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(DE94000005)

Combustion Engineering Integrated Gasification Combined Cycle (IGCC) Repowering Project -- Clean Coal II Project

Annual Report
November 20, 1990 - December 31, 1991

March 1993

Work Performed Under Contract No.: DE-FC21-90MC26308

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
ABB Combustion Engineering Systems
Windsor, Connecticut

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ANNUAL TECHNICAL PROGRESS REPORT

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I EXECUTIVE SUMMARY

CE is participating in a $270 million coal gasification combined cycle repowering project that will provide a nominal 65 MW of electricity to City, Water, light and Power (CWL&P) in Springfield, Illinois. The IGCC system will consist of CE's air-blown entrained flow two-stage gasifier; an advanced hot gas cleanup system; a combustion turbine adapted to use low-BTU gas; and all necessary coal handling equipment.

The project has just completed the first budget period of five. The major activities during this budget period were:

- Establishment of a design, cost and schedule for the project.
- Resolution of project business issues.
- Establishment of financial commitments.
- Acquire design and modeling data.
- CWL&P renewal and replacement activities.
- DOE data requests for the environmental process.

A Project Management Plan was generated. The conceptual design of the plant was completed and a cost and schedule baseline for the project was established. Preliminary engineering specifications for major equipment were done and preliminary process flow diagrams and plant arrangements were drawn. Environmental permitting activities were begun. All major project agreements were concluded.

II INTRODUCTION

CE is participating in a $270 million coal gasification combined cycle repowering project that will provide a nominal 65 MW of electricity to City Water, Light & Power (CWL&P) in Springfield, Illinois. The CE project will demonstrate Integrated Gasification Combined Cycle (IGCC) technology in a commercial application by repowering an existing CWL&P Plant in Springfield, Illinois. The project duration will be 126 months, including a 63-month demonstration period.

III PROJECT DESCRIPTION

The IGCC system will consist of CE's air-blown, entrained-flow, two-stage, pressurized coal gasifier; an advanced hot gas cleanup process; a combustion turbine adapted to use low-Btu coal gas; and all necessary coal handling equipment. CWL&P's Lakeside Station (Figure 1) will be the site for this project. The result of repowering will be an IGCC power plant with low environmental emissions and high net plant efficiency. The repowering will increase plant output by 40 MWe through addition of the combustion turbine, thus providing a total IGCC capacity of a nominal 60 MWe. Nearly half of the project will be funded by the United States Department of Energy (DOE), under the Clean Coal II Program, while CWL&P, State of Illinois, and CE will fund the rest.

The IGCC will include CE's slagging, entrained-flow, gasifier operating in a pressurized mode and using air as the oxidant. The hot gas will be cleaned of particulate matter (char) which is recycled back to the gasifier. After particulate removal, the product gas will be cleaned of sulfur prior to burning in a gas turbine.

The proposed project includes design and demonstration of two advanced hot gas cleanup processes for removal of sulfur from the product gas of the gasifier. The primary sulfur removal method features a newly developed moving-bed zinc ferrite system downstream of the gasifier. CE intends to use the General Electric (GE) moving bed, zinc ferrite sulfur removal system currently being piloted by GE Environmental Systems, Inc. The process data from these pilot tests is expected to be sufficient for the design of a full-scale system to be used in the proposed demonstration.

A second complementary process is in situ desulfurization achieved by adding limestone or dolomite directly to the coal feed. The benefit, should such an approach prove viable, is that the downstream cleanup system could be reduced in size.

In this plant, the gasifier will be producing a low-Btu gas (LBG). The LBG will be used as fuel in a standard GE gas turbine to produce power. This gas turbine will have the capability to fire

LBG and natural gas (for start-up). Since firing LBG uses less air than natural gas, the gas turbine air compressor will have extra capacity. This extra compressed air will be used to pressurize the gasifier and supply the air needed in the gasification process.

The plant is made of three major blocks of equipment as shown in Figure 2. They are the fuel gas island which includes the gasifier and gas cleanup, gas turbine power block, and the steam turbine block which includes the steam turbine and the HRSG.

As major equipment sections are completed, they will be individually started up and brought on-line to produce power. The gas turbine equipment will have the shortest lead time so this equipment will be installed, checked out, and brought into commercial service first. Initially, the gas turbine will be fired on natural gas operating as a combined cycle with a new heat recovery steam generator and a new steam turbine. All of this equipment will be checked out and operated prior to the start-up of the gasification plant.

The last major block of equipment will be the fuel gas island including the gasifier and gas cleanup equipment. When this equipment is put into operation, the plant will be a fully integrated coal gasification combined cycle plant.

IV RESULTS

a) PERFORMANCE SUMMARY

The DOE/CE Cooperative Agreement requires that CE complete the CE IGCC Repowering Project as spelled out in the Statement of Work with funding controlled by a number of Budget Periods.

This report covers the work performed in Budget Period 1. This Budget Period includes the first twelve months of the project and includes the following:

- Establishment of a design, cost, and schedule for the project.
- Resolution of Project business issues.
- Establishment of financial commitments.
- Acquire design and modeling data

- CWL&P renewal and replacement activities to insure that the project is compatible with the existing Lakeside Station.
- Resolution of DOE data requests as required for the NEPA process.

These work items were accomplished by a series of deliverables including:

- Project Evaluation Plan.
- Budget Period 1 Deliverables list.
- Major Project Agreements.
- Project Funding.
- Preliminary Engineering List.
- Cost Estimate.
- Gasifier Data.
- Zinc Ferrite System Design.
- Conceptual Design.
- List of Environmental and Construction Permits.
- CWL&P R&R Activities.
- Market Analysis.

All Budget Period 1 deliverables have been completed as required.

b) WORK BREAKDOWN STRUCTURE (WBS)

The Work Breakdown Structure for the Project is shown in Figure 3.

c) BUDGET PERIOD #1 ACCOMPLISHMENTS.

The required information as previously described was developed and submitted to the DOE as a series of deliverables. A list of these deliverables is found in Table 1. A Project Evaluation Report, a Continuation Application, an Environmental Monitoring Plan Outline, an Environmental Assessment were made. In addition several papers were submitted.

All the required plans and agreements were completed. Monthly status reports, quarterly status reports and quarterly review meeting minutes were issued during the budget period.

TABLE 1
BUDGET PERIOD #1 DELIVERABLES LIST

Deliverable	Completion date
Environmental Impact Volume	12/89
Environmental Monitoring Plan Outline	1/91
Kickoff Meeting Minutes	1/91
Project Evaluation Plan	3/91
Quarterly Status Reports	5/91, 7/91, 10/91, 1/92
Project Management Plan BP1	5/91
Environmental Assessment/FONSI (awaiting DOE approval)	4/91
Zinc Ferrite Design Report (initial)	10/91
Data Requirements	10/91
Project Evaluation Report	10/91
Continuation Application for BP2	10/91
1991 Gasification Conference	8/91
Plans and Agreements	1/89, 10/90, 11/90, 12/90, 5/91
Status Reports	as required

All commitments for project funding with DOE, CWL&P and ENR were completed and documented.

During Budget Period 1 a conceptual design of the plant was made. A steam cycle study recommended the replacement of the existing steam turbine with a new single pressure machine. A plant design philosophy and a plant cycle were developed. Based on these inputs, plant and equipment specifications were made. Component designs were developed or the specifications sent to vendors. The gasifier and its heat exchanger were selected and designed by CE. Other equipment was such as cyclones and barrier filters were specified by vendors. With the

conceptual designs provided, plant arrangement layouts and the individual sub-system drawings were made. The specifications and arrangement drawings were complemented with Process Flow Drawings and energy balances.

The plant cost was re-estimated based on the preliminary engineering work described.

A design report on the Zinc Ferrite hot desulfurization system was issued by GE. This report summarized the work done at GE's demonstration facility. To date preliminary test operation of their integrated fixed bed gasifier and the GEESI moving bed hot gas cleanup system has been completed. The first long term duration test has been completed. Recently added program tasks have allowed inclusion of a modified GE MS-6000 gas turbine combustor, impingement cooled transition piece and an air cooled, LM-6000 airfoil-based gas turbine simulator. Three more long duration tests are currently scheduled.

