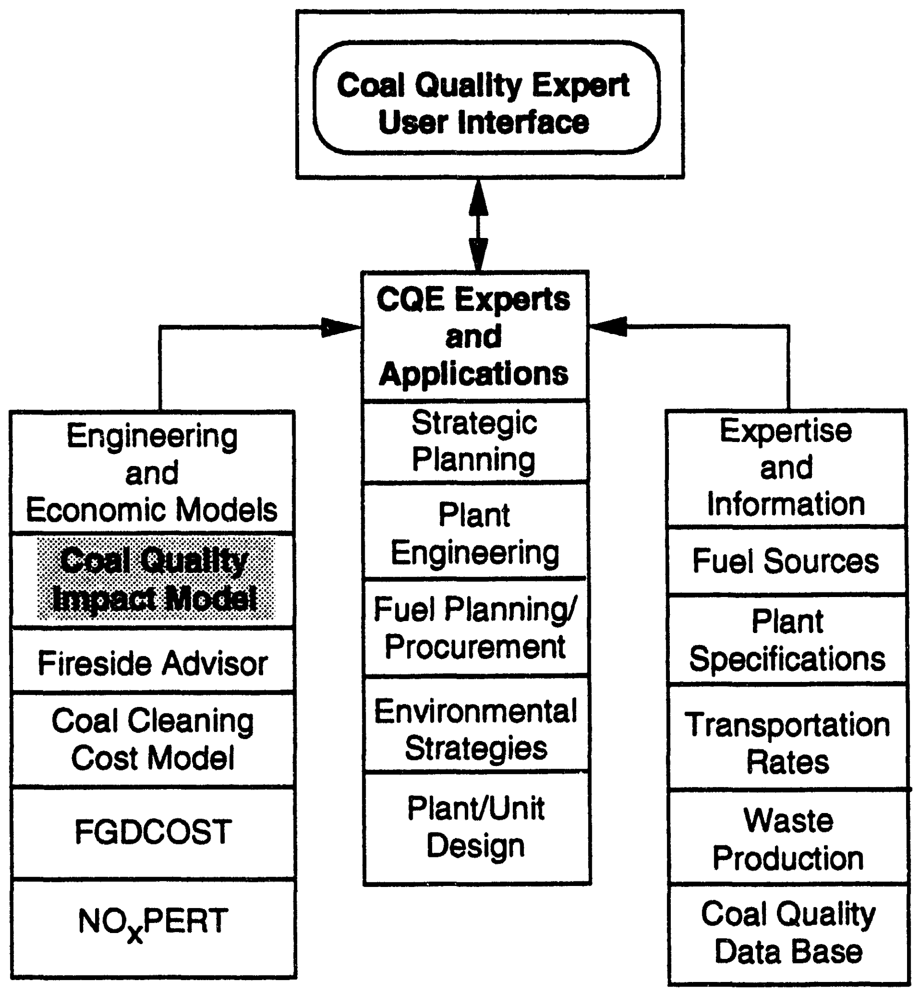


Figure 1 Coal Quality Expert Program

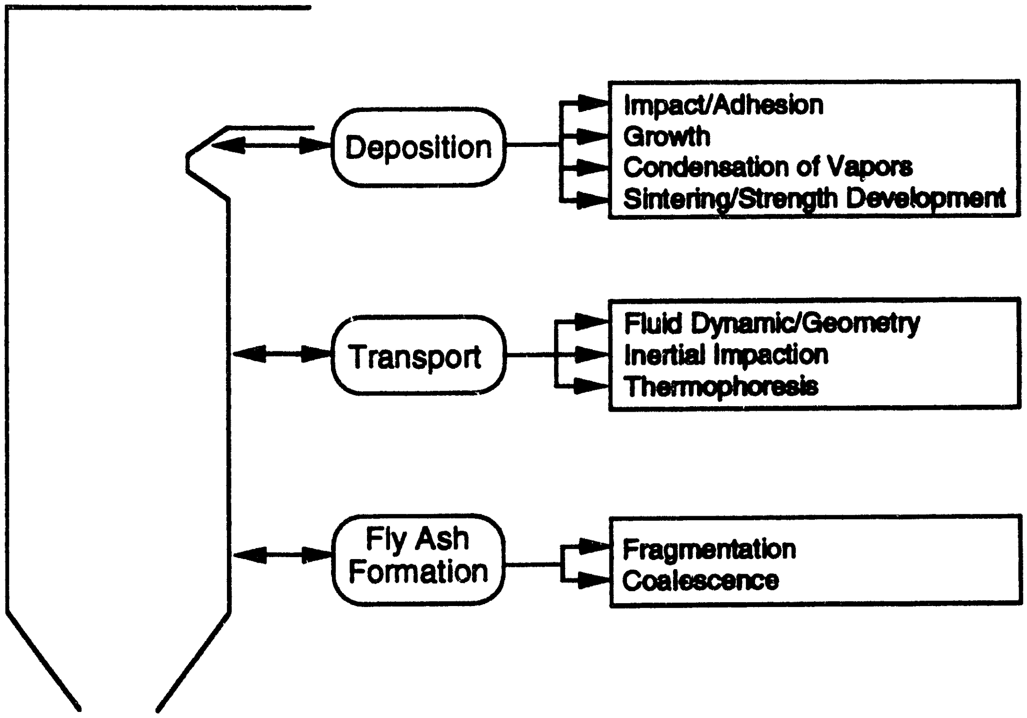
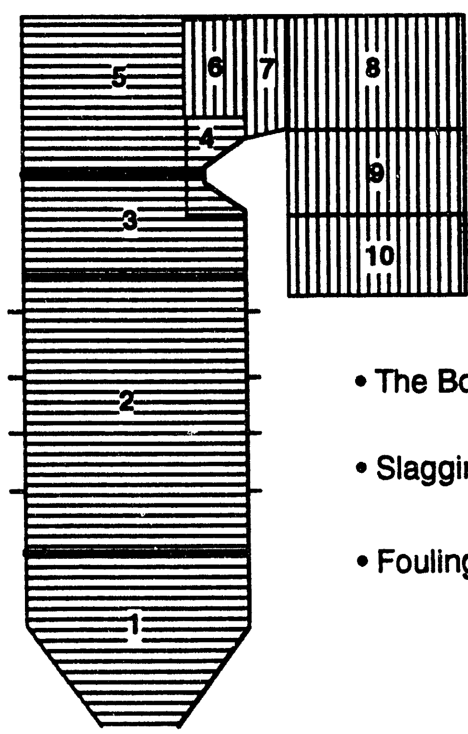


Figure 2 Key Processes Leading to Ash Deposition



- The Boiler is Divided Into Ten Regions
- Slagging Defined as Deposition in Regions 1-5;
- Fouling Defined as Deposition in Regions 6-10;

Figure 3 CQE Defined Boiler Regions for Slagging/Fouling

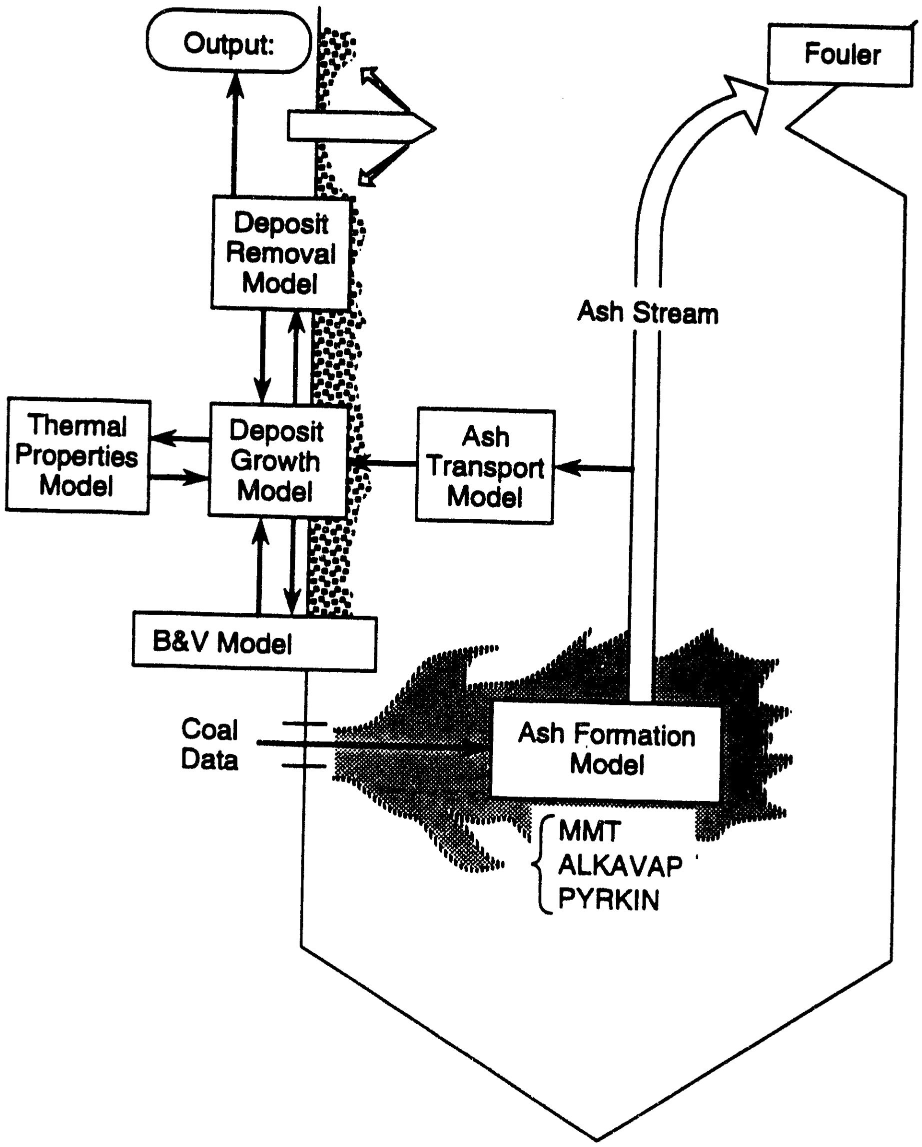


Figure 4 Various Components of SLAGGO

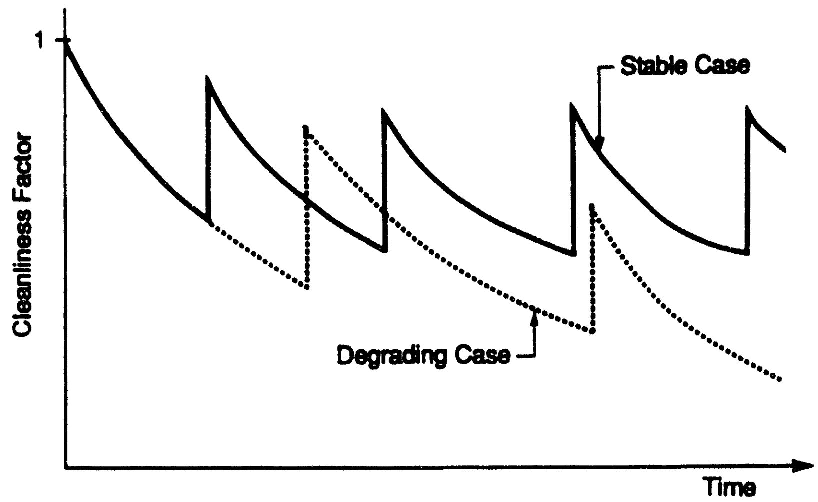


Figure 5 Cleanliness Factor Versus Time Behavior

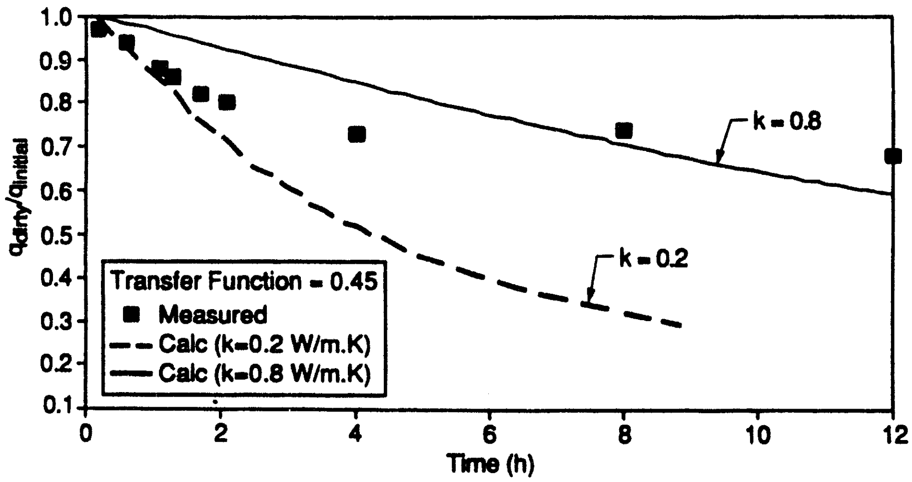


Figure 6 Comparision of Heat Flux Ratios for a hvA bituminous Coal

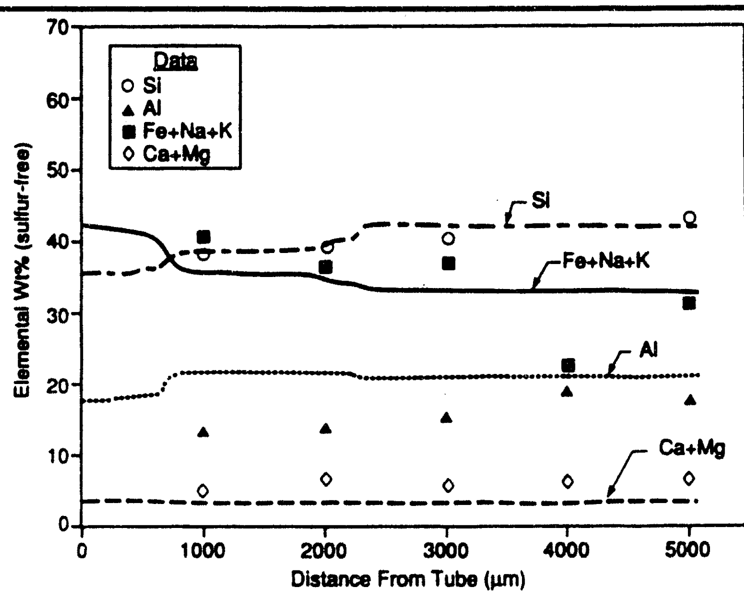
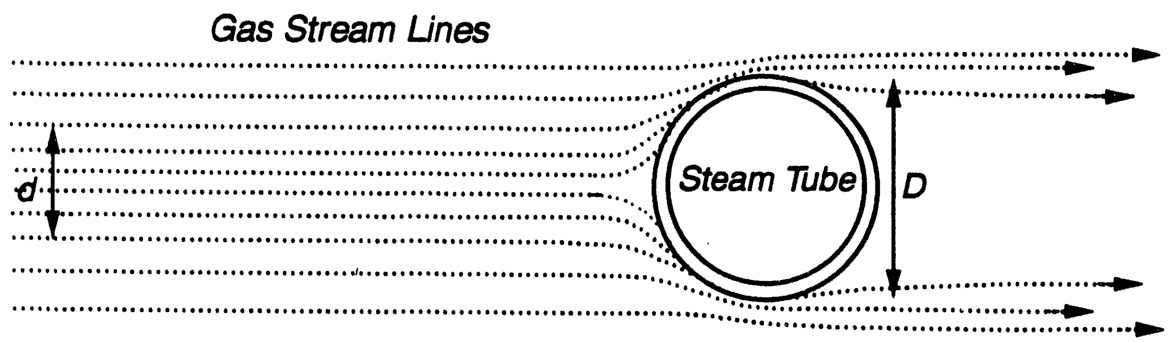


Figure 7 Deposit Composition Profiles for a hvA bituminous Coal



d/D = Impaction efficiency of system = $f(AD_p, V)$
sticking = $f(KE_p, \mu_p, \mu_s)$

Figure 8 The Inertial Impaction Process for Upstream Deposit Formation

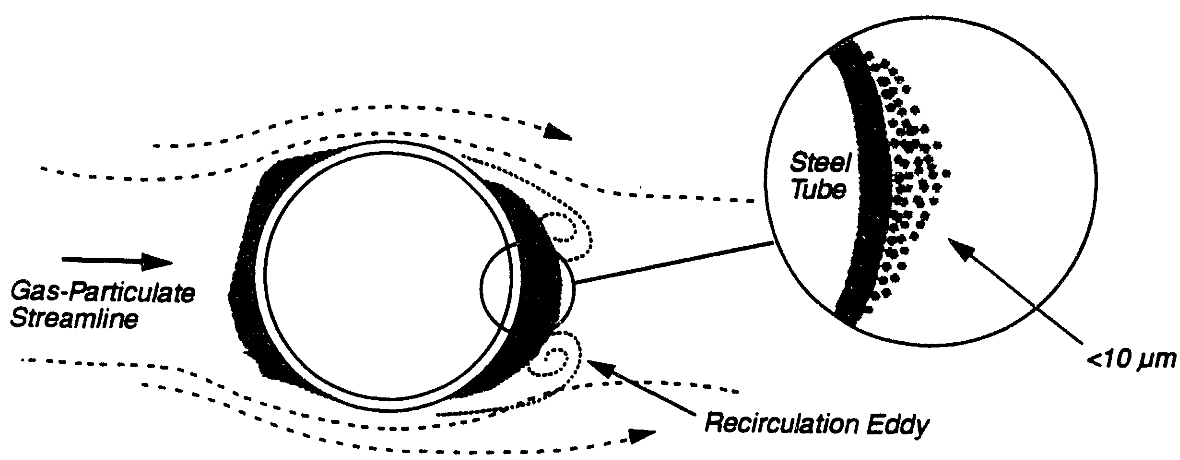


Figure 9 The Eddy Impaction Process for Downstream Deposit Formation

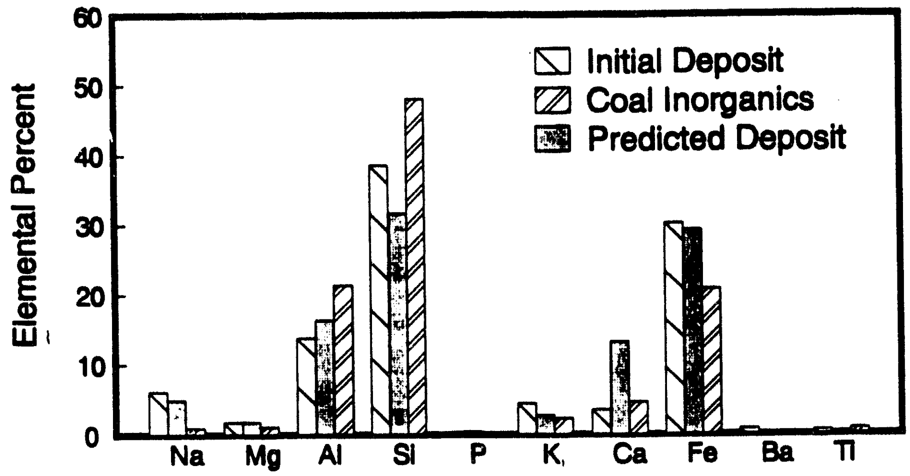


Figure 10 Comparision of Upstream Deposit Components Collected at 2320 °F in ABB-CE's FPTF

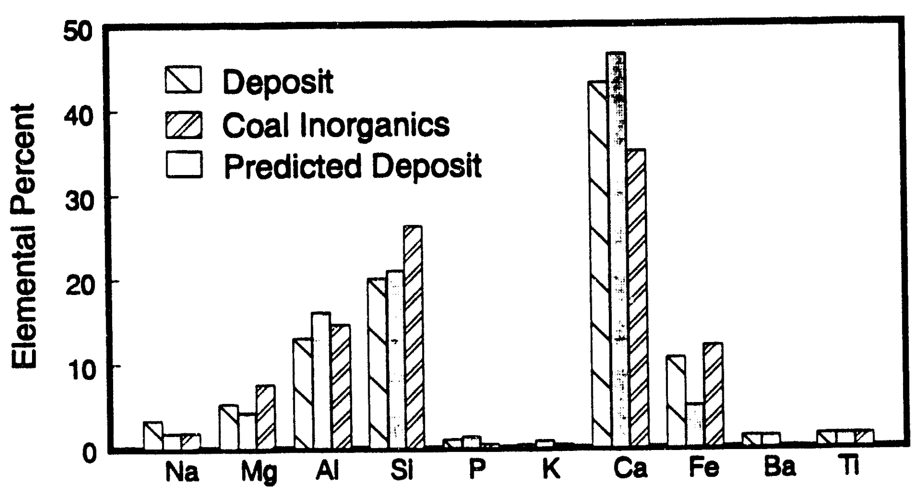


Figure 11 Comparision of Doenstream Deposit Component Collected at 1800 °F in Sherco Unit #1

SELF-SCRUBBING COAL: AN INTEGRATED APPROACH TO CLEAN AIR

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ABSTRACT

The Custom Coals advanced coal cleaning plant will be designed with a unique blending of existing and new processes to produce two types of compliance coals: Carefree Coal and Self-Scrubbing Coal. Carefree Coal will be produced by cleaning the coal in a proprietary dense media cyclone circuit utilizing fine magnetite to remove up to 90% of the pyritic sulfur and correspondingly greatly reduce the ash.

While many utilities can achieve full SO_2 reduction compliance with Carefree Coal, others face higher sufur reduction requirements due to the higher sulfur content of their existing fuel supplies. For these circumstances, a patented Self-Scrubbing Coal will be produced by taking Carefree Coal and pelletizing limestone-based additives with the finest fraction of the clean coal. These technologies will enable over 150 billion tons of non-compliance U.S. coal reserves to meet compliance requirements.

