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Integrated Gasification Combined-Cycle Research Development and Demonstration Activities

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INTEGRATED GASIFICATION COMBINED-CYCLE RESEARCH DEVELOPMENT AND DEMONSTRATION ACTIVITIES IN THE U.S.

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Abstract

The United States Department of Energy (DOE) has selected six integrated gasification combined-cycle (IGCC) advanced power systems for demonstration in the Clean Coal Technology (CCT) Program. DOE's Office of Fossil Energy, Morgantown Energy Technology Center, is managing a research development and demonstration (RD&D) program that supports the CCT program, and addresses long-term improvements in support of IGCC technology. This overview briefly describes the CCT projects and the supporting RD&D activities.

Introduction

In the United States, coal continues as an energy mainstay, supplying more than 56 percent of the nation's electricity. Through the Department of Energy's (DOE's) Clean Coal Technology (CCT) Program and Fossil Energy research and development (RD&D) programs, clean coal-based power generation will enable the nation to continue using its plentiful domestic coal resources while meeting existing and more stringent emerging environmental quality requirements.

An Integrated Gasification Combined-Cycle (IGCC) system would replace the traditional coal combustor with a gasifier and gas turbine. The primary advantages of IGCC systems are high system efficiencies, obtained with their combined-cycle configuration, and ultra-low pollution levels. In an IGCC system, sulfur and particulate from the coal are removed before the gas is burned in the gas turbine; nitrogen oxide (NO_x) is dealt with in conventional fashion in the combustor.

Clean Coal Technology (CCT) Projects

Through cost sharing cooperative efforts with industry, DOE is supporting the large-scale demonstration of key coal-based technologies as a necessary step toward the commercialization of advanced power generation and industrial systems. It is anticipated that following successful demonstration, industry will be able to provide commercial offerings of clean coal technologies at competitive market prices. A prominent technology in the DOE CCT program is IGCC.

Commercial offerings of IGCC systems are anticipated to provide several advantages over conventional coal-based power generation systems. These advantages include superior environmental performance, high energy efficiency, low capital cost and cost of electricity, fuel flexibility including the ability to use high-sulfur coals, and modular designs suitable for repowering or greenfield applications. A brief summary of the six IGCC projects (see Figure 1) in the CCT program follows:

Piñon Pine IGCC Power Project -- The Piñon Pine Power Project is a 95 megawatt electric (MWe) IGCC facility that is currently being built at Sierra Pacific Power Company's Tracy Power Station near Reno, Nevada. The facility is expected to begin operations in early 1997 to demonstrate an IGCC system utilizing the air-blown KRW agglomerating ash fluidized-bed gasifier; hot-gas cleanup for particulate removal and desulfurization; and a power island that includes the first commercial use of the General Electric MS6001FA gas turbine.

Tampa Electric Integrated Gasification Combined Cycle Project -- The Tampa Electric IGCC Project, hosted by Tampa Electric Company, will demonstrate the greenfield application of a 250 MWe IGCC system using a Texaco oxygen-blown entrained-flow gasification technology, using a full-flow cold gas cleanup system and a 25 MWe hot gas cleanup slipstream containing a General Electric moving bed desulfurization system followed by a Pall Company particulate control system. The demonstration is expected to begin in the latter half of 1996 in a commercial utility setting located at Tampa Electric Company's Polk Power Station near Lakeland, Florida.

Combustion Engineering Repowering Project -- The Combustion Engineering (CE) Repowering Project is in the process of being resited and restructured. The 250 MWe IGCC system will be based on the Shell oxygen-blown, entrained-flow pressurized gasifier with a cold gas cleanup system.

Clean Power from Integrated Coal/Ore Reduction (CPICOR - COREX®) -- The CPICOR project objective is to demonstrate an industrial process to produce both power and iron based on the COREX® process. Iron ore is charged into a reduction shaft furnace that receives reducing gas from a melter-gasifier located below it. Only a small percentage of the reducing gas from the melter-gasifier is used for ore reduction. Therefore, a significant amount of gas remains for power production in a gas-fired combined-cycle system. The project team has announced a project development agreement with Geneva Steel of Vineyard, Utah. The project is in the final stages of negotiations and if approved by DOE, the plant would be integrated into the existing Geneva mill in Vineyard, Utah, and use 2,920 tons/day of coal and 4,840 tons/day of iron ore to produce 150 MWe of power and 3,200 tons/day of hot metal.

Clean Energy Demonstration Project -- The Clean Energy Demonstration Project, proposed by Clean Energy Partners Limited Partnership (CEP), will feature an advanced, commercial-scale, 477-MWe IGCC system and a 1.25-MWe coal gas fueled molten carbonate fuel cell (MCFC). CEP consists of Clean Energy Genco, Inc. (an affiliate of Duke Energy Corp.); Makowski Clean Energy Investors, Inc. (an affiliate of J. Makowski Company); British Gas Americas, Inc. (an affiliate of BG Holdings, Inc.); and an affiliate of General Electric Company. Clean Energy Genco, Inc., is the managing general partner of the CEP. The MCFC portion of the project will be executed under a subcontract with Fuel Cell Engineering, a subsidiary of Energy Research Corporation.

The project will demonstrate four objectives: (1) scaleup of the British Gas/Lurgi gasifier to commercial size; (2) integration of major processes and equipment within the IGCC system; (3) operation of a 1.25-MWe MCFC with coal gas; and (4) construction and operation of an advanced coal-fired power plant by an Independent Power Producer under commercial terms and conditions.

Wabash River Coal Gasification Repowering Project -- The Wabash River Coal Gasification Repowering Project is a joint venture of Destec Energy, Inc., and PSI Energy, Inc. (PSI). The objective is to demonstrate the commercial application of an IGCC system to repower one of six existing units at PSI's Wabash River Generating Station in West Terre Haute, Indiana. Operations are expected to begin in the fall of 1995. The coal-fired boiler will be replaced by a gasifier island to convert coal to clean fuel gas. The station's refurbished steam turbine will be arranged in a combined-cycle power island configuration, with the addition of a gas turbine and heat recovery steam generator to generate a combined total of 262 MWe.

IGCC Enabling Technology

Advanced gas turbines are a key enabling technology for the IGCC power generation systems, and the foundation for efficiencies in the range of 52 to 55 percent. DOE is funding the development of advanced gas turbines in the Advanced Turbine Systems (ATS) Program. The turbines, which will have natural gas efficiencies of 60 percent, are being evaluated for coal gas compatibility as part of that program.

The ATS is one of DOE's highest priority natural gas initiatives. Ultimately, the program projects commercial demonstration for the year 2000 and will be adaptable for coal and biomass firing; the systems will be highly efficient, environmentally superior, and cost competitive. (See Table 1.)

