Renewed Interest in the Integrated Gasification Combined Cycle

The growing demand for electricity in the U.S. is fueling an interest in building new power plants. Although there is some activity in developing renewable resources, such as wind and solar energy, the more traditional energy sources are likely to be relied on for the majority of large increments in power generation. Yet, volatile natural gas prices, tightening emission regulations, and an abundant world coal supply provide an ideal backdrop for integrated gasification combined cycle (IGCC) to be a mainstream "clean coal" commercial offering.

Gasification is a commercially proven method of efficiently converting coal and other hydrocarbons into a clean gaseous fuel called synthesis gas (syngas) through a noncombustion, partial oxidation reaction. IGCC is the combination of gasification with a combined-cycle system to generate electricity. The total plant consists of four major operating components: an air separation unit (ASU); a gasification plant; a gas clean-up system; and a combined-cycle power plant (Figure). The ASU separates air into its component parts and sends the gasifier a stream of high-purity oxygen. The gasification plant then produces the syngas from a variety of fuels. Afterwards, the syngas can be cleanly burned in a combined-cycle gas turbine.

Although this technology has been available and proven for many years, a number of barriers have prevented it from entering the commercial mainstream, including cost and perceived performance challenges relative to other technologies, such as pulverized coal and gas-turbine combined cycle. Additionally, in order to construct an IGCC plant, energy providers have had to do business with multiple parties, including power equipment suppliers, gasification technology providers, and, typically, an engineering procurement contractor, and a construction contractor. However, this is all changing.

Turnkey IGCC

GE Energy, Inc. (Atlanta, GA; www.gepower.com), Bechtel Power (Frederick, MD; www.bechtel.com) and American Electric Power (AEP; Columbus, OH; www.aep.com) have taken critical steps toward construction of what would be "the first large-scale IGCC power plant built in the U.S. and the first IGCC plant to come online in the U.S. in nearly 10 years," says Dale Heydlauff, AEP vice president, New Generation. GE has formed an alliance with Bechtel to provide customers with a single-point responsibility for a turnkey IGCC plant providing everything from the coal feed to the power grid. GE will provide the technology design, development and system integration, while Bechtel will provide engineering, procurement and construction of the facilities. AEP, the plant owner and operator, has contracted with GE and Bechtel to conduct front-end engineering and design (FEED) for a proposed commercial, 629-MW IGCC facility slated for commercial startup in 2010.

The proposed GE-Bechtel Reference Plant will be based on the gasification technology GE acquired from ChevronTexaco in 2004. The combined-cycle-system model consists of two gas-turbine trains combined with a single reheat-steam-turbine generator. Each train comprises a 60-Hz gas-turbine generator and multipressure level heat-recovery steam generator (HRSG). Its performance when burning eastern U.S. bituminous coal at ISO conditions and zero feet elevation is given in the table above. "An important feature of the Reference Plant is its ability to handle a broad range of feedstocks," says GE engineer Allan Connolly. "An option to

GE Reference Plant Design Basis

Source	Power Output, MW
Gas Turbine	464
Steam Turbine	300
Total Gross	764
Auxiliary Power	135
Net Power	629
Heat Rate (Btu/kWh, HHV)	8,844
Coal Feed, ton/d (dry)	5,372
O_2 Feed, ton/d (pure)	4,894

This data is based on an Illinois basin coal containing 3.23 wt.% sulfur and 12.25 wt.% ash, both on a dry basis. The coal heating value is 12,650 Btu/lb on a dry basis.

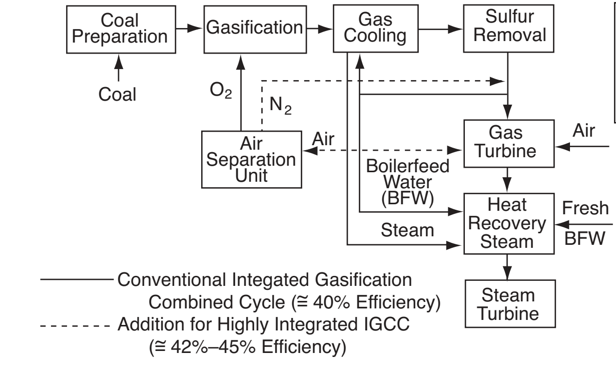

Figure. Schematic of an integrated gasification combined-cycle power plant.

blend petroleum coke with coal is available to further broaden the range of IGCC feeds that are possible," he continues.