INTRODUCTION

Approximately 65% of all coal shipped to utilities in 1990 was above 1.2 lbs SO_2/MMBtu. Even though most of that coal has been cleaned in conventional coal preparation plants, it still does not meet the SO_2 emission limitation the Clean Air Act Amendments mandate for the year 2000. Most utilities have announced compliance plans involving either switching to lower sulfur coals from Central Appalachia or the Power River Basin or the installation of scrubbers. Fortunately, for those of us attempting to commercialize clean coal technologies, relatively few long-term decisions have been made in Phase I - i.e. fewer scrubbers are scheduled than initially expected and new coal contracts rarely extend beyond the year 2000.

Through new coal preparation technologies, two compliance coal products can be produced by Custom Coals International (CCI) from most of the non-compliance coals east of the Mississippi River. They are termed Carefree Coal™ and Self-Scrubbing Coal™.

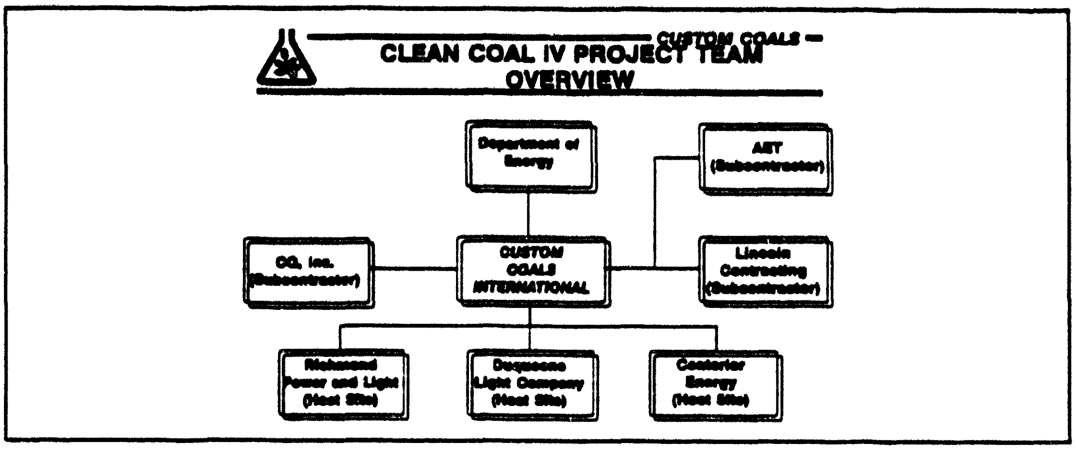
- Carefree Coal is produced solely through aggressive removal of ash and pyritic sulfur from non-compliance bituminous coal feedstocks. Carefree Coal is composed of coarse coal, fine coal and ultra fine coal. Some of the ultra fines may be briquetted.

- Self-Scrubbing Coal contains aggressively beneficiated coal with a limestone based additive. It is comprised of coarse coal, fine coal and briquettes. The additives are briquetted with the ultra-fine clean coal for convenience in handling.

  For Self-Scrubbing Coal, the reduction of sulfur to compliance levels occurs in two stages. Pyrite, an iron-sulfur compound, is first removed by aggressive coal beneficiation. Sulfur dioxide, generated in the boiler from the coal's organic sulfur and residual pyritic sulfur, is then captured by the additives.

Carefree Coal and Self-Scrubbing Coal meet the year 2000 sulfur dioxide limitations. They are derived from local coals and, therefore, are compatible with the boiler; they are priced competitively with compliance coals imported into the local region; and no capital investment is required by the utility. The net effect of CCI's technologies is that they revalue many noncompliance reserves to compliance reserves.

The objective of our Clean Coal Technology program is to design and construct a 500 ton per hour coal cleaning plant equipped with our unique and innovative coal cleaning technology which will produce competitively priced compliance coals. These coals will then be test burned at three commercial utility power plants to demonstrate that these coals can meet the Clean Air Act Amendment sulfur reduction requirements.



Custom Coals, which has overall project management responsibility, has assembled an exceptional team for this project. Associated Engineering Technologies (AET), will design and Lincoln Contracting will construct the demonstration plant. CQ, Inc., which will test and operate the demonstration plant and manage the power plant field tests, is a recognized authority in coal cleaning plant design, testing and operation. A project management committee of senior executives from the participating companies will oversee project progress and performance.

The project costs and timetable are shown below. The preparation plant will be located in Somerset County, Pennsylvania. The host sites for the test burns are located in Richmond, Indiana, Cleveland, Ohio and Pittsburgh, Pennsylvania.

	Dates	Proposed Costs
Pre-award	October 1991 - October 1992	$736,969
Project Definition	November 1992 - May 1993	2,000,000
Engineering & Construction	June 1993 - April 1995	49,200,000
Operation	May 1995 - March 1996	37,248,062
	TOTAL	$89,185,031

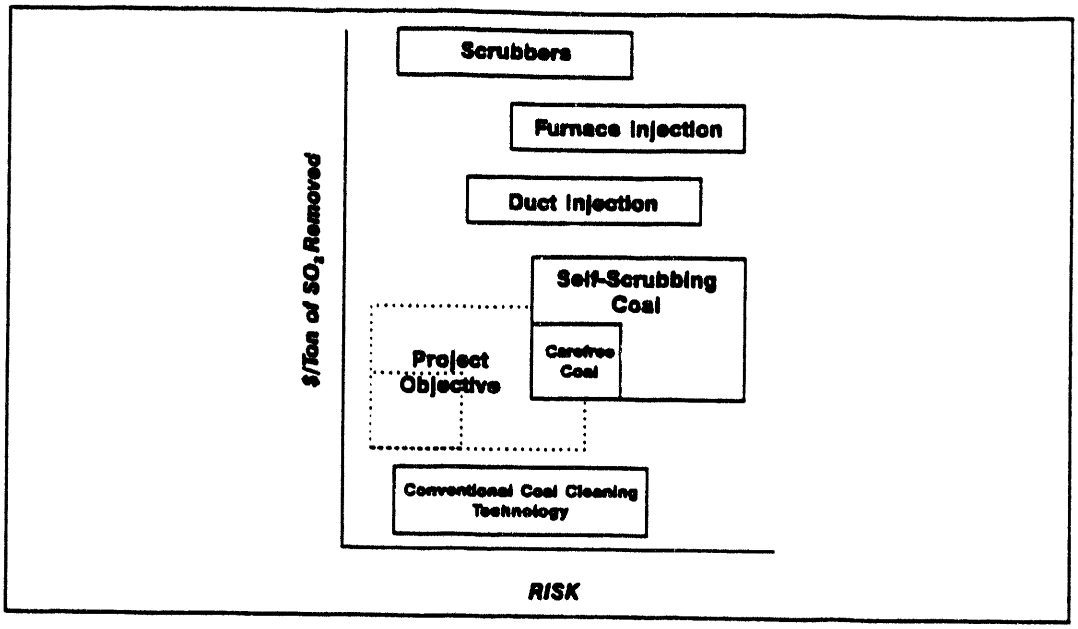
HISTORY OF TECHNOLOGY DEVELOPMENT

The Carefree Coal and Self-Scrubbing Coal technologies were developed through the proof-of-concept stage by Genesis Research Corporation, a small research and development company headquartered in Arizona. Dr. James Kelly Kindig, the inventor of the technology, had begun work on the technology in the late 1970's. A concerted effort to develop the products for commercial use began in the early 1980's. Funding during this stage of development was provided by equity raised from individual investors.

In 1988 Duquesne Light Company agreed to fund pilot scale testing of the technology. Cleaning tests in 2-inch cyclones were performed at CQ, Inc. and small-scale combustion testing occurred at Energy and Environmental Resources. The pilot scale test results supported Genesis Research claims of being able to reduce sulfur levels by up to 80%.

Given the encouraging pilot scale test results, in 1990 Duquesne agreed to fund commercial scale tests. Throughout 1990 and early 1991, a $2 million test program was conducted and documented. All unique aspects of the coal cleaning technology were tested at commercial scale equipment sizes at CQ, Inc. Fine magnetite was prepared by Hazen Research, the cyclones were manufactured by Krebs Engineers and the magnetite recovery scheme was tested by Eriez Magnetics. The coal cleaning results in 10-inch cyclones substantially duplicated the performance achieved in the earlier 2-inch cyclone work. Combustion testing in 600,000 Btu/hour boilers at Energy and Environmental Resources also confirmed the earlier smaller scale results on sulfur capture in the boiler.

The full-scale demonstration provided by the Clean Coal Technology Program will provide the opportunity to blend all of the innovative aspects of the technology and prove the effectiveness of Self-Scrubbing Coal in reducing emissions. The demonstration will also prove the cost-effectiveness of the technology, paving the way to full commercialization of Self-Scrubbing Coal.



TECHNOLOGY DESCRIPTION

Raw coal may be viewed as an aggregation of three basic types of components. They are organic material, pyrite and rock. Each of these three materials is found free in raw coal. A large portion of raw coal, however, is comprised of two or all of these components locked together. It is this locking that creates the spectrum of specific gravities characteristic of coal.

Most conventional coal cleaning partitions raw coal into components: one less-than and the other greater-than some pre-selected specific gravity. Clean coal, the former, contains both free and locked particles. The locked particles, unfortunately, carry sulfur (from pyrite) and ash (from rock) into the marketable clean coal product. The refuse also contains both free and locked particles. Locked refuse particles contain organic material that constitutes a loss of coal (heating value) and. for the producer, a loss of revenue.

Locked particles are liberated in the Carefree process. This is a major factor distinguishing the Carefree process from conventional coal cleaning. Coarse locked particles are crushed to produce smaller particles. Most of the smaller particles are relatively free, depending upon the nature of the coal. The Carefree process embodies an efficient method for separating the large quantity of smaller, relatively free particles into clean coal and refuse. This also distinguishes the Carefree process from conventional coal cleaning.

The principal steps in the Carefree process include the following:

- Recover a low specific gravity (1.30), coarse (plus ½mm) clean coal product.
- Reject a high specific gravity (2.00), coarse refuse.
- Crush the resulting middling product (specific gravity 1.30 by 2.00) to liberate pyrite, other ash-forming minerals and coal.
- Size and classify the resulting minus ½mm comminuted and "natural" material into three fractions: fines, ultra-fines and slimes.
- Clean the fines and ultra-fines in dense medium cyclone circuits. These circuits employ magnetite that is an order-of-magnitude smaller than conventional magnetite, and cyclones of unique design. Recover the magnetite in circuits designed for the size of the coal and refuse particles.
- Dewater all the clean coal fractions: coarse, fine and ultra-fine. Some thermal drying may be required depending upon the coal.

Self-Scrubbing Coal is a compliance product prepared from non-compliance coals that have moderate organic sulfur and pyrite that liberates easily. The sulfur is removed in two steps, one occurs in the coal preparation plant, the other in the boiler. Self-Scrubbing Coal is first aggressively beneficiated, as described above. Both pyrite and ash are reduced as much as possible while at the same time maintaining a high Btu recovery. The sorbent: dolomite, limestone or dolomitic limestone, is then agglomerated (pelletized) with the ultra-fine fraction of the clean coal. The purpose of the sorbent is to capture the sulfur dioxide produced when the organic sulfur and residual pyrite are oxidized during combustion. The final clean coal product from the above process is Self-Scrubbing Coal. It is comprised of clean coarse coal, clean fines and pellets containing clean ultra-fine coal and sorbents.

As an example, Custom Coals evaluated a Lower Freeport coal from eastern Ohio. The raw coal has 6.4 lbs SO_2/MMBtu. The organic sulfur content is moderate and the pyrite liberates easily. A 1.2 pound compliance Self-Scrubbing Coal can be made from this feedstock.

Through aggressive beneficiation the 6.4 lbs SO_2/MMBtu in the raw coal can be reduced to 2.1 pounds. Cleaning to 2.1 pounds removes 67 percent of the total sulfur in the raw coal. To produce Self-Scrubbing Coal, limestone is pelletized with the ultra-fines and the pellets are combined with the clean coarse and clean fine coal. The calcium-to-sulfur stoichiometry in the resulting product is 2.4. An estimated 43 percent of the sulfur in this Self-Scrubbing Coal will be captured in the boiler through sulfation of the sorbent. Predictions of sulfur capture in the boiler are based upon data from the literature from full-scale plant and test-boiler evaluations of SO_2 capture by sorbents entering the boiler with the fuel. Sulfur-capture values, as a function of sorbent stoichiometry, will be confirmed by full-scale boiler test burns as part of the CC IV project. The final emission limit of 1.2 pounds of sulfur dioxide comprises a total sulfur reduction of 81 percent.

Analyses of the products from raw coal to Self-Scrubbing Coal are given in the following table:

Product	Ash, Percent	Lbs SO_2/MMBtu	Incremental SO_2 Reduction Percent	Total SO_2 Reduction Percent
Raw Coal	12.8	6.35	N/A	N/A
Cleaned Coal	3.7	2.08	67.2	67.2
Self-Scrubbing Coal	13.3	1.18	43.3	81.4

Several improvements result from using Self-Scrubbing Coal compared to earlier combustion trials by others in which the sorbent and coal were injected together through the burner.

- Less sintering occurs with low-NO_X burners which are expected to be installed by most utilities to comply with the NO_X reduction requirements of the 1990 Clean Air Act Amendments. Sintering causes a loss of sorbent reactivity due to a reduction in the surface area of the sorbent. Greater sintering occurs at higher temperatures and less at lower temperatures. Sintering is minimized by low-NO_x burners that provide an improved time/temperature profile for SO_2 capture.

- The quantity of ash is not excessive. Aggressively beneficiating the coal before introduction of the sorbent keeps ash levels near or below pre-established levels.

- Higher removals of sulfur dioxide are possible due to greater calcium-to-sulfur stoichiometry. The aggressive beneficiation reduces sulfur substantially. For a given quantity of sorbent, lower sulfur levels mean greater calcium-to-sulfur ratios. And, proportionately greater capture of sulfur dioxide occurs with higher calcium-to-sulfur ratios.

- The percent removal of sulfur dioxide is good. A capture of 43 percent by dry sorbent injection, that attained in the above example, would be considered poor if viewed as a stand-alone technology. When dry sorbent injection is integrated with CCI's aggressive coal cleaning process, total sulfur reduction is a very respectable 81 percent. This is sufficient to bring many coals into long-term compliance.

Self-Scrubbing Coal attains year-2000 compliance with coals of moderate organic sulfur and pyrite that liberates easily. No additions to or modifications of the boiler are required with Self-Scrubbing Coal. It is received, stored, reclaimed, pulverized and burned the same as conventionally prepared coal.

PLANT DESIGN

The preparation plant will be located in Central City, Pennsylvania, Somerset County, at the site of the existing idled Laurel Preparation Plant built in the late 1970's by Consolidated Coal. A substantial percentage of the handling facility infrastructure will be refurbished and reused. The preparation plant building itself will be demolished and replaced. The site will include the following sections:

- <u>Raw Coal Handling</u> - The site will be equipped to receive coal by truck. The raw coal handling system consists of a truck dump, raw coal conveyors, a 20,000 ton stockpile and a rotary breaker.

- Coarse Coal Circuit - A conventional heavy media cyclone circuit is used to clean the coarse material defined as 1½" by 1mm. The circuit is operated to remove very clean coal using a 1.30 specific gravity float and refuse material using a 1.75 specific gravity sink. The middlings material (1.30 sink by 1.75 float) is crushed and proceeds to the Fine or Ultrafine cleaning circuit depending on the resulting coal size.

- Fine Coal Circuit - In advance of the fine and ultra-fine cleaning circuits, a classifying cyclone circuit is used to remove the -500 mesh material consisting primarily of clay slimes. The fine coal cleaning circuit utilizes both a spiral concentrator and redesigned heavy media cyclones to achieve effective cleaning in the 1mm by 150 mesh size fraction. This heavy media circuit utilizes ultrafine magnetite to improve separation efficiency.

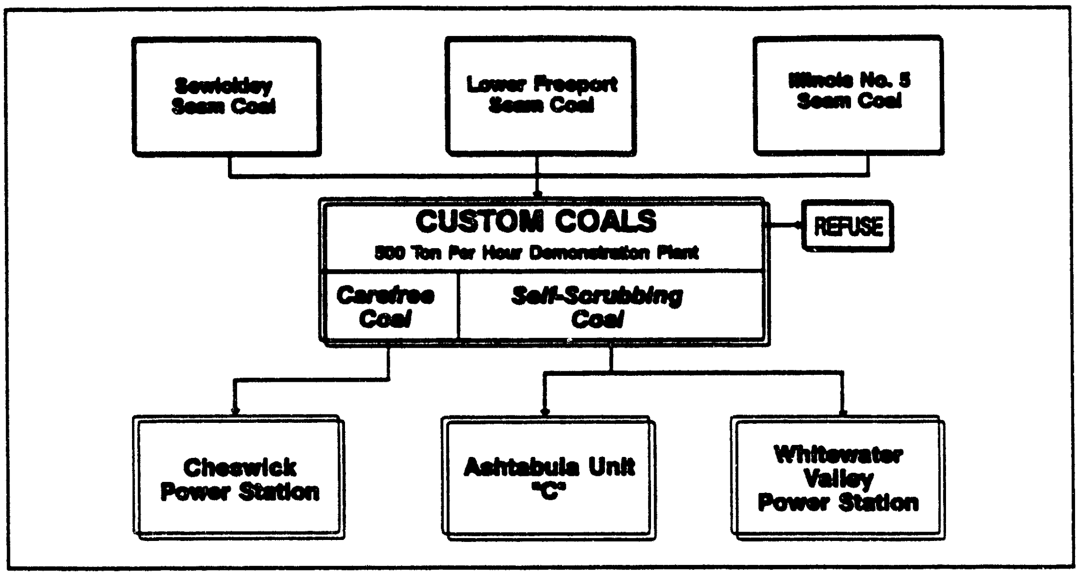
- Ultra-Fine Circuit - The ultra-fine magnetite and redesigned cyclones are also used to clean the 150-500 mesh material. The magnetite recovery system uses barium ferrite and rare earth magnetic separators to recover the ultra-fine magnetite.

- Coal Drying/ Pelletizing - Sorbent is mixed with ultra-fine clean coal which is then thermally dried and pelletized using a binder.

- Clean Coal Handling - Clean coal proceeds on a collecting conveyor through an automatic sampling system and on to three clean coal silos (5,000 tons each). From the silos either trucks or unit trains can be loaded. The plant has access to a Conrail siding on site.

TEST BURNS

The test burn phase of the project is comprised of test planning, coal preparation and combustion and data analysis and reporting. Test planning at each host site will include a detailed review of power plant performance records, a walk-down of each test unit to select appropriate access ports for test measurements, a meeting to discuss host utility requirements and test objectives and the preparation of a detailed test plan that documents required plant modifications to accommodate the test program, a test matrix of proposed operating conditions and measurements to be made during the test and a schedule for each of the tests to be conducted.



During each of the test burns, unit thermal performance will be determined for the entire combustion system - from the pulverizers to the precipitators. Specific coal samples, flue gas samples, ash and slag samples, pressures, temperatures and instrument data will be collected to determine energy consumption, efficiency and process performance for the combustion system. Comparison to design specifications and past performance will be the basis for measuring the costs and benefits of the test coals over a 30-day test period at steady-state baseload.

During the thermal performance tests, supplemental monitoring will be performed to measure environmental performance. On-line monitors, flue gas sampling and solids sampling will provide accurate measurements of:

- SO_2 emissions
- NO_X emissions
- CO_2 emissions
- Air toxics emissions
- Solid waste quantities and characteristics

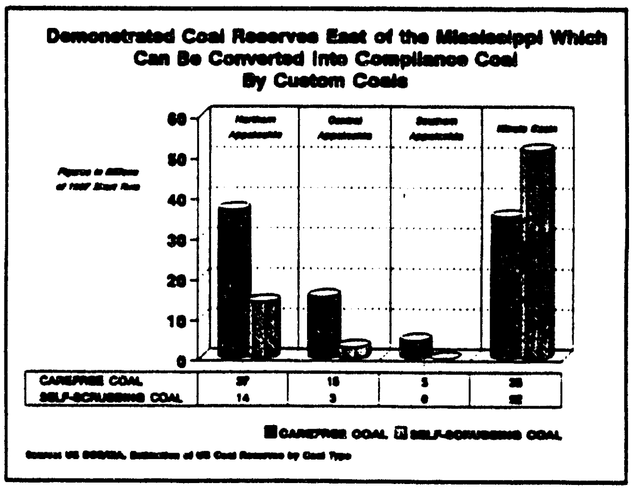
The results of the tests for each coal will be documented in detailed reports. These three reports will describe coal handling and sampling procedures, as-received coal quality of the test coals, power plant test procedures and data collected, results of data analyses and an assessment of the costs and benefits in terms of thermal performance and emissions for the test coals.

Custom Coals will facilitate technology transfer to the host utilities and to the utility industry as a whole. Technical briefings will be provided for each of the host utilities following completion of the respective field test efforts. The results of the field tests will also be presented at an appropriate national conference.

COMMERCIALIZATION

The current United States coal market is one billion tons per year. Of this, approximately 80% is sold to the electric utility industry. About 300 million tons of the utility industry consumption represents Western low-sulfur coal or unwashed strip mined coal. Of the remaining 500 million tons, Custom Coals has determined that at least half is burned in locations where strong economic or operating considerations could favor Self-Scrubbing Coal over alternate compliance solutions. Custom Coals seeks to achieve 10-20% share of this fraction of the market.

An analysis was performed of boilers affected by Phase I and Phase II of the Acid Rain Provisions. The best candidates for Carefree Coal and Self-Scrubbing Coal are thought to be those boilers over 20 years old and plants where scrubber retrofits are more costly. The analysis was combined with an assessment of available coals which can be brought into compliance with Custom Coals' technology as indicated in the following graph. From these combined analyses, the market size potential discussed above was developed.



