

Assessment of Hot Gas Contaminant Control

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Introduction

The National Research Council's (NRC) Committee on the Strategic Assessment of the DOE's Coal Program was asked to recommend the emphasis that DOE ought to consider in updating its coal program to respond to the Energy policy Act of 1992. The advanced coal-based Integrated Gasification Combined Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC) power generation systems under development with DOE and commercial funding were divided into three groups by the National Research Council committee based on projected efficiency:

- Group 1 approximately 40 percent efficiency - includes PFBC with a low temperature gas turbine; and IGCC with cold gas cleanup;
- Group 2 approximately 45 percent efficiency - includes PFBC with a carbonizer and a commercial gas turbine; and IGCC with hot gas cleanup, by 2000;
- Group 3 50 percent or greater efficiency - includes PFBC with carbonizer and advanced gas turbine; and IGCC with hot gas cleanup and advanced gas turbine, by 2010.

Hot gas cleanup is necessary to obtain the highest system efficiencies. Hot gas cleanup systems comply with environmental requirements, protect advanced gas turbines from corrosive impurities such as volatile alkali metals and from erosive particles. The NRC committee concluded that the components for the advanced IGCC and PFBC power plant systems needing the most development are the hot gas cleanup sections.

A key recommendation in the NRC report to DOE was that an assessment of hot gas cleanup systems for advanced IGCC and PFBC should be undertaken to determine the ability to meet, within the next 3 to 5 years, all requirements for future high temperature (>1260°C [2300 °F]) turbine operation and environmental acceptability.

Objective

The objective of this work is to gather data and information to assist DOE in responding to the NRC recommendation on hot gas cleanup by performing a comprehensive assessment of hot gas cleanup systems for advanced IGCC and PFBC including the status of development of the components of the hot gas cleanup systems, and the probable cost and performance impacts. The scope and time frame of information gathering is generally responsive to the boundaries set by the NRC, but includes a broad range of interests and programs which cover hot gas cleanup through the year 2010. As the status of hot gas cleanup is continually changing, additional current data and information are being obtained for this effort from this 1996 METC Contractors' Review Meeting as well as from the 1996 Pittsburgh Coal Conference, and the University of Karlsruhe Symposium.

Approach

The technical approach to completing this work consists of:

1. Determination of the status of hot gas cleanup technologies: particulate collection systems, hot gas desulfurization systems, and trace contaminant removal systems.
2. Determination of hot gas cleanup systems cost and performance sensitivities. Analysis of conceptual IGCC and PFBC plant designs with hot gas cleanup have been performed. The impact of variations in hot gas cleanup technologies on cost and performance was evaluated using parametric analysis of the baseline plant designs and performance sensitivity.

Status of Particulate Collection Systems

Particulate removal devices are required at the operating temperature of the IGCC gas stream and at the exit temperatures of the carbonizer and PFBC of the PFBC system. The IGCC operating temperature ranges from 340 to 600°C (650 to 1100°F), while the PFBC temperatures may be as high as 870°C (1600°F). High-temperature particulate collection has been accomplished using several types of equipment, ranging from modified traditional devices, such as upgraded electrostatic precipitators, to new devices such as candle filters developed specifically for this service. Most of the results of testing and development work has been published, discussed at meetings or distributed by vendors. The primary sources of particulate test results are through the DOE-supported meetings, such as the METC Contractor's Meetings. What is generally lacking, is long term operation under actual commercial scale conditions. Presently, a coordinated program is in place to commercialize hot gas particulate collection technology. This program includes Research & Development, slipstream/pilot plant testing, and CCT demonstration plants. There are two pilot facilities which will have a great impact on the development of PFBC filters: Wilsonville and Karhula. At the demonstration level only Wakamatsu is active and the only filter being tested there is the Asahi tube filter. The testing of various filters at Wilsonville and Karhula will be very important since the Clean Coal Technology demonstration plants, Four Rivers and DMEC, are still in the negotiating process.

Ceramic Monolithic Candle filters have the most extensive testing of any high-pressure, high-temperature particulate filtration device. Candle filters have been formulated from either clay bonded silicon carbide (SiC) or aluminum oxide, or, more recently, ceramic fiber filters using a variety of fibers embedded in either an organic or inorganic binder. New filter designs using different clay binders are being tested. Modified candle filters made of clay bonded silicon carbide and alumina mullite have been developed to minimize problems encountered in previous testing. These are presently undergoing testing.

