2

Conf-9209151--12

DOE/MC/26308-93/C0081

DOE/MC/26308--93/C0081

DE93 002745

Combustion Engineering IGCC Repowering Project

Authors:
Andrus, H.E.
Thibeault, P.R.
Gibson, C.R.

Contractor:
Combustion Engineering, Inc.
1000 Prospect Hill Road
Windsor, CT 06095-0500

Contract Number:
DE-FC21-90MC26308

Conference Title:
Twelfth Annual Gasification and Gas Stream Cleanup
Contractors Review Meeting

Conference Location:
Morgantown, West Virginia

Conference Dates:
September 15-17, 1992

Conference Sponsor:
U.S. Department of Energy, Morgantown Energy Technology Center

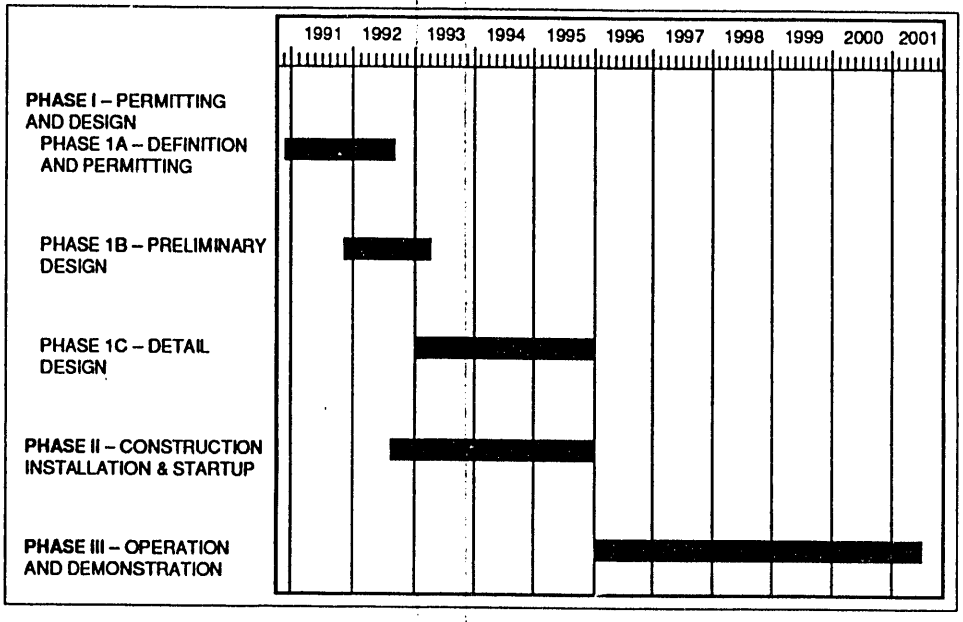
DISCLAIMER

Combustion Engineering IGCC Repowering Project

CONTRACT INFORMATION

Contract Number	DE-FC21-90MC26308
Contractor	Combustion Engineering, Inc. 1000 Prospect Hill Road Windsor, CT 06095-0500 (203) 688-1911
Contractor Project Manager	Herbert E. Andrus, Jr.
Principal Investigators	Paul R. Thibeault Cecil R. Gibson
METC Project Manager	R. Daniel Brdar
Period of Performance	August 1991 to July 1992

Schedule and Milestones



OBJECTIVE

The objective of this project is to demonstrate the Combustion Engineering, Inc. (C-E) advanced integrated coal gasification combined cycle system (IGCC) which is capable of providing high performance, cost competitive, environmentally compliant electric power. The integrated performance to be demonstrated will include all major subsystems in the IGCC system including coal feeding, C-E's advanced air-blown coal gasification, advanced methods of coal cleanup, a conventional combustion turbine adapted to use low-Btu coal gas as fuel, and the

integration of the combustion turbine with a steam turbine to provide a combined cycle.

BACKGROUND

In the United States, coal is currently used to produce approximately 55 percent of the country's electricity. With amendments to the Clean Air Act now firmly in place, coal-burning electric utilities throughout the country must comply with increasingly stringent environmental regulations.