Custom Coals' strategic plan is to acquire low cost non-compliance coal, bring it into compliance through the application of the technology and sell it near the avoided cost of other compliance alternatives. Custom Coals will construct a series of preparation plants to produce compliance coal products. The current forecast calls for 10 plants to be constructed in the United States by the year 2000.

A substantial market for Custom Coals' products is also developing in Eastern Europe. The Polish government has requested that a feasibility study be performed to assess the potential for constructing 14 coal cleaning plants with a total capacity of 50 million tons of coal per year. CCI has recently been awarded $375,000 from U.S. AID to complete this study. Also, CCI, on April 29, 1993, received letters of intent from three Polish coal mines to build two coal preparation plants within the next two years that have a capacity of 10 million tons per year. Similar opportunities exist elsewhere in Eastern Europe and in the former Soviet Union.

The United States market is being approached by developing conceptual project opportunities using Custom Coals knowledge of the electric utility industry and the coal markets. Potential clean coal purchasers from the project are then contacted to determine if a sufficient level of interest exists to proceed with the project. Given a positive response, Custom Coals then identifies raw coal supplies and a preparation plant site. Coal industry consultants and coal preparation plant engineers are used to assist Custom Coals in developing the project concept into a series of contracts that can be project financed. In May 1992 Custom Coals executed an agreement with Chase Manhattan Bank, establishing a vehicle through which up to $500 million of project financing capacity will be made available to construct at least 10 coal preparation plants.

Sales to Eastern Europe are being approached through the respective government entities as the coal supply and electric generating facilities are generally government owned. Again, coal industry consultants and coal preparation plant engineers are used to assess project opportunities and develop required contracts. Financing will be accomplished through bank loans guaranteed by international agencies and equity as required.

Custom Coals is also exploring the opportunities with the People's Republic of China, the biggest producer and consumer of coal in the world. Custom Coals would use its advanced coal cleaning technology to clean all or some of the coal currently being burned in the capital city of Beijing. Beijing, which is vying to host the Year 2000 Olympic Games although it has become one of the most polluted cities in the world, annually burns approximately 30 million tons of coal, all of it essentially unwashed. Beijing, as do other Chinese cities, relies on coal for some 80% of its energy use and a cleaner, more efficient coal will aid in resolving their environmental plight.

The cleaning costs should be fully offset by savings which would accrue from burning clean coal. For example, since the average rock content of the coal burned would be reduced from about 30% to 6%, rail costs would be reduced by some 24% and a comparable amount of scarce rail capacity would be released for alternate use. The program could be comprehensive and could include coal for utility boilers, industrial use, home and district heating and home cooking. A joint venture would be offered to the Chinese Government and to the Provincial Governments currently supplying coal to Beijing.

Initial discussions have also mentioned the possibilities for cleaning the rich coal reserves of Shanxi Province and to eventually transport some of the clean coal product of this North-West province to the more populous and industrial Eastern plain of China by pipeline or coal water slurry. This idea could be integrated with the Beijing Project.

THE HEALY CLEAN COAL PROJECT: DESIGN VERIFICATION TESTS

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ABSTRACT

As part of the Healy Clean Coal Project, TRW Inc., the supplier of the advanced slagging coal combustors, has successfully completed design verification tests on the major components of the combustion system at its Southern California test facility. These tests, which included the firing of a full-scale precombustor with a new non-storage direct coal feed system, supported the design of the Healy combustion system and its auxiliaries performed under Phase 1 of the project. Two 350 million BTU/hr combustion systems have been designed and are now ready for fabrication and erection, as part of Phase 2 of the project. These systems, along with a back-end Spray Dryer Absorber system, designed and supplied by Joy Technologies, will be integrated with a Foster Wheeler boiler for the 50 MWe power plant at Healy, Alaska. This paper describes the design verification tests and the current status of the project.

For presentation at the Second Annual Clean Coal Technology Conference, September 7-9, 1993, Co-Sponsored by the Department of Energy and Southern States Energy Board.

Part 1: Design Verification Tests

1.0 Introduction

The Healy Clean Coal Project (HCCP) was selected in December 1989 as one of the U.S. Department of Energy's Clean Coal Technology III programs under the sponsorship of Alaska Industrial Development and Export Authority (AIDEA). The goal of the HCCP is to design, fabricate, erect and operate a 50 MWe new coal-fired power plant at Healy, Alaska, based on advanced slagging coal combustion and flue gas desulfurization technologies for reducing NO_x and SO_2 emissions below current standards. The status of the HCCP and the roles of its major team members are described in Part 2 of this paper.

Figure 1 illustrates the basic schematic of the HCCP, highlighting the scope of supply of TRW and Joy Technologies, Inc., the suppliers of the advanced technologies. The major components of TRW's scope of supply consist of two 350 MMBTU/hr slagging combustors, two coal feed systems and one limestone feed system. Each slagging combustor consists of a precombustor, a slagging combustor and the associated high pressure cooling water system as its major subcomponents.

After the successful firing of a typical Healy coal in a 40 MMBTU/hr TRW slagging coal combustion system at TRW's Cleveland facility during 1990-1991 time frame, it was recognized early on that in the scale-up from 40 MMBTU/hr to 350 MMBTU/hr, the most critical components of the combustion system were the precombustor and the coal feed system. Therefore, to minimize project risk it was decided to conduct design verification tests on a scaled-up precombustor and a coal feed system prior to completing the final design. At that time, the slagging combustor scaling and operation was well understood, both from analytical and operational viewpoints; the limestone feed system was also operated successfully at the Cleveland facility. This experience was sufficient to allow scaling of these components to 350 MMBTU/hr without further testing.

Early in the design phase of the HCCP, it was recognized that a storage type of coal feed system, used in the Cleveland facility, was not desirable for the HCCP primarily due to safety concerns associated with the high volatile content of the Healy coals. Therefore, it was decided not to scale up the storage type of coal feed system, but to design, fabricate and test a new non-storage type direct coal feed system. Since the precombustor firing rate is 130 MMBTU/hr for a 350 MMBTU/hr slagging combustion system, it was decided to design, fabricate and test in conjunction with the precombustor a coal feed system also rated at 130 MMBTU/hr.

Part 1 of this paper covers the activities associated with the design, fabrication, installation and testing of a full-scale precombustor and an approximately one-third scale direct coal feed

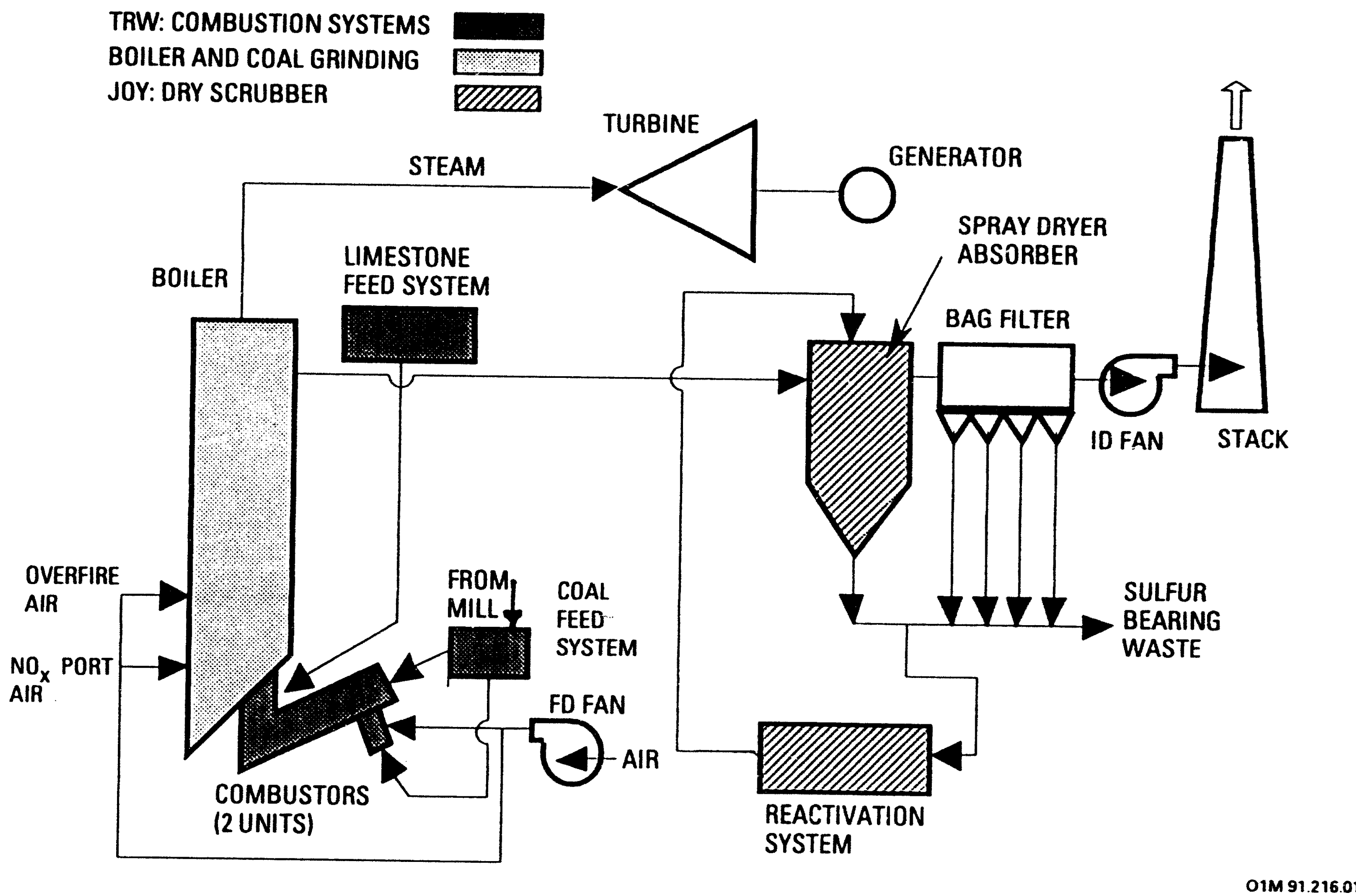

Figure 1: HCCP Overall Schematic

system (DCFS), each rated at 130 MMBTU/hr, at TRW's Fossil Energy Test Site in San Juan Capistrano, California. These design verification tests (DVT) were performed during the period August 1992 to February 1993. Figure 2 illustrates the DVT schedule in relationship with the total TRW Phase 1 design schedule. Both the combustor and coal feed system hardware design were supported by cold-flow tests conducted at TRW's Space Park facility, as illustrated in this figure.

The precombustor design was scaled from TRW's design of the 40 MMBTU/hr system in Cleveland, a scale-up by a factor of approximately 10. A significant change in the design approach was necessitated by the requirement that the precombustor be used for boiler warm-up and that during that time all the coal fines from the mill be combusted prior to entering the cold furnace. Also, because of scaling, it was recognized early that a multiple coal injector would be advantageous and to this end a commercial Foster Wheeler coal burner was incorporated into this design. The new DCFS was conceived, designed, fabricated, installed and tested all within a span of approximately one year. The successful completion of the tests mitigated the concerns on scale-up and operation of the total system.

Over 200 tons of Healy Performance Blend coal were supplied gratis by Usibelli Coal Mine Company for these tests. The coal was transported from Usibelli mine to Energy and Environmental Research Corporation (EERC) in Irvine, California by barge and rail cars. EERC pulverized this coal to TRW's specifications and a total of 160 tons was delivered to TRW's test site in hopper cars. Figure 3 lists the properties of the pulverized coal. This coal was stored in tanks and blanketed with nitrogen for safety reasons, and used during the tests as needed. All of the pulverized coal was utilized in a series of 28 tests. The total run time on coal was approximately 43 hours.

2.0 Test Hardware

Figure 4 depicts a three-dimensional overview of Cell No. 3 at the Fossil Energy Test Site (FETS), a facility dedicated to fossil fuel combustion research and development at TRW's Capistrano Test Site, located about 65 miles south of Los Angeles, California. A photograph of the test site is shown in Figure 5.

2.1 DVT Precombustor

A full-scale DVT precombustor was used to verify the Healy precombustor design by hot-firing with Healy Performance Blend coal. The design of the precombustor and the DVT system were completed during September 1991 - March 1992. The precombustor consisted of five subassemblies: Foster Wheeler coal burner with primary windbox and Forney ignitor, combustion chamber with secondary windbox, mill air spool (including splitter), transition

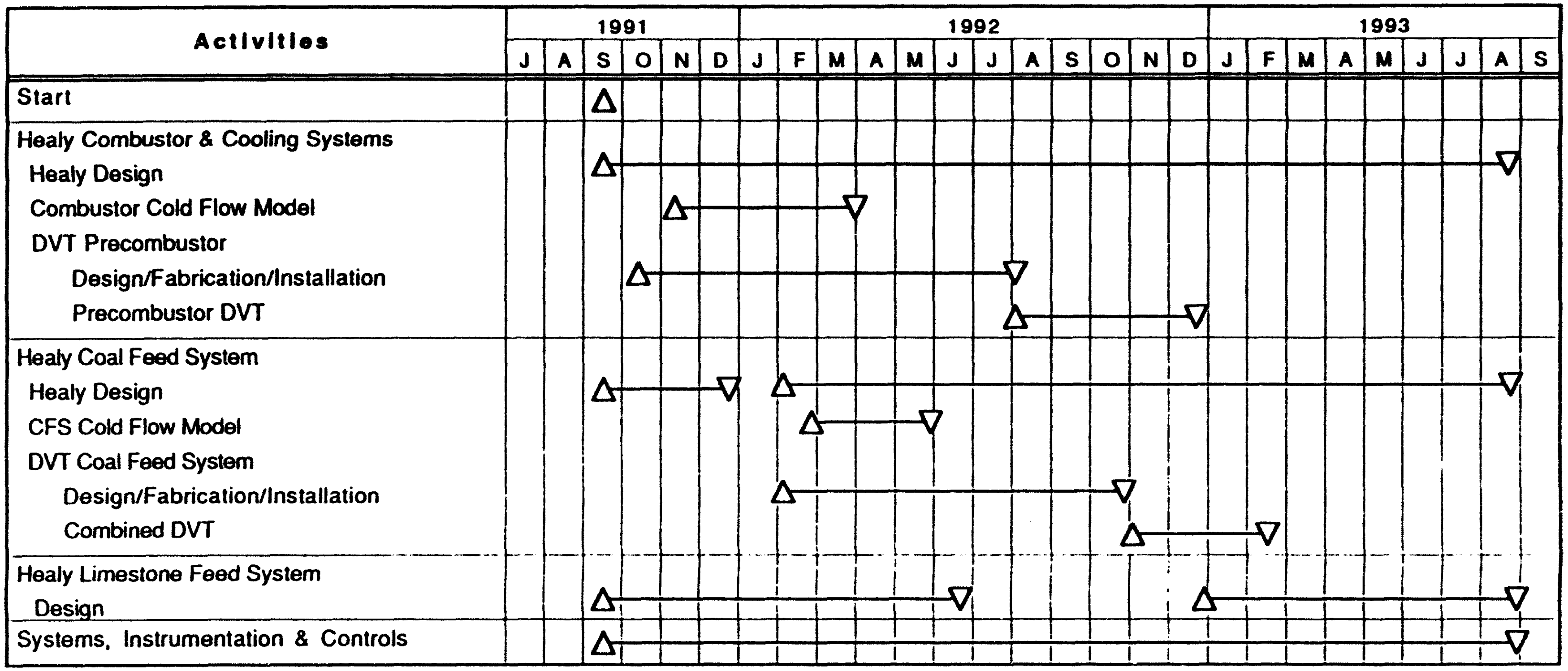

Figure 2: TRW Phase 1 Design Schedule

	As Received	Dry Basis
Proximate Analysis		
% Moisture	11.64	xxxxx
% Ash	17.15	19.41
% Volatile	39.59	44.80
% Fixed Carbon	31.62	35.79
	100.00	100.00
BTU/lb	8292	9384
Ultimate Analysis		
% Moisture	11.64	xxxxx
% Carbon	49.83	56.39
% Hydrogen	3.46	3.92
% Nitrogen	0.66	0.75
% Sulfur	0.14	0.16
% Ash	17.15	19.41
% Oxygen (by diff)	17.12	19.37
	100.00	100.00

Ash Analysis	Wt %, Ignited Basis
Silicon dioxide	55.68
Aluminum oxide	12.81
Titanium dioxide	0.54
Iron oxide	4.71
Calcium oxide	14.75
Magnesium oxide	2.25
Potassium oxide	2.84
Sodium oxide	1.84
Sulfur trioxide	3.67
Phosphorus pentoxide	0.16
Strontium oxide	0.19
Barium oxide	0.43
Manganese oxide	0.13
Undetermined	0.00
	100.00
Silica Value	71.95
Base: Acid Ratio	0.38
T_{250} Temperature	2433 °F
Size Distribution	50 - 60% through 200 mesh

Figure 3: Performance Blend Coal Properties

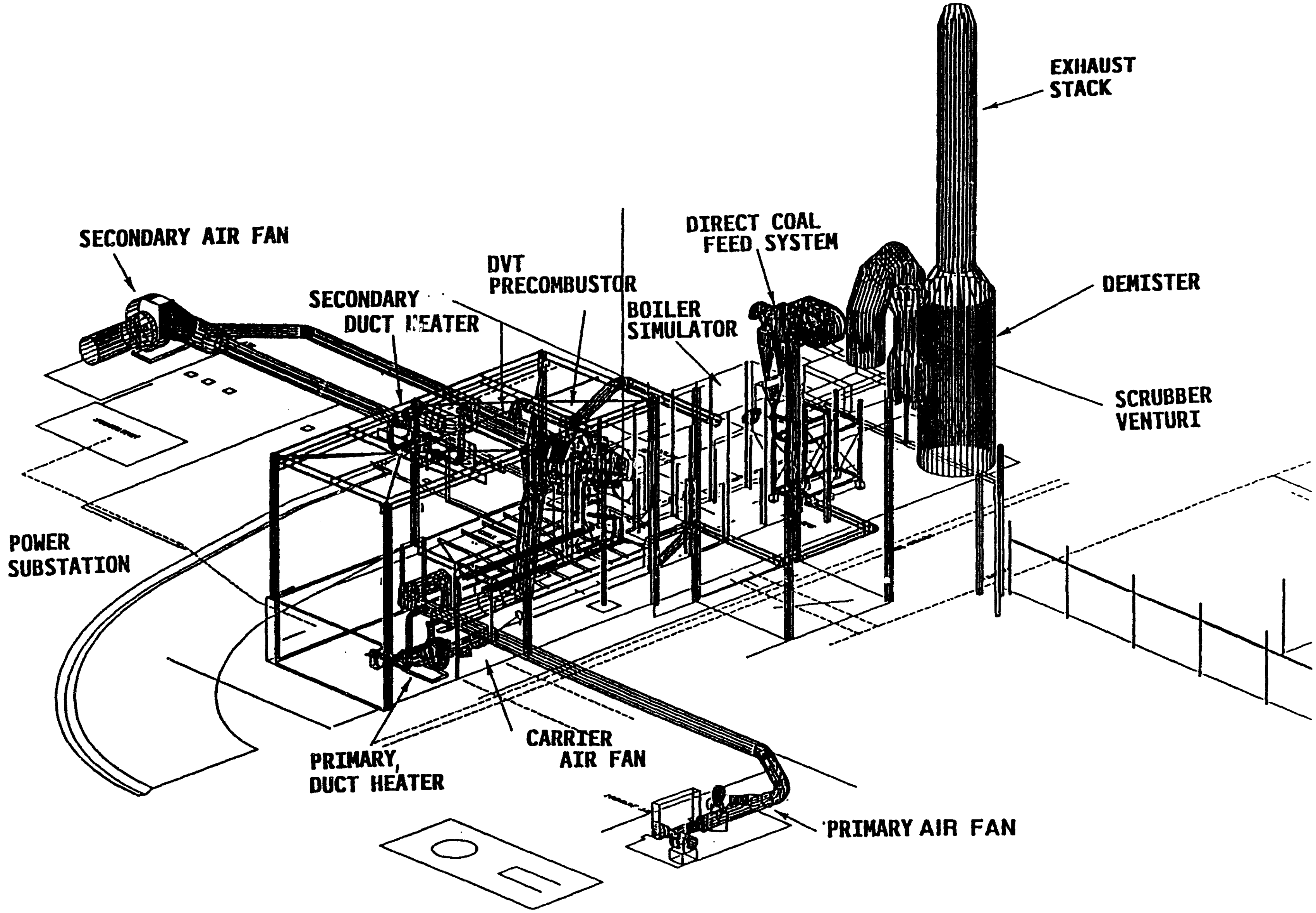

Figure 4 Fossil Energy Test Site, Cell No. 3 Overview

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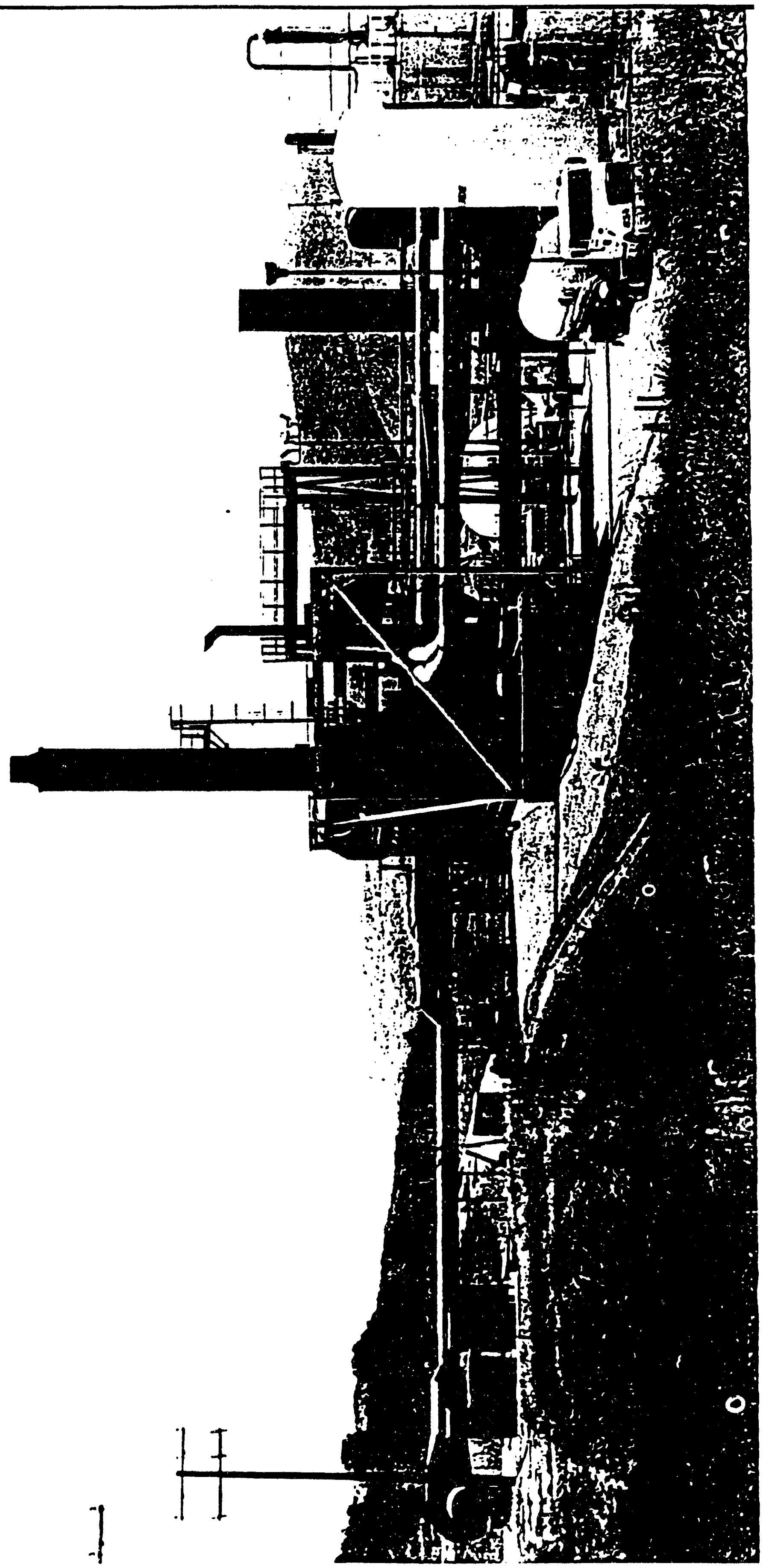


Figure 5 Test Cell No. 3 at Capistrano Test Site

section, and swirl dampers. A cross sectional view of the DVT precombustor is shown in Figure 6. Each subassembly is described separately in the following sections. The DVT precombustor overall dimensions, including the burner, were 18' as measured from burner flange to transition flange, with a maximum diameter of 10'. The dry weight of entire assembly, including refractory was approximately 38,000 lbs.