At CE KDL laboratory design support tasks were carried out. They are Flow Modelling Tests and Fuel Transport Tests.

The Flow Modeling Tests were made to assure that the required fluid mechanics occurred in the gasifier. This program consisted of two major parts. The first was to build and test a flow test facility to verify that gas only simulations of gas and solid streams would be acceptable for the expected range of gasifier operation. The second was the construction and testing of a ½ scale three-dimensional cold flow model. Gasifier fluid mechanics performance was studied by both qualitative and quantitative techniques.

The Fuel Transport Tests were made to provide design information such as: appropriate transport line size, pressure drop correlations, solids to gas ratio, and flow smoothness information. Coal has been transported successfully at conditions similar to the design conditions of the Demonstration Plant.

A list of the construction and environmental permit requirements and a schedule for application and permitting were prepared.

CWL&P renewal and replacement (R&R) activities have progressed. To provide space in the Lakeside building for part of the equipment required for the project, an asbestos abatement and demolition program is required. A specification was written and a contractor was selected. An upgrade of the rail spur to the Lakeside Station is being planned with a cost and schedule being developed.

The market for CE IGCC systems has been re-examined during Budget Period 1. The conclusion is that coal will emerge as the primary fuel during the late '90s which is about the same time that CE's IGCC systems will be commercialized. At that time it is believed that the power demand will pick up.

The work performed in Budget Period 1 went as anticipated. Areas perceived as having technical uncertainties or risks were targeted. In these cases, additional efforts were made such as using well-known consultants in those fields to identify weaknesses and to propose solutions, performing testing, and making all possible efforts to secure quality quotations from vendors. These efforts lead us to believe that all technical areas have manageable and sound engineering solutions.

d) WORK TO BE COMPLETED DURING THE NEXT BUDGET PERIOD.

The following tasks describe the work planned for the next budget period.

Task 1.3 Permitting and Environmental Activities

This task will include all of the required environmental activities necessary to construct and operate the plant. CE will start to obtain the necessary permits from the appropriate State, Local, and Federal agencies overseeing environmental regulations based on the permit schedule established previously in Budget Period 1.

Task 1.4 Preliminary Design and Basic Engineering

CE will complete all activities for the preliminary design and basic engineering of the demonstration plant including equipment specifications, P&ID's, engineering drawings, process descriptions, process control schemes, instrumentation specifications for process performance

and environmental data collection, and all other activities necessary to begin detailed plant design and construction including a list of long lead procurement equipment and materials.

Task 1.5 Design Support

This task is used for performing studies in support of engineering and design tasks. A topical report will be produced and made available to DOE which delineates the findings and analysis for each design support area studied in order to complete the design of the plant.

Support studies may include:

- Materials Recommendations
- Fuel Feed Modeling
- DTFS Testing
- Water Wall heat flux tests
- Instrumentation Recommendations
- ADARS
- Fuel Nozzles Mockup
- Hot Gas Cleanup
- Transient Study

Task 1.6 Project Plans, Licenses, and Agreements

CE will develop the plans necessary to implement the project and obtain the licenses, construction permits and perform other business related activities required. A schedule of construction permits established in Budget Period 1 will be used to perform this task.

Task 1.8 Procurement Documentation

CE will prepare all procurement documentation for long lead items.

Task 1.9 Technical Reports

This task covers the preparation of technical reports.

Task 1.10 Project Management, Accounting and Reports

This task will cover the activities required to manage the project including cost accounting, project review, meetings and scheduling.

Task 1.11 and Task 2.11 CWL&P R&R Activities

This task covers the renewal and replacement activities that CWL&P must perform in support of the CE IGCC Repowering Project. These activities include asbestos abatement and demolition work, upgrade of a railspur to the Lakeside Station and improvements to the 138KV system as well as other Lakeside demolition and refurbishment.

V ENVIRONMENTAL DISCUSSION

a) NEPA SUPPORT

NEPA support consisted of submitting and updating the Environmental Information volume, making presentations on its content to CWL&P, ENR, DOE METC, and DOE Headquarters personnel. Included within the document were the results of environmental surveys and modeling of the Lakeside site and the impact of the IGCC plant.

There was frequent interaction with METC to facilitate responses to Headquarters (Environmental, Health and Safety) questions. The NEPA was finally satisfied as METC prepared the Environmental Assessment and Headquarters granted the Finding of No Significant Impact.

b) ENVIRONMENTAL AND CONSTRUCTION PERMITTING

A list of the required permits for Environmental and construction activities was assembled. This list is shown in Table 2.

c) EMPO

An Environmental Monitoring Plan Outline, which contained recommendations of where and what to monitor in the process was prepared. Feedback was received from METC and the EMPO was finalized.

REQUIRED AND POTENTIAL REGULATORY PERMITS AND APPROVALS FOR IGCC PROJECT

REQUIRED PERMITS	RESPONSIBLE AGENCY	SCOPE	RESPONSIBLE FOR APPLICATION
Prevention of Significant Deterioration (PSD) review for modification to major source			
A. Construction Permit	IEPA Air Division	Project air emissions; modeling of ambient impacts	
B. Operation Permit	IEPA Air Division	Project air emissions; operation of facility	C.E. Environmental Inc.
NPDES permit modification	IEPA Water Division	Point-source discharges of project wastewaters	C.E. Environmental Inc.
Permits to construct and operate industrial pretreatment works	IEPA Water Division	Construction and operation of wastewater pretreatment facilities	C.E. Environmental Inc.
Industrial wastewater discharge permit	Springfield Metro Sanitary District	Discharge of project wastewater to public sanitary sewer system	C.E. Environmental Inc.
Building and occupancy construction permits	City of Springfield Develpment Department	Construction/alteration and occupancy of buildings and plumbing, heating, electrical systems	C.E. Environmental Inc.
Notice of Proposed Construction	Federal Aviation Admin.	Construction of new exhaust stack	C.E. Environmental Inc.
Notice of Construction or alteration	Ill. D.O.T. Division of Aeronautics	Construction of new exhaust stack	C.E. Environmental Inc.

TABLE 2

POTENTIALLY REQUIRED PERMITS	RESPONSIBLE AGENCY	SCOPE	RESPONSIBLE FOR APPLICATION
Operating Permit for coal delivery, handling and storage system (new or modified)	IEPA Air Division	Operation of new coal handling and storage systems	C.E. Environmental Inc.
Supplemental permit to modify solid waste management site development and operating permits for treatment and or storage facilities (required if solids are waste and not commodity)	IEPA Land Division	Storage of project solid wastes or sulfur in on site contained storage	C.E. Environmental Inc.
Supplemental solid waste stream authorizations (required only if solids are landfilled)	IEPA Land Division	Off-site storage/disposal of each project solid waste	C.E. Environmental Inc.
Supplemental solid waste stream hauling permit (required only if solids are hauled out by CWL&P)	IEPA Land Division	Road transport of project solid waste	C.E. Environmental Inc.
Flood hazard area development permit (required only for construction outside the existing berms)	Springfield-Sangamon County Regional Planning Commission	Development (including storage of materials) in flood hazard area	C.E. Environmental Inc.
Radioactive materials report	N.R.C. (Nuclear Regulatory Commission)	Reporting of presence of radio-active materials	Instrument Manufacturers (as Required)
Laboratory Certification	To be determined if required	Modification of existing certification if required	CWL&P
Section 404 Nation wide permit (required only for construction of new intakes or outfalls)	U.S. Army Corps of Engineers. IDOT Water Resources Division	Construction of new intake or outfall structures in Lake Springfield or Sugar Creek	C.E. Environmental Inc.
Highway/Roadway Utilization Permits	Illinois State Highway Dept./City of Springfield	Truck Delivery of large heavy equipment as required	Equipment Shipping Company
Railroad Utilization	Railroad Clearance Bureau	Rail delivery of large equipment	Rail Transportation Company

TABLE 2

REQUIRED CERTIFICATION/CLASSIFICATION/INSPECTION	RESPONSIBLE AGENCY	SCOPE	RESPONSIBLE FOR APPLICATION
NEPA Documentation	DOE	Assessment of project environmental impacts	C.E. Environmental Inc.
Environmental Monitoring Plan	DOE	Compliance and environmental characterization monitoring	C.E. Environmental Inc.
Large-scale development review	City of Springfield	Industrial development on more than 1/2 - acre	C.E. Environmental Inc.
Modification of emergency and health and safety plans	U.S. Occupational Safety and Health Administration	Project occupational safety and health	C.E. Environmental Inc.
Boiler and pressure vessel Safety Inspection Certificate	Ill. State Fire Marshal Div. of Boiler and press. vessel safety	Installation and operation of new boilers and pressure vessels	Boiler and Vessel Manufacturers
Request for special waste classification	IEPA Land Division	To classify waste or commodity for sulfur and Zn fines	C.E. Environmental Inc.
Spill prevention, control and counter measures plan	IEPA	Plans for prevention and controls for spills of oil/hazardous materials	C.E. Environmental Inc.

