DEMONSTRATION OF ADVANCED COAL CONVERSION PROCESSES AT THE POWER SYSTEMS DEVELOPMENT FACILITY

(PSDF web site: http://psdf.southernco.com)

Background

The Power Systems Development Facility (PSDF), located near Wilsonville, AL, is a large pilot plant designed to provide an engineering-scale demonstration of key components and advanced coal-fired power systems at sufficient size to provide data for commercial scale-up. It is a joint project of the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), Southern Company, and other industrial participants currently including the Electric Power Research Institute (EPRI), Siemens Westinghouse Power Corporation, Haliburton KBR, and Peabody Energy.

The PSDF concept was started in 1992. Coal was first fed to the Haliburton KBR Transport Reactor, operating as a combustor, in August 1996. After 5000 hours of combustion testing the Transport Reactor was modified for operation as a gasifier. Coal was fed to the Transport Gasifier in September 1999 and over 2300 hours of gasification testing have been completed to date. A third five-year operating period is currently being negotiated.

Recent Progress

The Transport Reactor (Figure 1) operates at considerably higher circulation rates, velocities and riser densities than conventional circulating beds, resulting in higher throughput, better mixing, and higher mass and heat transfer rates. Fuel, sorbent, steam, and air are combined in the mixing zone with solids recirculated from the standpipe. The gas with entrained solids moves up the mixing zone into the riser (which has a slightly smaller diameter) and enters the disengager. The larger particles in the syngas are removed by gravity separation in the disengager and most of the remaining particles are removed in the cyclone. The syngas stream exits the cyclone to a gas cooler and then goes to a Particulate Control Device (PCD), a high-temperature, high-pressure filter, for final particulate removal. The solids collected by the disengager and cyclone are recycled to the mixing zone through the standpipe and J-leg. When configured as a combustor, the transport reactor also includes a fluidized-bed solids cooler (not shown in Figure 1) that removes heat from the circulating solids before they are returned to the mixing zone.

The first gasification commissioning runs were hampered by poor PCD cleaning due to high solids loading and uneven gasification system operation. The highest heating values were achieved with Powder River Basin (PRB) subbituminous coal, since PRB coal is more reactive than bituminous coals. The carbon content in the circulating solids was extremely low due to inefficient solids collection and recirculation. After these runs the Transport Gasifier was modified to improve solids collection and recirculation by adding a loop seal underneath the primary cyclone. The modifications were very effective, allowing much higher solids circulation rates and higher coal feed rates. This resulted in lower solids loading to the PCD and higher char retention in the reactor loop, giving a higher carbon conversion.

The second gasification commissioning run was completed in March 2001 after 242 hours of operation. A PRB coal blend with Bucyrus limestone from Ohio was used. Gasifier and PCD operations were stable, but the coal feed system experienced problems with fine coal grinds. Based on the experience of this run, several additional modifications were made to the system. To prevent tar formation during startup, a coke breeze feed system was implemented that raises the gasifier temperature to 1,600°F before starting coal feed.

Several challenges were also encountered with the PCD. The solid particle characteristics changed dramatically from those encountered during combustion, large pressure drops were encountered, the syngas and char caused filter materials problems, and particulate-laden syngas sometimes leaked through the filter holders. These problems were overcome by the gasifier modifications mentioned above and by adjusting the PCD operating conditions, selecting better materials, and designing improved filter holders. Monolithic SiC, composite, and metal filter elements were all used during gasification commissioning runs.

The first gasification test campaign was started in July 2001 and continued until September 2001. Gasifier and PCD operations were very stable, with the longest period of continuous operation being more than 500 hours. Synthesis gas heating values, corrected for heat losses and dilution effects, were between 100 and 120 Btu/SCF and cold gas efficiencies, with the same corrections, were between 70 and 75 percent. Carbon conversion rates consistently over 95 percent were achieved. Modifications are under way that will allow finer coal to be reliably fed.

The second test campaign was started in December 2001 and completed in April 2002. The main focus was commissioning the reactor modifications for oxygen-blown operation. Data evaluation from these tests is ongoing. Iron aluminide filters were used extensively, with the longest exposure time (1,700 hours) being in the 700-900°F temperature range. PCD performance was within design parameters of stable baseline and peak differential pressures. Char removal efficiencies were excellent, with outlet dust measurements consistently less than 1.0 ppmw.

Future Plans -

Initial gasification tests have concentrated on PRB subbituminous coals because their high reactivity and volatiles content enhance gasification. Future gasification tests are planned with bituminous coals to verify their commercial suitability. Sulfur emissions are expected to be low with bituminous coals, despite their typically higher sulfur content. Because of the high mass transfer rates in the reactor, sulfur capture depends on equilibrium characteristics of the syngas components, rather than on the amount of sulfur in the coal. When temperature and CO_2 levels are properly controlled, PRB coal gasification produces less than 100 ppmv of sulfur in the syngas (or stack SO_2 emissions of about 25 ppmv). The equilibrium of syngas components from bituminous coal will yield a lower sulfur concentration than with PRB coal, despite larger quantities of sulfur in the coal.