Ceramic Candle Filters Modified with Ceramic Fibers have been developed to solve the problems that were experienced with ceramic filters, such as creep and brittle failure. METC is sponsoring a program to design, build and test a group of these advanced filters. The program is focused on providing a diversity of approaches at obtaining a stronger more durable candle filter by building on work done elsewhere in government programs, such as the Energy Efficiency and Renewal (EE) Program in DOE and the Air Force Materials Program.

Ceramic tube filters, manufactured by Asahi Glass Co., Japan, are typically made of porous cordierite. The tube differs from a candle filter in that it is generally of much larger diameter and is mounted to tube sheets at the top and bottom of the butted tubes. Asahi ceramic tube filters were tested at Karhula with mixed results and are now being tested at the Wakamatsu PFBC facility in Japan. Preliminary results have indicated some tube failures.

Sintered Metal Candle Filters are being developed by Pall Corporation for high temperature applications. They have recently received a patent for a high-temperature, high-pressure filter vessel design for any type of filter that uses an inner filter in each candle for protection when a ceramic candle breaks. Pall will provide a filter having 56 sintered stainless candles for testing at the Tampa Electric Company CCT demonstration plant on a 25 MWe slipstream in 1996.

Granular bed filters have been used to filter hot particulate at temperatures above 425°C [800°F] for over 80 years. Fluidized, packed or moving bed granular bed filters are an option for both PFBC and IGCC conditions. Testing was done by the Coal Mining Research Center at Yubari, Japan in the 4 MWe IGCC pilot plant. In addition to the work done in Japan, Combustion Power Company (CPC) and Westinghouse have been developing versions of a granular bed filter in the United States, sponsored by DOE. Proof testing of a large CPC granular bed filter is scheduled to be performed at the 4 MWe Wilsonville Test Facility, at both oxidizing and reducing conditions, and these tests should provide data on which commercial offerings can be based.

Advanced Materials: There are several advanced materials now under development that appear promising for ceramic tube filters: Dupont Lanxide PRD-66, 3M CVI silicon carbide/Nextel, Dupont Lanxide silicon carbide, Westinghouse/Techniweave continuous fiber ceramic composite, and Pall iron aluminide and stainless steel sintered metal candles. The development of ceramic composites is sponsored by DOE's Office of Industrial Technology's Continuous Fiber Ceramic Composite (CFCC) Program. The Oak Ridge National Laboratory is conducting a program for DOE which is focused on increasing knowledge of operational degradation, measurement of mechanical properties, long term performance, thermal shock and cycling, creep and fatigue, and non-destructive characterization.

Status of Hot Gas Desulfurization Systems

The major issue associated with hot gas desulfurization (HGD) is the need for the technology to be demonstrated for an extended period at a scale equivalent to commercial operation. Sorbent capacity and physical attrition of hot gas desulfurization sorbents are the key issues in sorbent development. A third issue for HGD sorbents is the formation of sulfates during regeneration. Research objectives are aimed at developing sorbents to resolve these issues.

Desulfurization Sorbents

In the mid-1970's, work at METC resulted in development of iron oxide sorbent, but the need for a regenerable sorbent that could lower the sulfur levels to 10 ppm or less led to zinc ferrite as a likely candidate for testing as a regenerable sorbent in 1980. There has been no further METC development on iron oxide, but the Japanese continue to utilize iron oxide in a fluid bed reactor.

Zinc-based sorbents such as zinc ferrite and zinc titanate are capable of reducing the COS and H₂S level in syngas to about 10 ppm in both air blown and oxygen-blown syngas. Z-Sorb III, another zinc-based sorbent is being developed by Phillips Petroleum Company. It is about to be used in two of the Clean Coal Technology projects. Table 1 lists the sorbents under development and their status.