Table 1. Advanced Turbine System Goals
(Based on Natural Gas-Fired System)

Parameter	Goal for Utility Scale Systems
Highly Efficient	60% combined-cycle -- lower heat value.
Environmentally Superior	10% reduction in NO_x emissions over today's best system.
Cost Competitive	10% reduction in cost of electricity.

The ATS program is a cooperative effort by DOE's Office of Fossil Energy and Office of Energy Efficiency and Renewable Energy. A steering committee including Electric Research Power Institute (EPRI), Gas Research Institute (GRI), and the Environmental Protection Agency, along with the DOE offices, is designed to ensure that ATS-developed products are consistent with user industry needs and will be locatable throughout the country.

The ATS Program Phase I activities, which consisted of concept feasibility and system studies, have been completed. Under Phase II of the ATS Program, component design and sub-scale testing is currently being conducted by Allison Engine Company, Asea Brown Boveri, General Electric, Solar Turbines, and Westinghouse Electric. As the result of a recent solicitation, negotiations are currently underway for the third and forth phases of the ATS Program, which will test full-scale components and lead to power plant demonstrations.

IGCC RD&D Projects

DOE's IGCC RD&D program focuses on system improvements that will lead to lower cost systems and efficiency improvements without compromising the excellent environmental performance of this technology. This RD&D investment will result in the achievement of performance goals of over 50 percent efficiency at costs of $1000 per kilowatt or less, by incorporating high-temperature gas cleanup and advanced gas turbine systems. These increased power plant efficiencies will result in a 35 percent reduction of carbon dioxide emissions, compared with today's coal-fired power plants. Because of system improvements, capital cost will be reduced. Lower capital costs and increased efficiencies will lower the cost of electricity.

A number of major RD&D projects are key components of the development path for IGCC products. In some areas, RD&D applicable to one system is also applicable to another system (e.g., pressurized fluidized-bed combustion). An example of this philosophy is the development, evaluation, and commercialization of high-temperature ceramic filters for IGCCs and PFBCs. A great deal of the information that will be developed in the ceramic filter projects will be directly applicable to both types of systems, regardless of whether the actual ceramic filter testing is done on a PFBC or an IGCC. Major RD&D projects are discussed below.

<u>METC In-house Research</u> -- The Office of Technology Base Development (OTBD) within METC has been developing advanced hot-gas cleanup sorbents for IGCC advanced power systems, providing experimental support to DOE contractor and CCT participants. Current process development activities consist of three bench-scale projects: the Modular Gas Cleanup Rig (MGCR), the Riser Reactor, and a Fluid-Bed Hot-Gas Desulfurization (HGD) Process Development Unit (PDU) project. These projects are designed to provide process performance data addressing concept feasibility, technology barriers, engineering process and scaleup information. The MGCR rig cleans the process gas from METC's pilot-scale fluid-bed gasifier to provide particulate cleanup information, and provides a coal-derived low-Btu fuel gas to

generate performance data on sorbent desulfurization and ammonia reduction catalyst development and performance. Both the laboratory and MGCR data will be utilized to design the PDU, which will provide a test bed for verifying the integrated process operation, control, and long-term durability at a scale large enough to be meaningful and applicable to full-scale plant designs. Construction has begun on the 150,000 standard cubic feet per hour Fluid-Bed HGD PDU and the syngas generator that will supply fuel gas to the PDU. Operation of the PDU will support commercialization of advanced IGCC technologies. Startup for the PDU is scheduled for September, 1997.

Power Systems Development Facility (PSDF) -- The PSDF facility will be located at the Southern Company Service's Clean Coal Research Center near Wilsonville, Alabama. Participants in this cost-shared RD&D project include DOE, Southern Company Services, Foster Wheeler, M. W. Kellogg, Westinghouse, Industrial Filter and Pump, Combustion Power Company, Allison, Southern Research Institute, and the Electric Power Research Institute.

The Wilsonville PSDF will be a focal point of DOE's RD&D program in the coming decade. The PSDF will be used to resolve systems integration issues and to develop product improvements to enhance the environmental performance and cost competitiveness of IGCC and advanced PFBC technology. The PSDF will contain five separate modules (see Figure 2): an advanced PFBC, a transport reactor gasifier, several hot-gas particulate control devices (PCD), a combustion gas turbine, and a fuel cell test skid provided by EPRI. The PSDF modular design maximizes the flexibility of the facility. Testing of various technologies can be conducted in stand-alone and integrated test configurations, providing a flexible test facility that can be used to develop advanced power system components, evaluate advanced power system configurations and product enhancements, and assess the integration and control issues of these advanced power systems.

The advanced gasifier module uses M. W. Kellogg's transport reactor technology (see Figure 2), which was selected for the gas generator due to its flexibility to produce gas and particulate under either pressurized combustion (oxidizing) or gasification (reducing) conditions. The transport reactor will provide for parametric testing of the PCDs over a wide range of operating temperatures, gas velocities, and particulate loadings. The transport reactor potentially allows the particle size distribution, solids loading, and characteristics of the particulate in the gas stream to be varied in a number of ways. The transport reactor is sized to process nominally 2 tons/hr of coal to deliver 1,000 actual cubic feet per minute (acfm) of particulate laden gas to the PCD inlet over the temperature range of 1,000 to 1,800°F at 184 to 283 psia. Two PCDs will be tested alternately on the transport reactor. Startup is scheduled for late 1995.

A Molten Carbonate Fuel Cell will be added to the transport reactor, and integrated with a Molten Fuel Cell Test skid supplied by EPRI to provide cleanup of the hot fuel gas.

The advanced PFBC consists of Foster Wheeler's technology for second-generation PFBC (see Figure 3). The advanced PFBC system consists of a high-pressure (170 psia), medium temperature (1600-1800°F) carbonizer to generate 1,500 to 1,700 acfm of low-British thermal unit (Btu) fuel gas. This is followed by a circulating pressurized fluidized-bed combustor (CPFBC), operating at 150 psia, 1600°F, and generating 6,200 acfm combustion gas. The coal feed rate to the carbonizer will be 2.75 tons/hr. With the Longview limestone, a calcium to sulfur molar ratio of 1.75 is required to capture 90 percent of the sulfur in the carbonizer/CPFBC. Particulate laden gas from the carbonizer and the CPFBC will be routed to a separate PCD to remove particulate prior to entering a topping combustor. Tests of this module will lead to the first commercial demonstrations of a second-generation PFBC under the CCT program. Startup of the PFBC module is scheduled for mid-1996.

A Westinghouse developed Multi-Annular Swirl Burner (MASB) topping combustor will raise the inlet temperature to the combustion gas turbine to 2350 F, consistent with turbine inlet temperatures offered on advanced commercial high-efficiency turbines, which will raise the net plant efficiency of advanced PFBC systems to 45 percent, while maintaining low levels of NOx. At the PSDF, however, the topping combustor flue gas will be cooled to 1970°F in order to meet the temperature limitation on the small, standard gas turbine (Allison Model 501-KM) which will be used to power both the air compressor and an electric generator to produce a nominal 4 MW of electric power.