TABLE 2

VI TECHNICAL DISCUSSION

The basic technical goal for Budget Period 1 was to develop a conceptual design for the project and to use this to update the preliminary schedule and cost estimate for the project. The following sections describe the major technical activities.

a) CONCEPTUAL CYCLE STUDIES

From a conceptual standpoint the gasifier and the gas turbine portion of the combined cycle are relatively straight forward. The steam cycle, however, needed to be examined in significantly greater detail to determine the optimum cost versus cycle efficiency. A study of steam cycle options was undertaken to resolve these cost and performance issues.

Several options for the steam cycle were available. The options were:

1. Modify the existing steam turbine/generator.
2. Modify the existing steam turbine/generator plus add a new topping turbine.
3. New reheat steam turbine/generator.
    a. 2400 psig throttle
    b. 1800 psig throttle
4. New non-reheat steam turbine generator.
    a. 1500 psig throttle
    b. 1250 psig throttle

Each of the options was rated based on the heat rate effect they had on the overall plant. The heat rates ranged from below 8200 btu/kwh to over 9800 btu/kwh. Each option was also rated on the impact on the cost of the plant. Criteria that were used to generate the cost ranking were: turbine generator costs (new/modified), HRSG costs, foundation costs, piping costs, and auxiliary equipment costs.

One conclusion of the study was the elimination of option 1 because the heat rate was too high. It was felt that this high heat rate was incompatible with the goals of the project. Of the remaining options option 4b was the most cost effective. The conceptual design was therefore completed using that option in the combined cycle.

b) HEAT AND MATERIAL BALANCES

Conceptual level heat and material balances were done for the cycle analysis mentioned above. After selecting the cycle configuration, additional heat and material balances were completed to determine the pressure, temperature, and flows for the major process equipment. These results were used to help write system duty specifications and equipment duty specifications for the conceptual design. An overall plant heat and material balance was done to estimate cycle performance. A summary of the results of this balance is given in Table 3.

Table 3

Project Performance Summary

Coal to Gasifier (TPD)	580
Combustion Turbine Power (Mwe)	33
Steam Turbine Power (Mwe)	32
In-Plant Use (Mwe)	5
Net Power (Mwe)	60
Heat Rate (Btu/Kw)	8800

c) PROCESS FLOW DIAGRAMS

A conceptual design was developed for the plant and process flow diagrams were generated for the following systems:

- Gasifier and Heat Exchanger
- Coal Prep and Feed System
- Char Recycle System
- High Temperature Sulfur Removal
- Product Gas Train
- Steam System
- Coal Handling
- Slag Handling

Simplified flow diagrams for these systems are shown in Figures 4 through 7.

Figure 4 shows the CE IGCC Flow Diagram. This shows the overall concept for the IGCC. Figure 5 Shows the coal Preparation and Feed System. Figure 6 shows the Char System including particulate removal, and Figure 7 shows the Sulfur Removal System. The steam system is shown on the IGCC flow system diagram. Coal Handling and Slag Handling are not discussed here because they deal with more conventional equipment.

d) PRELIMINARY ARRANGEMENT

Using the process flow diagrams and the mass and energy balances, preliminary equipment specifications were generated for the major process equipment. From this the size of this equipment was estimated and a preliminary arrangement for the gasifier island was drawn. The gasifier island equipment includes the gasifier and heat exchanger, the char recycle equipment, the HGCU system, and the coal feed system. Not included in the gasifier island is the coal handling from the coal pile or the sulfur recovery part of the HGCU system. Also not included is the HRSG, Gas Turbine, and Steam Turbine. A bird's eye view of the gasifier island is shown in Figure 8. The gasifier is arranged at the center of the gasifier island structure.

This preliminary arrangement is used to estimate piping runs and other equipment requirements that would need approximate dimensions of the structure. The actual arrangement of the plant will probably change significantly once the basic engineering begins in a later Budget Period.

Other arrangement drawings, not included here, were made for the Lakeside building modifications for the combined cycle including several alternate methods of installing the combined cycle equipment. Over all site plot plans were also generated to study possible locations for the various IGCC equipment.

e) EQUIPMENT

The process flow diagrams and the mass and energy balances were used to generate system and equipment duty specifications. These specifications identified the equipment needed for the project and were used to reconfirm the project cost estimate. The following sections describe the equipment anticipated to be used in the gasification portion of the plant.

i) COAL FEED

The coal preparation and feed system is designed to pulverize crushed coal, dry and heat it, feed it through a pressure barrier, and meter it into the gasifier. The system utilizes lockhoppers to overcome the pressure barrier and a pressurized feed bin with metering devices to smoothly feed pulverized coal into feed lines. Inert gas will be used to convey

the coal to the gasifier, which avoids undesirable reactions between the coal and its transport medium.

Crushed coal from the raw coal bin will be metered into a pulverizer by the raw coal feeder. The pulverized coal will be dried and conveyed to a separation system which is positioned above the feed system (to promote gravity flow into the various feed system vessels). The coal flows by gravity through a coal heater, a receiving bin, then into one of two lockhoppers. Each lockhopper will be capable of pressurizing its contents from atmospheric pressure to the gasifier operating pressure and discharging its contents into a feed bin at this pressure. The lockhoppers will be sequenced in such a way that one will be filling will the other is dumping coal into the feed bin. The feed bin will provide a relatively stable inventory of coal which can be metered smoothly into the gasifier.

Metering devices drop the coal into their respective pickup devices, where an inert gas mixes with the coal and transports it through coal feed lines to the gasifier.

An alternate coal feeding system which is being considered involves the use of a Kinetic Extruder, designed by MPG (now Penn Trading Co.) and Lockheed. This device would feed coal through the pressure barrier and into the feed bin.

ii) PARTICULATE REMOVAL

The particulate removal system is utilized to remove all the char in the product gas line and return it to the gasifier. There are two particulate removal devices in series. The first is a cyclone with a barrier filter following. The cyclone removes the larger size particles while the barrier filter removes the remainder. The cyclone may be either a single stage or two stages in series. The barrier filter may be any of the new technologies available. The leading candidate for the barrier filter is a design which is similar to a conventional baghouse, but with an advanced high temperature material for the bags. With the baghouse concept, the particles are collected on the outside of the bags. To remove the collected material a cleaning system and media is required. The method is periodic pulsing. This is called a pulse jet system and is integral with and

supplied with the baghouse. The cleaning cycle is established by monitoring the pressure differential across the collector. When a target pressure differential is reached, either all or some of the collecting elements are cleaned.

iii) CHAR FEED

The ungasified char collected from the product gas is repressurized and fed back into the gasifier. Inert gas is utilized to convey the char to the gasifier.

