the ENERGY lab

PROJECT FACTS

Gasification Technologies

Power Systems Development Facility

Background

The Power Systems Development Facility (PSDF) was established by the Department of Energy (DOE) to bolster the nation's efforts to develop environmentally clean, cost-effective, and reliable coal-based power generation technologies. Located in Wilsonville, Alabama, the PSDF was constructed as a highly flexible test center where researchers could economically demonstrate and evaluate innovative power system components on a semi-commercial scale.

Under the management of Southern Company Services, Inc., the PSDF was constructed and began operation in 1996. Development of advanced power systems at the PSDF focused specifically on identifying ways to reduce capital cost, enhance equipment reliability, and increase efficiency while meeting strict environmental standards. Testing at the PSDF led to the development of several types of first-of-a-kind technologies and successfully demonstrated their integration into a reliable gasification process for generating data for scale-up to commercial applications. These technologies included high pressure solids feed systems; a Transport Gasifier; hot gas filtration; continuous ash depressurization systems; and various instrumentation, sampling, and controls systems.

After successfully meeting the project goals, the facility adapted its processes and operations to become a leading test center focused primarily on developing technologies related to carbon dioxide (CO_2) capture from both coal gasification and coal combustion power plants. In 2009, the PSDF became the home of the National Carbon Capture Center (NCCC) for accelerating the development of cost-effective CO_2 capture technologies and ensuring continued use of coal for power generation.

The PSDF

Project Description

The PSDF was constructed at a scale large enough to produce commercially representative data while remaining sufficiently small for economic operation. Researchers used data from the PSDF to identify and guide further research and development (R&D) needed for the tested technologies or to confirm the readiness of technologies for scale-up to commercial operations.

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PROJECT DURATION

Start Date	End Date
09/14/1990	01/31/2009

COMPLETED

COST

Total Project Value
$441,541,425

DOE/Non-DOE Share
$380,900,815 / $60,640,610

PROJECT NUMBER

DE-FC21-90MC25140

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U.S. DEPARTMENT OF ENERGY

The PSDF offered the infrastructure to support a range of testing scales and conditions, as well as a highly trained and specialized staff. The main process at the original facility was the Transport Reactor train, which featured (and continues to demonstrate) key components of an advanced power generation plant. These components included:

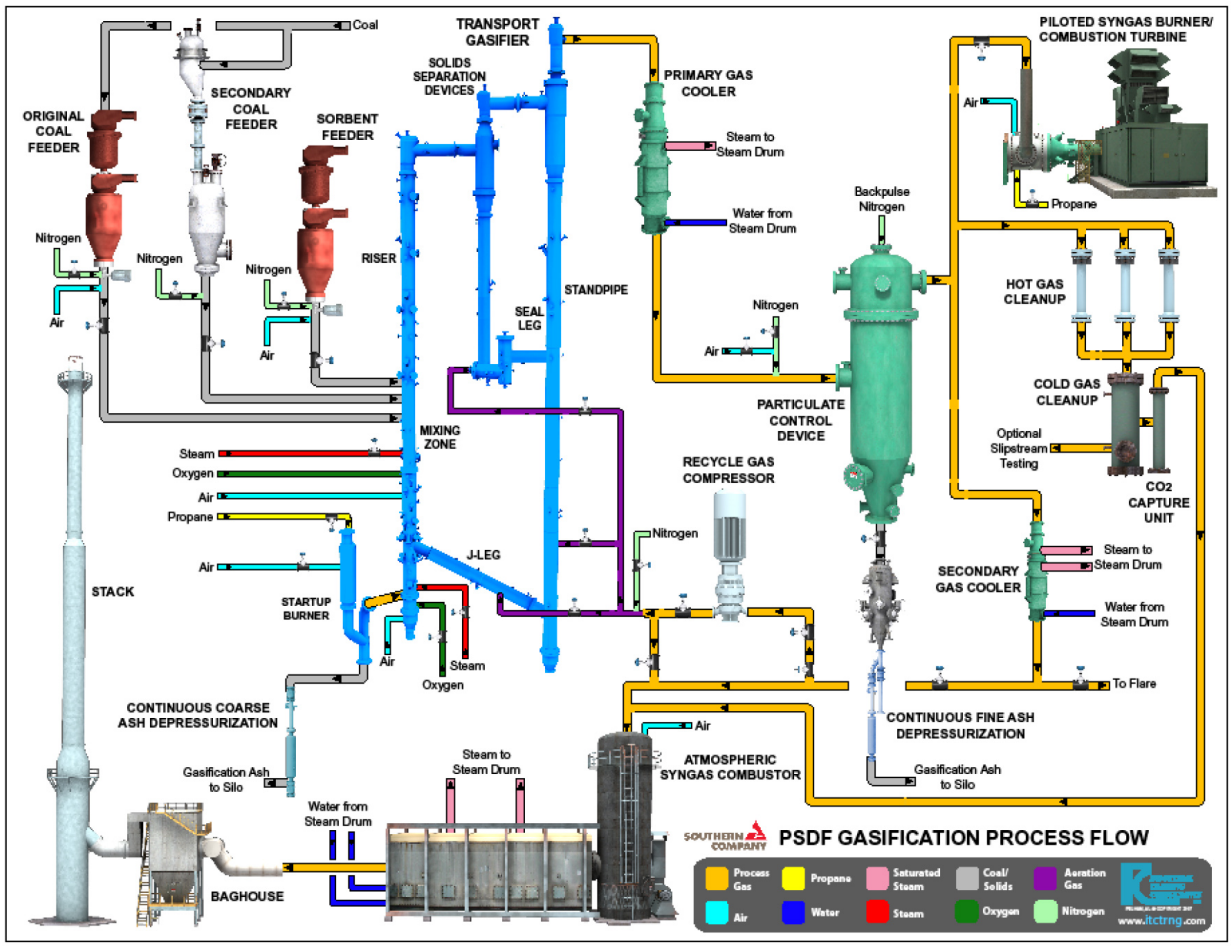
- High-pressure dry solids feed systems
- A Transport Reactor
- Synthesis gas (syngas) coolers
- A hot gas filter vessel; the particulate control device (PCD)
- Continuous ash depressurization systems developed at the PSDF for ash cooling and removal
- A piloted syngas burner and combustion turbine
- A slipstream syngas conditioning unit to test various pollutant control technologies
- A recycled syngas compressor to provide syngas for reactor aeration

The facility also accommodated a stand-alone cold-flow test unit, with small-scale replicates of the Transport Reactor, coal feeders, and the PCD. This equipment allowed specialized study of reactor and coal feed flow dynamics and initial screening of PCD filter elements.

Primary Project Goal

The PSDF operated to meet DOE's goal of accelerating the development and deployment of advanced coal-based power systems components, technologies, and processes. In support of this goal, the PSDF conducted testing of components and advanced power systems under realistic conditions using coal-derived gas streams and demonstrated the performance of components in an integrated mode of operation and at a size readily scaled to commercial systems.

The primary focus of the PSDF project originally centered on two key technologies: hot gas filtration and gasification of low-rank fuels. These two technologies progressed to the demonstration phase and are incorporated in a DOE Clean Coal Power Initiative project in Kemper County, Mississippi Details of these major accomplishments as well as some of the secondary accomplishments achieved at the PSDF are provided below.



PSDF Process Flow Diagram

Accomplishments

• ***Commercial Deployment*** In record time, the PSDF and DOE private/public collaboration efforts introduced to the commercial marketplace a new advanced coal-power generation process, which utilizes low-rank coal. After only eight years from the time of construction and commissioning, the Transport Integrated Gasification (TRIG™) process was selected for commercial deployment through the DOE Clean Coal Power Initiative. The TRIG process is being applied at the Mississippi Power Plant Ratcliffe in Kemper County, Mississippi. The data generated at the PSDF provided the basis for scale-up of the Transport Gasifier for commercial demonstration.