The PCDs will be tested at temperatures, pressures, and other gas conditions characteristic of a number of gasifiers and pressurized fluidized-bed combustors. The critical issues include integration of the PCDs into the advanced power systems, on-line cleaning, chemical and thermal degradation of components, fatigue and other modes of physical failure, blinding, collection efficiency as a function of particle size, and scaleup issues.

The PCDs selected for testing at the PSDF are being developed by Westinghouse Electric Corporation of Pittsburgh, Pennsylvania; Industrial Filter and Pump Manufacturing Company (IF&P) of Cicero, Illinois; and Combustion Power Company (CPC) of Menlo Park, California.

Westinghouse Filtration System -- Westinghouse will install a tiered vessel for use on the transport reactor which can be fitted with ceramic or metal candle filters, or alternate concepts such as cross flow filters or flexible ceramic bag filters (see Figure 4). The filter vessel will be a refractory-lined, coded, pressure vessel. The filters will be individual filter elements attached to a common plenum and discharge pipe to form clusters. Clusters of filters will be supported from a common, uncooled tubesheet. Each plenum of the filter will be cleaned from a single pulse nozzle. Qualification testing is in progress at Westinghouse to filter element for testing at the PSDF.

Combustion Power Company (CPC) Granular Bed Filter System -- In the CPC granular bed filter, gas from the M.W. Kellogg transport reactor gas is introduced into the center of a downward moving bed of granules, 6 mm spheres mostly made of aluminum oxide and mullite, which serve as the filter media to remove the particles from the gas. The gas reverses direction and moves counter current to the direction of the filter media to leave the pressure vessel. Clean media is constantly introduced from the top of the vessel. The particulate-containing media is removed from the bottom of the filter vessel and pneumatically conveyed and cleaned in a lift pipe. At the top of the lift pipe the particulate and clean media are separated in a disengagement vessel and the clean media is returned to the filter vessel. The transport gas and dust are cooled in a regenerative heat exchanger and the dust is removed in a baghouse.

Industrial Filter and Pump Filter System (IF&P). The IF&P filters are ceramic candles made of low density aluminosilicate fiber/silica and alumina binder and have densified monolithic end caps and flanges. The tubesheet is made of the same densified material. The 60-inch diameter, refractory-lined filter vessel will contain 78 candles arranged in 6 groups of 13 each for pulse cleaning. Individual jet pulse nozzles are provided to each candle. The IF&P PCD will operate at 1,500 to 1,700 acfm gas flow rates at 1600 to 1800°F, 170 psia, and 11,000 ppmw particle loading.

Westinghouse Ceramic Candle Filter System -- A larger Westinghouse PCD system will be tested on the PFBC combustor. This filter will contain six clusters of ceramic candles in a refractory-lined pressure vessel. Each array of filters is attached to a common plenum and discharge pipe and is cleaned from a single pulse nozzle source. Several arrays of individual candle filter elements are assembled into a cluster and the clusters are arranged vertically in the filter vessel. The cluster concept allows replacement of individual filters and provides a modular approach to scaleup. The Westinghouse PCD will operate at 6,200 acfm gas flow rate at 1600°F, 150 psia, and up to 15,000 ppmw particle loading.

An additional important role for the PSDF will be as a host site for collaborative and cost-shared RD&D partnerships with developers and users of power systems equipment. This RD&D could be conducted through CRADAs or through participation in the existing consortium. The PSDF provides an excellent opportunity for utilities to obtain hands-on evaluation and operational experience with IGCC and PFBC components and subsystems.

Hot-Gas Desulfurization

The cleanup systems targeted for IGCC must control contaminants such as sulfur and nitrogen compounds, particulate, alkali metals, and chloride compounds. Previous contaminant control requirements have been based on New Source Performance

Standards (NSPS). However, the IGCC and advanced PFBC technologies emission targets are one-tenth of the NSPS requirements and tolerance criteria for process sub-systems such as gas turbines.

The effort to develop HGD technology to remove hydrogen sulfide from IGCC gas streams has two distinct thrusts. The first is to develop suitable reactors for the process, and the second is to develop suitable sorbents for use in the reactor. RD&D activities are being focused on several reactor types and a wide array of sorbent formulations applicable to each reactor design. The most promising techniques for removing hydrogen sulfide from the gasifier product gas employs a dry, mixed-metal oxide sorbent for use in moving-bed, fluidized-bed, or transport or entrained reactors.

Zinc-based sorbents are currently the most well-developed desulfurization sorbents are near commercialization with vendor warranties. They are currently being evaluated for all reactor designs using RD&D and process development facilities. A brief description of selected RD&D facilities and activities are as follows:

General Electric Environmental Services, Inc. (GEESI). GEESI is developing a moving-bed, high-temperature desulfurization system (see Figure 4) at their corporate RD&D center in Schenectady, New York. A fixed-bed, air-blown gasifier capable of processing about 1800 pounds per hour of bituminous coal supplies fuel gas to a desulfurization system at a pressure of 20 atm and a nominal temperature of 1000 F and to a turbine simulator. Hydrogen sulfide is removed from the fuel gas in the counterflow absorber, which contains up to 3000 pounds of a mixed-metal oxide sorbent. An external sorbent regeneration loop produces an off-stream of sulfur dioxide suitable as feed stream to a sulfuric acid plant. Over 800 hours of testing have been completed in the 3-MWe scale unit to investigate the performance and durability of mixed-metal oxide sorbents. The control systems have been developed for the hot gas dsulfurization system so that successful automatic control of the integrated gasifier/hot gas desulfurization system has been demonstrated. A circulating fluidized bed chloride removal system has been designed, installed, and operated. Up to 95 percent chloride removal has been demonstrated with sodium bicarbonate with up to 50 percent sorbent utilization. At 1,000 degrees °F, vapor phase alkali metals have been well below specifications for gas turbines. In addition to being an undesired pollutant, chlorine can damage hot gas desulfurization sorbents and cause fouling of process piping.

Gas turbine components are also being tested to measure combustor performance on low-Btu gas, assess the effect of impurities in the fuel gas on deposition/corrosion in the gas turbine hot flue gas path, measure the level of trace impurities in the exhaust, and test staged combustion configurations to reduce nitrogen oxide emissions. Using dimensions suitable for axial combustors, novel staged combustion technology has produced significant reductions in the formation of nitrogen oxides from fuel-bound nitrogen. As little as 15 percent of fuel bound nitrogen is converted to nitrogen oxides in the configurations tested to date. This work directly supports the systems being designed for Tampa Electric and Combustion Engineering projects in the CCT program.

