COAL AND REFINERY IGCC, INCLUDING GAS TURBINE ENGINE DEVELOPMENTS

Coal and refinery IGCC are large-scale applications of the technology. The prime mover is the gas turbine engine, frequently a F-class engine. The information is drawn from the panel discussions on Integrated Gasification Combined Cycles (IGCC) presented at ASME Turbo Expo 2002. The panel presented state-of-the-art information on IGCC. Quite interesting was the presentation by the General Electric speaker (Brun, 2002), strongly indicating GE's commitment to coal IGCC.

Siemens: The Siemens speaker (Hannemann, 2002): stated five IGCC systems with Siemens GTs are in operation (or under development). This includes one coal IGCC system in The Netherlands (the Buggenum facility discussed below under NUON), and four refinery IGCC systems in Italy (in cooperation with Ansaldo). Typical net efficiency (LHV basis) is 42.8%, and NOx is about 25 ppmv (15% O_2 dry). Oxygen-blown gasification is used, with the oxygen produced in an on-site air separation unit (ASU)

The *economics* of IGCC is strongly dependent on the fuel feedstock type and its cost. The speaker emphasized that IGCC is competitive with natural gas-fired IGCC if the fuel feedstock cost is 2.0 to 2.5 USD per GJ cheaper than natural gas. This implies an IGCC fuel feedstock cost in the range of 1.0 to 2.0 USD/GJ. The capital cost of the Siemens IGCC system was stated as 1070 USD/kw. For comparison, the cost of a conventional pulverized coal steam power plant (PC-SPP), with full state-of-the art environmental control, was stated as $700/kw.

General Electric: The GE speaker (Brun, 2002) reiterated the interest of the Bush Administration for coal. GE is focusing on coal IGCC rather than PC-SPP. It sees very few PC-SPP units receiving the permits to operate, and believes coal IGCC is a superior technology for using the nation's coal. Data supporting this position is given below. [Of course there are many 30-40 years old PC-SPP systems operating in the US. Changes recently introduced for the Prevention of Significant Deterioration Rules will probably improve the economics of upgrading the old PC-SPP plants rather than shutting them down and bringing totally new technology online.]

GE is concerned about the long term cost of natural gas and sustaining the recent significant growth in gas-fired CCCT systems. Since 1997, about 100 GW of generating capacity, mainly as gas-fired GTs, has been installed in the US. GE expects the following growth in electricity generation capacity over the 2002-2006 period: 328 GW in the USA, 194 GW in Asia, and 166 GW in Europe, for a total of 688 GW. This is about a 20% growth.

With respect to an overall energy strategy, GE has recently bought into the wind turbine business (through purchasing Enron wind turbine operations), views nuclear power as a political long shot, and sees natural gas as the big player for the next 10-20 years, because of the attractive cost of natural gas CCCT, the easy development of CCCT power plants, and their cleanliness. GE believes coal IGCC will win out over PC-SPP in the US and Europe, though the marketplace needs to become convinced of the reliability and reasonableness of cost of coal IGCC. GE is currently involved in several IGCC plants: three in the US on coal, one in Europe on coal, one in Europe on refinery residue, and one in Europe on industrial waste.

The following table of air emissions was given, indicating significantly lower air emissions from coal IGCC compared to PC-SPP. The environmental impacts on water and land were not copied down, though they are of concern for coal IGCC (as they are for PC-SPP). [The residue from coal IGCC may have non-leachable characteristics compared to the leachable characteristics of PC-SPP residues.] With IGCC, the stream requiring cleanup is relatively small (0.8 million #/hr) compared to 8 million #/hr for a PC-SPP plant of equivalent output (500 MW).

Table 1
Comparison of Pollutant Emissions for Large Coal Power Plants: IGCC versus PC-SPP

Pollutant	Coal IGCC	PC-SPP
SO2	0.1 #/MW-hr (98% removal)	13.8 #/MW-hr
NOx	0.38 #/MW-hr (0.07 #/MMBtu also stated)	5.5 #/MW-hr
Particulate Matter	0.02 #/MW-hr	0.5 #/MW-hr
Mercury	95% removal (by activated carbon filtration)	0% removal at present

For all of its gas turbines run on coal gasification synthesis gas, GE uses diffusion flame combustors. Low NOx, in the range of 15-25 ppmv (at 15% O_2 dry), is obtained because the fuel has a low energy content. Additionally, either nitrogen (the waste product of the ASU) or steam is injected into the diffusion flame for temperature reduction and thus NOx control. In the future, GE expects to be able to guarantee NOx of 9-15 ppmv (15% O_2 dry) for its IGCC systems.