2.1.1 Fabrication and Installation

The fabrication of the precombustor was subcontracted to Monroe Inc. Figure 7 shows a view of the combustion chamber during fabrication. A very tight schedule was maintained to deliver the hardware by truck from Pittsburgh and to install it at TRW's test site on time.

The downstream transition and mount sections were installed first without the refractory which was provided later. The precombustor, Foster Wheeler coal burner, and Forney oil burner were preassembled on the ground and the refractory was installed. An overhead crane lifted and held the assembled unit in place while it was secured to a specially designed and fabricated support system. The final connections of air supply ducts, cooling water supply and return lines, etc., were field fabricated to assure fit-up. Figure 8 illustrates the fully installed view of the precombustor on the test stand. Leak and cold flow checks were performed prior to the first lightoff.

Most of the features of the DVT precombustor were identical to the Healy design. Figure 9 compares features of the DVT and Healy designs.

2.1.2 Foster Wheeler Burner/Primary Air Windbox

This subassembly consisted of a commercial-design Foster Wheeler coal burner and a primary air windbox. The primary air windbox interfaced with the facility air system to provide air to the Foster Wheeler burner. A Foster Wheeler dual air register within the primary windbox controlled both swirl and distribution of air to the burner.

2.1.3 Forney Oil Burner

The Forney oil burner system as delivered consisted of a retractable oil gun assembly with removable tip and swirler. Cold tertiary air was supplied by a separate fan. The air flowed into a housing which is part of the Foster Wheeler burner assembly surrounding the oil gun. The air provided external cooling for the oil gun, purged the housing cavity, and added swirling air into the oil flame for flame stabilization purposes.

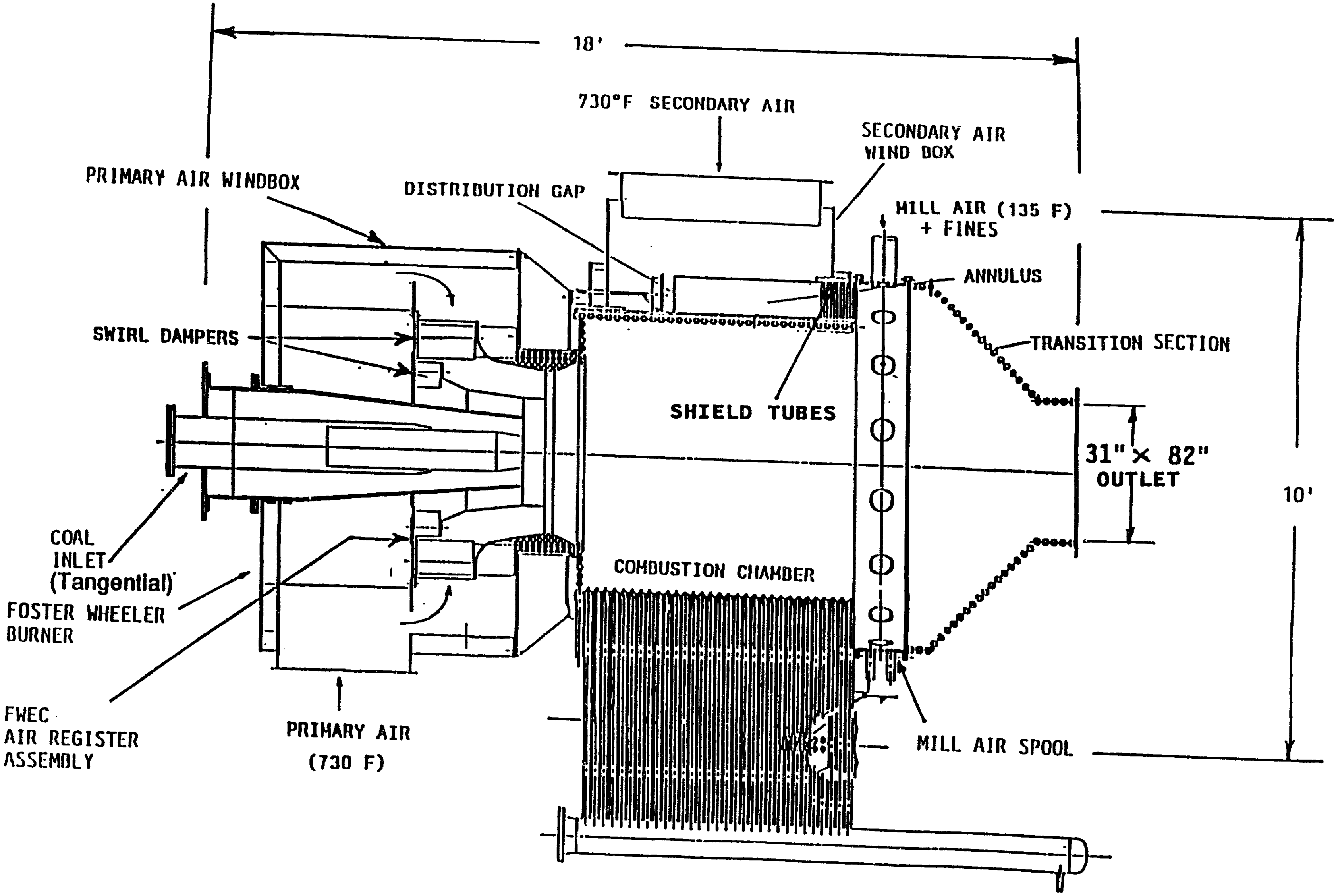


Figure 6 DVT Precombustor Configuration

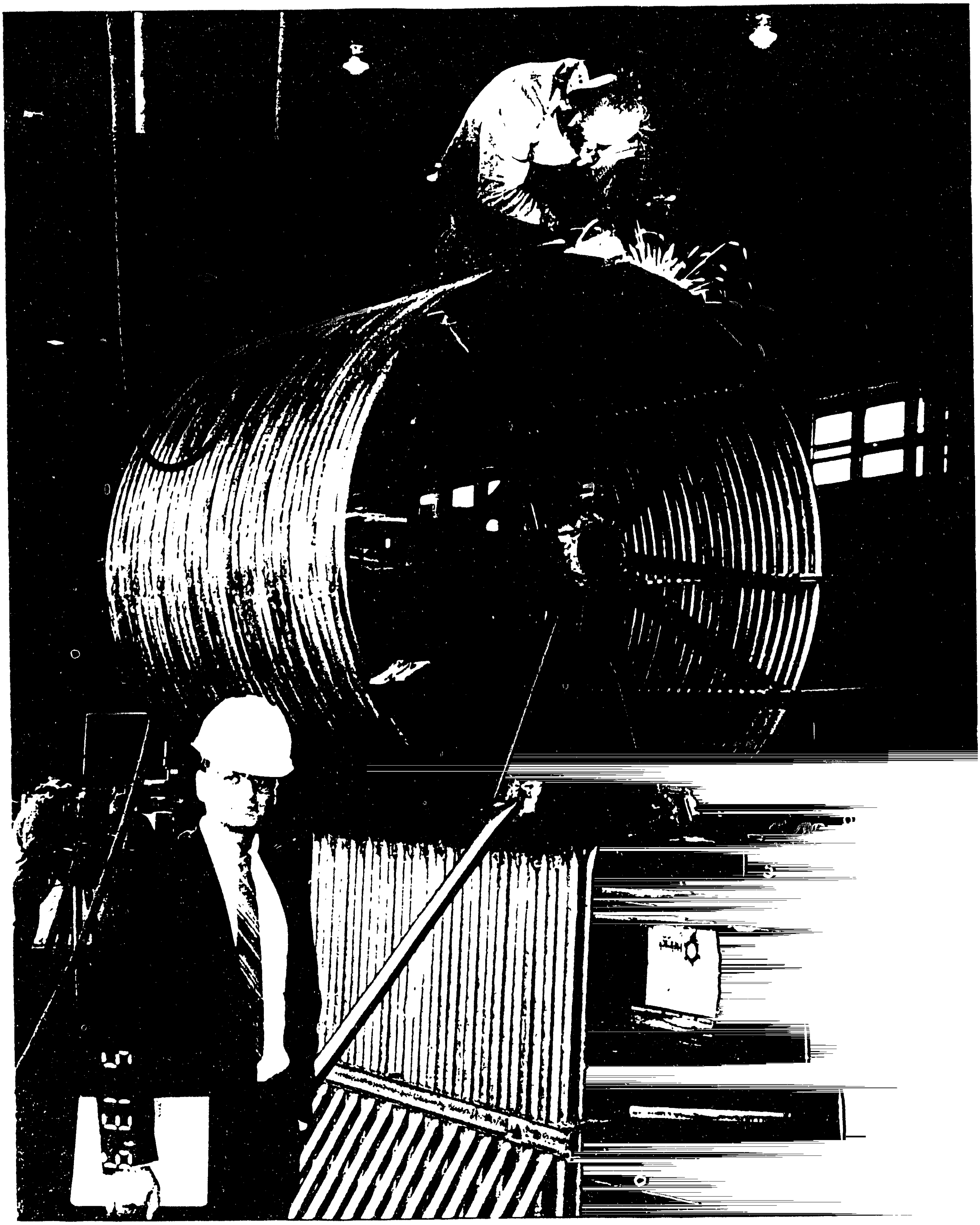


Figure 7 DVT Precombustor Shell During Fabrication

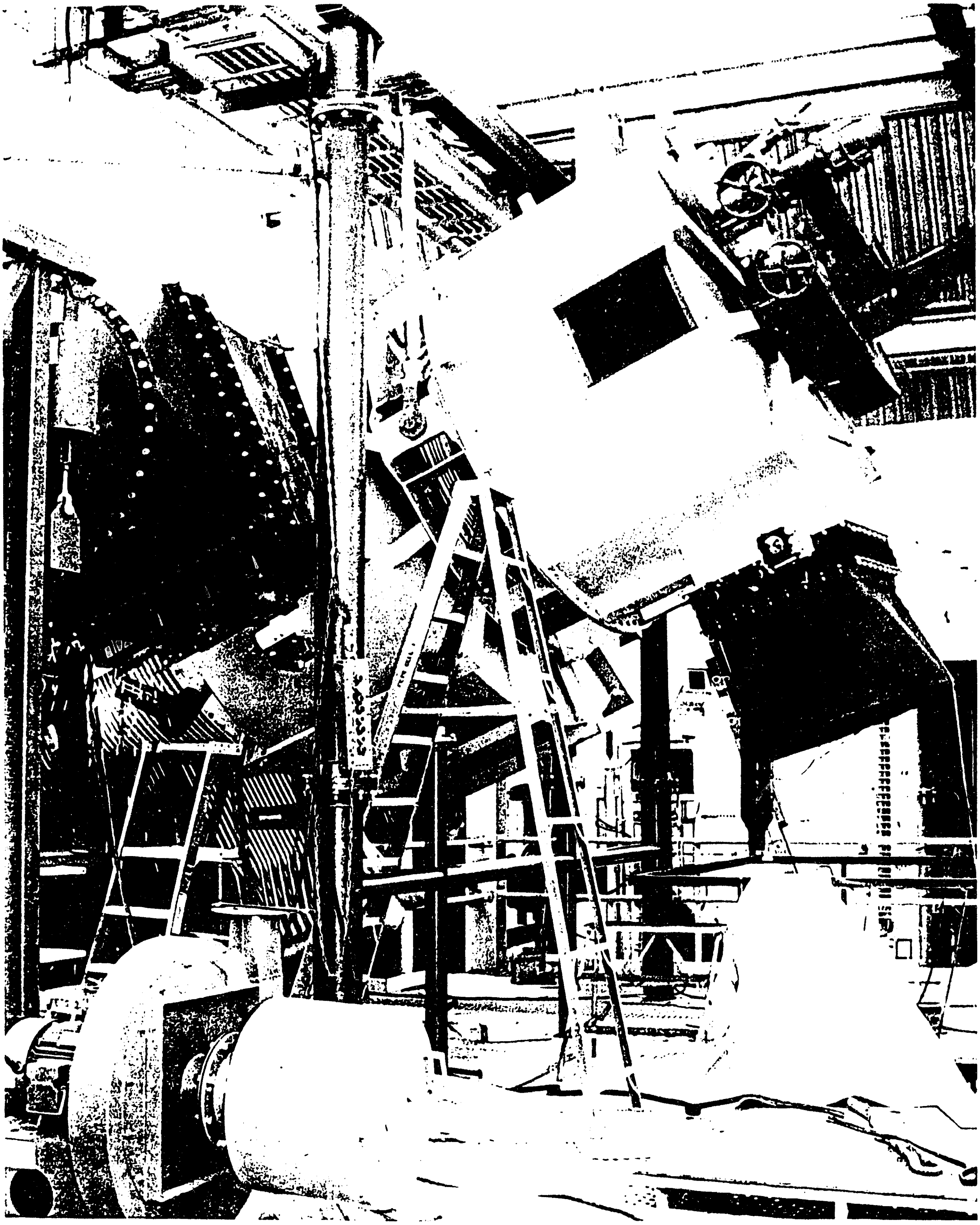


Figure 8 DVT Precombustor Installation

FEATURES	DVT	HEALY
COMBUSTION CHAMBER DIMENSIONS	62″ I.D. X 62″ L	62″ I.D. X 62″ L
BURNER THROAT DIAMETER	37″	37″
COAL BURNER TYPE	FWEC SPLIT FLAME w/o WEAR LINERS	FWEC SPLIT FLAME WITH LINERS
OIL IGNITOR TYPE	FORNEY 70 MMBTU/HR	FORNEY 70 MMBTU/HR
PRECOMBUSTOR EXIT DIMENSIONS	31″ X 82″	31″ X 82″
COOLING WATER	100 °F, 150 PSI	592 °F, 1405 PSI
COOLING CIRCUIT GEOMETRY	SINGLE FULL LOOP (360°)	TWO HALF LOOPS (180°)
MILL AIR INJECTION COOLING	SEPARATELY COOLED SPOOL	INTEGRAL WITH WATER WALL
MILL AIR INJECTION PORTS	16 - 4.813″ I.D.	6 - 5.5″ I.D.
MIX ANNULUS WINDBOX INLET	1 - 45″ X 45″	2 - 40″ I.D.
TUBE DIMENSIONS	1.50″ O.D. X 0.25″ MWT	1.50″ O.D. X 0.18″ MWT
TUBE INSIDE SURFACE	RIBBED	SMOOTH
TUBE MATERIAL	SA-210 GR A-1	SA-213 T2
MEMBRANE DIMENSIONS	0.50″ WIDE X 0.50″ THICK	0.75″ WIDE X 0.25″ THICK
MEMBRANE MATERIAL	SA-515 GR 60	SA-387 GR 11

FIGURE 9: PRECOMBUSTOR FEATURES, DVT VERSUS HEALY

2.1.4 Combustion Chamber/Secondary Air Windbox

Figure 6 shows the secondary air windbox and water-cooled combustion chamber. The windbox interfaces with facility air system to provide air downstream of the chamber. A refractory-lined combustion chamber was constructed using a tube membrane design with 1.5" ribbed tubing (0.24" MWT) illustrated in Figure 10. The 62" diameter chamber was enclosed by the secondary air windbox.

2.1.5 Mill Air Spool

The 82" diameter mill air spool, shown in Figure 11, was constructed with a water-cooled, double wall design. The function of this spool was to direct mill air laden with coal fines primarily during boiler warm-up to the precombustor downstream of the Foster Wheeler burner. A coal splitter upstream of the mill air spool distributed coal fines to precombustor through 8 individual 5" diameter ports. Diagnostic precombustor gas pressure was measured in this component.

2.1.6 Transition Section and Swirl Damper Assembly

This subassembly provided a transition from the 82" diameter chamber to the 31"x82" rectangle required at the slagging combustor inlet, as shown in Figure 12. The mechanical design was based on a water-cooled tube membrane design similar to the combustion chamber construction. A swirl damper assembly, consisting of a housing and two damper blades, was also designed, fabricated and installed at the rectangular exit of the transition section. The components of this assembly were constructed based on a water-cooled tube membrane design. A key function of the blades is to maintain minimum gas velocity at the precombustor outlet. Remote actuation of blade position allowed operators to control blade position individually, or as a pair, during 100% MCR load conditions.

A video camera located in swirl housing sidewall provided a useful diagnostic tool for evaluating flame stability over various operating conditions. In addition, the camera images confirmed both damper blades and housing remained free of ash attachment during the entire DVT series.

2.2 DVT Direct Coal Feed System (DCFS)

Figure 13 shows a schematic of the DCFS, consisting of primarily a variable splitter followed by two blowdown cyclones. The discharge from the one of the two blowdown cyclones feeds the precombustor and the discharge from the other feeds the slagging combustor (or a collection tank during the DVT.)