Research Triangle Park (RTI). In support of a fluid-bed reactor configuration, activities by RTI center on developing new and/or commercially available sorbent formulations and fabrication methods that enhance long-term chemical reactivity and mechanical strength. Work is being conducted in a bench-scale reactor for use in pilot-plant tests. A major achievement has been the successful completion of a 100-cycle test using a commercially made, 200-pound batch of zinc titanate (ZT-4) sorbent. This sorbent formulation was produced by a granulation technique that can promote long-term chemical reactivity and mechanical strength for fluidized-bed applications. The average sulfur capacity was enhanced and an order of magnitude improvement in attrition resistance was achieved. The sorbent was tested in a fluid-bed desulfurization unit at the Messukyla Research and Development Center in Tampere, Finland. Sorbent reactivity was excellent, reducing the hydrogen sulfide levels to less than 20 ppm in the cleaned exit gas.

RTI has also developed a direct sulfur recovery process (DSRP) to treat the regenerator gas from sulfided metal-oxide desulfurization sorbents to produce elemental sulfur. Beginning in late 1994, RTI began operation of a field test unit. Initially the unit consisted of RTI's existing, 2-stage DSRP reactor system integrated with a single stage, 3-inch fluidized-bed reactor for the sorbent. Field tests at METC's 10-inch fluid-bed gasifier demonstrated that a single stage DSRP was effective, providing 96% to 99% recovery of elemental sulfur. A larger skid-mounted unit is under construction and is scheduled for testing in 1996 at the 30 ton-per-day gasification pilot plant at the Messukyla Research and Development Center in Tampere, Finland.

An alternate advanced sulfur control process is under investigation that provides for direct product of elemental sulfur during sorbent regeneration, thereby eliminating the need for a separate sulfur conversion process (i.e., sorbent regeneration followed by conversion to elemental sulfur). The work is ongoing at the Louisiana State University and RTI. The goal is to reduce the desulfurization, regeneration and sulfur recover process complexity to provide an economically superior processing for regenerable desulfurization sorbents. Results to date are promising.

An RTI project addressing desulfurization mixed-metal oxide sorbent and catalyst combinations to simultaneously reduce hydrogen sulfide, as well as decompose fuel-bound nitrogen compounds (chiefly ammonia) at HGD operating temperatures suffer from continuing hydrogen sulfide poisoning of the ammonia catalyst. Current studies are examining high temperature process conditions (above 1450 °F). Some catalysts are effective at the high temperatures and do not suffer for hydrogen sulfide poisoning. Encouraging results were obtained from a recent test using the RTI mobile field-test unit (containing the DSRP reactor - see previous discussion) in conjunction with the MGCR facility. Ammonia decomposition ranged from 80 to 95 percent during the 120 hour test conducted at the METC MGCR facility.

General Electric Environmental Services, Inc. (GEESI). IGCC system efficiency studies have shown that hot-gas cleanup systems operating at temperatures above about 1000°F increase efficiency by only about 1 percent. Operation at lower temperatures may reduce cost of equipment, materials of construction, refractory and insulation requirements, and also, reduce ceramic filter operating temperatures. For these reasons, a contract was awarded to GEESI to conduct a study to develop a regenerable sorbent for use in the moderate temperature range of 650 to 1,000°F. Results to date are encouraging.

SRI International. SRI is currently developing and testing alkali-based disposable sorbents to remove hydrogen chloride vapor from high-temperature coal-derived fuel gas streams for IGCC and fuel cell applications. Several formulations are being optimized for three different reactor types (fixed-, fluidized-, and entrained-bed). The goal is to reduce the hydrogen chloride concentration to less than one part-per-million. One sorbent formulation has been tested successfully at pilot-scale in GE-CRD's development facility in Schenectady, NY.

High-Temperature, High-Pressure Particulate Control

Tidd Station Hot Gas Cleanup (HGCU) Slipstream Program. The HGCU slipstream program was conducted at American Electric Power Service Corporation's Tidd Station using a slipstream from a 70 MWe PFBC. The HGCU program objective to assess the readiness and economic viability of high-temperature and high-pressure (HTHP) particulate filter systems for PFBC applications. The filtration system was provided by Westinghouse, and utilized a three-cluster filter element system, incorporating 384, 1.5-meter long silicon carbide candle filters (see Figure 5). This system filtered approximately 7,360 acfm from the Tidd 70-MWe PFBC.

Proof-of-concept (POC) tests were used to qualify mullite and other silicon carbide candle filters as potential candidates for testing at the Tidd 70-MWe PFBC. In the POC tests, a Westinghouse filter system one-third the size of the Tidd filter system was used. The smaller filter vessel was installed on a PFBC owned by Ahlstrom/Pyropower, and used to qualify advanced candle filters for additional testing at the Tidd Station PFBC facility as well as the ascertain the effects of different coals on filter system performance.

With the conclusion of the Tidd Station PFBC HGCU slipstream program, 7,900 hours of coal fired operation have been accumulated (Tidd 5854 hours, Ahlstrom/Pyropower 2046 hours). Some major conclusion of the program are as follows: 1) The Westinghouse filtration system has demonstrated the ability to clean large groups of filters (up to 52 at this time) from a single remote high pressure pulse gas source; 2) The Westinghouse filter system design including the tube sheet, filter sealing approach, filter blow back system, and the plenum and cluster assembly is a successful design with room for additional scale-up; and 3) The Westinghouse system is a viable concept to provide particulate control for IGCC systems.

Other Particle Control Activities: A summary of other pertinent activities are as follows:

Westinghouse is currently assessing the suitability of damage-tolerant filter elements by providing lab-scale and bench-scale testing. Westinghouse is performing corrosion testing in their lab-scale flow-through test rig. Porous material coupons or sub-scale filters are exposed to a high temperature atmosphere containing alkali and steam, in conjunction with thermal pulsing. A bench-scale test facility capable of holding 16 full sized candle filters is used to evaluate basic filtration characteristics including filtration efficiency, pressure drop, and cleanability. Filter elements are also subjected to accelerated thermal pulsing and simulated process thermal transients in this facility to assess the effect to thermal stress on candle filter elements. The current test program includes evaluations of the 3M silicon carbide-Nextel composite filter, the Dupont Lanxide Composites silicon carbide-Nicalon composite filter, the Industrial Filter and Pump vacuum formed, chopped fiber Fibrosics filter, and the Dupont Lanxide Composites PRD-66 oxide filter. The main thrust of this project is to assist filter manufacturers' RD&D efforts to bring hot-gas filters to market.