The federal Department of Energy (DOE) forecasts that coal will maintain its dominance in power generation and that after 2005 significantly more than 50 percent of the growth in electricity generation will come from coal-fired plants.

Coal gasification is a process in which coal is used to produce a clean fuel gas which, in turn, is burned to produce power. Because most pollutants (such as sulfur) are removed prior to the combustion process, the fuel gas can be burned in an environmentally acceptable manner.

For over two decades, Combustion Engineering, Inc. (C-E) has been involved in developing a coal gasification process to produce clean fuel gas from coal for power generation. C-E 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.

The air-blown, entrained-flow, slagging bottom gasifier being developed by C-E produces low-Btu gas with a higher heating value (HHV) of 100-150 Btu/Scf. This gas can be burned in turbines of all the major gas turbine manufacturers for integrated gasification combined cycle (IGCC) applications. It is possible to achieve net plant heat rates of better than 8000 Btu/KW-Hr for an IGCC system using the C-E gasification process.

Superior environmental performance of the C-E coal gasification process makes it especially attractive to satisfy the electric power industry's need to meet the most stringent environmental regulations. The C-E process produces non-leachable fused ash which can be disposed of in an environmentally-acceptable manner without requiring any additional processing.

For site specific reasons, the demonstration project will produce sulfuric acid. Other options for sulfur disposal would include the production of elemental sulfur, which would minimize volume requirements for sulfur disposal. The low-Btu gas produced in the C-E gasification process produces lower NOx compared to medium-Btu gas or natural gas when burned in the gas turbines.

C-E is now 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 under the DOE Clean Coal II Program. After a successful demonstration period, C-E is planning to offer the gasification process to the electric power industry on a commercial basis starting in 1996-1997.

C-E GASIFICATION PROCESS

The C-E gasification process uses an entrained-flow, two-stage, slagging bottom gasifier. Figure 1 shows a schematic of the gasifier concept. Some of the coal and all of the char is fed to the combustor section, while the remaining coal is fed to the reductor section of the gasifier. The coal and char in the combustor is mixed with air and the fuel-rich mixture is burned creating the high temperature necessary to gasify the coal and melt the mineral matter in the coal.

The slag flows through a slag tap at the bottom of the combustor into a water-filled slag tank where it is quenched and transformed into an inert, glassy, granular material. This vitrified slag is non-leaching, making it easy to dispose of in an environmentally acceptable manner.

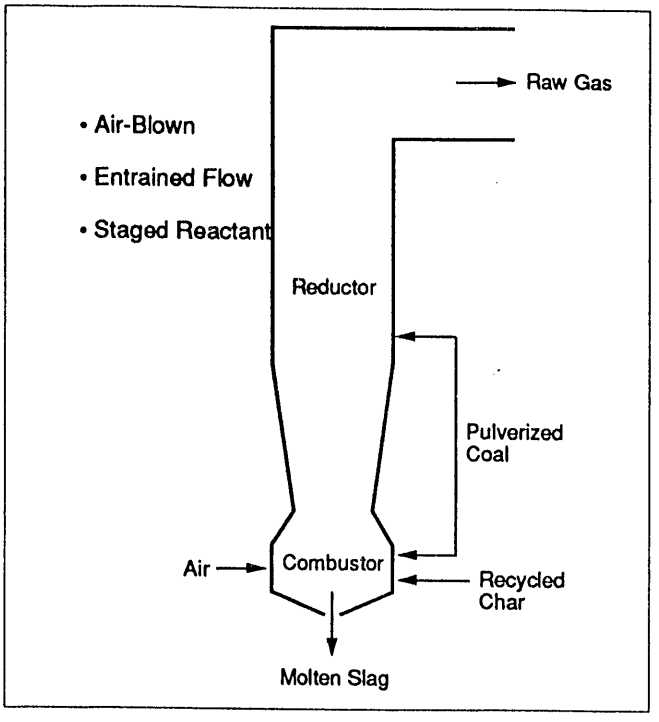


Figure 1. CE Gasifier

The hot gas leaving the combustor enters the second stage called the reductor. In the reductor, the char gasification occurs along the length of the reductor zone until the temperature falls to a point where the gasification kinetics become too slow. Once the gas temperature reaches this level, essentially no further gasification takes place and the gases subsequently are cooled with convective surface to a temperature low enough to enter the cleanup system.