Char reclaimed from the product gas is deposited in a receiving bin. From the receiving bin char flows by gravity into one of two lockhoppers, where it is pressurized and gravity fed into the char feed bin. The lockhoppers are sequenced in such a way that one will be filling while the other one is discharging into the feed bin. From the feed bin char is metered through pickup devices and conveyed through feed lines.

iv) GASIFIER AND HEAT EXCHANGER

The gasifier and its heat exchanger are utilized to produce a pressurized product gas stream containing 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 the heat exchanger. 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 the gasifier are delivered pressurized.

Product gas leaves the gasifier and passes through a crossover and enters the heat exchanger. The bounding walls of the gasifier, crossover, and heat exchanger are water cooled. The product gas is cooled in the heat exchanger with both water cooled and superheat heat transfer surfaces. The heat transfer surface arrangement is of a configuration that will yield an outlet gas temperature over the operating load range which will satisfy the requirements of the hot desulfurization system. The steam flow generated and the superheating of steam is integrated into the steam cycle.

In the gasifier, the stream of molten slag continually flows through a slag tap into a slag tank. Quench slag is periodically let down from this tank. The slag tank is located just below the gasifier.

A sootblower system will be provided to clean all the water cooled bounding walls and the heat transfer surface in the heat exchanger. Cooling water via inlet and return lines is provided for those components that require it.

v) AUXILIARY EQUIPMENT

A list of the major auxiliary equipment was compiled. This list was used to estimate the auxiliary power requirements for the plant. The list is presented in Table 4.

vi) HOT GAS CLEANUP

The hot gas desulfurization system that CE is considering to use for this system is being developed by GE. It is a sorbent system as developed by METC. The GE version of this system is known as a moving bed system. This system and the current status of pilot plant testing is described in the paper presented by GE at the 1991 METC Coal Gasification Contractors Conference: "Integrated Operation of a Pressurized Fixed Bed Gasifier and a Hot Gas Desulfurization System".

The sorbent originally considered for this application is Zinc Ferrite. However, it may be recommended by GE that the sorbent be changed to Zinc Titanate, a potentially more durable and cost effective sorbent candidate.

CE is committed to incorporating a full scale hot gas desulfurization system into the demonstration plant, if it is technically and financially feasible. If possible, CE intends to use the GE HGCU system. However, CE reserves the right to develop its own design, and even to incorporate a small pilot plant HGCU on a slip stream of the product gas at the demonstration plant. There are several areas of technical and financial uncertainties.

TABLE 4

PLANT AUXILIARY EQUIPMENT

GASIFIER ISLAND:

- Coal Pulverizers
- Coal Crushers and Conveyors
- Coal and Char Feeders
- Coal Pulverizer System FD Fan
- Coal Pulverizer System ID fan
- Coal Heater Condensate Pump
- Gasifier Circulation Pump
- Slag Handling System
- Hot Gas Desulfurization System
- Sulfur Recovery system
- Heat Tracing
- Booster Air Compressor
- Raw Water Supply
- Gasifier Process Water
- Waste Water Treatment

COMBINED CYCLE:

- GT Auxiliaries
- Feedwater Pumps
- Condensate Booster Pumps
- Condenser Circulation Pumps
- Cooling Tower Pumps
- Cycle Make-up Water

MISCELLANEOUS:

- Transformer, Switchgear, Lighting, etc
- Instrument Air Compressor
- Heating Ventilation & Air Conditioning

They are: -Performance guarantees
-Sorbent attrition
-Long term performance
-Durability of components
-Steady state regeneration of sorbent
-Sorbent Selection

Because of the issues raised, CE intends to continue the design only of an alternate cold desulfurization system just in case the technical and financial issues with HGCU are insurmountable. CE intends to continue this design through Budget Period 2 at least.

f) SUPPORT TASKS

i) FUEL FEED (TRANSPORT)

Coal transport studies were conducted to support the CE IGCC Repowering Project in 1991. The purpose of these tests was to provide as much practical information for the field design as possible, including appropriate transport line size, pressure drop, solids to gas ratio, and flow smoothness information.

The test program consisted of construction, shakedown, and operation of a test rig laid out to replicate, as closely as possible, the total transport distance, vertical rise, and direction changes expected in the field gasifier installation. A pressurized feed hopper suspended on weigh cells with a variable speed rotary valve was used to meter coal into the transport line. This hopper included an air fluidizing pad for maintaining the coal in a fluidized state at the rotary valve inlet. Main transport air and fluidizing air were metered via orifices. One inch schedule 40 pipe was used to transport the coal.

For cost and material disposal considerations the test rig used an available 100 psi source of compressed air. A capacitance flow meter was used near the top of the vertical test section to monitor transport air density and coal velocity. After transport, the coal air mixture entered a cyclone and a pressurized receiving hopper. The pressurized air was then relieved to a baghouse. The test rig was extensively instrumented.

Results from the test were that coal was transported successfully at conditions similar to the design conditions of the demonstration plant. Also horizontal and vertical pressure

drops correlated well using a combined theoretical and empirical equation which accounts for frictional, extrusion, and hydrostatic pressure drops.

ii) FUEL PROPERTIES

A test was performed on a sample of the design coal for the project, Illinois #5 coal. The tests were done to determine the characteristics of the coal when subjected to elevated temperatures in the presence of air. The results of these tests were then used to make decisions on the configuration of the coal handling and coal feed systems. Results of these tests are considered proprietary and are not presented here.

iii) FLOW MODELING

Flow modeling was done at CE's KDL laboratory to characterize the gasifier. The objective of the modeling program was to develop a gasifier design which would provide performance over the range of expected operating conditions.

In order to assure that the required fluid mechanics occur in the gasifier, a cold flow model test program was undertaken. The program consisted of two major parts. The first was to build and test a cross flow test facility to verify that gas only simulation of gas and solid streams would be acceptable for the expected range of gasifier operation. The second was the construction and testing of a 1/2 scale three-dimensional cold flow model.

The model was constructed from plexiglas to facilitate observation, with ambient temperature air being used as the principle modeling fluid.

Gasifier fluid mechanics performance was studied by both qualitative and quantitative techniques. The qualitative technique was a flow visualization technique developed at KDL. The quantitative measurements included both steady state methane concentration and three-dimensional velocity measurements for flow patterns.

Results of the flow tests indicated that the geometry selected for this gasifier met the requirements of proper mixing of fuel air and product gas in the reactor. Further, it was

shown that the proper orientation of the fuel nozzles was important. These results are being incorporated into the design of the gasifier vessel.

iv) GASIFICATION DATA

The DOE/CE Cooperative Agreement specifies that CE consider data obtained from other gasification plants in relation to CE's demonstration plant. Accordingly, at the request of DOE, CE attended the Japanese/U.S. Joint Gasification Meeting in Tokyo, Japan 25-27 September 1991. This meeting included a discussion of and a field trip to a gasifier which is in startup and has just completed a preliminary gasification trial. During the meeting data from a six-hour gasification run at 50% load was provided.

It is important to point out that CE's demonstration project is based on CE's 120 TPD PDU. Information from other plants is not necessary for the design of CE's gasifier. In fact, the design and performance of CE's gasifier were determined prior to beginning work on Budget Period 1.

Information obtained from other plants will be used to monitor progress at these plants. The information will be used to assess the performance. If any problem thus uncovered is determined by CE to impact the demonstration gasifier, CE will develop its own solution for application to the demonstration program. CE will keep the DOE advised as to the use of additional data.

VII) SITE RELATED ACTIVITIES

CWL&P renewal and replacement activities in support of the CE IGCC Repowering Project are ongoing.

In order to provide space in the Lakeside building for part of the equipment required for the project, an asbestos abatement and demolition program is required. A specification to bidders dated October 1, 1991 has been issued. A pre-bid meeting was held on October 16, 1991 and potential bidders were required to attend this meeting at CWL&P's facilities.

CWL&P selected Aires Environmental Corporation as a consultant for the asbestos abatement portion of the work and they assisted in the preparation of the specification to the bidders.

CWL&P have added additional personnel in order to de-energized the plant electrical system, perform necessary isolation of the various plant systems as well as plant clean-up and minor equipment removal. The additional personnel were requested for six months to prepare the Lakeside Station for the asbestos abatement and the demolition.

