE & OPERATING ACCESS
TO COMBUSTORS

SORBENT RECYCLE &
INDUCT HUMIDIFICATION



CYCLE FEATURES

- CASE 1 - INDIRECT

  COMBUSTOR COOLING INDEPENDENT OF FW FLOW
  HP HEATERS BYPASSED

- CASE 2 - DIRECT

  COMBUSTOR DESIGN PRESSURE LIMIT
  COMBUSTOR COOLING DEPENDENT ON FW FLOW
  HP HEATERS BYPASSED

- CASE 3 - FLASH TANK FW HEATING

  INCREASE FW HEATER OPERATING PRESSURE
  OPERATING > DESIGN PRESSURE

- CASE 4 - FLASH TANK MAIN STEAM

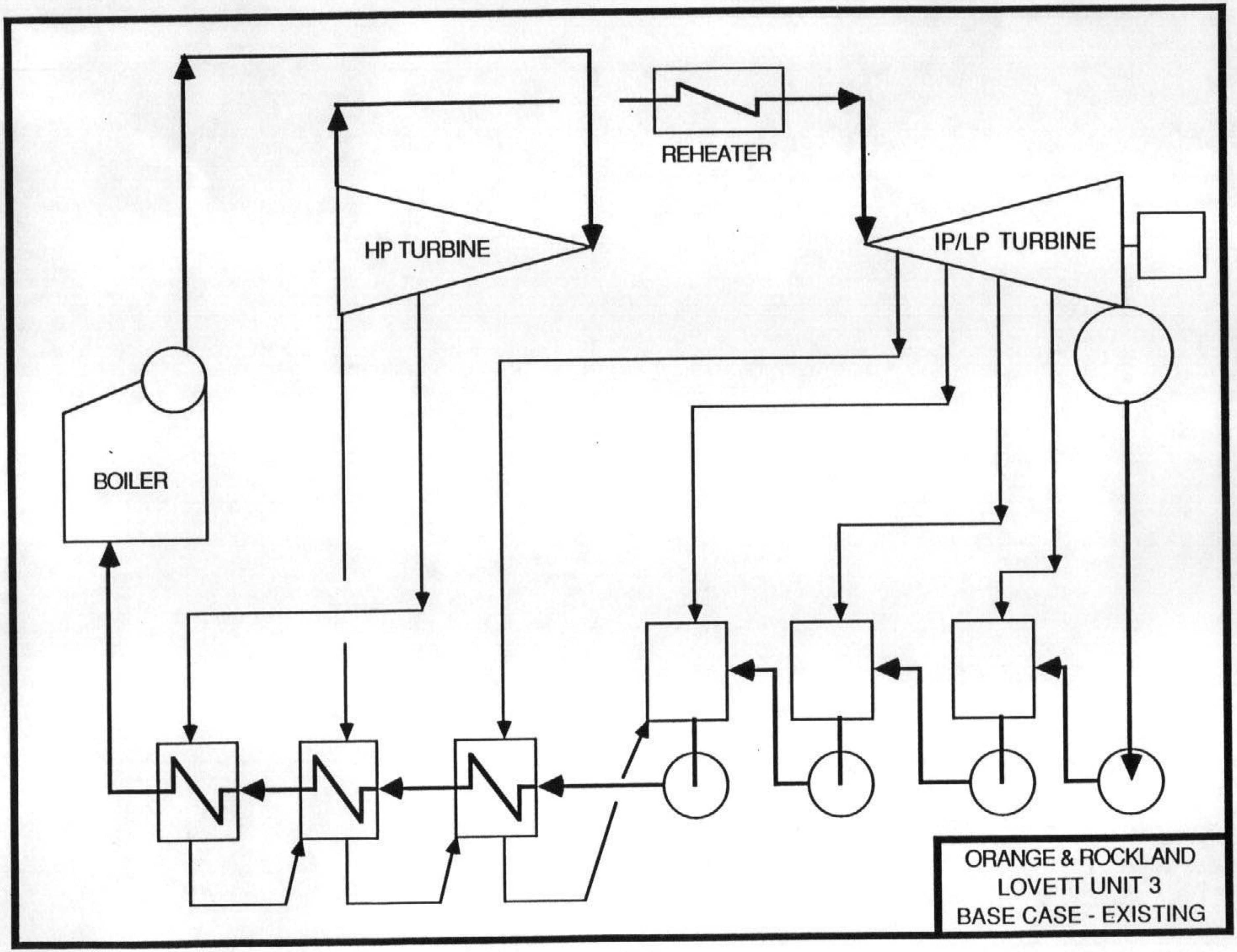
  BOILER MODIFICATIONS
  COMBUSTOR CIRCULATING PUMP PRESSURE > COMBUSTOR DESIGN PRESSURE