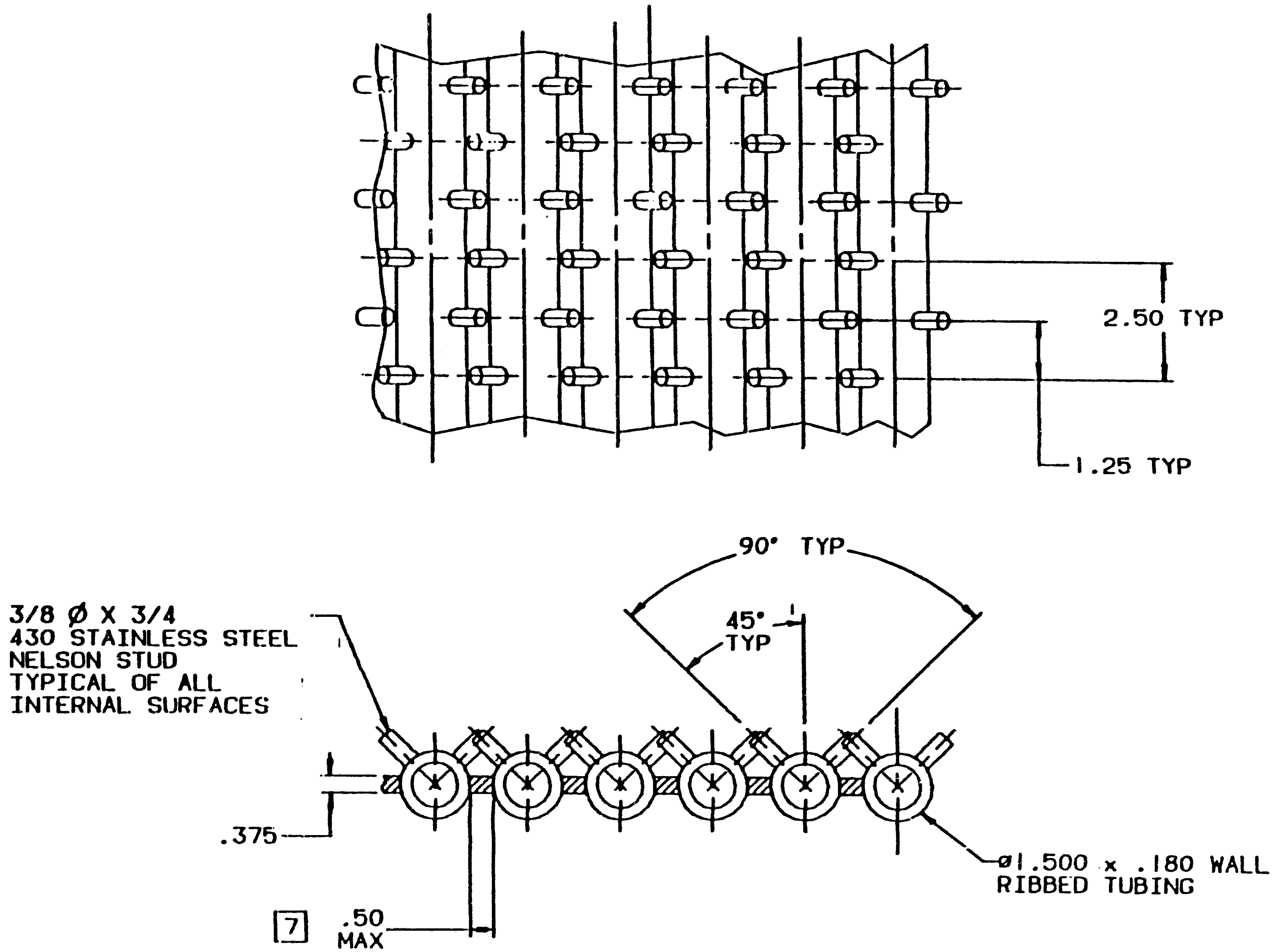


Figure 10 DVT Precombustor Stud Pattern for Refractory Retention

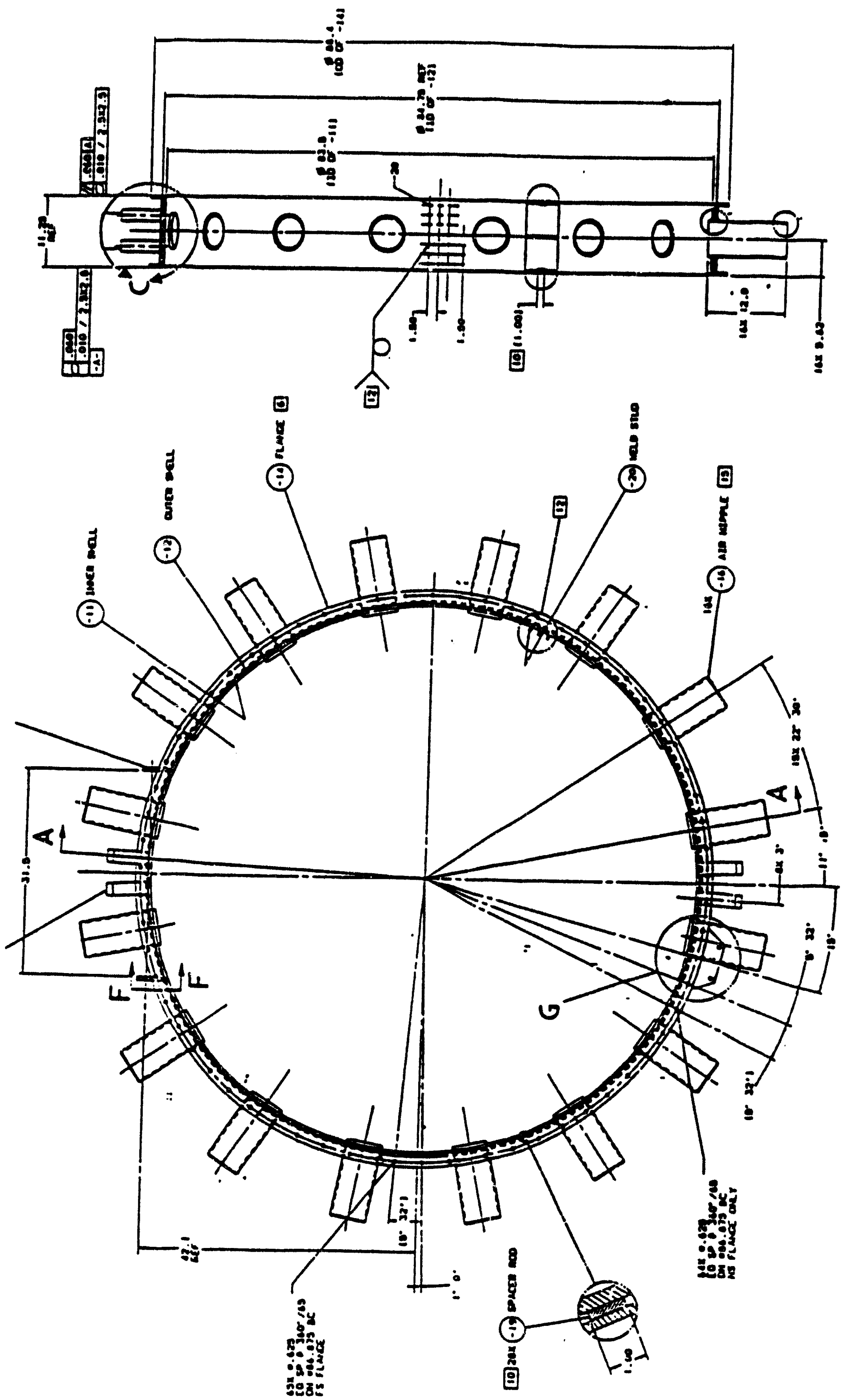
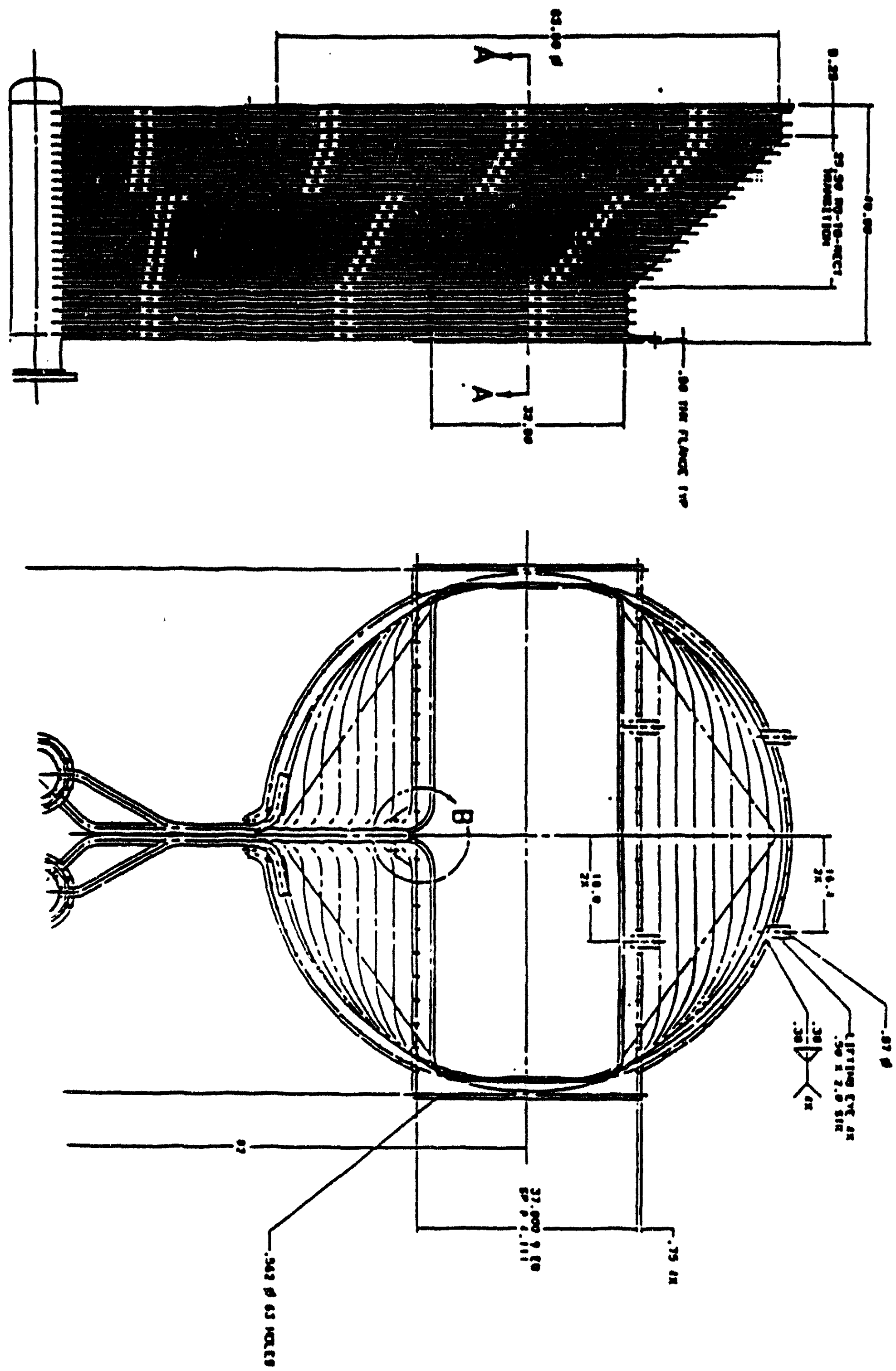


Figure 11 DVT Precombustor Mill Air Spool



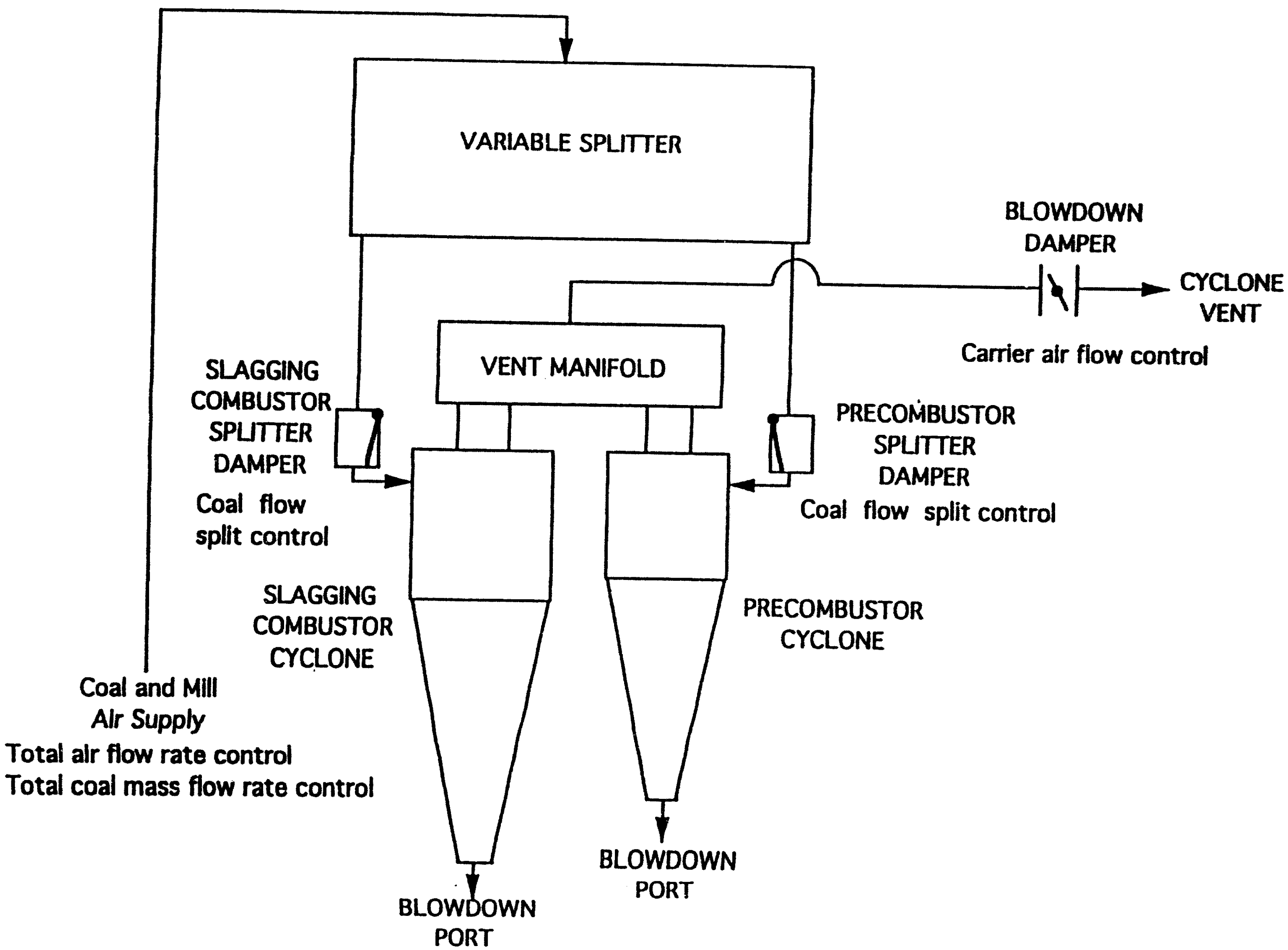


Figure 13 Direct Coal Feed System Schematic

The design of the variable splitter and the blowdown cyclones was based initially on TRW's concept evaluation and analytical calculations. The DCFS concept was then tested a one-tenth scale cold flow model prior to the DVT hardware fabrication. Talcum powder was used to simulate coal in the cold flow modeling tests. After the successful completion of the cold flow tests, the design of the one-third scale DCFS was finalized . TRW's subcontractor, Delta Ducon, prepared the final detailed design and fabrication drawings. This DCFS matched the full-scale rating of the precombustor since the precombustor utilizes approximately one-third of the total coal flow.

2.2.1 Configuration

The DVT series was planned for two DCFS configurations: One configuration was for firing the precombustor at full load with the total coal flow from both the outlet legs of the DCFS. The other configuration was in the split mode, with only the split coal stream used for firing the precombustor while the other (which would have fired the slagging combustor) was just collected and weighed.

The DVT DCFS was designed and constructed so that if and when problems were encountered with the DCFS, precombustor testing could still be continued using the existing facility coal feed system simply by closing and opening manual valves without any hardware changes such that coal could be directed from the facility system to the precombustor without flowing through the DCFS.

A CO monitor was installed in the vent line of the DCFS to monitor CO levels during testing for detecting fires, if any. A CO_2 fire extinguishing system was also connected to the coal feed system in the event a problem occurred. Water deluge ports were also incorporated into the design for fire extinguishing.

Access and observation ports were installed at critical locations to inspect for coal accumulations.

2.2.2 Installation

The precombustor coal transport line assembly was installed at the same time as the precombustor was installed to allow testing just the precombustor. The remaining DCFS components were installed during night shifts on a non-interference basis while the precombustor test series was being completed.

2.3 Facility Systems

Combustion air for DVT precombustor testing was provided by the primary and secondary air systems. Each system was complete with electric fan, power substation, oil-fired duct heater, flow control and diagnostic measurement equipment. The DVT precombustor was mounted to a boiler simulator in the same orientation relative to gravity, as in the Healy application. The boiler simulator was a rectangular chamber with flood-cooled water walls. The simulator provided residence time for radiant cooling of the exhaust gases prior to a water quench. The downstream support equipment required to meet the Southern California Air Quality Management District regulations consisted of a quench system, scrubber system, and exhaust stack.

3.0 Objectives of Design Verification Tests

The design verification tests (DVT) were performed as part of the total design of the TRW coal combustion system for the Healy plant primarily to mitigate the risks associated with the scale-up of the precombustor and the direct coal feed system.

The tests were grouped into two major categories: (1) Full-scale precombustor tests only, using the existing coal feed system at TRW's Capistrano Test Site (CTS), (2) Flow, check-out and hot-fire tests of the one-third scale direct coal feed system coupled to the precombustor. Specific objectives are delineated in Figure 14.

4.0 Design Verification Test Logic

Figure 15 shows the [illegible]gn verification test logic. Since the precombustor was des[illegible] fabricated and installed significantly earlier than the DCF[illegible] precombustor tests were first performed using the existing fa[illegible]y coal feed system, and in parallel, the DCFS was fabricated and installed at CTS. This was accomplished by operating the site on two shifts. The timing was important to complete the installation of the DCFS just prior to the time the precombustor testing was completed. The precombustor testing consisted of the following major tasks:

- Coal Lightoff
- Coal Firing
- Burner Tuning
- Swirl Damper Check out
- Load/Stoichiometry Series
- Load/Preheat Series
- Healy Light-off/Warmup Sequences
- Swirl Damper Evaluation

The following tasks were performed during the DCFS tests:

- Cyclone Efficiency Evaluation
- Blowdown Control and Evaluation
- Evaluation and Improvement of Flow Stability
- Evaluation and Elimination of Coal Accumulation in the Lines

	PC Tests	DCFS-PC Tests
Proof of Concept		X
Validate Scale-up	X	X
Validate Stability, Performance	X	X
Validate Ignition, Flame-holding	X	X
Disposition of Cyclone Vent Air		X
Startup and Shutdown Sequences	X	X
Measure Heat Fluxes	X	X
Measure Pressures/Pressure Drops	X	X
Demonstrate FWEC Burner	X	X
Demonstrate Forney Ignitor	X	X
Demonstrate Safe Operation	X	X
Obtain Design Data	X	X
Identify Design Changes, if any	X	X

FIGURE 14: DESIGN VERIFICATION TEST OBJECTIVES

- Evaluation and Minimization of Pressure Drops

The only activity which was eliminated from the original logic in Figure 15 was the Captive Flow Test. The original plan called for evaluating cyclone performance with coal prior to the actual hot firing into the precombustor. However, it was determined that it was more expeditious, safer and less expensive to perform these tests while firing the precombustor. This was possible because by the time the DCFS was ready for operation, the precombustor had been completely checked out and could be operated reliably.

5.0 Test Results

5.1 Precombustor

Figure 16 summarizes the major precombustor issues which were addressed by the DVT, with applicable test results and the impact on the design and operation. Toward the conclusion of the precombustor tests a nominal accumulation of slag was noted on the lower edge of the water cooled combustion chamber and on adjacent hardware. The last three feet of the chamber had a wet slag appearance around the periphery, but no significant buildup. Analysis of the Performance Coal used throughout the test program indicated a T_{250} (temperature at which the molten ash viscosity is 250 poise) nearly 300 F less than that originally specified for that coal. This raised the concern that over long operating periods, a significant buildup of slag may interfere with the lower injection ports. The injection configuration was therefore changed as shown in Figure 17. In the modified configuration the number of injection ports was reduced from eight to six and the lower ports were eliminated.

5.2 Direct Coal Feed System

The tests utilizing the DCFS in conjunction with the pre-tested precombustor proved that the total pressure drop from the DCFS inlet to the boiler was within the 60 inches water pressure budget provided in the technical specification. Figure 18 illustrates the required DCFS inlet pressure as a function of the load. The DVT also assured that there was no need for additional eductors to transport the coal to the combustor.

Coal accumulations in the first version of the splitter discharge ducts occurred during attempts to achieve full load. After evaluating corrective solutions, both analytically and via cold flow modeling, a relatively simple modification to the splitter discharge duct design eliminated the accumulations, incurring an additional pressure drop of only 3 inches of water. This design change was incorporated into the full-scale Healy design.