CWL&P expects to let the asbestos abatement and demolition contract in December 1991 with all the work to be completed by the end of 1992.

An upgrade of the rail spur to the Lakeside Station is planned. Equipment and materials for construction of the IGCC Repowering Project can be brought in over this spur. The existing track and tie conditions are being evaluated and a specification for their renovation will be prepared. Cost and schedule are being developed.

High line improvements to the 138KV system required to support the CE IGCC Repowering Project continue. A major line in this improvement program is expected to be completed during the summer of 1992. Progress continues also on the Lakeside electrical improvements related to the CE IGCC Repowering Project. These improvements are expected to be completed by the late fall of 1992.

VIII PROJECT MANAGEMENT

a) PMP

A Project Management Plan was written for this project as required by the Cooperative Agreement between CE and the DOE. This plan was issued by CE and approved by the DOE during the beginning of Budget Period 1. The PMP will be implemented and maintained by CE throughout the life of the project. This document includes the management procedures that are intended to be used for this project as well as the statement of work and the work breakdown structure.

b) SCHEDULES

A schedule for the overall project was developed during Budget Period 1. This schedule is shown in Figure 9. The Schedule breaks down the project duration into 3 Phases and 5 Budget Periods and shows major milestones.

c) SUB-CONTRACTORS

Project business plans were established during Budget Period 1. These plans required the establishment of the following sub-contracts to execute the project:

- CWL&P/CE Site Access Agreement.
- CWL&P/CE Project Agreement.
- State of Illinois (ENR)/CE Agreement.
- CE/LCI Project Agreement.

All of the required agreements have been signed.

d) COST ESTIMATES

The overall project cost was reviewed in Budget Period 1. The cost estimate is shown in Figure 9 broken down by Budget Periods.

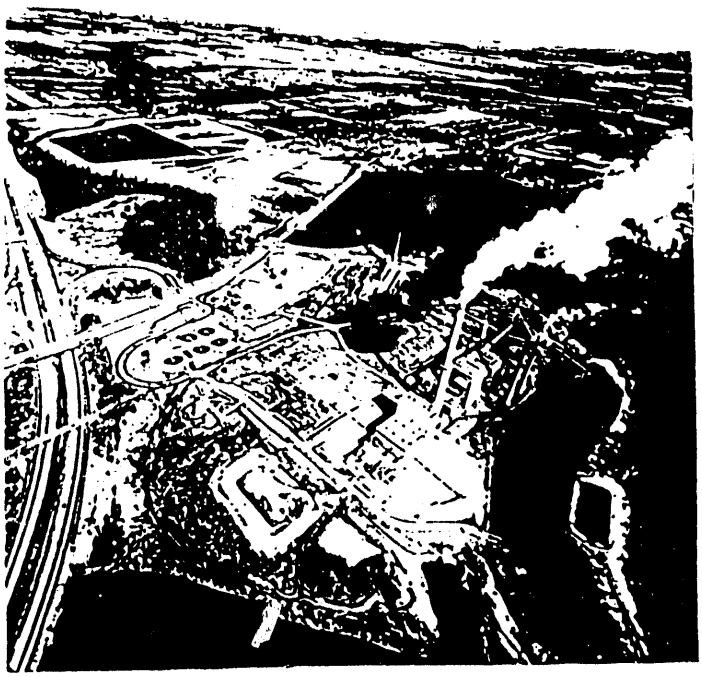


FIGURE 1

SIMPLIFIED IGCC REPOWERING

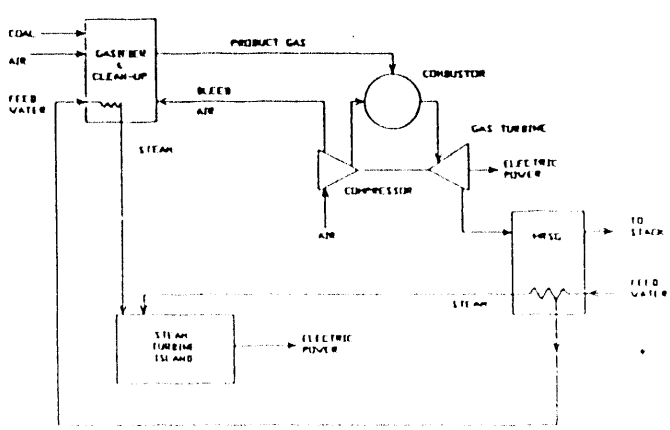
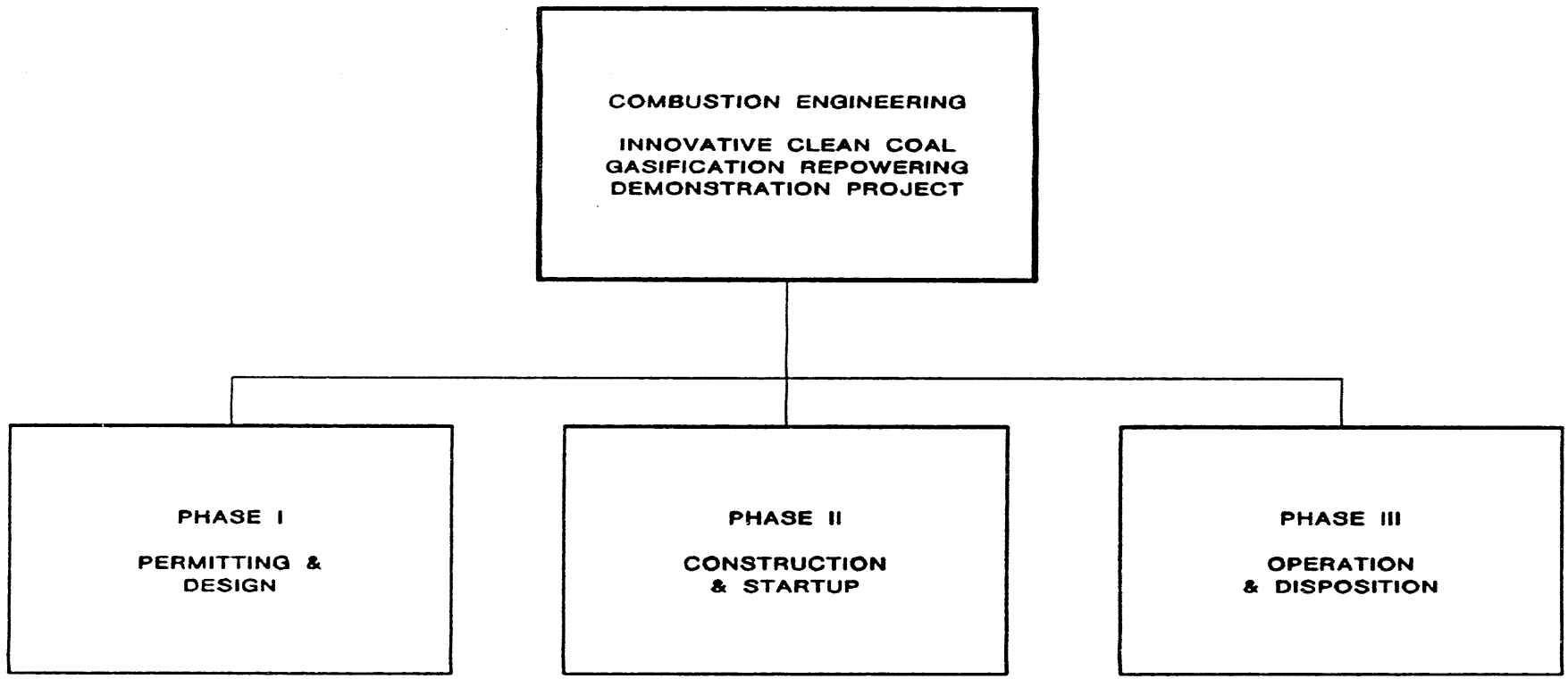