**TABLE 1
STATUS OF SORBENT DEVELOPMENT**

SORBENT	DEVELOPER	MOLAR RATIO COMPOSITION	APPLICATION	LEVEL OF TESTING	TEST RESULTS	ADDITIONAL TESTING	MANUFACTURER
METC-9	METC	50% ZINC OXIDE	MOVING BED	50 CYCLE HP BENCH SCALE	ACCEPTABLE	NONE PLANNED	UCI
METC-10	METC	50% ZINC OXIDE	MOVING BED	50 CYCLE BENCH SCALE	ACCEPTABLE	200 HR AT GE PDU 3/96	UCI
ZT-4, 180 MICRON	RTI	1.5 ZnO/TiO ₂	FLUIDIZED BED	100 CYCLE AT RTI BENCH SCALE	POSITIVE	CIEMAT-SPAIN; COAL TECHNOLOGY DEVELOPMENT DIVISION, BRITISH COAL	CMP
ZT-4L UCI-5	RTI	1.5 ZnO/TiO ₂	FLUIDIZED BED	5-6 DAYS ENVIROPOWER 15 MWe	POSITIVE	NONE PLANNED	CMP/UCI
CMP-5, 80 MICRON RTI/CMP-107	RTI/CMP	1.5 ZnO/TiO ₂	FLUIDIZED BED	50 CYCLE AT MW KELLOGG TRTU, 1995	ATTRITION LEVEL TOO HIGH	NONE PLANNED	CMP
ICCI-2	E&A ASSOCIATES/RTI	EXCESS TiO ₂ ZnO·2TiO ₂	FIXED BED/ MOVING BED	BENCH SCALE	PRELIMINARY	50 CYCLE AT RTI WAITING FOR MANUFACTURE	UNITED CATALYSTS
Z-SORB III	PHILLIPS PETROLEUM COMPANY	ZINC-BASE PROPRIETARY	FIXED BED/MOVING BED/FLUIDIZED BED/TRANSPORT REACTOR	200 HR TESTING AT GE PDU, 1994 MW KELLOGG TRTU	GE DETERIORATION WITH STEAM REGENERATION ATTRITION RESISTANT /TRTU POSITIVE	FIRST FILL AT TAMPA ELECTRIC CCT SLIPSTREAM FIRST FILL AT SIERRA PACIFIC CCT	CALCICAT AND UNITED CATALYSTS
Z-SORB IV	PHILLIPS PETROLEUM COMPANY	ZINC-BASE PROPRIETARY	FIXED BED/FLUIDIZED BED/MOVING BED	50 CYCLE TEST TO BE SCHEDULED	N/A	ONGOING	TBD

N/A: NOT AVAILABLE

HGD Test Facilities

METC is conducting high-pressure test at 20 bar (300 psia) in a bench scale fixed bed hot gas desulfurization unit with a 5.6-cm (2.2-inch) I. D. reactor. METC is also currently in the process of constructing a Fluidized Bed/Transport Reactor Process Development Unit (PDU) to support METC strategic plans for IGCC. METC also has available for testing a 9-mm (0.334-inch) I. D. riser tube reactor which operates as a transport reactor.

General Electric, with support from DOE, has been developing the moving bed hot gas desulfurization process which consists of a moving bed absorber and regenerator with a recycle regeneration gas system to produce a consistent level of SO₂ product. The moving bed PDU, integrated with a fixed-bed gasifier and a turbine combustion test rig is located at GE CR&D in Schenectady, New York.

Research Triangle Institute (RTI) is conducting testing with a 10-cm (4-inch) bench-scale fluidized bed sorbent test facility capable of operation up to 870°C (1600°F) at 20 bar (300 psia). Sorbent tested in the test rig varies in particle size range from 100 to 300 microns and pellets to 5 millimeters.

M. W. Kellogg completed their Transport Reactor Test Unit (TRTU) pilot plant in May 1995 to operate either as a dense-phase fluid bed or as an entrained reactor, and either as an absorber or as a regenerator.

Table 2 lists the prominent HGD processes and their test status.

Sulfur Fixation

Hot gas desulfurization (HGD) results in sulfur being produced from the regeneration of sorbent as SO₂, or as CaS from the bottom of the gasifier. In order for the sulfur to be acceptable for landfill or commercial use, the IGCC products must pass through a fixation process which produces elemental sulfur, CaSO₄, or sulfuric acid.

There are several approaches to sulfur fixation once the HGD sorbent is regenerated. If the HGD is utilized as a sulfur polisher when the gasifier uses a limestone or dolomite sorbent for in-situ sulfur capture, the SO₂-rich regeneration gas and the gasifier solids are fed to a sulfator where sulfides are oxidized to sulfates for disposal. Also, METC has sponsored the development of the Direct Sulfur Recovery Process (DSRP), in which SO₂ with stoichiometric fuel gas is converted directly to elemental sulfur over a catalyst. Other approaches to sulfur fixation include commercially available contact acid plants and the Wet Sulfuric Acid Process.