Flow stability was also improved during the DVT through transport

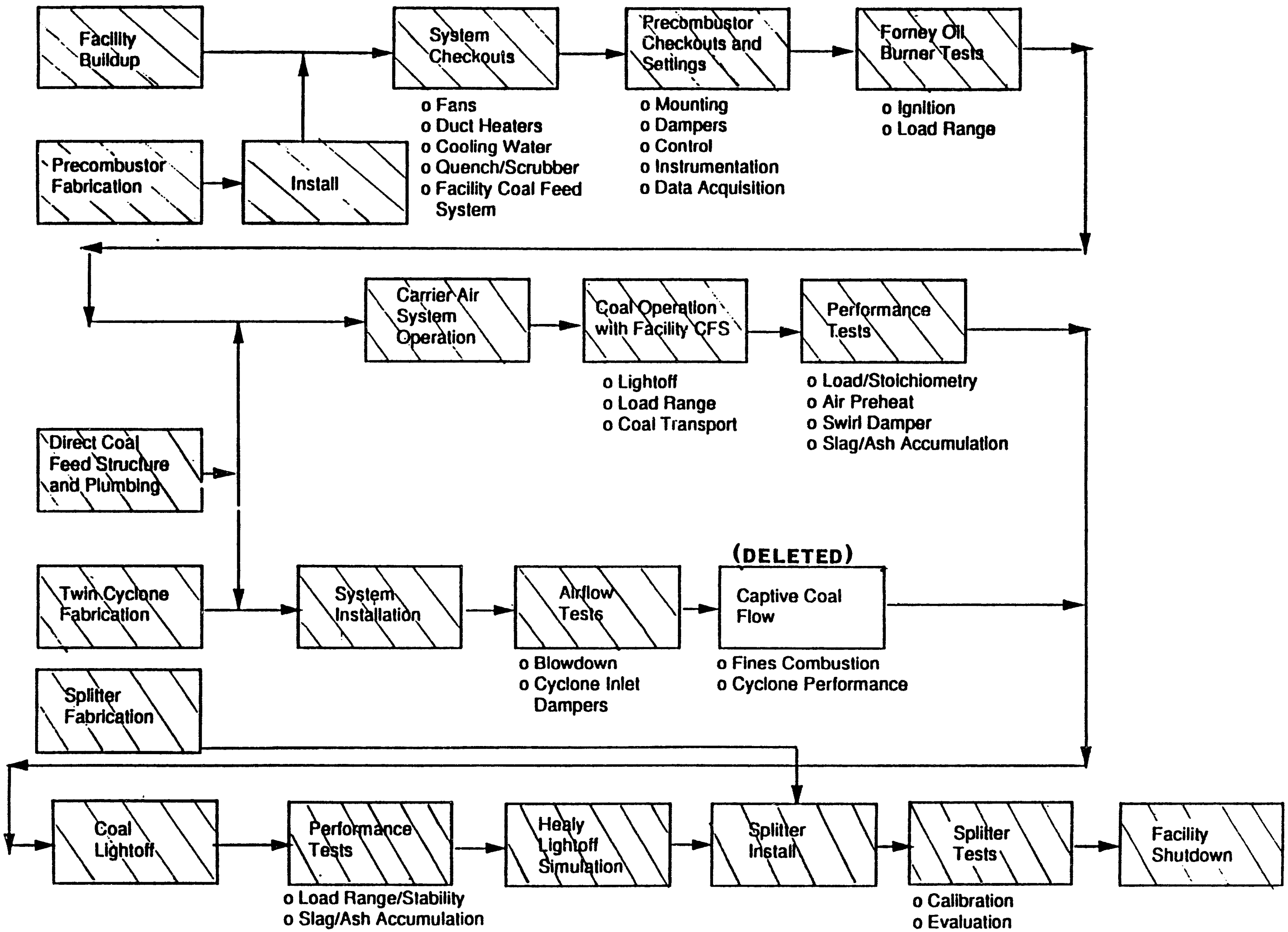


Figure 15 DVT Logic

Issue	Test Results	Design/Operation Impact
Coal burner performance including ignition, stability and load variation	o Demonstrated stable operation over the full load range o Demonstrated reliable coal light off o No flame failures experienced o Burner delta-P measured o Close agreement between measured and predicted stack oxygen	o High level of confidence in reliable burner operation at Healy o Adds margin to pressure budget o Good indication of high combustion efficiency
Prevention of slagging and fouling	o No significant fouling seen during test series o Portion of combustion can covered with thin (1/4-1/2") slag layer. Due to low T250 (2400°F) o Some slag deposits seen in bottom of transition and near PC exit	o No major impact. Will use lower stoichiometry for low T250 coals at Healy o Mill air injectors rotated for Healy design to avoid possible injector plugging
Combustion of cyclone vent air including coal fines	o Demonstrated burning of fines during DVT coal feed system o No adverse effects on precombustor operation o No evidence of fouling due to coal fines	o Precombustor can reliably burn fines as required during start-up at Healy
Demonstration of Healy start-up and shut-down sequences	o Successfully demonstrated Healy sequence including coal/oil exchange with oil ignitor at 70 MMBtu/hr	o Validates method proposed for combustor start-up/shut-down
Validate design heat fluxes and cooling loads	o Measured heat loss slightly over target due to lack of refractory o Measured heat fluxes are within predicted range	o Healy design will include refractory lining throughout
Operation of 70 MMBtu/hr Forney oil burner	o Smokeless operation demonstrated at minimum (20 MMBtu/hr) and minimum (70 MMBtu/hr) loads. Slight stack haze at intermediate loads o Pressures for atomization and oil significantly higher than Forney estimates, exceeding plant capability. Changed operating mode to reduce pressures to reasonable levels. o Forney recommended tertiary air flow causes oil flame failure at low loads	o Haze can be eliminated at Healy with tighter air flow controls o Required pressures for Healy Atomization: 95 psig Oil: 150 psig o Reduce tertiary air flow for Healy
Verify pressure budget for Healy design	o Measured delta-P's in relatively good agreement with predictions	o Pressure budget leaves sufficient margin for flow control at Healy
Reliable operation of flame scanner system	o Not able to discriminate between oil and coal flames using Forney supplied system o Forney has indicated that this problem is common to all of their installations o Flame scanner on burner periphery provides a strong signal whether firing oil only, coal only or oil and coal o Repeatable coal ignition was obtained with oil burner firing at 70 MMBtu/hr	o DVT experience suggests that oil/coal flame discrimination may not be required for safe operation at Healy o Working to obtain resolution through NFPA and/or industry experience
Thermal effects, thermal mismatches	o Small cracks appeared on joint with high thermal stresses (T = 600°F) o Measured high temperature on mix annulus windbox coupons due to back radiation	o Redesigned for Healy delta-T limited to 300°F o "Shield tubes" required for Healy design

Figure 16: Precombustor DVT Results

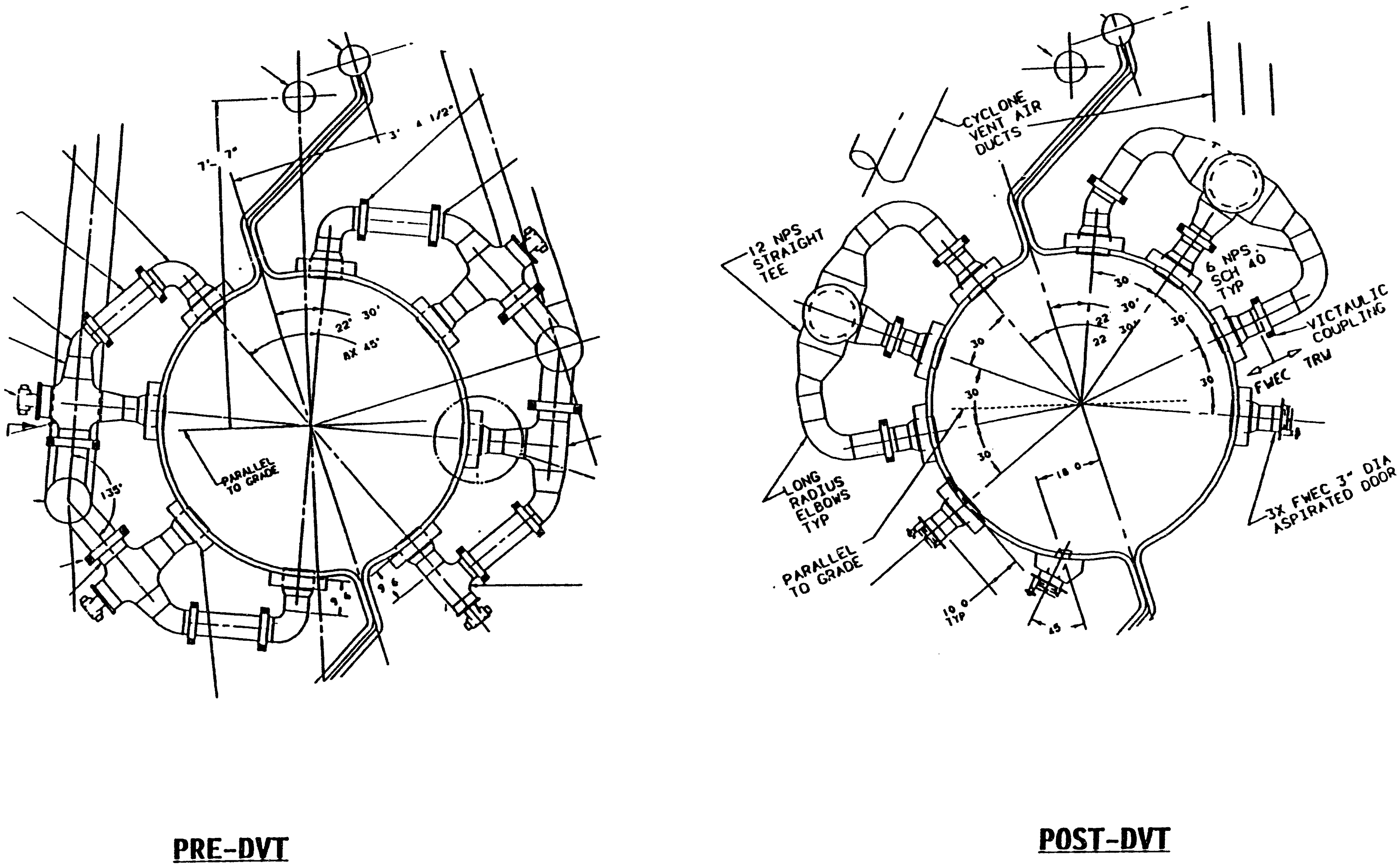


Figure 17 Changes to Cyclone Vent Air Injection Configuration

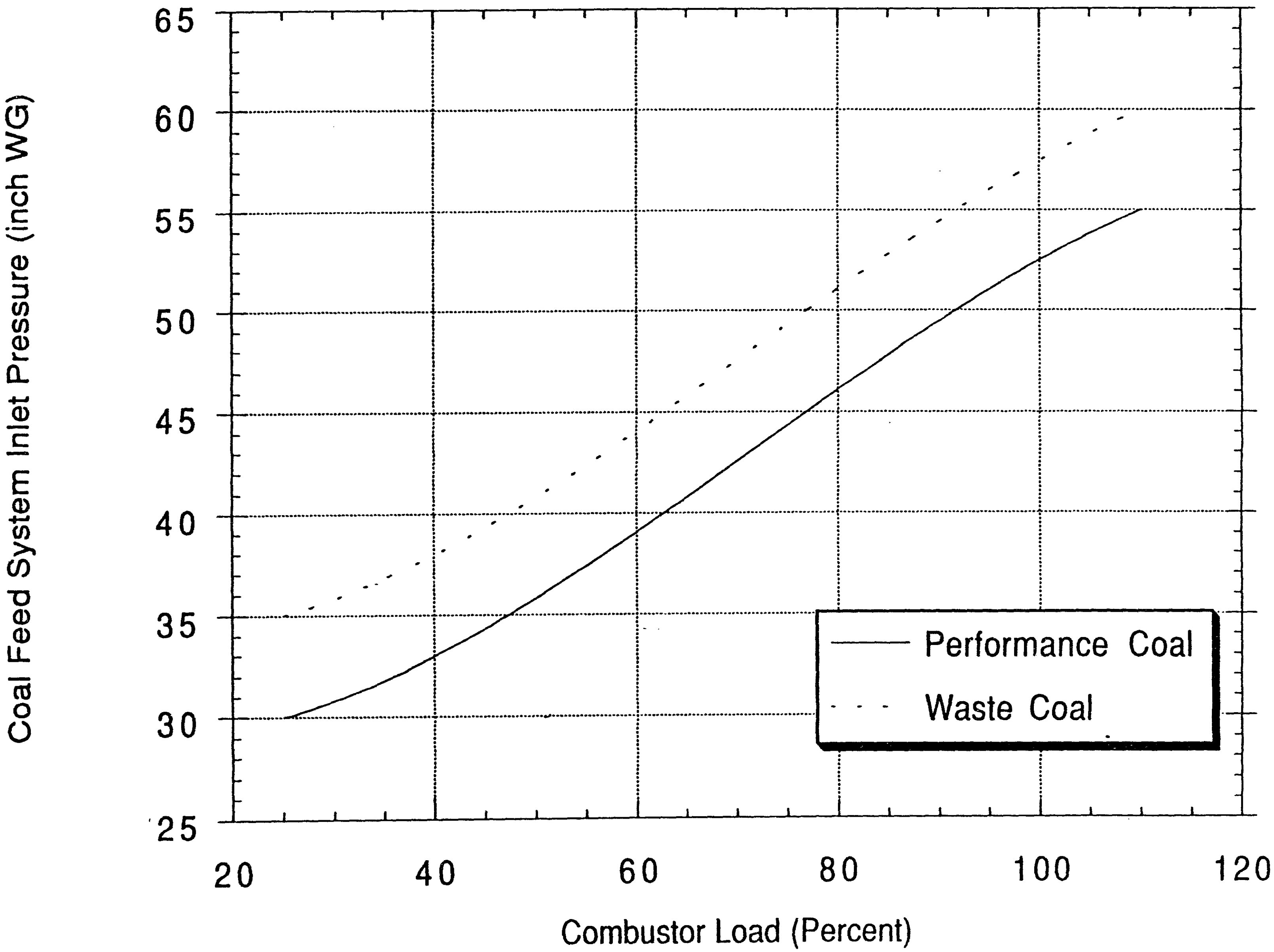


Figure 18 DCFS Inlet Pressure Requirements

line modifications as well as operational changes. Figure 19 illustrates the results of the hardware improvements. Peak to peak precombustor and burner pressure variations of 4 inches water were reduced to less than 2 inches of water after the transport line modifications were implemented.

Cyclone blowdown port size and blowdown leg diameter effects were also evaluated during testing. Minimum sizes were established based on pressure drop measurements and the total flow rates of air and coal per cross sectional area. Cyclone blowdown port sizes and blowdown pipe sizes were established for the Healy design in which the precombustor and the slagging combustor cyclones are sized in proportion to the total flow received by each cyclone.

Flow control was also improved during the DVT. Controlling the blowdown based on input from the annubar flow meter proved to be difficult to tune. The blowdown damper was either overdamped or underdamped in response to fluctuations in the input flow emanating from the mill air fan and lock hopper coal supply system. Therefore, an orifice plate was added upstream of the blowdown damper which enabled the damper to control in a more stable regime and be less responsive to fluctuations in total inlet flow. Figure 20 illustrates stable precombustor and burner pressures even though flow from the facility coal supply system experienced fluctuations due to periodic coal transfers. The DCFS dampened the fluctuations in the supply pressure, a feature which is valuable in the Healy design since an exhauster fan is located upstream of each DCFS.

A method for ascertaining velocity and margin above the saltation was also determined during the DVT. The precombustor burner pressure drop proved to be a reliable metric for predicting flow velocities.

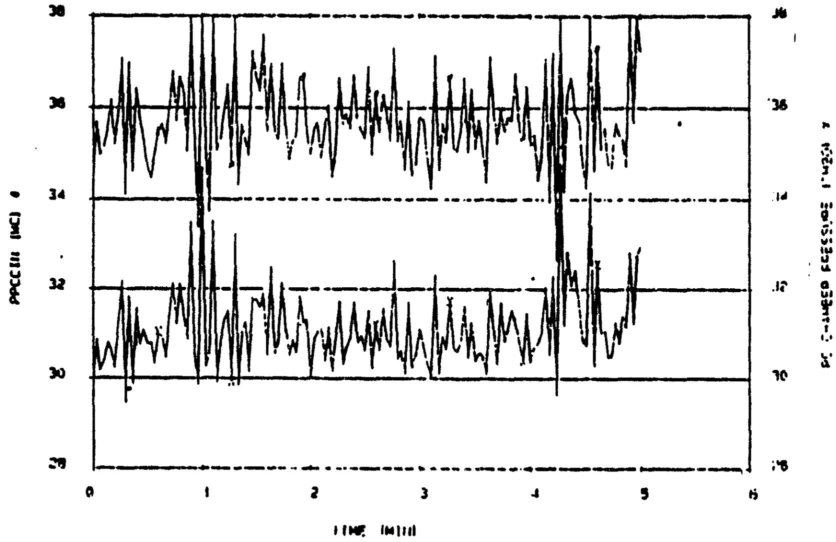
7.0 Conclusions

The results of the design verification tests and their impact on the Healy design are summarized below:

- The tests validated the basic sizing, geometry and operation of the precombustor. The Healy precombustor design was modified to include structural improvements based on a few thermal stress problems observed during the tests.

- The tests proved that the departures from the Cleveland precombustor design were beneficial as exemplified by (i) the validation of the new mill air injection port configuration used for accommodating the cyclone vent air with coal fines during startup, ramp-up and shutdown sequences and (ii) the successful implementation of the commercially proven Foster Wheeler coal burner in the precombustor.

Before



After

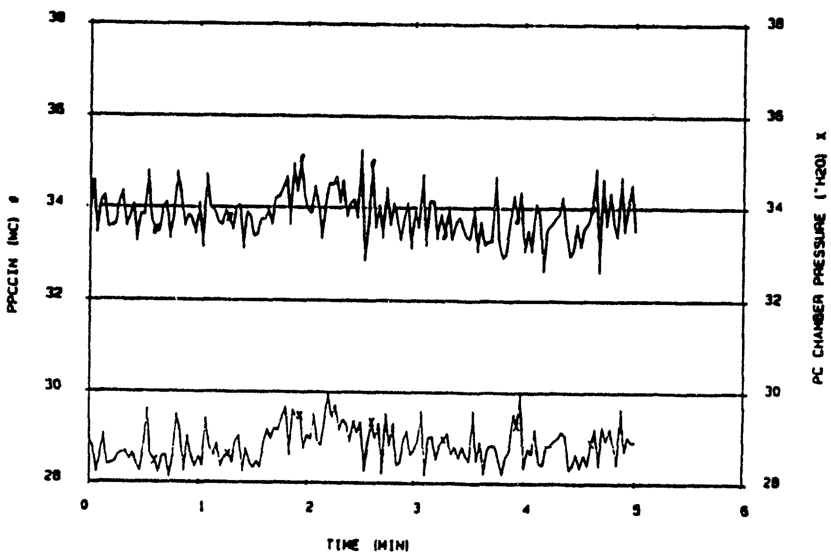


Figure 19 Flow Fluctuations Before and After Transport Line Modifications

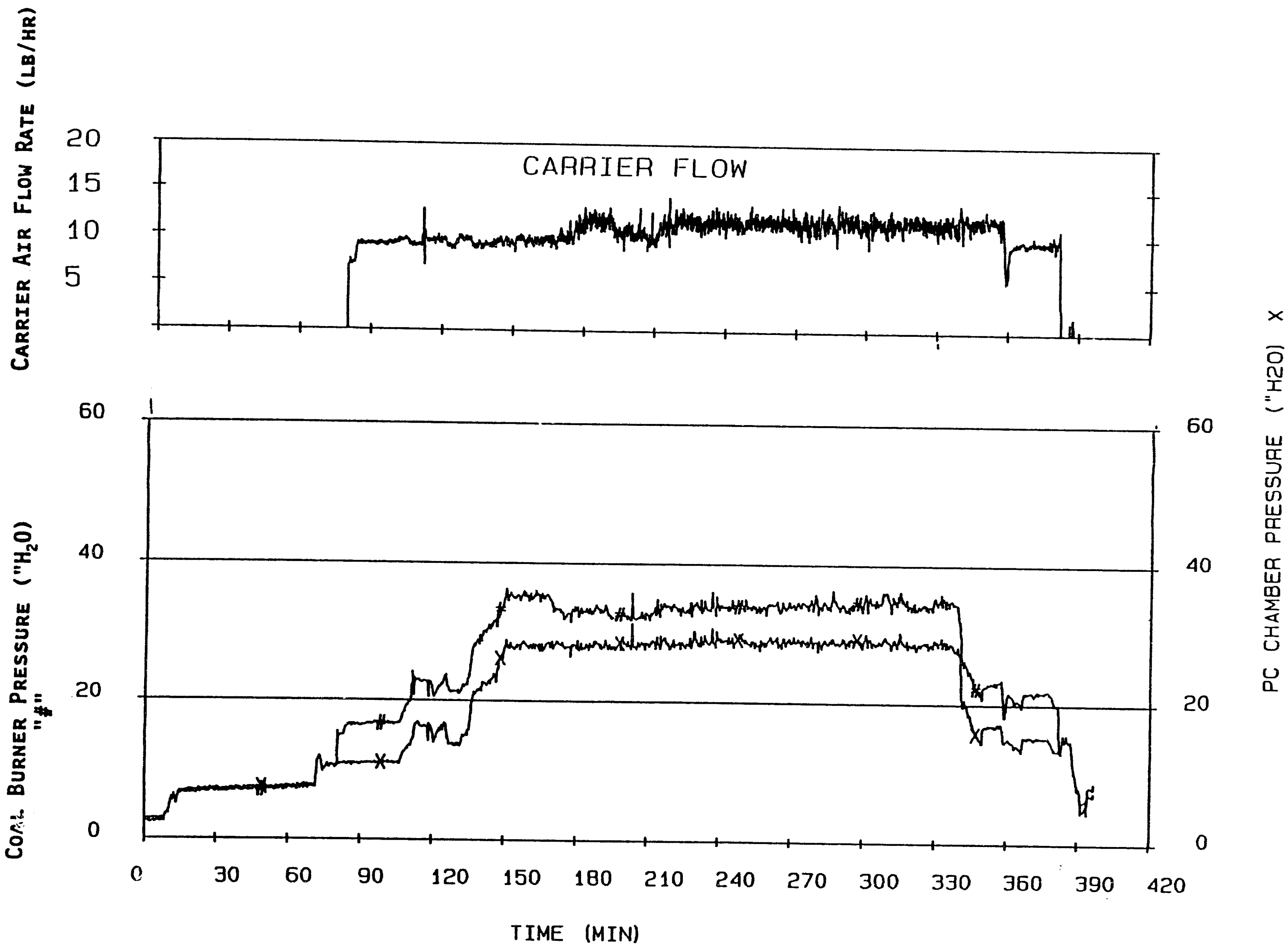


Figure 20 Stable Flow After Design Modifications

- The one-tenth scale cold-flow model tests on the novel direct coal feed system proved the viability of the concept. The design verification tests on the first configuration of the one-third scale direct coal feed system in conjunction with the precombustor indicated undesirable coal accumulations in a few regions of the system. These results provided the valuable data and operational experience to improve the design, make the required hardware modifications and resume testing. The tests on the modified hardware validated its operation successfully through the entire startup, ramp-up and shutdown sequences, thereby giving sufficient confidence to scale it up by a factor of three to the Healy size. Cyclone efficiencies and pressure drops indicated that the blowdown cyclones could be designed using conventional cyclone design techniques.

- The tests were repeatable and the data were reproducible.

- The tests provided valuable operational data on startup, ramp-up and shut-down procedures, heat fluxes in various sections of the precombustor, pressures and pressure drops, saltation velocity diagnostics, etc.