FIGURE 2

WORK BREAKDOWN STRUCTURE



1.1 POST-SELECTION ACTIVITIES
1.2 COMMERCIAL PLANT DENIGN
1.3 PERMITTING & ENVIRON. ACTIVITIES
1.4 PLANT DEFINITION & BASIC ENG.
1.5 DESIGN SUPPORT
1.6 PROJECT PLANS & AGREEMENTS
1.7 DETAILED ENGINEERING
1.8 PROCUREMENT DOCUMENTS
1.9 TECHNICAL REPORTS
1.10 PROJ. MANAGEMENT, ACCT., & REPORTS
1.11 CWL&P PHASE I R & R

2.1 PURCHASED EQUIPMENT & MATERIALS
2.2 SHOP FABRICATION
2.3 TRANSPORTATION
2.4 CONSTRUCTION
2.5 AS-BUILT DRAWINGS UPDATE
2.6 MANUALS & PROCEDURES
2.7 O & M STAFFING & TRAINING
2.8 CHECKOUT,STARTUP,MOD'S & ACCEPTANCE
2.9 TECHNICAL REPORTS
2.10 PROJ. MANAGEMENT,ACCT., & REPORTS
2.11 CWL&P PHASE II R & R

3.1 PROCUREMENT
3.2 OPERATION
3.3 TESTING
3.4 MAINTENANCE & INSPECTION
3.5 AS-OPERATED DRAWINGS UPDATE
3.6 TECHNICAL REPORTS
3.7 PLANT DISPOSITION
3.8 FINAL REPORT
3.9 PROJ. MANAGEMENT, ACCT., & REPORTS