Five new projects have recently been initiated under a Program titled "Advanced Hot Gas Filter Development". Contracts have been issued to Babcock and Wilcox, Dupont Lanxide Composites, Pall Aeropower, Textron Specialty Materials, and Westinghouse to develop and test a second generation of damage-tolerant hot-gas filters. Filters developed under this program are expected to be tolerant of thermal stresses. The Babcock and Wilcox concept is an alumina based continuous fiber ceramic composite (CFCC) material incorporating a chopped fiber matrix in a filament wound continuous fiber structure. Dupont Lanxide Composites is developing a unique microcracked oxide material that is thermal shock resistant. Pall Aeropower is building on iron aluminide technology developed at the Oak Ridge National Lab to develop a sulfur tolerant porous metal filter. Textron Specialty Materials is incorporating their SCS-6 monofilament in a porous nitride bonded silicon carbide matrix to form a CFCC filter material. Westinghouse, in conjunction with a Techniweave, is developing a mullite based CFCC filter material using a three dimensional weaving process. Tests of these filter elements will be conducted at DOE's Power System Development Facility, located in Wilsonville, AL.

Summary

Based on engineering studies and verification of on-going bench-scale and pilot plant operations, IGCC technology offers tremendous potential benefits over conventional coal-based power generation technologies in terms of efficiency and environmental performance.

In addition to greatly reduced emissions of sulfur dioxide, NO_x, and particulate, efficiency improvements result in approximately 35 percent lower emissions of carbon dioxide. The superior environmental performance of this coal-based technology and the timing of the demonstration projects should expand the choices available to utilities to meet their future power generation needs while simultaneously complying with Clean Air Act requirements.

Due to the diverse nature and configuration of the IGCC projects in the CCT Demonstration Program, a wide variety of technical and business approaches to advanced power generation projects will be addressed. In addition to achieving the specific efficiency, cost and environmental goals identified above, the projects will demonstrate: (1) the applicability of the technology to power generation or cogeneration in repowering or greenfield applications; (2) the use of modular construction for economic increments of capacity to match load growth; (3) fuel flexibility; and (4) the potential for design standardization due to modular construction to reduce engineering, construction time, and permitting complications for subsequent plants.

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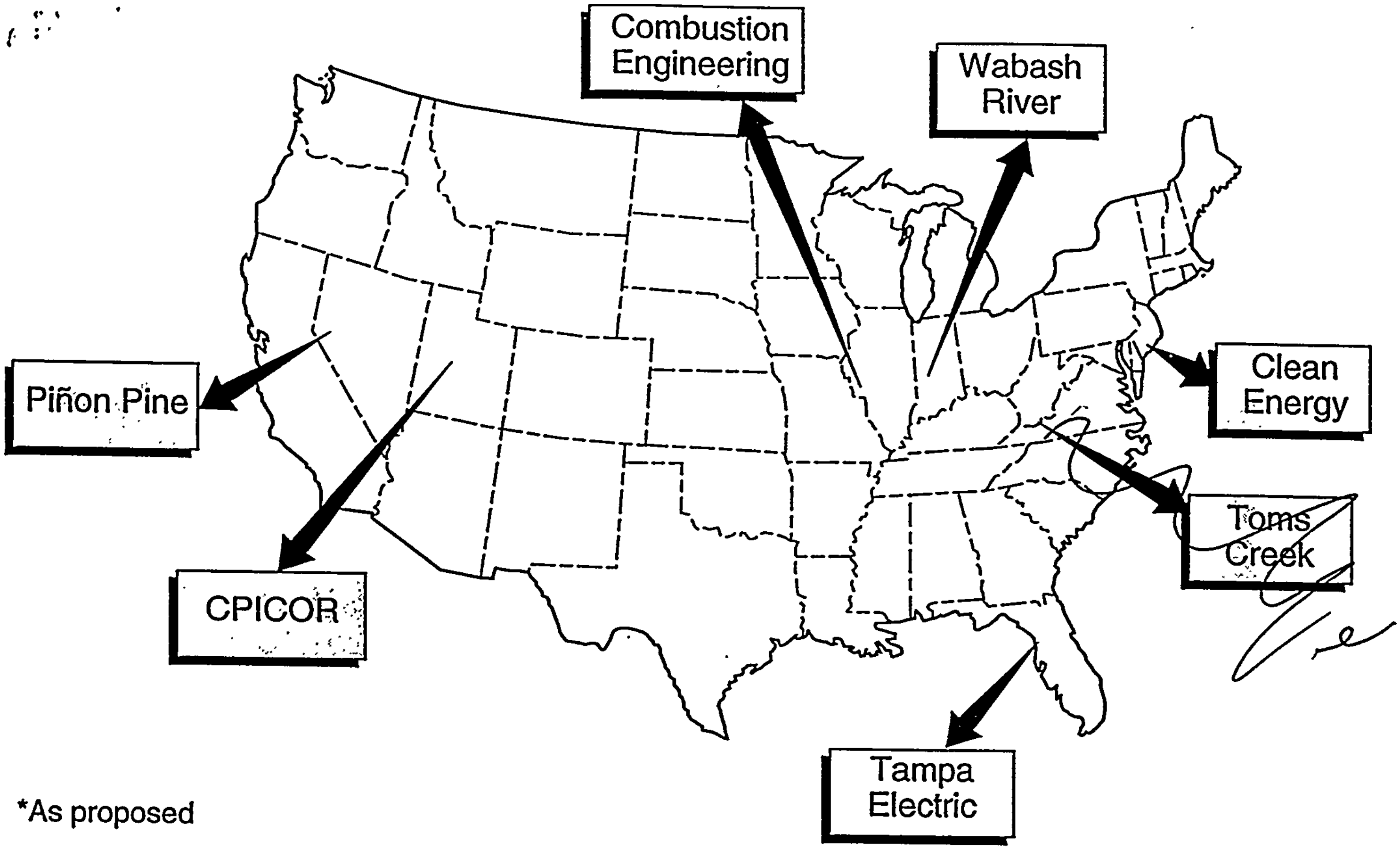