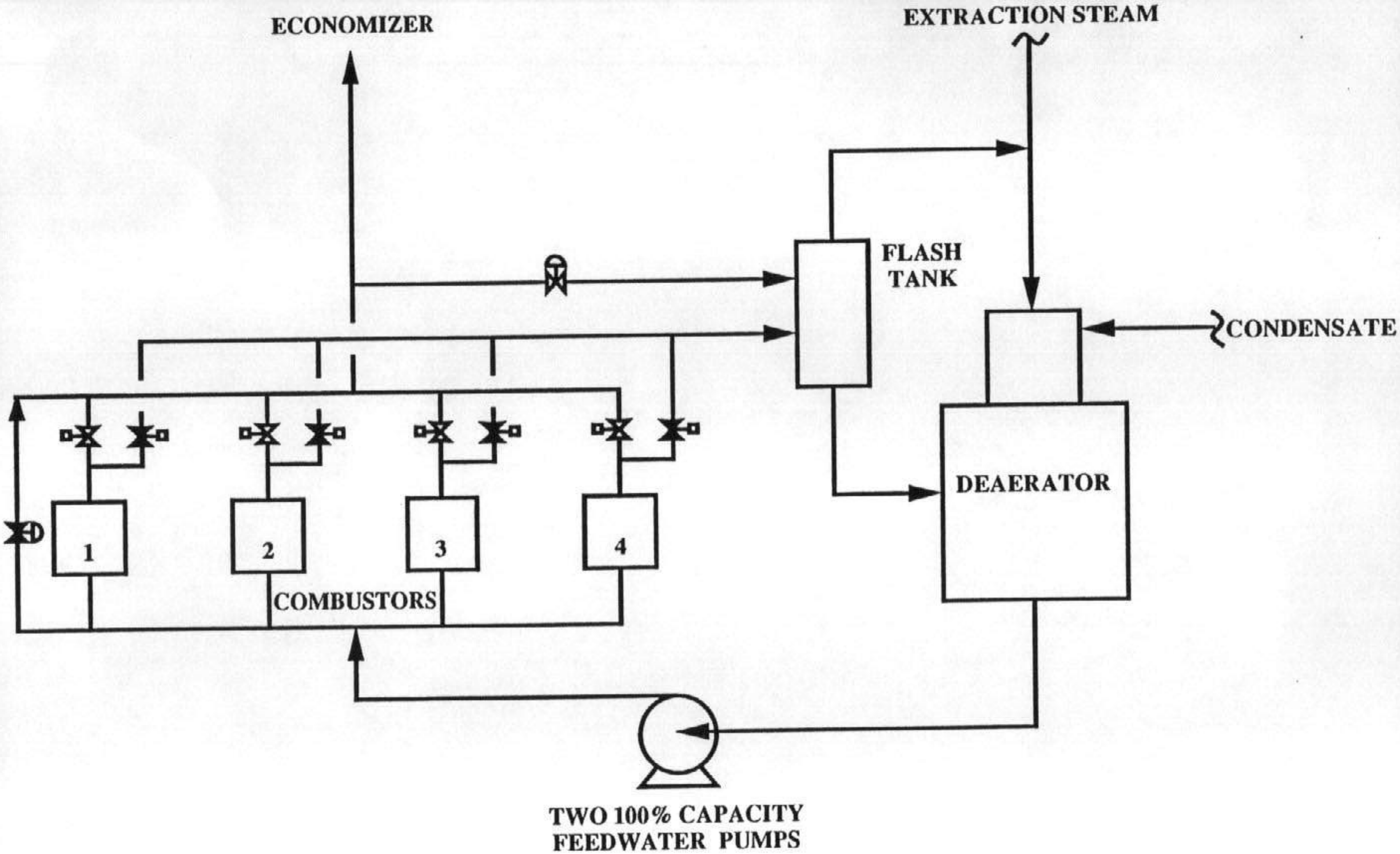
- CASE 5 - FLASK TANK REHEAT STEAM

  COMBUSTOR CIRCULATING PUMP PRESSURE < COMBUSTOR DESIGN PRESSURE