Thus, nearly all of the liberated energy from the coal that does not go into producing fuel gas is collected and recovered with steam generating surface either in the walls of the vessel or by conventional boiler convective surfaces in the backpass of the gasifier. This boiler style design provides for recovery of coal energy as either fuel gas or steam (for use in a steam turbine to generate electricity).

A mixture of unburned carbon and ash (called char) is carried out of the gasifier with the product gas stream. The char is collected and recycled back to the gasifier where it is completely consumed. Thus, there is no net production of char which results in negligible carbon loss.

The product gas then enters a desulfurization system where it is cleaned of any sulfur compounds present in the fuel gas. The clean fuel gas is now available for use in the gas turbine combustor for an integrated coal gasification combined cycle (IGCC) applications (Figure 2).

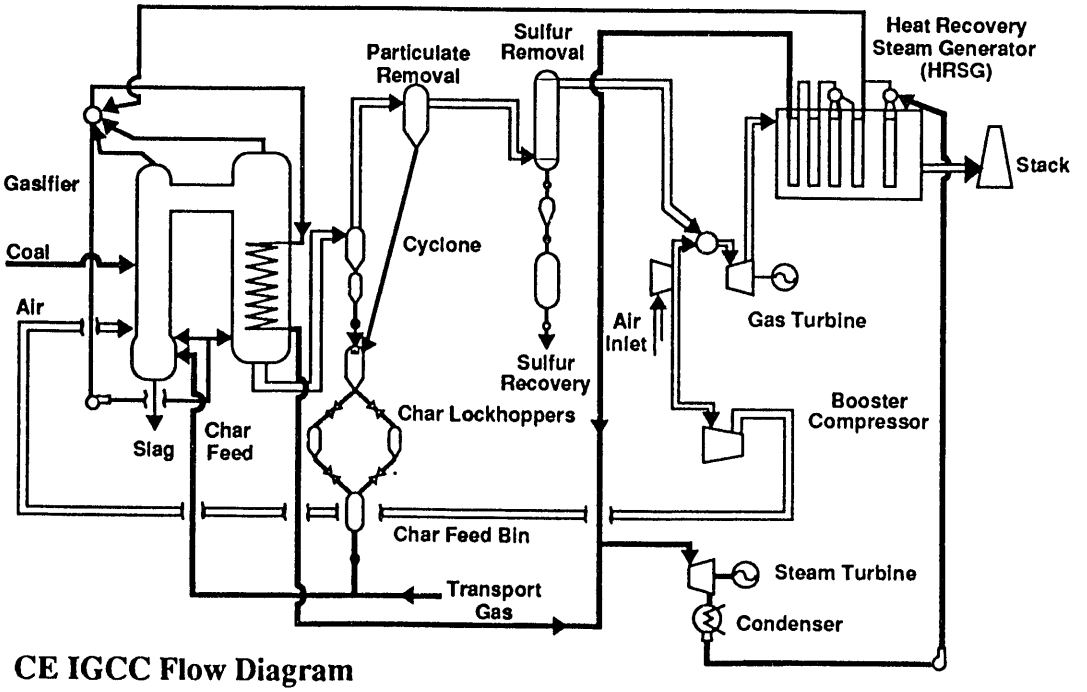


Figure 2. CE IGCC Flow Diagram

The C-E gasification process provides many advantages for high-efficiency electric power production. These include:

- C-E's gasifier is well suited for scale-up to the sizes required to achieve economy of scale in large power plants.
- All types of coal can be processed without special pretreatment.
- Virtually all char produced is consumed. There is no net char production and carbon loss is negligible.
- Ash disposal is minimized by fusing the ash into a molten slag in the gasifier. After water quenching, the coal ash is in its most acceptable form for disposal.
- C-E's gasifier does not produce unwanted tars and oils in the product gas.
- Air blowing avoids the complexities and high cost of an oxygen separation plant. This results in lower capital and operating costs.
- C-E has considerable experience in building reliable entrained-flow pulverized coal boilers. The use of standard boiler practices means that the plant will be operated more like a power plant than a chemical plant, an important aspect for electric utilities. The design provides for fast load following similar to a pulverized coal boiler. This allows an easier start-up from cold and hot status.
- SOx and NOx emissions are very low.

PROJECT DESCRIPTION

C-E 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 C-E 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.

The IGCC system will consist of C-E'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 necessary to repower CWL&P's Lakeside Station.

The result of the 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 65 MWe. Nearly half of the project will be funded by the DOE under the Clean Coal II program, while CWL&P, State of Illinois, and C-E will fund the rest.

The demonstration plant schematic is shown in Figure 2. The IGCC will include C-E'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 sulfur removal method features a newly developed moving-bed zinc titanate system downstream of the gasifier. C-E intends to use the General Electric (GE) moving bed sulfur removal system currently being piloted by General Electric Environmental Services, Inc. (GEESI). 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 (Figure 3).

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

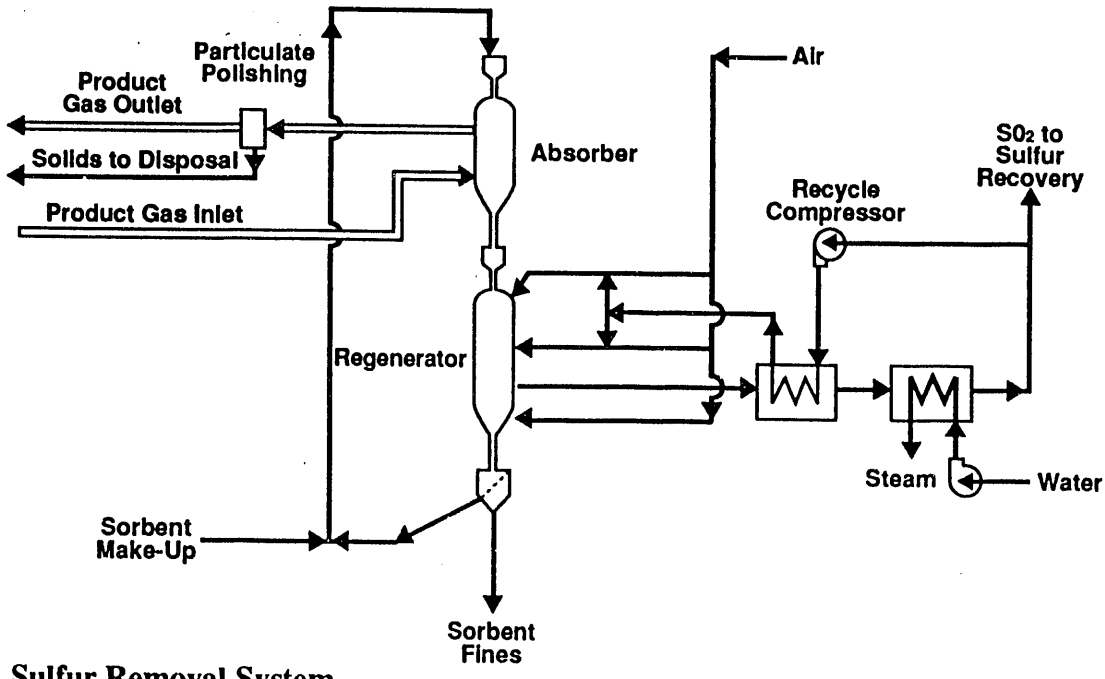


Figure 3. Sulfur Removal System

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.

Table 1 shows the planned project performance as well as the projected performance corresponding to today's advanced gas turbines. As each major equipment section is completed, it will be brought on line to produce power to facilitate startup of the IGCC.