- By performing the design verification tests at TRW's Capistrano Test Site, the HCCP avoided the high cost and adverse schedule impact the project would have experienced without the benefit of such tests due to potential hardware modifications at Healy.

In general, the design verification tests provided the confidence and valuable data and procedures needed to finalize the Healy design.

Part 2: Project Status

1.0 Introduction

The Healy Clean Coal Project (HCCP) features the innovative integration of TRW's slagging combustion system with Joy Technologies' advanced flue gas desulfurization system. The integration of these technologies is expected to cost effectively result in low emissions of NO_x and SO_2.

The HCCP is jointly funded by the Alaska Industrial Development and Export Authority (AIDEA) and the U.S. Department of Energy (DOE). The HCCP was selected by DOE in Round III of its Clean Coal Technology Program. AIDEA has assembled a team comprised of TRW Inc. (TRW), Joy Technologies, Inc. (Joy) and its European associate Niro Atomizer (Niro), Foster Wheeler Energy Corporation (FWEC), Golden Valley Electric Association Inc. (GVEA), Usibelli Mine, Inc. (UCM), and Stone & Webster Engineering Corporation (SWEC) to design, build, operate, and test the plant through demonstration. The following provides a summary of the project status through July 1993.

2.0 Permitting

The following major permitting milestones have been completed:

- The Prevention of Significant Deterioration (PSD) permit was issued by the Alaska Department of Environmental Conservation in March 1993.

- A camera-based visibility monitoring program was completed in April 1993.

- The Draft Environmental Impact Statement (EIS) was issued by DOE in November 1992. The final EIS is expected to be issued later this year.

- Applications for other major permits were submitted and are expected to be approved after the Final EIS is completed.

3.0 Design/Engineering

Overall engineering and design is approximately 85% complete. All major equipment procurements were placed. The following identifies the status of activities for the major participants:

AIDEA- AIDEA is the owner of the HCCP and provides overall project management

GVEA- GVEA owns the existing Healy Unit No. 1 power plant which is immediately adjacent to the proposed HCCP. GVEA is providing design review for HCCP and will operate and maintain HCCP as well as purchase all electric power from HCCP. GVEA has obtained the Alaska Public Utilities Commission approval for the AIDEA/GVEA power purchase agreement. GVEA has also prepared the HCCP site to accommodate the HCCP construction.

TRW- TRW is the slagging combustion system technology developer and supplier of the combustion system and auxiliary systems. TRW has completed the Phase 1 design activities including the Healy coal test burns at Cleveland, the cold flow modeling tests at Redondo Beach, and the DVT at San Juan Capistrano. TRW has signed a contract with AIDEA for the supply of the slagging combustion system, the coal feed system and the limestone feed system.

FWEC- FWEC is under contract with AIDEA for the supply and erection of the boiler and its auxiliaries. TRW is also subcontracting the fabrication of the slagging combustors to FWEC.

Joy- Joy is the technology developer and supplier of the flue gas desulfurization (FGD) system with reactivation and recycle of the fly ash. Joy has completed testing of the FGD and reactivation process at the Niro facility in Copenhagen. Joy has also completed the design of the FGD system for HCCP.

SWEC- SWEC has responsibilities for permitting, and for the balance of plant engineering, design, and procurement. All procurements were awarded including the turbine generator supply and erection contract to Sumitomo Corporation of America.

Vendor engineering and design are currently in progress, and are scheduled for completion by May 1, 1994.

4.0 Construction

Construction is currently scheduled to begin in Spring of 1994. Start of the demonstration test phase is scheduled to begin September 1996. Commercial operation is scheduled to begin after the demonstration test program.

5.0 Conclusions

The HCCP team participants look forward to the successful operation of the project and expect the project to demonstrate:

- o Advanced U.S. based clean coal technologies.
- o Economical, reliable, and environmentally acceptable commercial operation.
- o Emissions significantly below the current New Source Performance Standards limits.
- o Economical use of limestone as a sorbent material.

Session 6
Advanced Electric Power Generation Systems

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IGCC DEMONSTRATION PROJECT STATUS

COMBUSTION ENGINEERING IGCC REPOWERING PROJECT

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Abstract

This demonstration project was originally conceived as the repowering of an existing plant facility, the Lakeside Station in Springfield, Illinois. The Owner, City Water, Light and Power (CWL&P), has removed five of the original boilers and three of the original turbines. The buildings have had asbestos insulation removed and the interiors have been prepared for the construction of a single Integrated Gasification Combined Cycle (IGCC) process train that will generate a net output of 60 megawatts. The plant consists of a combined cycle (gas turbine, heat recovery steam generator, steam turbine) power train located in the existing buildings and a coal gasification system in a new building. The gasification system contains ABB CE's air-blown, entrained flow, two stage gasifier, an advanced hot gas desulfurization system by General Electric Environmental Services, Inc. and the necessary auxiliary systems. The plant is designed to produce a nominal 60 MW net output with an ambient air temperature of 95°F and a cooling water temperature of 89°F on either Natural Gas or Illinois No. 5 coal. Space has been provided for the future installation of a second combined cycle power train. After the completion of plant start up and commissioning, the project was to begin a five year demonstration period to establish the operability and commercial viability of this technology. The Project has completed Budget Period 2 which was to include the completion of the preliminary plant design and a ±20% estimate for the installation, start-up and commissioning of this turnkey facility. Due to site specific conditions, increased capital costs and the small power output of the facility, the estimate has exceeded what can be funded and the project will not continue at this site.

Combustion Engineering IGCC Repowering Project
IGCC Demonstration Project Status
Springfield, Illinois

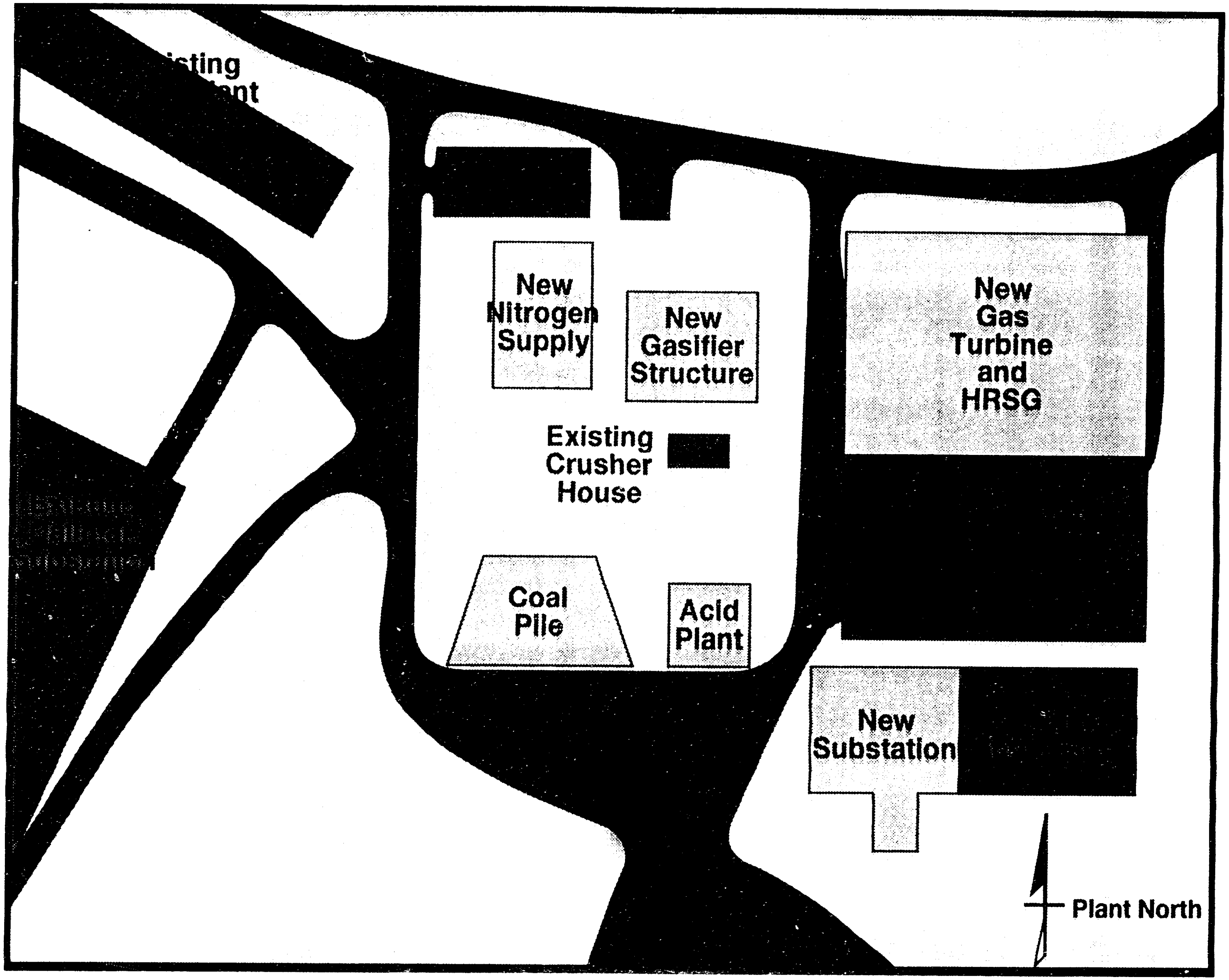
1.0 PROJECT STATUS

Combustion Engineering, Inc. (ABB CE) applied for and was awarded a cooperative agreement by the U.S. Department of Energy (DOE) under the Clean Coal Technology Program to build and operate a plant to demonstrate ABB CE's air blown coal gasification process in an IGCC application. For the demonstration project, an existing facility was to be repowered with new equipment. The concept is to use as much of the existing plant as possible to minimize the total cost. The site chosen for this project is City Water Light & Power's (CWL&P) existing Lakeside Station in Springfield, Illinois where it was initially believed that most of the boiler island could be refurbished and reused. Fifty percent of the project was funded by DOE and the balance split between ABB CE, CWL&P and the State of Illinois. The Project application was for $270,100,000 to cover the total cost of designing, renovating and building the facility and demonstrating the technology for five years.

The Integrated Gasification Combined Cycle process train will generate a net output of 60 megawatts. The plant will consist of a combined cycle (gas turbine, heat recovery steam generator (HRSG), steam turbine) power train located in the existing buildings and a coal gasification system in a new building. Figure 1 is a plot plan of the site with the new equipment layout. The gasification system contains ABB CE's air-blown, entrained flow, two stage gasifier, an advanced hot gas desulfurization system by General Electric Environmental Services, Inc. and the necessary auxiliary systems. The plant is designed to produce a nominal 60 MW net output with an ambient air temperature of 95°F and a cooling water temperature of 89°F. Figure 2 is a flow schematic of the gasification process for this project.

Under the terms of the DOE cooperative agreement, the project is divided into five budget periods. Budget Period 1 was conceptual engineering, analysis and planning. During this budget period, the plant definition was to be established and basic engineering was initiated. This budget period was completed in December of 1991. Budget Period 2 started January 1992 and runs through September 1993. Budget Period 2 included the completion of the Preliminary Plant Design, preparing a $\pm 20\%$ cost estimate of the Preliminary Design and obtaining the necessary Air Emissions Permits. Budget Periods 3 and 4 cover final engineering, procurement, construction, start-up and commissioning while Budget Period 5 is the five year demonstration period. At the end of Budget Period 5, the gasification plant would be removed if the customer did not wish to take possession.

ABB Lummus Crest Inc. (LCI) was retained to produce preliminary designs for the balance of plant, produce the preliminary plant estimate and assist in obtaining the Air Emissions Permits. In June 1992, ABB CE and LCI issued a budget estimate for Budget Periods 3 and 4 of $318,400,000. This estimate was developed using a factored equipment methodology and was independent of the Process Flow Diagrams, Piping & Instrumentation Diagrams and Equipment Specifications being developed during Budget Period 2. The engineering definition was not



* NOT TO SCALE

Figure 1

ABB C-E IGCC Flow Diagram

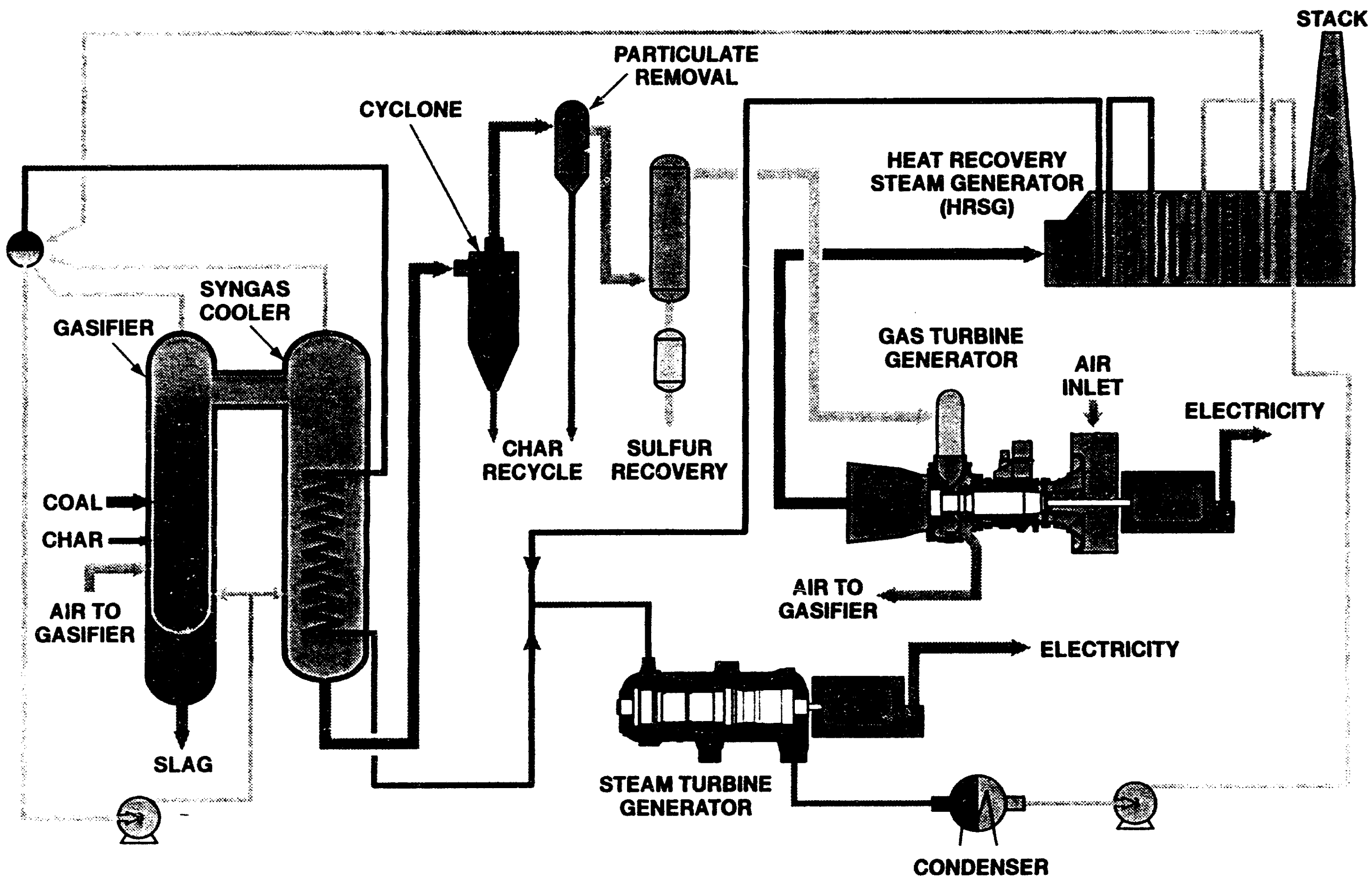


Figure 2

complete. There were no specifications or quotations obtained from vendors for this initial budget estimate and therefore the margin for error was high. This estimate was considered excessively high by all of the project participants.

During the second half of 1992, ABB Lummus Crest Inc. and ABB CE produced Process Flow Diagrams, Piping and Instrumentation Diagrams, Equipment Specifications and Quotations for almost all of the major equipment.

At the end of 1992, a decision was made by the Fundees to obtain an independent assessment of the project estimate. Duke Engineering and Services(DE&S) was retained to assess the design and produce a new estimate. DE&S used the design information generated by ABB Lummus Crest Inc. as a starting point for developing a total plant design. DE&S contracted for a labor study of the Springfield, Illinois area to determine actual labor rates. DE&S utilized their own data base for equipment, construction and operating costs. During this effort, several cost reduction efforts were initiated by ABB CE and DE&S. The plant was originally designed to maximize efficiency rather than minimizing cost per kilowatt of generation. The time constraints prevented performing a complete cost benefit analysis but some large systems were redesigned to reduce cost.

In April 1993, DE&S and ABB CE formally issued the new estimate of $274,400,000 for the Budget Periods 3 and 4. This is a complete turnkey plant estimate including Start-up and Commissioning. The estimate for Budget Period 5 is $133,200,000. The total, $407,600,000, is considered too high and the funding participants have decided not to continue funding the project in it present structure.

The high cost of this project is the result of many factors. The estimate developed for this project should not be used to compare air blown gasification to other gasification technologies. There are three primary factors which contribute to the high cost of this project when it is compared to other DOE IGCC projects. The small generating capacity of this facility, the lack of reusable equipment in the Lakeside location and site specific requirements.

The small size of this facility, 60 MW net output, results in a very high cost per kilowatt because some of the fixed costs on a development project are independent of size. Engineering costs are approximately $500 per net kilowatt. If the plant were five to ten times larger, the total cost of Engineering would essentially be unchanged. Since larger gasification projects generate significantly more megawatts, the cost per megawatt is substantially lower due to economies of scale. However, this does not mean that this is the wrong size for this plant. This is to be a demonstration project and the purpose is to determine the commercial feasibility and reliability of the technology. Given that this is a first of a kind plant, it is purposely kept small to minimize total capital expenditures and possible rework costs. It was not meant to have the optimum cost per kilowatt or compete with other gasification technology projects which are larger and second and/or third generation designs.

When the initial project estimate was conceived, it was to be a repowering project funded under the Clean Coal Program. Some of the equipment that was assumed to be usable, the steam turbine and generators, the steam turbine crane, turbine hall, feedwater treatment system and electrical transmission equipment was later found to be inadequate or limited in capacity. The customer, CWL&P, also imposed requirements that the gasification plant be independent of the existing boilers. Since the initial estimate was based on conceptual engineering, no definitive project scope had been developed or included in the contract, and thus, no adjustments were made which provided for an increased scope in the project funding. It was assumed that a typical owner's scope of supply would be provided. This assumption was incorrect. Major items such as rebuilding the natural gas pipeline for 1.5 miles and rebuilding the railroad spur added significant cost. There were no significant changes in the process equipment but there were substantial changes in the layout and scope of equipment. A layout of the gas turbine/heat recovery steam generator train was required that used both buildings and provided space for a symmetrical future gas turbine/heat recovery steam train. This required approximately 100 feet of high temperature (1000°F) ductwork to connect the gas turbine to the HRSG. The only existing systems that were used in the final design were the water supply tunnels and the waste water treatment facility. Building a complete new plant next to the existing buildings would be less expensive due to the avoidance of the building renovation costs. Additionally there was concern about construction activities damaging the City's public water supply pipelines which originate in this same building. Due to the possible consequences resulting from stopping the only water supply to the Capitol of Illinois and from the structural instability of the building while it was being renovated, DE&S was unable to obtain a quotation for insurance from any major carrier in the time that was available. Relocating and possible rebuilding of these water pipelines has been included in the project estimate.

The methodology used by DE&S and ABB CE to develop the operating budget for Budget Period 5 took into consideration the fact that the gasification facility would be a stand alone facility that would operate over the five year demonstration period at specific operating levels.

Being a stand alone facility, it was assumed that the unit would be staffed accordingly. It would be self-supportive and none of the spare parts, process chemicals, fuel, rolling stock, etc., purchased for the gasification facility would be shared with the existing Lakeside Station.

Several other factors were considered in developing the operating criteria and the resultant operating budget. First, DE&S and ABB CE utilized historical operating experience with conventional gas fired turbines, circulating fluidized bed boilers and atmospheric coal gasification technologies to develop estimated annual capacity factors. Second, vendor assistance in understanding operating characteristics for the proposed equipment was solicited; ie., char recycle system, hot gas desulfurization system and sulfuric acid production system.

Once the predicted operating criteria were finalized, operations and maintenance costs were developed for the five year operating budget plus a 20 month commissioning period. The O&M estimate included costs for labor, spare parts and consumables, fuel, process chemicals, waste disposal, transportation costs, nitrogen, auxiliary power costs and subcontract labor costs.

2.0 BACKGROUND

Combustion Engineering, Inc. has been involved in developing a coal gasification process to produce clean fuel gas from coal for power generation for over two decades. ABB CE has chosen to place the emphasis on developing a process for electric power generation by selecting an air blown, entrained-flow gasifier which operates in many ways similar to pulverized coal-fired boilers used by the electric power industry for many years.

In the early 1970's, under joint sponsorship of the U.S. Government and Consolidated Edison Company of New York, ABB CE evaluated various types of gasification schemes for electric power generation on terms of economic, technological and environmental considerations. The study recommended that a two-stage, entrained flow, low-Btu, slagging bottom gasification process be developed for utility power generation applications.

In 1974, ABB CE initiated a program under the joint sponsorship of the United States Energy Research and Development Administration (predecessor of the Department of Energy), the Electric Power Research Institute (EPRI) and ABB CE to develop a two-stage, atmospheric pressure, entrained-flow coal gasification system.

The process was developed in a Process Development Unit (PDU) located in Windsor, Ct. The unit gasified Pittsburgh seam coal at a nominal firing rate of 120 tons per day (TPD). The gas making operation at the PDU began in June 1978 and continued over a period of three years. The objectives of the program were to produce clean, low-Btu gas from coal and to provide the design information for scale-up to commercial-size plants. These objectives were met.