The potential commercialization of the KRW gasifier with in-situ desulfurization is dependent upon successful integration with a sulfator to convert CaS to CaSO₄ by roasting in air at a temperature high enough for rapid conversion without excessive emissions of SO₂. Significantly higher oxidation levels were obtained in air at 900°C (1,700°F) with DASH (dolomite and ash) rather than LASH (limestone and ash).

This reinforced the recommendation that dolomite be used as an in-situ sorbent. Pinon Pine utilizes circulating bed heavy oil cracking technology for the sulfator.

A 160-hour DSRP test at the METC RTI Trailer in 1994 has shown that sulfur recovery in excess of 99% can be achieved in a single stage. Because of the high conversion with a single stage, the DSRP design will be changed from a two stage to a single stage system, with improved economics.

**TABLE 2
HGD PROCESS DEVELOPMENT STATUS**

PROCESS/ DEVELOPER/ CONTRACTOR	DATES OF DEVELOPMENT FOR HGD	OTHER APPLICATIONS	OPERATIONAL ISSUES	LEVEL OF TESTING	FACILITIES AVAILABLE FOR TESTING	PLANNED DEMONSTRATION
FIXED BED/ METC	1985-1990	CPI CATALYST BEDS	HIGH TEMPERATURE VALVING IN-BED TEMPERATURE CONTROL PLUGGING FROM FINES RETENTION	BENCH-SCALE AT METC WALTZ MILL PDU	BENCH-SCALE AT RTI, IGT, GE, METC	NONE
MOVING BED/ GEESI/METC	1990-PRESENT	PETC CuO PROCESS	HIGH TEMPERATURE VALVING IN-BED TEMPERATURE CONTROL PLUGGING FROM FINES RETENTION SORBENT ATTRITION	3 MWe PDU AT GE CR&D 1990 TO PRESENT	GE 10 CYCLE TEST FOR BENCH-SCALE TEST GE 3 MWe PDU AT GE CR&D FOR 200 HR TESTING	10 PERCENT SLIPSTREAM (25 MWe) SCHEDULED AT TAMPA ELECTRIC POWER CCT
FLUIDIZED BED METC/ REGENERABLE	1988-PRESENT	PROCESS REACTORS REQUIRING PRECISE TEMPERATURE CONTROL	SORBENT ATTRITION FLUIDIZING VELOCITY CONVERSION EFFICIENCY	BENCH SCALE AT METC AND RTI ENVIROPOWER CRADA	BENCH SCALE AT RTI METC PDU IGT	NONE
FLUIDIZED BED/IHI/ REGENERABLE	1981-PRESENT	NONE IDENTIFIED	OPERATES ON IRON OXIDE AT 427-482C (800- 900F)	4 MWe PILOT PLANT 20 MWe NEDO DEMO.	4 MWe PILOT PLANT	20 MWe NEDO DEMO.
TRANSPORT REACTOR/ M. W. KELLOGG	1992-PRESENT	TECHNOLOGY BASED ON MANY YEARS OF COMMERCIAL OPERATION WITH FLUIDIZED CATALYTIC CRACKER BY MWK	SORBENT ATTRITION DUE TO FAST BED CIRCULATION LOW TEMP REGENERATION	BENCH-SCALE TESTING AT METC AND M. W. KELLOGG TRTU	METC PDU METC RISER KELLOGG TRTU	95 MWe FULL SCALE DEMONSTRATION PLANNED AT PINON PINE

HGD Demonstrations

Pinon Pine will be the initial demonstration of the integrated hot gas cleanup system at a full scale of 100 MWe. Hot gas cleanup will consist of; desulfurization in-situ by dolomite feed with the coal; sulfur polishing by Z-Sorb III sorbent in a transport reactor desulfurizer; regeneration with neat air initiated at 550°C (1000°F); regeneration stream and DASH sulfated in a fluid bed heavy oil cracker; and particulate cleanup with a ceramic candle filter. Plant startup is projected for 1997.