• ***Reactor Development*** Researchers at the PSDF commissioned and operated the Transport Reactor as both a coal combustor and a coal gasifier. Transport Reactor operations became extremely reliable during test campaigns of typically 250 to 750 hours in duration.

• Between 1996 and 1999, the Transport Reactor was successfully operated as a pressurized combustor for approximately 5,000 hours. These operational hours were accumulated over nine test campaigns during which five different fuels (three bituminous coals, one sub-bituminous coal, and petroleum coke) and four in-bed sulfur sorbents (three types of limestone and one dolomite) were evaluated.

• Between 1999 and the 2009, the Transport Reactor was operated as a gasifier (in both oxygen- and air-blown modes), generating syngas for a cumulative 11,500 hours. These operational hours were accumulated over 25 gasification test campaigns during which 9 fuels (4 bituminous, 1 sub-bituminous, and 4 lignite) and 2 in-bed sulfur sorbents (limestone and dolomite) were evaluated.

• The reactor was modified in 2006 to improve the solids collection efficiency, increase the residence time in the gasifier for higher carbon conversion and syngas heating value, and test a solids collection system better suited for commercial scale-up. In subsequent testing with air-blown operations using Powder River Basin (PRB) coal, there was about a 20 percent increase in the raw syngas lower heating value and an improvement in carbon conversion.

• High-sodium lignite, a difficult fuel to process, was successfully tested at PSDF on behalf of the Lignite Energy Council. The test concluded with 300 hours of operation. The addition of kaolin sorbent was effective in preventing agglomerate formation.

• ***Coal Preparation Advancements*** Improvements in the coal preparation system were incorporated to facilitate continuous feed operation of the advanced feeder system at pressurized conditions. Coal preparation was performed with crusher fluid roller bed mill systems designed for bituminous coal and modified for lignite and other coals. A fluid bed dryer was used to facilitate continuous operation with high-moisture lignite coals. Instrumentation and control logic were enhanced to improve system control reliability.

• ***Coal Feeder Development*** A key system that was tested and developed at the PSDF was the Pressurized Decoupled Advanced Coal (PDAC) feeder, a non-mechanical feed control device which reduces capital and maintenance costs versus commercially available lock-hopper systems. This device was scaled up based on cold flow testing and integrated into the PSDF gasification process. It was moved into commercial operation at the Kemper County facility.

• ***Design of Ash Removal Systems*** The PSDF staff developed advanced ash removal systems for cooling and depressurization of fine and coarse ashes. These systems improved overall process reliability.

• ***Advancement of Hot Gas Filtration*** Advanced particulate removal technology and many filter element types were tested to filter the product gases at high temperature and pressure. The material requirements were shared with vendors to aid their filter development programs.

Hot Gas Filter Elements and Failsafes

• The evaluations led to the identification of suitable filter elements to achieve the long-term high collection efficiency required by commercial gas turbines.

• To enhance reliability and protect downstream components, failsafe devices were identified that reliably seal off failed filter elements.

• The filtration system routinely operated with very high collection efficiency, with outlet solids concentrations in the syngas less than 0.1 ppmw. PSDF staff also developed a reliable on-line particulate monitoring system to detect particulate leakage.

• The PSDF tested specific filter elements for 1,000 hours to provide support data to Westinghouse for use on the City of Lakeland Clean Coal Technology project.

• ***Fuel Cell Testing*** Two test campaigns were successfully completed on 0.6 kW solid oxide fuel cells (SOFC), marking the first time an SOFC had been operated on coal-derived syngas. PSDF staff identified certain design improvement recommendations in testing a developer's fuel cell under the sponsorship of DOE's National Energy Technology Laboratory (NETL).

NETL Fuel Cell at the PSDF

• ***Stamet Feeder Testing*** The PSDF supported Stamet, Inc., in testing its dry-feed coal pump for 500 hours—the longest test duration yet achieved. Testing revealed the need for several design modifications for the pump to perform reliably at high pressure.

• ***Incorporation of Recycle Syngas Compressor*** To demonstrate gasifier operation in a more commercially viable way, a recycle gas compressor was installed for gasifier aeration, which increased the raw syngas heating value by up to 10 percent. Reliable process operations were achieved with the use of the recycle compressor.