  REHEATER MODIFICATIONS

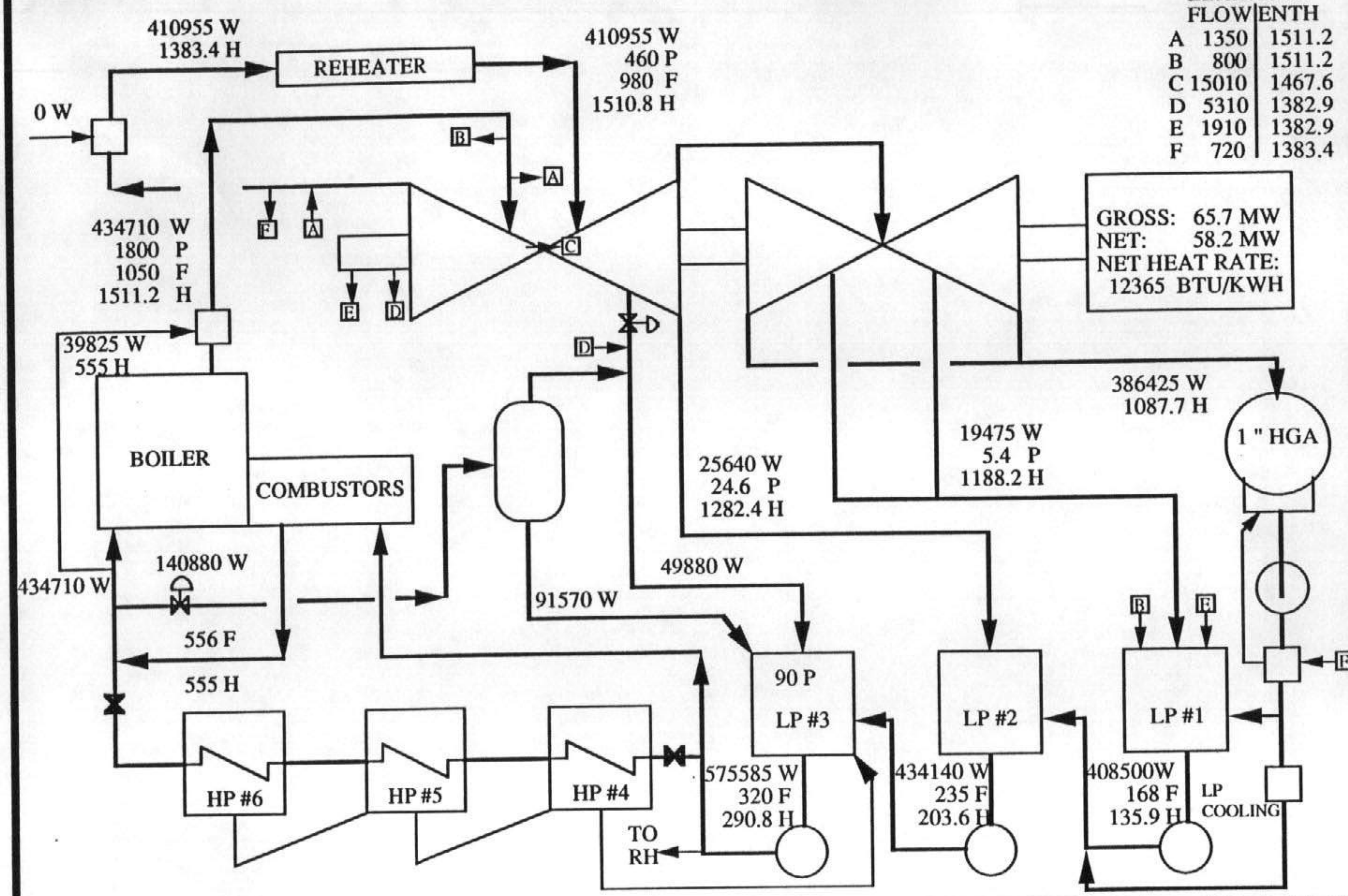
- CASE 6 - FLASK TANK IP/LP CROSSOVER STEAM