NETL, Southern Company, and other participants are currently planning the next five years of research at the PSDF. The main goals are to support DOE's Vision 21 program for developing syngas-based processes and to support commercialization of an air-blown transport gasifier-based power production system. Major proposed activities for 2002 through 2006 include the following:

- continue air-blown and oxygen-blown gasification development
- integrate oxygen-blown gasifier with advanced air separation technology
- integrate gasifier with existing combustion turbine at the PSDF
- evaluate multi-contaminate (H_2S, Hg, HCl, etc.) control systems
- evaluate novel CO_2 and H_2 separation systems
- test advanced materials in gasifier and combustion turbine environments
- evaluate high temperature gas and particle sensors
- improve system integration and controls
- improve gas cooling technology
- improve coal and limestone feed systems and ash removal and cooling systems

Benefits –

Because of its operating conditions, the Transport Gasifier is well-suited to high ash, high melting point coals. Synthesis gas from a Transport Gasifier can be used to fuel a combustion gas turbine for the production of power, or it can be used to power a fuel cell or produce fuel or chemicals. Operation of the Haliburton KBR Transport Gasifier at the PSDF, in combination with a high-temperature, high-pressure filter, has shown that it offers many advantages over current gasifiers and combustors, including high carbon conversion, high sulfur capture, a small footprint, and a simple mechanical design.

Southern Company has developed a conceptual commercial plant design and cost estimate for an air-blown Transport Reactor–based integrated gasification combined cycle (IGCC) power plant based on a General Electric (GE) 7FA combustion turbine. In a paper presented at the DOE Clean Coal and Power Conference in Washington, D. C. on November 19-20, 2001, Southern Company stated that the design produces 298.4 MW (net) with a lower heating value (LHV) heat rate of 7,830 Btu/kW-hr (43.6 % efficiency) at average annual ambient conditions. With projected SO_2 emissions of 0.10 lb/MMBtu and NO_X emissions of 0.07 lb/MMBtu. The estimated total plant cost for this Serial No. 1, greenfield plant is $1,290/kW (excluding the cost of capital during construction and startup costs). The total plant cost for a second 600 MW plant was projected to be $1,040/kW and the LHV heat rate was projected to be 7,420 Btu/kW-hr (46.0% efficiency). All capital costs are given in January 2001 dollars.

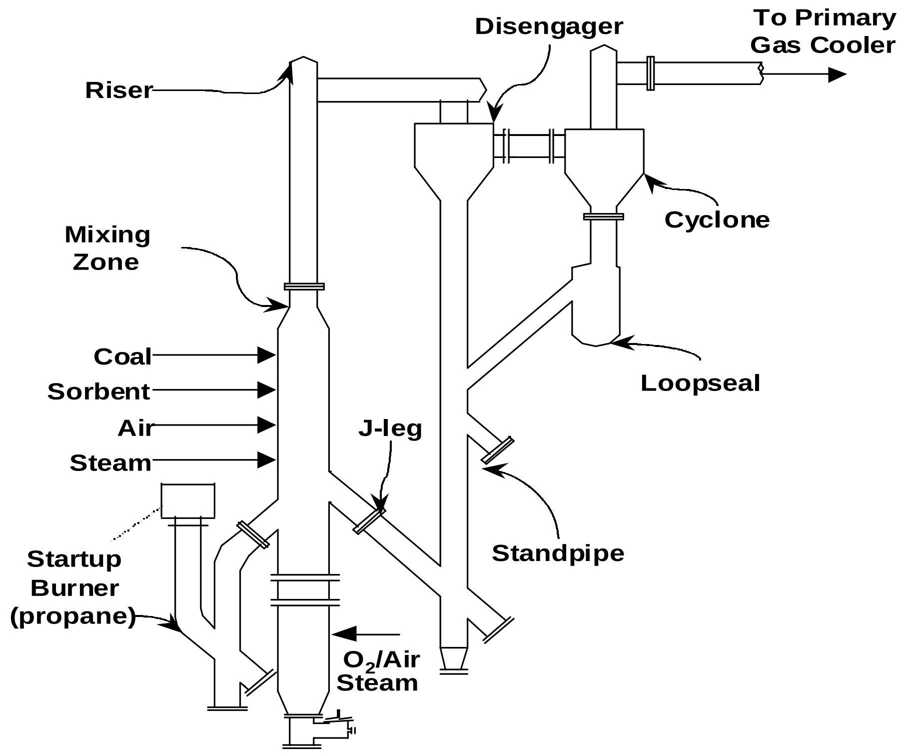

Figure 1. Transport Gasifier