Figure 1. Clean Coal Technology Program IGCC Project Locations

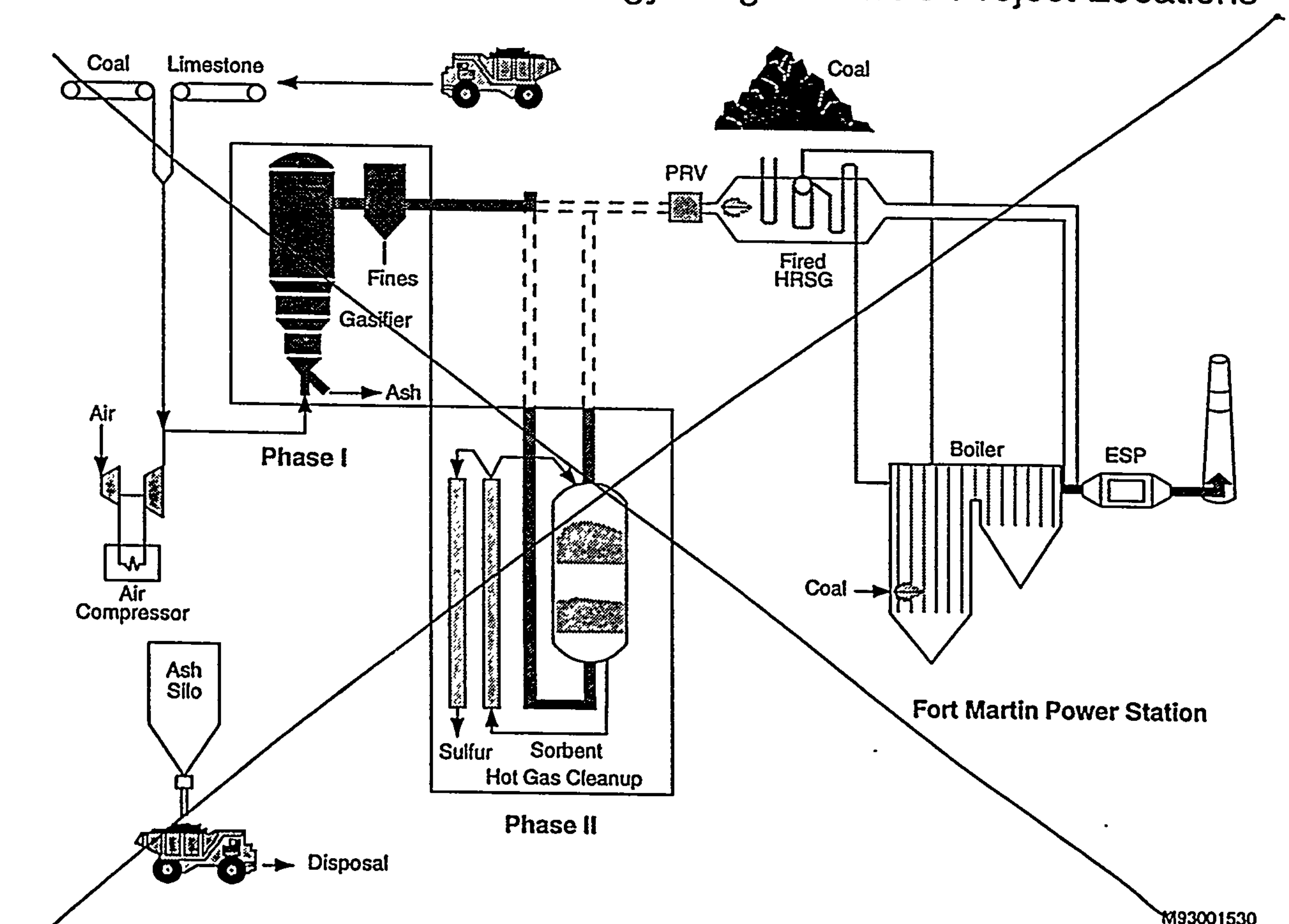


Figure 2. Gasification Product Improvement Facility - Process Schematic

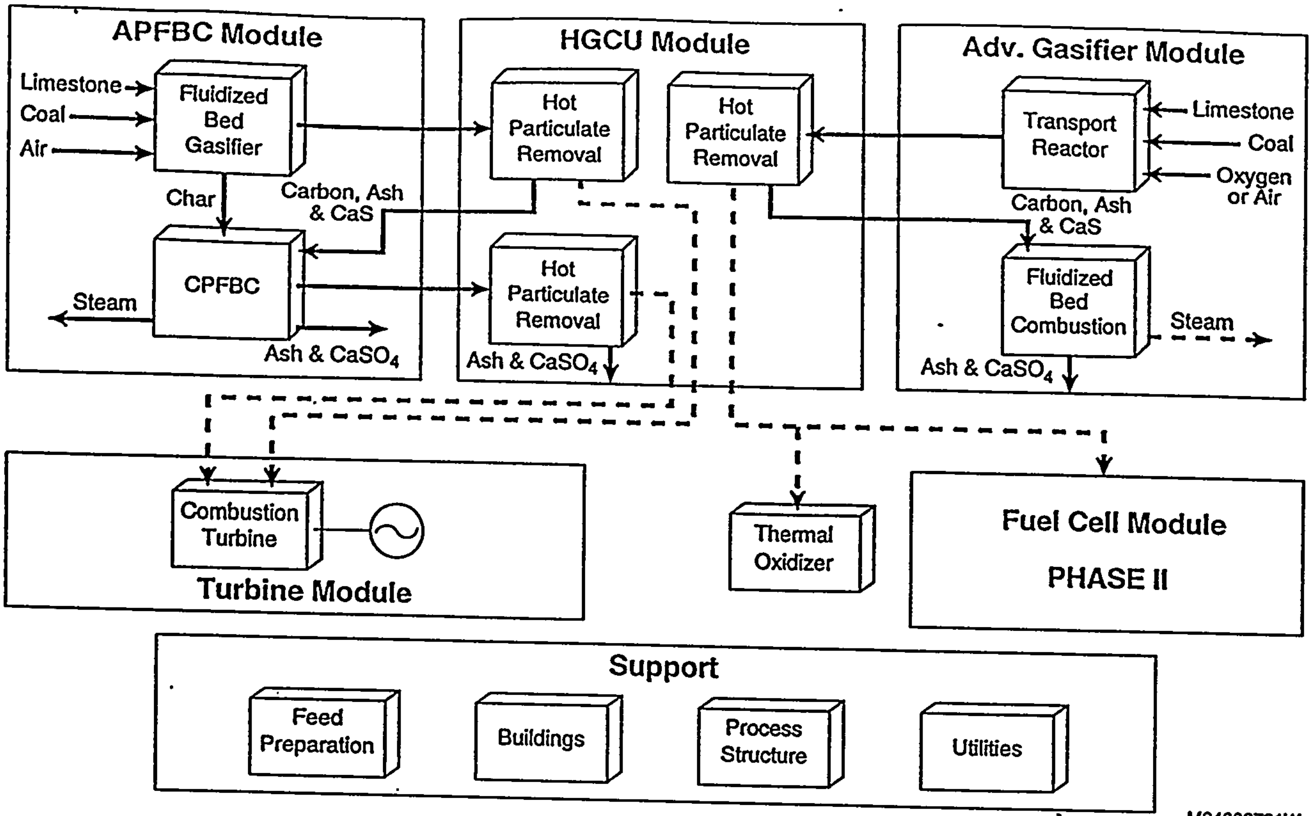


Figure ~~3~~ 2. Power Systems Development Facility - Technology Modules

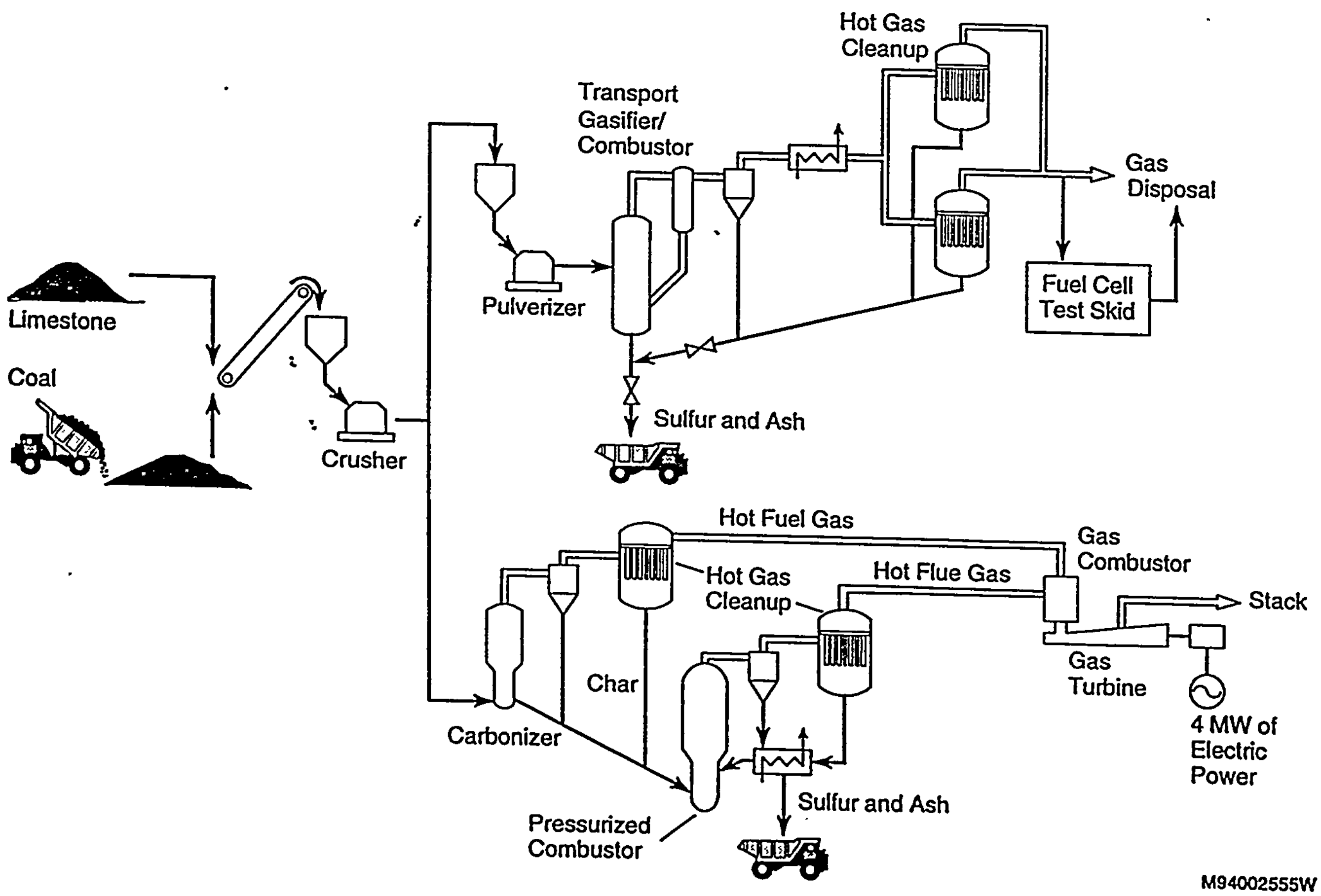