Figure 3

ABB CE IGCC Flow Diagram

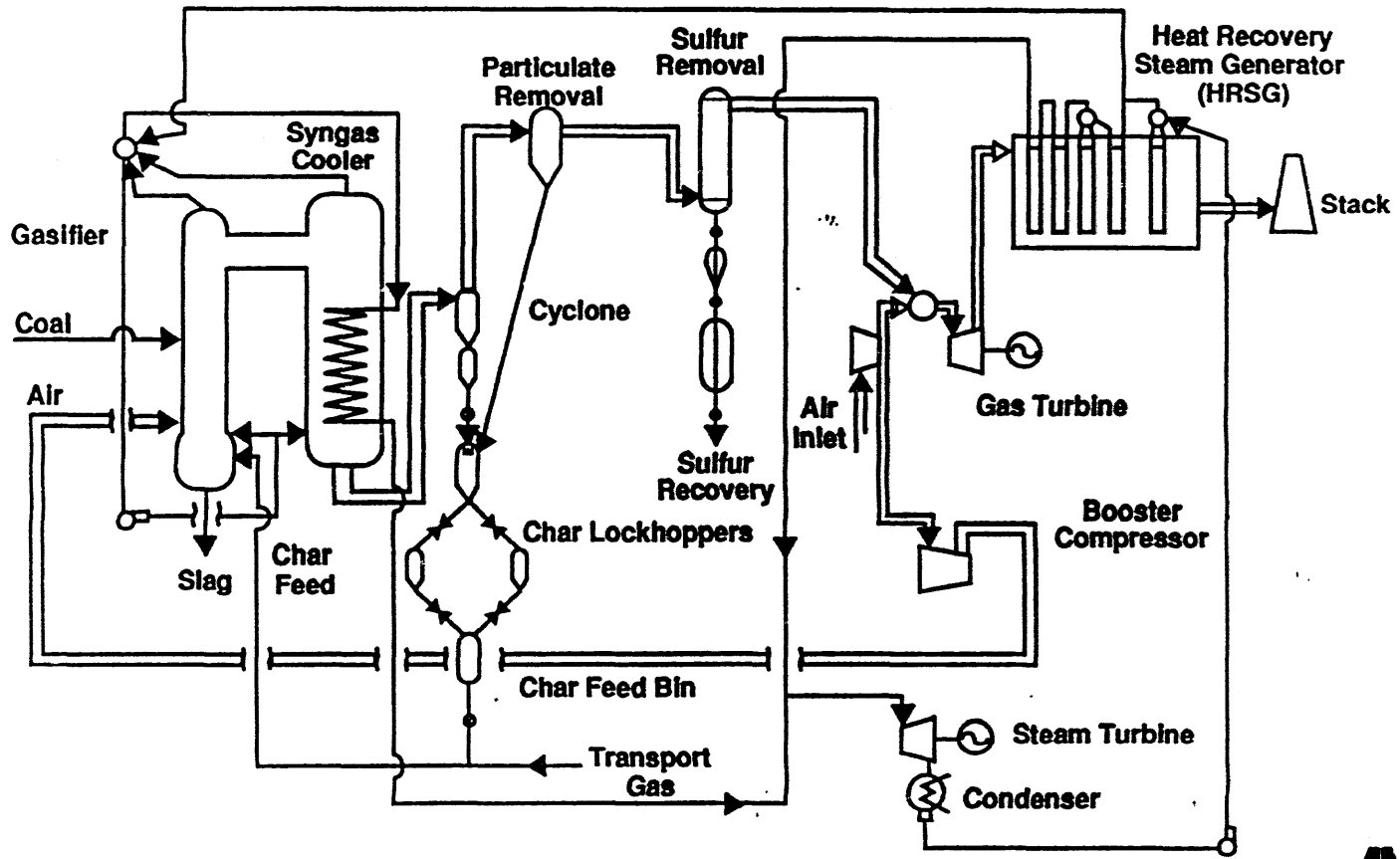


ABB
ASEA BROWN BOVERI

Figure 4

Coal Preparation and Feed System

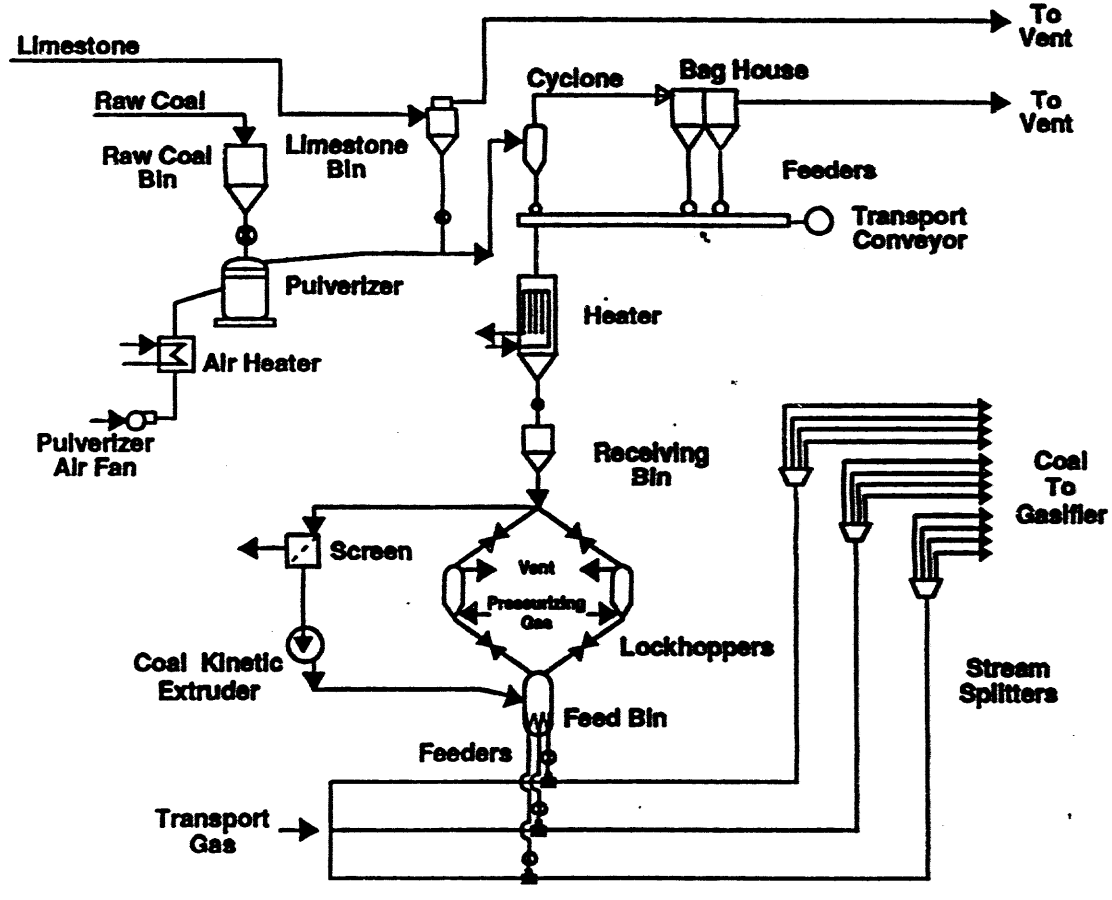


Figure 5

ABB
ASEA BROWN BOVERI

Char Recycle System

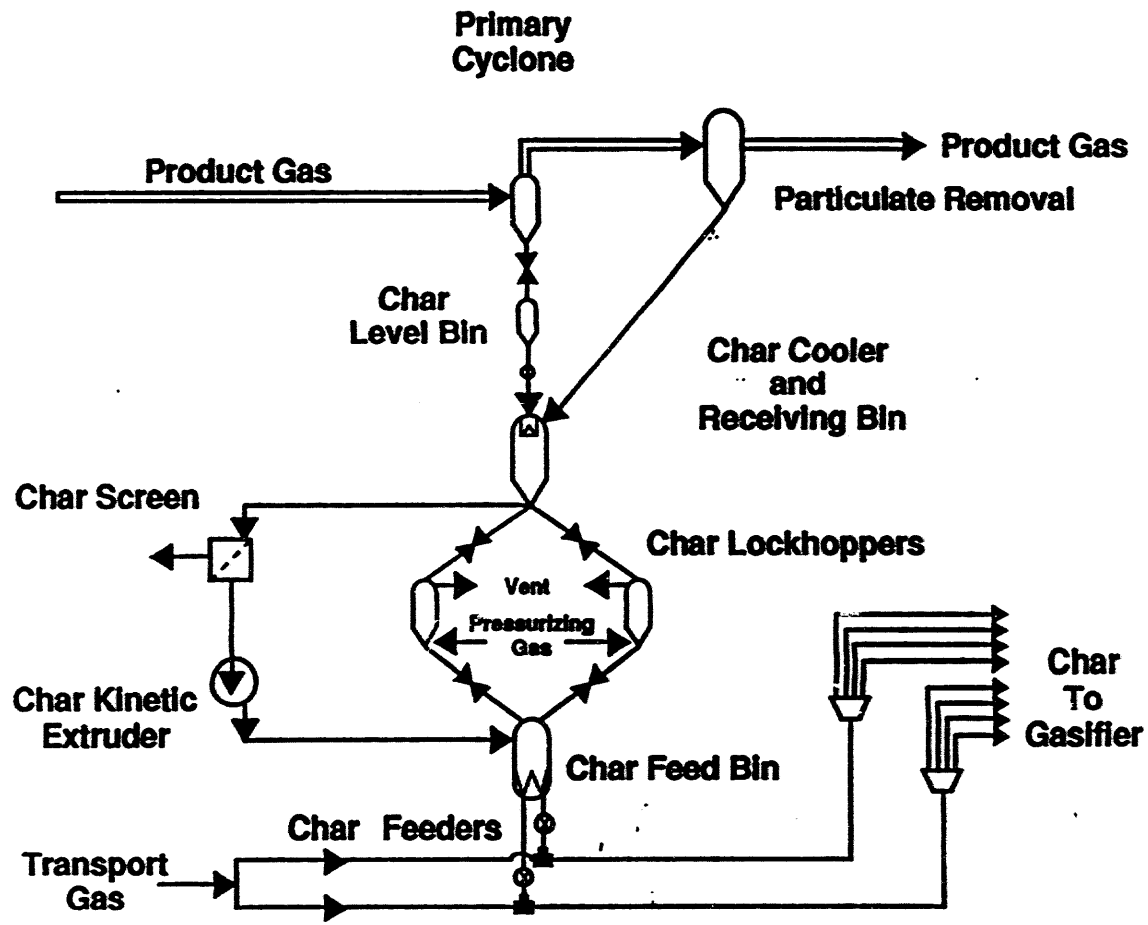


Figure 6

ABB
ASEA BROWN BOVERI

Sulfur Removal System

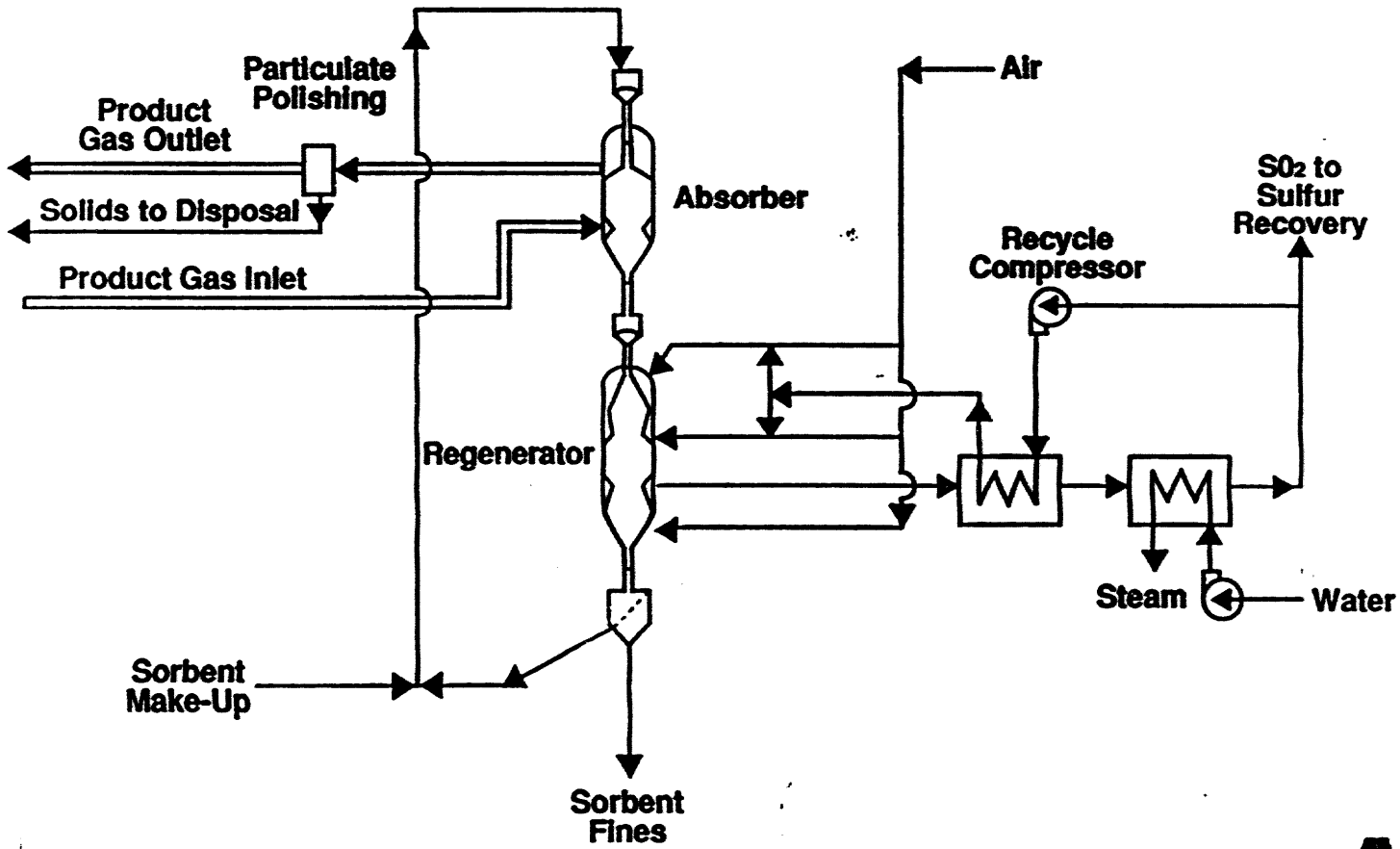


ABB
ASEA BROWN BOVERI

Figure 7