  HIGHEST LP STEAM FLOW
  HIGHEST THERMAL DISCHARGE


REHEATER
HP TURBINE
IP/LP TURBINE
BOILER
ORANGE & ROCKLAND
LOVETT UNIT 3
BASE CASE - EXISTING



1	CONCEPTUAL		07-31-89	DIRECT INTEGRATION VARYING FLOW
ISSUE	DESCRIPTION	PE	DATE	TRW COMBUSTOR DEMONSTRATION LOVETT STATION UNIT 3
STONE & WEBSTER ENGINEERING CORP NEW YORK, NY				DWG NO: 18561 - SK - 1



LEAKAGES

	FLOW	ENTH
A	1350	1511.2
B	800	1511.2
C	15010	1467.6
D	5310	1382.9
E	1910	1382.9
F	720	1383.4

ISSUE	DESCRIPTION	PE	DATE
2	CONCEPTUAL		07-25-89
1	CONCEPTUAL		06-21-89

STONE & WEBSTER ENGINEERING CORP
NEW YORK, NY

OHIO COAL - @ 180MMBTU - DIRECT
28% ECON SURFACE REMOVAL
TRW COMBUSTOR DEMONSTRATION
LOVETT STATION UNIT 3

DWG NO: 18561 - 2 - HB - 6

TRW SLAGGING COMBUSTOR CYCLE INTEGRATION COMPARISON
PERFORMANCE BEFORE AND AFTER RETROFIT
ORANGE & ROCKLAND LOVETT STATION UNIT 3
DESIGN DATA BASIS

PARAMETERS	BEFORE RETROFIT		AFTER RETROFIT
FUEL	Coal Design	Gas Existing	Predicted Performance Coal
COMBUSTOR			
No. Combustors Operating	---	---	4
Fuel per Combustor MMBTU/H	---	---	180
CYCLE			
Main Steam Pressure PSIA	1815	1815	1815
Main Steam Temperature F	1050	1050	1050
Throttle Steam LB/H	500,000	543,000	434,710
Feedwater Temp to Econ F	544	543	555
CYCLE EFFICIENCY			
Gross Generation KW	68,700	69,800	65,700
Auxiliary Power KW	3,900	3,600	7,500
Net Generation KW	64,800	66,200	58,200
Fuel Input Total MMBTU/H	610	765	720
Net Heat Rate BTU/KWH	9,355	11,580	12,365

Lovett Unit 3 Emission

(#/MMBTU)

Pollutant	Existing Oil-fired	Proposed Coal-fired	New York State Standard for Coal-fired Plant
TSP	.10	.03	.03
SO_2	.4	.4	.4
NO_x	.30	.27	.60

Program Demonstration Coals*

	Low Sulfur	High Sulfur**	
Origin Supplier	W. VA Rawls Mine	Ohio Industrial Mining	
		1	2
Ash (%)	6.6–7.7	6.0–10.5	7.6–8.4
Sulfur (%) Minemouth		6.0	3.5
As Received	0.5–0.6	2.4–2.6	1.7–1.9
HHV (Btu/lb)	13,000–13,250	12,600	13,100
Ash Fusion Temp (°F) (Reducing; Fluid)	2700+–2800+	2300	2280
T_{250} (°F) (Reducing)	2800–2900	2400–2600	

* All Properties as Received

** A Third Ohio Coal With 0.9% Sulfur Tested at Cleveland

Utility Boiler Demonstration Plan

Design and fabricate four 160 MMBtu/hr commercial combustors

Integrate with 69 MW oil-fired utility boiler

Run long duration tests

- Integrated system performance
- Life, reliability and maintenance data on system
- Load following characteristics
- Emissions compliance

Evaluate alternate coals/further NO_x and SO_x reduction