Tampa Electric Power will use a 10-percent slip stream at the 250 MWe Tampa Electric Company CCT plant to demonstrate hot gas desulfurization utilizing the GE Moving Bed Process. This demonstration is for physical checkout only and, as such, the Z-Sorb III sorbent is being supplied by METC.

Status of Trace Contaminant Removal Systems

A number of trace and minor species including alkali metals, chlorides, nitrogen compounds and hazardous air pollutants (HAPs) may require control either for process reasons or to ensure that environmental standards are met. Interest in the formation and control of HAPs in IGCC and PFBC systems is just beginning. Research to date has been aimed at defining a HAPs emission data base and documenting the effectiveness of present control technologies in reducing HAPs emissions. At present, mercury is the HAP emission of greatest concern, and is the only HAP likely to be recommended for control from power plant emissions.

Trace contaminants that form compounds that condense at operating temperatures [370 to 595°C (700 to 1100°F) for IGCC and 760 to 870°C (1400 to 1600°F)] for PFBC can be captured by efficient particulate removal devices. At the lower temperatures of IGCC, it is possible that these contaminants can be controlled by simply filtering the gases. In addition to condensation and filtration mechanisms being investigated, other methods including the use of sorbents and catalytic decomposition are also being studied and tested. Table 3 lists the trace contaminants of interest and the sorbents planned to control them.

Alkali Control Using Sorbents

Several research organizations are conducting programs to evaluate alkali removal using sorbents. In addition, testing of an alkali control device is planned at the Power System Development Facility in Wilsonville, Alabama. The alkali problem in IGCC systems is not as severe as in PFBC systems because of the lower gas temperature in IGCC systems. At IGCC temperatures, alkali should be controlled by condensation and efficient particulate filtration. At higher PFBC temperatures, a method to reduce these vapors may be necessary. Additional work may be needed to demonstrate techniques to reduce alkali efficiently upstream of the particulate filters.

Chloride Control

A primary concern for IGCC power plants is the formation of chloride compounds. If they build up in recycle loops (such as in the GE moving bed process), they can subsequently deposit on syngas coolers and heat exchangers. Bench-scale experiments have demonstrated that nahcolite pellets and granules are capable of reducing HCl levels to less than 1 ppm in high temperature coal gas streams at the temperatures between 400 and 650°C (750 to 1200°F). The GE Hot Gas Cleanup (HGCU) Program focuses on an enhanced circulating fluidized bed (CFB) chloride removal system.

TABLE 3
STATUS OF TRACE CONTAMINANT CONTROL SYSTEMS

TRACE CONTAMINANT	SORBENTS	INVESTIGATORS
Alkali	Emathlite, Activated bauxite kaolinite, fullers earth	Surrey University EERC, Westinghouse CPC
Chloride	nahcolite sodium bicarbonate	SRI International RTI GE Corporate R&D
Ammonia	NH ₃ decomposition catalysts Co-Mo-zinc titanate Ni and Ru-based catalysts	Krishnan and others (1988) SRI International RTI GE Corporate R&D Hampton University Enviropower

Ammonia Control

The approaches to NH₃ removal being developed involve rich-quench-lean (RQL) combustion and catalytic decomposition. RQL combustion techniques are being developed to meet present NO_x emission limits for fuels that contain fuel-bound nitrogen. Development of another ammonia removal system may be necessary to meet stringent NO_x limits for certain gasifiers that produce higher levels of NH₃.

Nickel-based catalysts have been tested which can reduce NH₃ by greater than 90 percent at high temperature [800-1000°C (1470-1830°F)] in the presence of high levels of H₂S, a known catalyst poison. Combined sorbent-catalysts to simultaneously remove H₂S and NH₃ are actively being pursued. Recent test results on Hart-49, a Hampton University/RTI material, demonstrated that this is a viable concept.

Hazardous Air Pollutants

Title III of the CAAA of 1990 requires that EPA study HAP emissions from utility boilers. The field sampling efforts are primarily being concluded by DOE and EPRI, with a few utility companies generating data for their specific systems.

The testing results demonstrate that the plants studied have fairly low emission factors for total CAAA trace elements on average. While HCl is the largest HAP emission from coal-fired power plants, it has not been determined to be a health hazard and thus is not likely to be controlled. Mercury is the only HAP likely to be controlled.