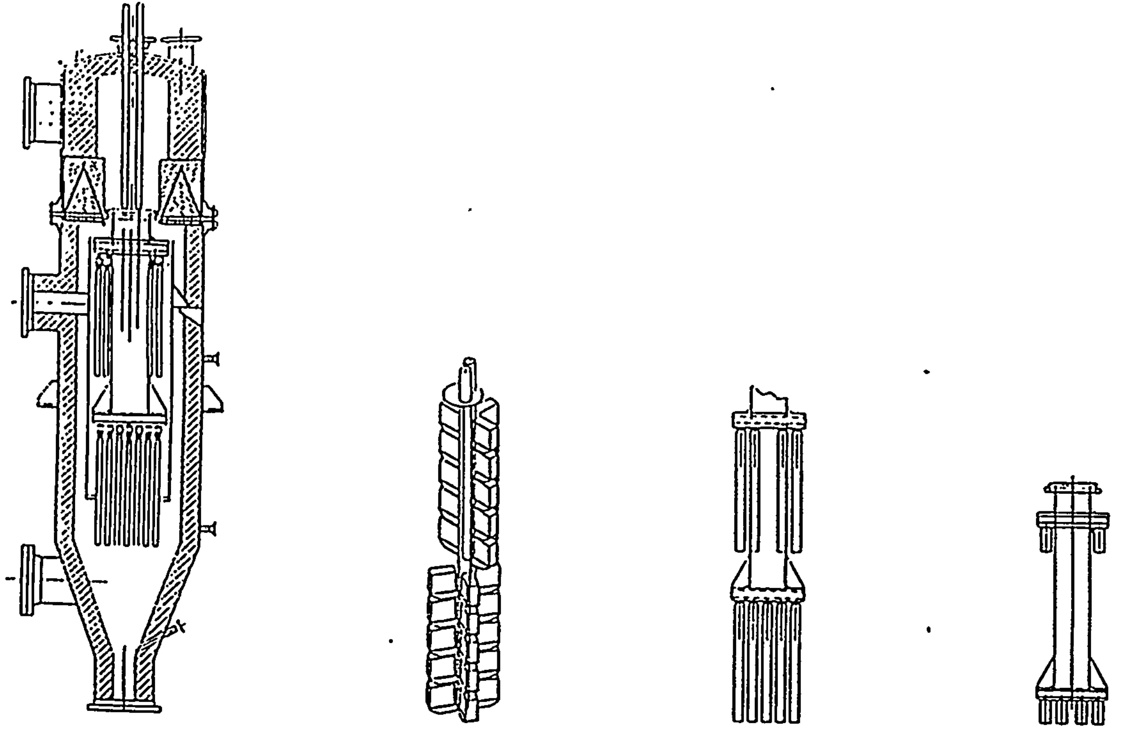


Figure ~~4~~ 3. Power Systems Development Facility - Process Diagram



PCD With Candle Cluster Test Section

Cross Flow Cluster Test Section

Ceramic Bag Cluster Test Section

Ceramem Cluster Test Section

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Figure 5. PSDF Westinghouse Filter Vessel and Filter Options