Because of the improved efficiency of coal IGCC over PC-SPP, GE claims a 13% reduction in CO_2 emissions. Additionally, GE claims coal IGCC holds the promise of CO_2 sequestration. However, many details need to worked out on the engineering and economics of coal IGCC with CO_2 sequestration, and demonstration plants need to built and tested, with understanding and knowledge gained in this critical area.

GE states the cost of coal IGCC as $1000-$1250/kw. This is quite a bit less than the first coal IGCC plant in the US: the Cool Water plant in California, with a cost of $2500/kw. The cost of electricity is given by GE as:

Table 2
Comparing the Cost of Electricity
Generated by State-of-the-Art Power Plants

System	Cents/kwh
Gas fired CCCT	3.5
Coal IGCC	4.5
Refinery Bottoms IGCC	3.5
PC-SPP (with state-of-the art environmental control)	4.5

Coal IGCC is approaching the cost of PC-SPP (if all of the appropriate environmental controls are included for PC-SPP).

The speaker indicated GE has a dedicated IGCC product line, from the GE10 engine to the 9FA engine. The H-class engines are not offered for IGCC service. GE maintains two IGCC test facilities.

The GE combustors for the IGCC systems are rated for fuel H_2 contents from 10 to 95%. HOWEVER, EACH IGCC APPLICATION REQIRES THE COMBUSTORS BE CUSTOM DESIGNED BASED ON THE ANTICIPATED FUEL COMPOSITION AND HEATING VALUE. “One size does not fit all.” Once the GT system, with combustors, is designed and built, the GE system can tolerate a ±10% variation in the Wobbe index of the synthetic gas. For natural gas-fired GE engines, the permitted variation of the fuel Wobbe index is ±5%. GE’s experience is that the initial estimate of the fuel composition and heating value is pretty close to that actually obtained – they are not reporting difficulties. [However, during the comment period, Ansaldo pointed out it has experienced difficulties in this regard.]

GE permits co-firing of synthetic gas and natural gas into its IGCC systems. .

There is a tendency to move the coal IGCC system to the coal mine. [In the future this might prove advantageous for CO_2 sequestration – other possibilities for sequestration are salt domes and the Texas CO_2 pipelines.]

Shell Global Solutions: Shell is significantly involved in refinery IGCC through several plants, including the Pernis Refinery, the Sannazzaro Refinery in Italy (with the GT provided by Ansaldo), and the Indian Oil Company (eastern India refinery under development). Overall, Shell is involved in 26 gasification plants around the world, though only two currently produce power (Zuideveld, 2002):.

Mainly, the plants are located in India, China, and Europe. Most of these are old systems dedicated to ammonia and hydrogen production.

Shell views the products of refinery IGCC as POWER, STEAM, and HYDROGEN.

A hydrogen plant might use two gasifiers to produce the H_2, and one to produce electricity. Oxygen-blown gasifiers are used.

The Shell Pernis refinery IGCC was started up in 1997. In 2001, the system utilization was 88%, and the hydrogen production experience only a 0.5% outage. GE Frame 6 engines are used.

NUON: NUON, a power company providing about 36% of the electricity in The Netherlands, now operates the Dutch (Buggenum) coal IGCC facility (Kanaar, 2002):. This facility has been in operation for several years, and has been thoroughly debugged. Presently, it operates about 7000-7500 hours per year, including about 6000 hours on synthetic gas, with the balance of the time on natural gas. Availability of the system is about 94%, the gasifier availability is about 92%.

There is a desire to partly convert the Buggenum IGCC facility to biomass gasification. The stakeholders are interested in sustainable power production, and the conversion to biomass will help The Netherlands meet its Kyoto commitment. NUON sees business opportunities for biomass (and green power) in Europe, though the speaker cautioned the Americans in the audience “do not try this at home.” His comment reflects the significant government subsidy provided for biomass use – about 5 cents per kwh of electricity. The overall investment associated with the switch to co-gasification on biomass appears to be about 20 million euros.

The types of biomass planned for the IGCC system are sewage sludge, chicken litter, and wood. The chicken litter and wood will be milled off site prior to trucking to the site. It will important to determine how well the biomass fuels can be handled and fed into the coal-designed gasifier. Also of issue is the large number of the trucks passing through the local area.

The schedule calls for 30% (by weight) co-gasification on biomass by 2003, and 50% by 2005.

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