Currently, the syngas is cooled below 100°C for conventional cleaning, and it is subsequently reheated before combustion, a process that requires substantial heat exchange capacity. The HRSGs remove the heat from the gas-turbine exhaust gases and use it to superheat the saturated steam and economize the boiler feed water to the gasification unit's radiant syngas coolers. The total superheated steam from both HRSGs is fed to the steam turbine to generate power. The gas turbine is specifically configured to combust the clean syngas and is also integrated with the ASU. A portion of the ASU air requirement (about 40%) is supplied by extracting air from the compressor and using byproduct nitrogen to increase output energy and reduce NO_x emissions.

GE is also developing state of the art computational fluid dynamics (CFD) and reactive flow modeling tools to understand the breakup and flow of particulates, and the heat transfer process within the radiant cooler. These accurate and validated models are the key to improving the design of its next-generation radiant cooling system.

A related issue is the ultimate destination of water purged from the syngas scrubbing system within the gasification unit. Water must be purged from this system to control dissolved species such as chlorides. The design offers evaporation of the process water purged from syngas scrubbing to provide a water stream for recycle and to minimize the discharge from the plant. This zero-process-discharge option has already been commercialized at Tampa Electric Co.'s (TECO) Polk Power Station, which produces enough electricity to serve 75,000 homes.

"For the Reference Plant design, we targeted a deep-sulfur removal level from the syngas (as low as 20 ppmv) to allow the option of including a selective catalytic reduction (SCR) catalyst section in the HRSG," says Connolly. This deep-sulfur removal target was a leading driver for the final selection of a physical solvent for the Acid Gas Removal (AGR). In addition, an activated carbon adsorption bed will remove 90–95% of the mercury (Hg) contained in the syngas. An SCR system would further reduce NO_x in the gas-turbine exhaust gas to single digit levels, well under the limits established by the New Source Emissions Standards for coal plants.

Energy Northwest (Richland, WA; www.energy-northwest.com) is developing the first IGCC power plant for the Pacific region. Project manager Tom Krueger says that "IGCC is not only the lowest cost energy option, but the realistic, environmentally responsible option for producing large quantities of base load power at affordable rates.

The proposed design gasifies coal or petroleum coke to fuel combustion turbines and generates 300–600 MW. The estimated design and procurement cost for the power complex, named the Pacific Mountain Energy Center, is approximately $1 billion, including $35 million to make the facility compatible with potential future technologies to remove and capture CO_2 from the feedstocks.

The reliability, capital costs and environmental results of modern gasification technologies have been extensively documented. There are now over 10 IGCC plants operating in the world with one to two years of operating experience. The syngas produced from coal, petroleum coke or heavy liquids can be used to produce hydrogen, steam, transportation fuels and chemicals, or as a direct replacement for natural gas to produce power.

Of particular interest is the fact that IGCC plants can be designed to capture CO_2 and make it available for disposal. In a coal- or gas-fired power plant, CO_2 can only be removed after combustion, which is not economically practical. However, CO_2 may be removed before the syngas is fed to the gas turbines in IGCC plants. This is currently being done at gasification plants operating in refineries that remove CO_2 to obtain pure hydrogen.

The next frontier for power generation technology will be to use gasification to produce hydrogen as the sole power plant fuel and capture CO_2 for disposal in deep underground reservoirs. It may be possible to use the hydrogen from an IGCC facility in fuel cells and have pure water as the only emission. This is the vision of FutureGen, a zero-emission coal-fueled power plant funded by the DOE. CEP