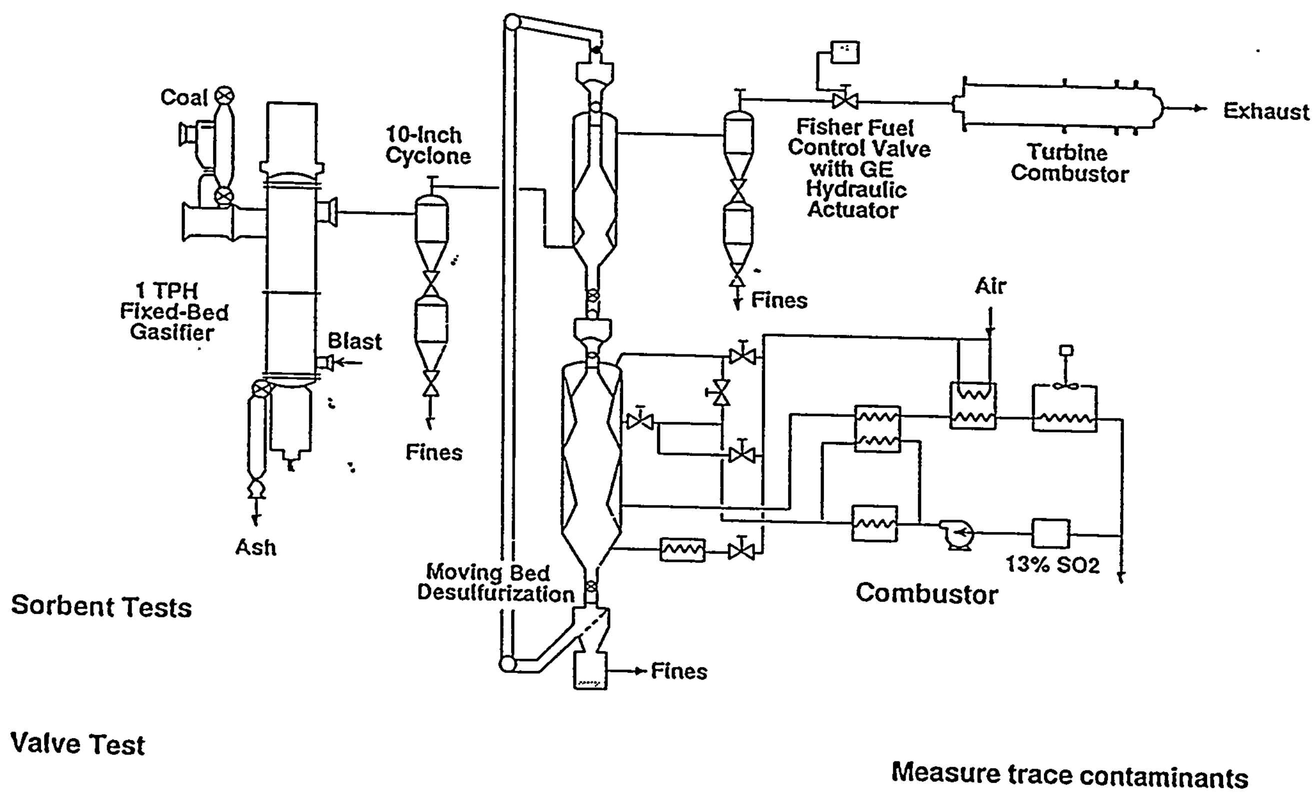

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Figure 6. GEESI Moving Bed Desulfurizer

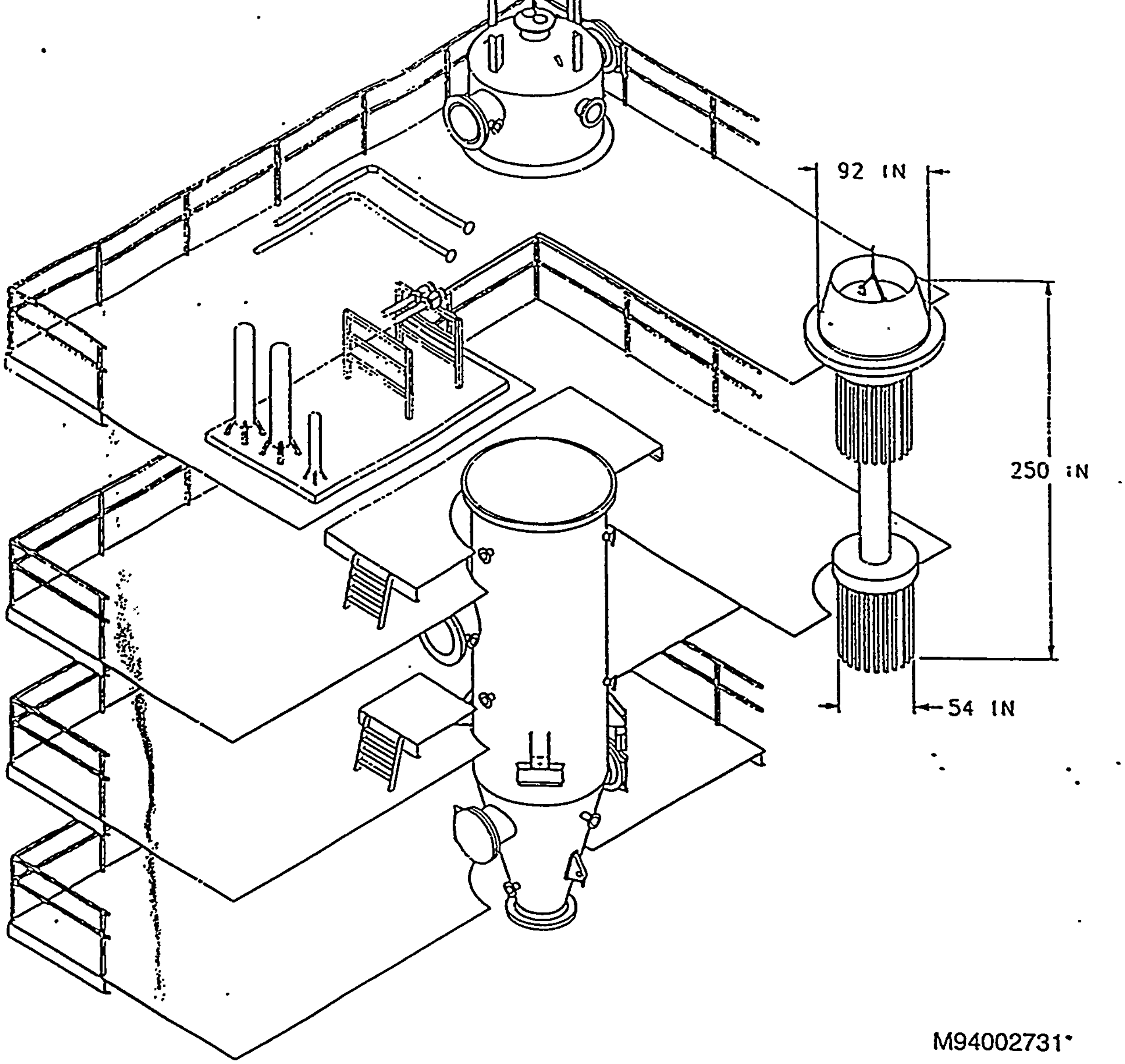

Figure 1. TIDD PFBC Hot Gas Clean Up System