After completion of the PDU program, ABB CE directed its efforts to data analysis and the development of a pressurized version of the gasification process. Analysis of the PDU data has provided the basis for developing, refining and checking mathematical process models and design procedures. The engineering analysis performed has significantly enhanced ABB CE's ability to design multistage, entrained-flow gasifiers to allow more flexibility and to better predict performance.

ABB CE's continued development of its gasification technology led to the introduction of a pressurized version of its reactor. In the early 1980's, the design for a 2-TPD pressurized pilot plant was developed. This pilot plant was built in 1983 and ran until 1985. A second 2-TPD pilot with design improvements was built in 1985 and operated successfully.

In 1990, ABB CE began participation in the coal gasfication combined cycle repowering project that would provide a nominal 60 MW of electricity to City Water, Light & Power in Springfield, Illinois.

3.0 EQUIPMENT DESCRIPTION

Plant Layout

Like most repowering projects, there is not enough room left for new equipment to allow optimal layout. The gasification unit is in a separate building from the combined cycle equipment due to the lack of room in the existing building. A conceptual layout for the gasifier and auxiliaries is attached in Figure 3. The railroad line into the plant will be refurbished to allow heavy components to be transported into the site. After construction, the line will be removed to allow continued operation of the coal yard. The roads through the site must remain open during construction so that coal trucks delivering to the adjacent power facility are not obstructed.

Coal Storage System

Illinois No.5 coal is washed at the mine and delivered to the site in trucks. The trucks dump into open-top drive-over hoppers, with coal dropping into the receiving hopper. From the receiving hoppers, coal is transported by conveyor to the enlarged storage pile. This storage pile serves both the IGCC project and the existing Lakeside units. A new reclamation hopper beneath the coal pile reclaims coal from the storage pile and conveys it on a conveyor to the gasifier building. The reclaim hopper receives material by gravity after it has passed through a grizzly and a dust tight coal valve. The coal is transferred to the raw coal storage bunker in the gasifier building. The coal handling system for the existing Lakeside units remains unchanged and will be available throughout the construction period.

IGCC Coal Pulverizing System

The coal fed to the gasifier is pulverized in the pulverizer, while air, heated to 500°F, dries the coal to approximately 3 percent moisture and heats the coal to between 200 and 250°F. The coal is air classified by size in the pulverizer and pneumatically transported to the pulverized coal baghouse. In the baghouse, the coal is separated from the carrier air and the coal flows by gravity into the coal receiving bin. The carrier air, cleaned of particulate matter in the baghouse, is released through the coal vent stack.

Raw Coal Storage Bunker

The Raw Coal Storage Bunker will store enough coal for the operation of the gasifier for 24 hours. The bunker will feed the coal through a slide gate shut off valve and connecting pipe to the coal feeder. The Raw Coal Storage Bunker is sized to hold 1,200,000 pounds of coal.

Raw Coal Feeder/Pulverizer Mill

The raw coal feeder meters the flow of coal to the pulverizing mill. It is a volumetric feeder at the outlet of the raw coal storage bin. The coal pulverizer mill grinds the coal to a fineness that can be transported pneumatically and combusted in the gasifier. It is located below the raw coal feeder.

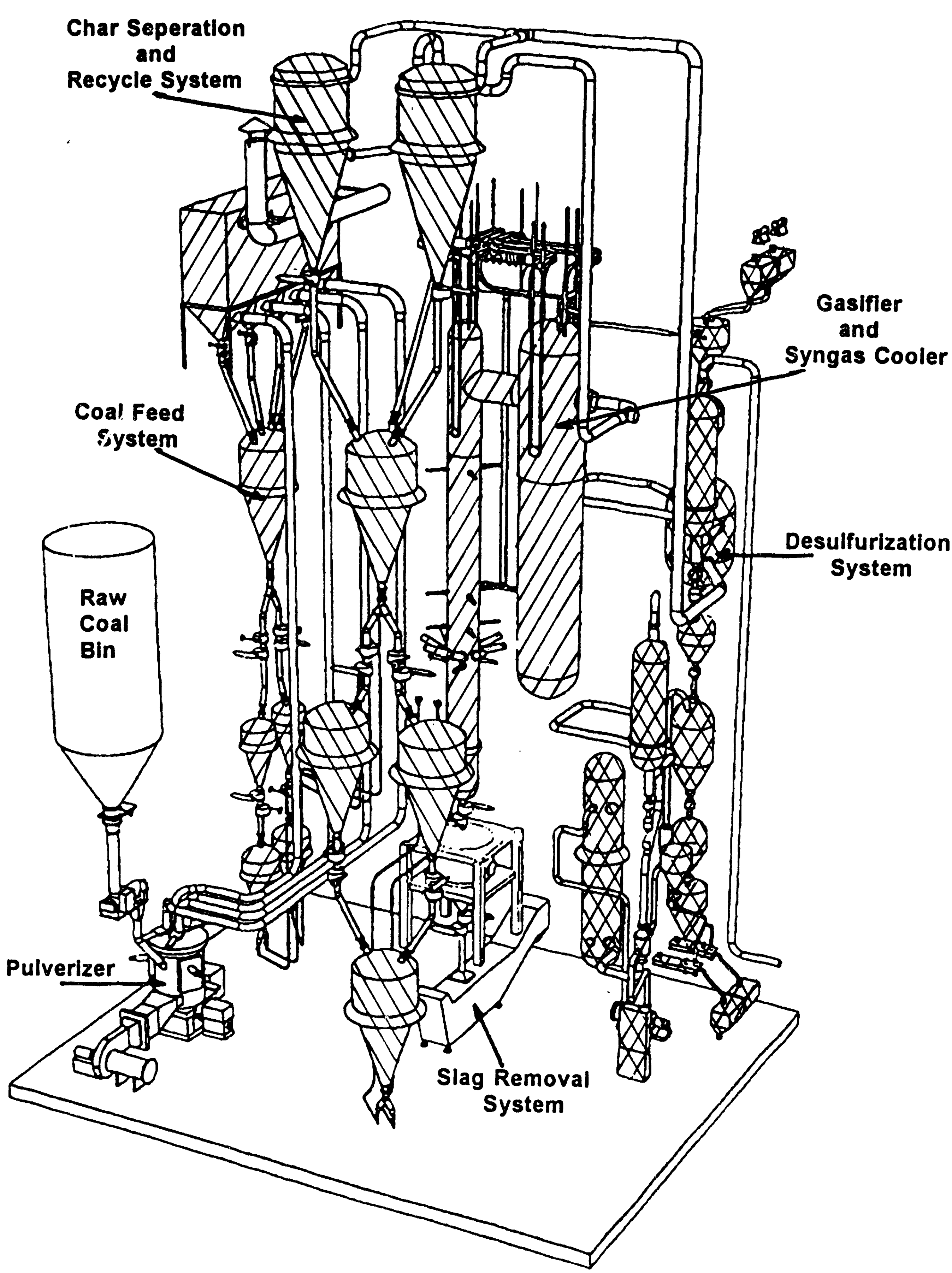

Char Seperation
and
Recycle System
Gasifier
and
Syngas Cooler
Coal Feed
System
Desulfurization
System
Raw
Coal
Bin
Pulverizer
Slag Removal
System

Figure 3

Pulverized Coal Baghouse

The pulverized coal is entrained in the air leaving the pulverizer and is transported through four individual pipes to the pulverized coal baghouse. The pulverized coal baghouse separates the transport air from the pulverized coal for storage in the coal receiving bin.

Pulverized Coal Receiving Bin

The pulverized coal continuously flows by gravity to the pulverized coal receiving bin. The receiving bin stores the pulverized coal for the intermittent feeding of the lockhoppers

Pulverized Coal Lockhoppers and Feed Bin

There are four pairs of coal handling valves which control the flow of pulverized coal into and out of each of the two lockhoppers. The pair of valves at the inlet of each lockhopper isolate the lockhopper from the receiving bin while the lockhopper is pressurized. The pair of valves at the outlet of the lockhopper isolate the lockhopper from the pulverized coal feed bin while the lockhoppers are depressurized and coal is flowing from the receiving bin into the lockhopper.

Pulverized Coal Flow Control Valves

The gasifier has three separate levels where the pulverized coal can be injected for combustion. Each level must be controlled separately. The pulverized coal flow control valves meter the flow of coal from the feed bin to the pickup Tee's and control the firing rate of each burner level in the Gasifier.

Gasifier/Heat Exchanger/Steam Drum

The gasifier and syngas cooler are utilized to produce a pressurized low-btu gas (LBG) or "syngas" stream which also contains char and H_2S. Pulverized coal is delivered and combusted in a deficiency of air. Gasification occurs in an entrained reactor. Sensible energy is removed from the gas in a heat exchanger called the syngas cooler. The gas exits the system for char removal and desulfurization. Coal ash is fused and tapped from the bottom of the gasifier as molten slag. All streams to and from the gasifier are pressurized.

Product gas leaves the gasifier and passes through a crossover and enters the syngas cooler. The bounding walls of the gasifier, crossover and syngas cooler are water cooled. The gasifier and syngas cooler are vertically oriented while the crossover is horizontal. Convective superheat surface is located in the syngas cooler. The heat transfer surface arrangement is configured to yield an outlet temperature over the operating load range which is within the limits imposed by the hot gas desulfurization system. Steam that is generated and superheated is integrated into the combined cycle.

The gasifier unit is a fusion welded, eight sided water walled pressure vessel. It consists of multiple stages for air, steam, coal and char introduction into the gasifier. The combustion zone is the lower section of the gasifier and the reduction zone is the upper section of the gasifier.

In the combustor, coal and recycled char are burned with almost all of the combustion air to form a hot gas to start the gasification reactions and melt the ash in the coal and char. In the oxygen deficient reductor, the rest of the coal reacts with CO_2 and water vapor to generate a synthetic gas consisting primarily of N_2, CO, H_2, water and char. The char consists of unreacted carbon, ash and trace metals from the coal. Collecting the char after it exits the gasifier and reinjecting it into the gasifier provides for complete burnout of all carbon in the fuel, thereby enhancing the efficiency of the process.

All surfaces exposed to gas from the slag floor to the outlet of the crossover are studded and covered with refractory. This includes the slag tap, waterwalls and all water cooled nozzles which penetrate into the gas pass. The product gas flows from the gasifier vessel at a temperature of approximately 2000°F, to the heat exchanger where it is cooled to approximately 1000°F before being piped to the hot gas desulfurization system.

The syngas cooler is comprised of a pressure vessel and an internal water cooled gas pass which contains convective heat exchanger surface. The arrangement has two vertical passes. Gas enters horizontally from the crossover and is directed into a downward channel. At the bottom of the channel it is redirected upward into the pass containing the convective surface. The downward gas pass and the upflow pass share a common division wall. Gas then enters a horizontal transition section which is coupled to a removable pressure vessel nozzle.

Steam is generated in the waterwalls of the gasifier vessel and the heat exchanger and superheated in the heat exchanger. Separation of the steam and water occurs in the steam drum. The waterwalls are contained inside of the gasifier and heat exchanger pressure vessels. The superheater elements are located in the gas path of the heat exchanger. Steam leaving the superheater is piped to the turbine for the generation of electric power. The annulus area between the gas pass and the ID of the pressure vessel is pressurized with steam at a pressure slightly higher than the gas pass. This maintains a blanket of non-corrosive gases on the internal walls of the pressure vessels to prevent possible corrosion by the product gas. A water seal accommodates the differential movements and provides for a gas tight seal between the annulus area and the gas pass. It allows for pressure equalization between the annulus and the gas pass during transients. Air for combustion of the coal is taken from the gas turbine compressor section. A booster compressor raises the pressure to that needed for the gasifier burners.

Slag Tank/Slag Grinder/Slag Grinder Vessel

The high temperatures in the combustion zone of the gasifier melt the slag which flows down the refractory covered waterwalls of the gasifier to the slag tap. Molten slag drops from the gasifier slag tap into a water filled tank located at the bottom of the gasifier vessel bolted to the bottom flange connection of the gasifier vessel. An inner cylindrical and conical shroud is used to funnel the slag to the grinder. The grinder is a motor driven shear shredder located inside the slag grinder pressure vessel. An auxiliary heat exchanger maintains the slag tank water temperature. Located beneath the gasifier vessel is the slag lockhopper with the associated double valving at the inlet and outlet.

Slag Lockhopper/Transport Conveyor System

The slag and water are discharged through a pair of valves to a lockhopper. The slag and water then flow through a second set of valves into a submerged scraper conveyor for dewatering and transport to the load out belt conveyor. The load out belt conveyor carries the slag to a three sided concrete ash storage bin. Ash will be loaded from the bin into trucks by a front end loader for disposal offsite.

Slag Water Recycling System

The water processing portion of this system consists of collecting and recycling as much of the slag quench and the slag lockhopper water as possible. This recycling will reduce the load on the industrial wastewater treatment facility and minimize the makeup water requirements. The water is sent to a new concrete lined settling basin located just outside the gasifier building.

Char Cyclone, Seal Bin and Char Removal Bagfilters

Product gas leaves the heat exchanger and flows through the char cyclone and then to the char removal bagfilters. The char removed in the cyclone flows by gravity via the char seal bin to the char receiving bin. Char collected in the bagfilters discharges by gravity to the char receiving bin. The baghouse is cleaned by pulsing the bags with low pressure steam. The filtered product gas is piped to the hot gas desulfurization system. The char cyclone and char removal bagfilters operate at approximately 1000 °F and 300 psi. The bagfilter is designed to use Nextel ceramic bags at present. Sintered metal and ceramic crossflow filters are also being considered.

Char Receiving Bin and Char Lockhoppers

The char is collected in the char receiving bin and feeds out intermittently to two char lockhoppers. The flow is controlled into and out of each lockhopper by pairs of char sealing valves. The char lockhoppers are pressurized with steam to a pressure higher than the operating pressure of the gasifier and intermittently discharge to the char feed bin by gravity. During start up and shut down, the lockhoppers and feed bin are pressurized using nitrogen. Inside of each lockhopper, receiving bin and feed bin, there are fluidizing devices to keep the char from compacting and keep the char flowing from vessel to vessel.

Char Feed Bin and Transport System

The char feed bin continuously feeds char through the flow control valves at a pressure high enough to overcome the gasifier operating pressure. The char is fed through either of the two flow control valves to char pickup Tee's. When the unit is operating, transport steam is introduced to carry the char to stream splitters where the char flow is divided and piped to the char burners. During start up, nitrogen is the transport medium. The char is reinjected into the gasifier at either or both char burner levels to finish volatilization of the char particles. There will be no waste stream other than slag during normal operation.

Hot Gas Desulfurization System

The syngas leaving the char removai baghouse has been cleaned of particulate matter. The syngas is expected to consist primarily of N_2, CO, H_2 and water with low concentrations of H_2S, COS, CS_2 and chlorides. The sulfur and chlorine compounds must be removed prior to combustion of the syngas in the gas turbine. To maintain the overall thermal cycle efficiency, the gas is not cooled before entering the gas desulfurization system. The syngas enters the absorber and flows countercurrent to a moving bed of zinc titanate (ZnTi) pellets. The absorber is a high pressure and temperature vessel filled with zinc titanate sorbent material. The gas enters the side of the absorber in the lower section and flows upward causing the gas to come in direct contact with the zinc titanate and the sulfur in the gas combines with the sorbent. The sulfur compounds (mainly H_2S, COS and CS_2) in the gas will react with the sorbent. Following sulfur adsorption, sorbent material is conveyed to a lockhopper and then to regeneration. In the regenerator, the metal oxide is regenerated and SO_2 produced. Regenerated sorbent, purged of SO_2 is recycled to the absorber lockhopper. The supply of regenerated metal oxide is slightly depleted during regeneration and handling. Fine particles of sorbent entrained in the cleaned gas stream are captured in a downstream high efficiency cyclone. The ZnTi fines, because of their high zinc content, are recycled to the sorbent supplier and will not be a waste byproduct. Chlorides are removed from the gas upstream of the absorber. Nahcolite is injected into the syngas after the char removal baghouse. The Nahcolite converts the chlorine into NaCl which is a solid and can be filtered out and disposed of offsite. Heat generated in the regeneration process will be used to generate steam which is piped back to the gasifier steam drum. The clean syngas is piped to the gas turbine for combustion. The SO_2 produced during sorbent regeneration is piped to the sulfuric acid production plant.

When a set pressure drop has been reached in the absorber on the gas side, a portion of the absorber bin's inventory is discharged through a lockhopper to the sorbent regenerator, At atmospheric pressure and under controlled solids flow rates, temperatures, air quantities and locations, the sorbent is regenerated by oxidation, producing an SO_2-rich gas which is cooled and sent to an acid plant for conversion to sulfuric acid. With the regeneration of sorbent completed, the sorbent is discharged from the bottom of the regenerator, screened and sent to a bucket elevator. The elevator carries the sorbent back to the top of the absorber where it is introduced back into the absorber feed bin. In this way the freshest sorbent is in contact with the cleanest gas to get the best sulfur removal. The cleaned gas leaves the absorber and any entrained particles are removed as the gas goes through the secondary cyclone.

Sulfuric Acid Recovery System

The gas stream leaving the regenerator of the hot gas desulfurization system consists primarily of SO_2 and nitrogen. The gas stream is humidified, cooled and dried so that the moisture remaining in the gas is equivalent to the water content of the product acid. The gas is heated in a recuperative heat exchanger against exiting gases and passed through a four stage catalyst bed, which converts 99+ percent of the SO_2 to sulfur trioxide (SO_3). The bed will be periodically cleaned and replaced as necessary. The mixture is further cooled in another recuperative heat exchanger and passed through either one or two contact absorption towers, where the SO_3 is absorbed into 98 percent H_2SO_4. The acid is then transferred to an acid storage tank. The acid is of commercial grade quality and represents a marketable byproduct rather than a waste stream. The sulfuric acid production plant is free standing and separate from the gasifier building or from the Lakeside Station building.

Gas Turbine

After particulate and sulfur removal, the syngas is fired in the combustion turbine. The turbine is a GE Frame 6 model. The turbine will have the capability to be fired with natural gas if the gasifier is out of service. The gas turbine is located in the renovated Lakeside Station building. The exhaust from the gas turbine is approximately 1030°F at full load. This exhaust gas is routed to the heat recovery steam generator. The air for the combustion of the coal and char in the gasifier is extracted from the compressor section of the gas turbine. A booster compressor controls the amount of air extracted and further increases the pressure of the combustion air. The air is cooled after extraction from the gas turbine. The heat is captured in a heat exchanger and is used to generate steam for the steam turbine cycle.

Heat Recovery Steam Generator

The heat recovery steam generator (HRSG) takes the hot exhaust gas from the gas turbine and recovers the heat to generate steam. The HRSG is able to fire natural gas to supplement the gas turbine output during high ambient temperature conditions and when the gasifier is off line and the gas turbine is firing natural gas only. The HRSG is located in the Lakeside Station building. The exhaust gas leaving the HRSG is ducted up and over the roof to a new stack. The HRSG will be delivered in preassembled modules with final assembly being performed in the field. The inlet ducting is a prefabricated and pre-insulated construction.

Steam Turbine

Steam from the HRSG plus steam from the waterwalls of the gasifier and various gasifier heat exchangers is piped to the steam turbine. The steam turbine will operate with steam at 1265 psia and 950°F at the throttle inlet valve. The steam turbine is connected to a synchronous generator that will produce 37 megawatts. The steam is exhausted from the turbine down into the steam condenser. The condenser cools the steam back to condensate and returns the water back into the cycle. The cooling water for the main condenser comes from the lake water circulation system.

Nitrogen Supply System

The Nitrogen Supply System (NSS) Provides N_2 which is used to pressurize, fluidize and displace coal in the lockhoppers and feed bin. It is also used as the conveying medium in the coal transport lines. Nitrogen is the purge gas in the coal feed vessels, the gasifier, heat exchanger, char feed and recycle vessels, hot gas desulfurization, gas turbine, flare and all interconnecting piping. Purging is necessary to prevent explosive mixtures from accumulating in the gasifier area. Nitrogen has been chosen as the purge gas because it is the least expensive inert gas that can be provided in the required quantities.

Plant Control System

The control and information system for the plant is a Distributive Control System (DCS) with a new control room located adjacent to the existing control room. The DCS consists of controller, console, data processor and high density I/O subsystems linked together by a data highway. Various plant maintenance functions can also be tracked and stored so that the system can inform staff of required equipment maintenance. All functions of the plant performance computer are accessible through the DCS control room console workstations or through the DCS engineer's console.

Demineralized Water System

The demineralized water system consists of three 40 gpm trains. Potable water is used as the demineralized water system supply. Continuous makeup to the condenser hotwell is supplied by the demineralizer water system at the normal system flow rate. Demineralized water is also supplied to the chemical injection package, the nitrogen supply system and is an emergency source of cooling for the gasifier cooling water heat exchanger. A 25,000 gallon capacity demineralized water storage tank is provided. Sulfuric acid used for system regeneration is obtained from the sulfuric acid storage tank located near the sulfuric acid plant. Caustic used for system regeneration is supplied by a 3000 gallon storage tank.

Feedwater Chemical Injection System

Boiler feedwater quality control is provided by a vendor supplied chemical injection package. The system conceptual design utilizes phosphate, morpholine and hydrazine additives.

Circulating Water

Circulation water will be taken from the intake tunnel by two motor driven pumps. A flow of 50,400 gpm will be sent to the surface condenser. The remaining flow will be diverted to the slag water makeup pond and the closed loop cooling system.

Potable Water System

The potable water system distributes potable quality water to the existing building, the new gasifier building and the surrounding areas. Potable water is supplied to a system header by the existing CWL&P site potable water system. No new makeup pump or storage capacities are employed.