The combined cycle will be installed, checked out, and brought into commercial service first. The complete operation of this equipment will make the plant a combined cycle fired on natural gas. All the equipment will be checked out and operated prior to the start-up of the gasification plant.

The other major block of equipment will be the fuel gas island, including the gasifier and hot gas cleanup equipment sections. When this equipment is put into operation, the plant will be a

Table 1
CE IGCC Nominal Performance (ISO)

	Demonstration	Commercial
Gas Turbine	2020°F	2300°F
Steam Turbine	1265 psia/ 950°F	2400 psia/ 1000°F/ 1000
Gas Turbine (MW)	38	150
Steam Turbine (MW)	33	100
Aux Power (MW)	9	15
Total Net Power (MW)	62	235
Net Plant Heat Rate (Btu/Kw Hr)	9000	<8000
SO_2 Emissions (lb/MWBtu)	<0.1	<0.1
NO_x Emissions	<0.1	<0.1
Particulate Emissions	<0.03	<0.03

fully integrated coal gasification combined cycle plant.. The project budget, schedule and milestones are shown in Figure 4.

MAJOR ACCOMPLISHMENTS

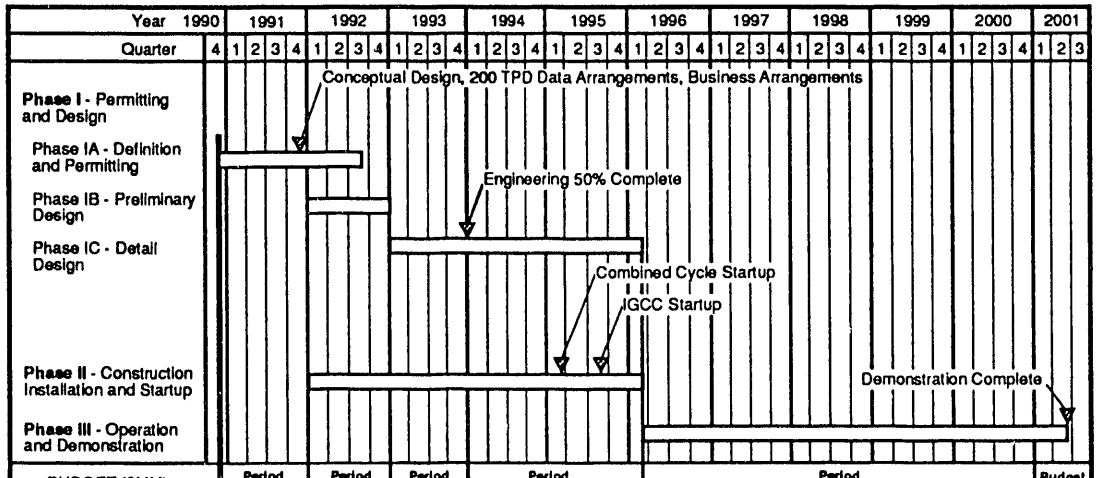
As show in Figure 4, the project has been divided into five budget periods. Budget Period 1 was successfully completed in December, 1991. During this period, a conceptual design of the plant was made. A plant design philosophy and a plant cycle were developed. Based on these inputs, plant and preliminary major process equipment specifications were made. Component designs were developed and the specifications were sent to vendors. The gasifier and its heat exchanger were specified by C-E.

Other equipment, 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 preliminary process flow diagrams and energy balances.

A design report on the hot desulfurization system was issue by GE. Preliminary test operation of their integrated fixed bed gasifier and the General Electric Environmental Services, Inc. (GEESI) moving bed hot gas cleanup system were completed. The first long term duration test was completed. 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.

At C-E's KDL laboratory, design support tasks were carried out. Flow modeling tests were conducted to assure that the required fluid mechanics occurred in the gasifier. This program consisted of the construction and testing of a 1/2 scale three-dimensional cold flow model. Gasifier fluid mechanics performance was studied by both qualitative and quantitative techniques.