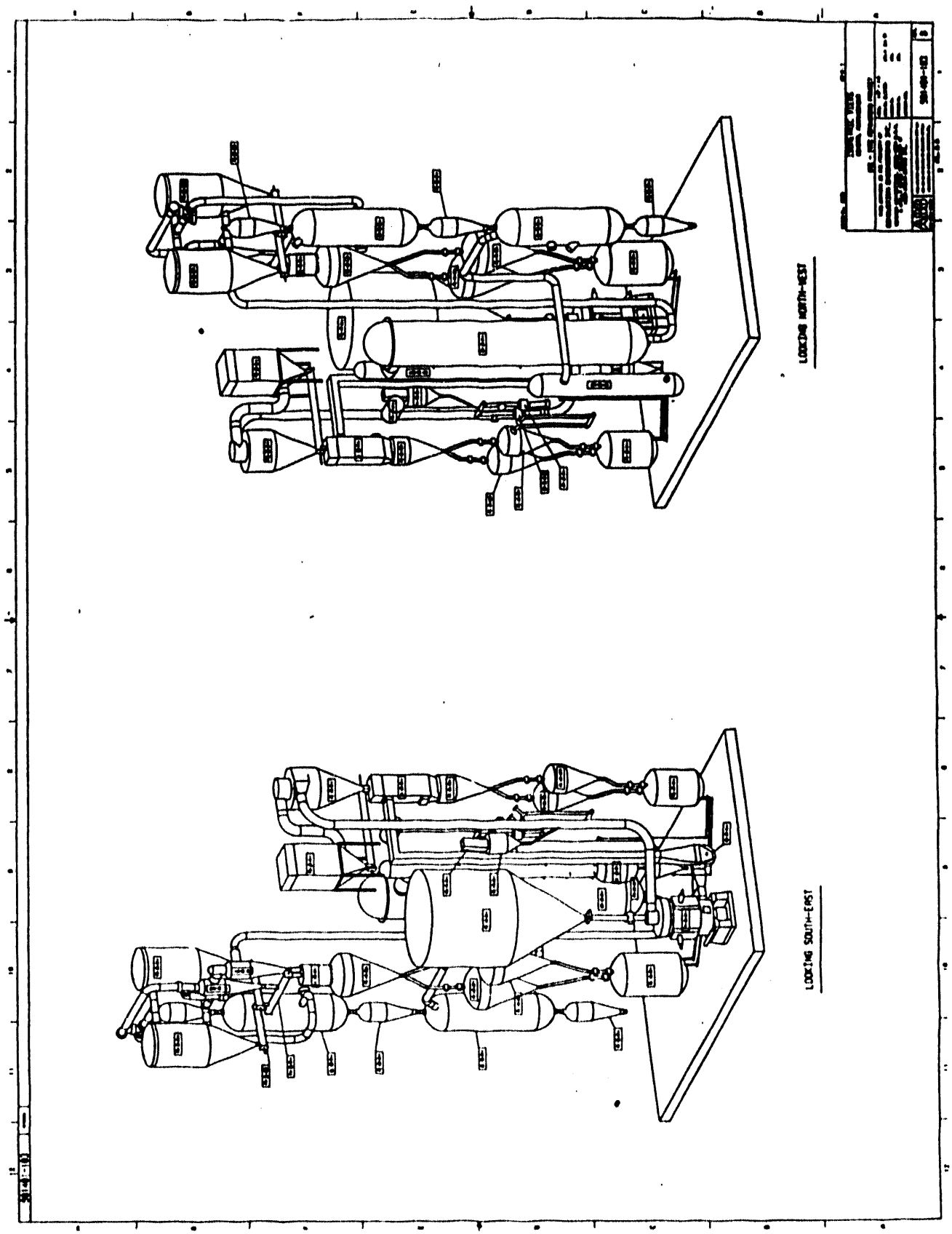
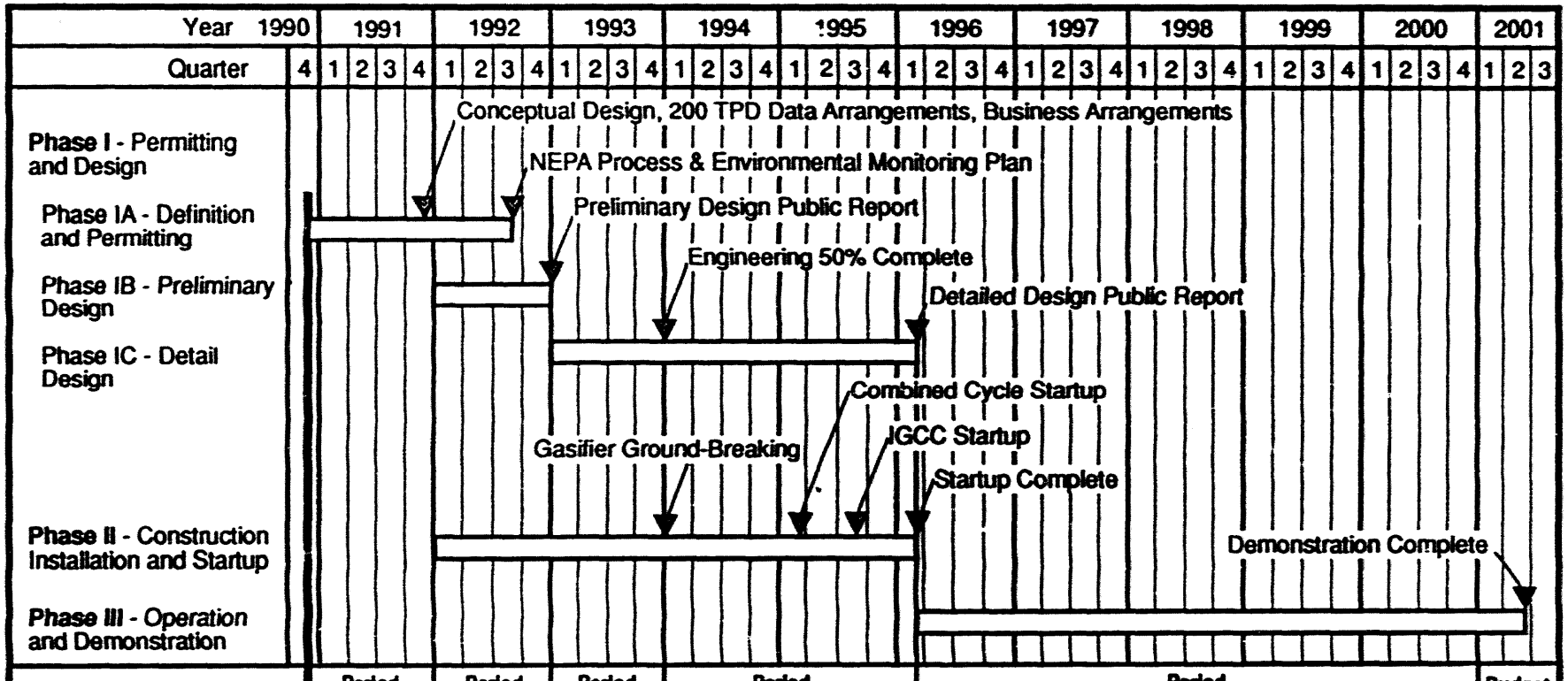


Figure 8

Combustion Engineering IGCC Repowering Project – Schedule and Budget



BUDGET ($MM)	Period #1	Period #2	Period #3	Period #4	Period #5	Budget Totals
Phase I	5.8	11.0	22.3	17.6	–	56.7
Phase II	–	–	6.0	88.3	–	94.3
Phase III	–	–	–	–	119.7	119.7
Totals	5.8	11.0	28.3	105.9	119.7	270.7

Project Funding Plan
(Dollars in Millions)

Figure 9