Impact of Hot Gas Cleanup on Advanced Power Systems Costs and Performance

The sensitivity of the capital cost, operating cost, and cost of electricity to variations in hot gas cleanup system parameters was determined by adjusting the parameters, and assessing the changes to baseline plant design and cost figures. Sensitivities were determined for IGCC and PFBC applications.

HGCU Impact on IGCC Plant Costs

Two 400-MWe IGCC plants were selected as baselines to encompass the wide range of gasifier products and the utilization of desulfurization as either a polisher or as a bulk sulfur remover. The first plant is based on the KRW air-blown gasifier with in-situ desulfurization and a hot gas desulfurizer. The second plant is based on the Destec oxygen-blown entrained flow gasifier with a hot gas desulfurizer to remove the bulk of the sulfur. Both IGCC plant designs utilize ceramic candle filters as final particulate control devices before combustion in the gas turbine.

As a general observation, the gas cleanup portion of the capital cost has a relatively minor impact on COE, as does the cost of consumables. The capital cost of hot gas cleanup systems are between 10 and 15 percent the IGCC total plant cost (TPC). Desulfurizer and particulate filter costs are 8 to 11 percent and 2 to 4 percent, respectively, of the TPC of an IGCC plant. The changes in IGCC COE resulting from 10-percent increases in selected hot gas cleanup parameters are shown in Table 4.

**Table 4
HGCU Influences on IGCC COE with 10% Increase in Parameter**

Parameter	Destec Percent COE change	KRW Percent COE change
Desulfurization Cost	+0.4%	+0.7%
Sorbent cost	+1%	+0.4%
Sorbent attrition rate	+1%	+0.4%
Candle filter face velocity	-0.2%	-0.3%
Candle filter cost	+0.1%	+0.1%
Candle filter life	-0.05%	-0.1%

PFBC Plants

The 535 MWe PFBC baseline plant was based on a Foster-Wheeler design with a coal pyrolyzer and a circulating PFBC. The hot gas cleanup systems associated with the PFBC power plants include only ceramic candle filter particulate control at 871°C (1,600°F). Sulfur control is achieved by dolomite injection into the carbonizer and FBC. Changes in the capital and consumables have less impact on the PFBC COE than on the IGCC.

The capital cost of hot gas particulate filter is about 10 percent the total plant cost of a PFBC plant. Changes in the PFBC COE due to 10-percent increases in selected hot gas cleanup parameters are shown in Table 5.

**TABLE 5
HGCU Influences on PFBC COE with 10% Increase in Parameter**

Parameter	Carbonizer Percent COE change	PFBC Percent COE Change
Candle filter face velocity (FBC)	-0.2%	-0.5%
Candle filter cost (FBC)	+0.1%	+0.3%
Candle filter life (FBC)	-0.1%	-0.2%

Findings

- Hot gas cleanup is necessary to obtain higher system efficiencies, comply with environmental requirements, and protect advanced gas turbines from corrosive and erosive impurities. Several development programs for hot gas desulfurization systems and the more critical hot gas particulate removal systems are underway. Results to date have verified the technical ability to clean hot gases, and longer duration tests would establish the long term durability record required for commercial acceptance.
- A coordinated program is in place for the development of hot gas cleanup systems and to resolve critical issues. This program consists of research and development, proof of concept tests and technology demonstrations. A timetable is in place to implement this program.
- Successful completion of these plans will demonstrate the ability to meet, within the next 3 to 5 years for IGCC and 4 to 6 years for PFBC, all requirements for future high temperature turbine operation and environmental acceptability.
- Key tests planned for 1996 and 1997 are critical to the demonstration of both IGCC and PFBC cleanup systems. IGCC tests include filter tests at Wilsonville; slipstream tests of a filter and desulfurization system at Tampa; and hot gas cleanup demonstration at Pinon Pine. PFBC tests include filter tests at Karhula, Finland; Wilsonville Alabama.; and Wakamatsu, Japan.
- Hot gas cleanup systems costs are about 10 to 15 percent of the total plant costs. While significant, this is a much smaller portion than any other major system. The most critical parameters impacting costs include the face velocity for particulate control and sorbent attrition and costs for desulfurization.
- The rapid progress in the development of advanced gas turbines coupled with the successful development of reliable hot gas cleanup systems will assure that the IGCC and PFBC program goals are achieved in the proposed time frame.

Contract Information

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