• ***Syngas Cooler Enhancement*** Devices to inhibit erosion, made from several different materials, were tested at the inlet of the gas cooler, and suitable material was identified. This enabled reliable operation of the primary syngas cooler, an integral part of the gasification process.

• ***Instrumentation and Controls Improvements*** Significant progress with sensor development and process automation was achieved. Development of reliable and accurate sensors for the gasification process focused on coal feed, gasifier, and filter systems. PSDF controls specialists implemented effective automatic control of gasifier temperature, standpipe level, and aeration velocity.

• ***Gas Sampling Progress*** Advances in syngas sampling and analysis improved the operational reliability of the systems and provided the data needed for technology development and process understanding.

• ***Testing in Syngas Conditioning Unit*** A slipstream syngas cleanup unit provided a flexible test platform for testing numerous syngas contaminant removal technologies. The syngas conditioning unit was used for testing the removal of compounds such as CO_2, trace metals, sulfur, hydrocarbons, and ammonia. The unit was also used to test catalytic filter elements for simultaneous syngas filtration and water-gas shift reaction catalysis to enhance CO_2 removal.

• ***Technology Transfer*** The PSDF staff cultivated testing and technology transfer relationships with numerous third-party developers to ensure that test results and improvements developed at the PSDF were incorporated into future plants.

• ***Patented Processes*** Patents were filed and are pending for the solids separation unit incorporated in the 2006 gasifier modifications, the continuous ash depressurization systems, and catalytic filter elements.

Benefits

The PSDF provided U.S. industry with the world's most cost-effective, flexible test center for evaluating the critical components of advanced coal-based power-generating systems. When compared to the cost of building each of the technologies in use at the PSDF at stand-alone facilities, the initial construction in the mid-1990s at one site saved more than $32 million. Similarly, additional savings have been realized over the life of the project with this centralized test facility. The commercial deployment of the Transport Gasifier technology developed at the PSDF will demonstrate one of the cleanest, most energy-efficient coal power plants built to date. The Transport Gasifier demonstrated its suitability for cost-effective use with low-rank coals, which represent over half of the total coal reserves in the U.S. and world. In some instances, testing eliminated potential technologies from further consideration. Such screening was valuable in that it concentrated R&D efforts on those technologies most likely to succeed, and was an essential part of managing the U.S. DOE's financial resources.

Current Emphasis

With the incorporation of the NCCC, the facility is leading the way to development of lower-cost CO_2 capture technologies and to enable coal-based power generation to remain a key contributor to providing affordable, reliable, and clean power generation. The NCCC offers a flexible applied R&D test facility that provides commercially representative flue gas and syngas and the necessary infrastructure in which developers' technologies are installed and tested to generate data for performance verification under industrially realistic operating conditions. This effort is a less costly way to bridge the gaps between fundamental R&D and more costly large-scale commercial demonstrations. By operating a unique, but centralized, R&D test facility available to CO_2 technology developers, redundancy in testing sites and equipment is minimized and cost-effective use of R&D funds is achieved. The new facility accommodates a range of equipment sizes and provides commercially representative test conditions that allow results to be scaled confidently to commercial application, a crucial element in shortening development times.

The facility includes the PSDF gasification process, which provides syngas for testing of pre-combustion CO_2 capture and related technologies. Testing in the area of pre-combustion has thus far incorporated several developers' technologies, such as CO_2 solvents, a solid CO_2 sorbent, CO_2 and hydrogen gas separation membranes, and water-gas shift catalysts. The NCCC facilities also include the Post-Combustion Carbon Capture Center (PC4), located at the Alabama Power E.C. Gaston Plant. The PC4 has provided the test site for third-party developers to test technologies including solvents, gas separation membranes, and enzyme catalysts on coal-fired flue gas. The technologies can be tested at either component or integrated process scales.

Gasification and Pre-Combustion CO_2 Capture Facilities

Post-Combustion CO_2 Capture Facilities

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