Fuel transport tests were conducted to verify the design criteria for the coal and char feed system. The tests were aimed at verifying transport line size, pressure drop correlations, solids to gas ratio, and flow smoothness information. Coal was transported successfully at conditions similar



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 4. Combustion Engineering IGCC Repowering Project - Schedule and Budget

to the design conditions of the Demonstration Plant. A list of construction and environmental permit requirements and a schedule for application and permitting were prepared.

CWL&P activities 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 selected.

The market for C-E IGCC systems was re-examined during Budget Period 1. The conclusion was that coal will emerge as the primary fuel during the late 1990's, which is about the same time that C-E's IGCC systems will be offered commercially. At that time it is believed that the power demand will pick up.

Other Budget Period 1 activities included updating the cost and schedule baseline. Environmental permitting activities were begun. All major project agreements were concluded. All commitments for project funding with DOE, CWL&P, and ENR were completed and documented.

Budget Period 2 activities were initiated in January, 1992. The final design basis for the approved for design (AFD) heat and material balance was established. This heat and material balance will establish the baseline performance for the plant. The design basis requires that the plant will produce 60 MW at an ambient temperature of 95 degrees F.

A high level schedule for the C-E manufactured equipment (principally the gasifier and gas cooler) was established. The schedule was used to help define the detailed project schedule under development. The initial mechanical design for the gasifier and heat exchanger was started. This work will define special details for the C-E equipment and will supply the information that is needed to produce a detailed schedule and cost.

The materials task was started. The purpose of this task is to document materials that are to be used in the plant. Areas of special interest include:

- heat exchanger superheater, evaporator, and waterwall tubes,
- major process piping,
- and pressure vessels.

These components need to be designed for high temperature gas containing sulfur and particulate matter. Plot plans and design support have been provided to ABB Environmental Systems for air permitting issues. They are developing three-dimensional block models of the gasification and combined cycle areas for plume dispersion studies.

CWL&P is working on demolition and asbestos abatement. The constructors are on site and abatement on Units 4, 5, and 6 is underway.

During this budget period, GEESI has continued testing on the hot gas clean up (HGCU) pilot plant. They have supplied C-E with their latest version of the HGCU system process flow diagram (PFD) and mass and energy balance information and are currently working on equipment specifications. Design activities underway include completion of approved for design (AFD) process flow diagrams.

Piping and instrumentation diagrams (P&ID's) and plant layouts will be completed as necessary to support the Budget 2 cost estimating.

The Environmental Information Volume (EIV) was completed delineates the full range of environmental impacts anticipated to result from the project. The EIV was submitted to the DOE for use in preparing the environmental assessment (EA). Based on analyses in the EIV and further project refinement, DOE published the final EA for the IGCC project at Lakeside Station. The EA assessed the impact of the project with respect to each of the following:

- air quality
- surface waters
- groundwater
- land use and solid waste disposal
- floodplains and wetlands
- terrestrial ecology
- aquatic ecology
- threatened and endangered species
- health and safety
- social, economic, historic, and archeological resources.

The EA supported a conclusion that the project would not cause any adverse environmental impact that should preclude it from further consideration and permitting. The DOE subsequently issued a Finding of No Significant Impact, concluding the National Environmental Policy Act (NEPA) process for the project. A study to recommend the best available control technology for the project has been drafted. Air permit applications will be submitted later this year.

REFERENCES

1. S.L.Darling, et al., "Combustion Engineering Two-Staged, Atmospheric Pressure, Entrained Flow Coal Gasification Process Development Unit Program, EPRI Report AP-2846, February 1983

2. U.S. Dept. of Energy, "Comprehensive Report to Congress, Clean Coal Technology Program, Combustion Engineering IGCC Repowering Project," Assistant Secretary for Fossil Energy, October 1990.

3. H.E. Andrus, et al. "Combustion Engineering IGCC Repowering Project," Eleventh Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting, Morgantown (METC), West VA., Sept. 1991.

DATE
FILMED
02/02/93