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W. Renzenbrink, M.H. Scholz

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H_2 Gas Turbine – a Stepping Stone to CCS

Werner Renzenbrink, RWE Power AG, Germany
Marcus H. Scholz, GE Energy - Europe

Abstract

Innovative coal technologies are as indispensable to preventive climate protection as coal is to satisfying the world's thirst for energy. With its Clean Coal Power strategy, RWE faces the challenge of preventing climate change and is now introducing further elements of this strategy. In this respect, carbon capture and storage (CCS) play a key role if CO_2 reductions more substantial than is possible by merely increasing efficiencies are to be achieved.

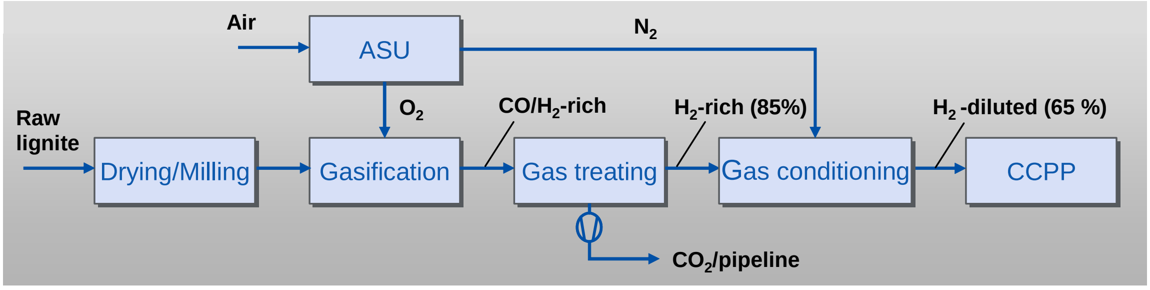
The 450 MW IGCC CCS project, focusing on capture and storage of the CO_2 from a fossil fired power plant, is part of RWE's overall strategy aimed at developing and implementing Clean Coal Power

Integrated Gasification Combined Cycle (IGCC) combines chemical process and power technologies to meet future requirements of fuel flexibility in a carbon-constrained environment. IGCC can operate on a multi-fuel basis with various coal types and waste fuels and produce valuable products beyond electricity generation via poly-generation, thus can be seen as a vehicle to introduce the hydrogen economy.

Over the past 10 years, the most common application of gasification technology has been in the process and chemical industry as well as in the power industry, using a variety of feedstock for the production of chemicals and electric power..

In parallel the power generation industry has increasingly evaluated IGCC solutions to prepare for a regulatory shift towards Carbon Capture & Storage (CCS) requirements, and to use this technology as a sustainable means of converting coal to electricity.

Coal gasification and associated fuel gas process treatment units provide the mechanisms inherently needed to effectively separate carbon components on a “pre-combustion” basis (IGCC CCS), leaving essentially carbon free hydrogen available for use in energy storage, transport or for combustion within a combined cycle power plant. Figure 1 shows the typical key components of an IGCC CCS power plant using the example of RWE’s 450 MW demonstration projekt.



> **Coal drying & milling**	WTA drying technology, roller mills.
> **ASU:**	Conventional concept, large size (3600 t/d O_2).
> **Gasification:**	Entrained flow gasification (1,000 MW $_{th}$, 40 bar) quench mode.
> **Gas Treating:**	Sour shift, H_2S/CO_2 capture, SRU, CO_2 compr.
> **Gas Conditioning**	Dilution with N_2, H_2O
> **CCPP:**	F class GT technology, Diffusion burners

Coexistence of proven technologies and new developments.
Above all the demonstration of their interaction is decisive.

Figure 1: Concept of the 450 MW IGCC CCS demonstration plant.

Rhenish lignite from the opencast mines serves as the fuel. In a first process step, its moisture content is reduced from approx. 55% to 12% using RWE's own WTA drying technology. Subsequently, the lignite is ground by roller mills according to gasification requirements. An entrained-flow gasifier with a dry lignite inlet and a thermal capacity of approx. 1,000 MW, operated at a pressure of approx. 40 bar, is employed for gasification. The hot, CO/H_2-rich raw gas is quenched to approx. 200°C using water. The resulting high portion of steam is used in the subsequent shift stage to convert the CO into more hydrogen and CO_2.

The hydrogen-rich gas left over after the H_2S/CO_2 separation process is conditioned with N_2 from the air separation unit and if necessary with steam to create moderate combustion conditions and meet the legal requirements for NO_X values. The conditioned fuel gas is used to generate electricity in the CCPP unit. The capacity of the gas turbine (F class), which has a share of approx. 300 MW in the total electricity generation capacity of 450 MW, determines the capacity of the overall process. Thus, the process design largely corresponds to the concept of the HTW (high-temperature Winkler) demonstration plant that RWE already operated on an industrial scale from 1986 – 1997 to produce synthesis gas/methanol from lignite. The essential technical challenges of the new project consist in demonstrating the interaction of all individual processes and achieving normal power plant availability.

Gas turbines have been applied to a wide range of syngas application with varying hydrogen fuel content. Based on that experience, it is expected that combustion turbines will likely become the primary hydrogen energy conversion unit for the foreseeable future. Worldwide, GE gas turbines continue to demonstrate their proven, reliable performance on hydrogen bearing fuels, including existing Gas Turbine installations, which operate on high hydrogen fuels up to 95% hydrogen by volume. Table 1

Table 1: Industrial H_2 gas Turbine experience with >50% H_2 by volume.

Project / Site	GT Model	No. Units	Fuel Gas	Features
Geismer, US	MS6001B	1	PG	up to 80% H2
Refinery, US	MS6001B	1	RFG	12 - 50% H2
Korea	MS6001B	1	PG	up to 95% H2
Tenerife, Spain	MS6001B	1	RFG	~70% H2
Cartagena, Spain	MS6001B	1	RFG	66% H2
San Roque, Spain	MS6001B	2	RFG	70% H2
Antwerpen, Belgium	MS6001B	1	RFG	78% H2
Puertollano, Spain	MS6001B	2	RFG	up to 60% H2
La Coruna, Spain	MS6001B	1	RFG	up to 52% H2
Rotterdam, NL	MS6001B	1	RFG	59% H2
Germany	MS6001B	1	IGCC	62% H2
Vresova, CZ	MS9001E	2	IGCC	46.8% H2
Fawley, UK	MS9001E	1	RFG	~50% H2
Georgia Gulf, US	MS7001EA	3	Blend	Methane + 50% H2
Milazzo, ITA	MS5001P	1	RFG	30 - 50% H2
Ref., India	MS5001P	1	RFG	50% H2
Paulsboro, US	MS5001P	2	RFG	20 - 60% H2
Ref., Int'l	MS5001P	1	RFG	Propane + 60% H2
Reutgerswerke, US	MS3002J	1	PG	60% H2
NUP	MS3002J	1	TG	~60% H2
Donges, US	GE10	1	RFG	76% H2
Refinery, Jordan	PGT10	1	RFG	82% H2

RFG = Refinery Gas, TG = Tail Gas, PG = Process Gas, IGCC = Syngas

GE continues to expand on this experience and to develop advanced gas turbine platforms, including F-class units operating on synthesis gas.

The early F-class gas turbines have been operating for over 12 years on hydrogen bearing fuels up to 45% hydrogen content by volume. Table 2.

Table 2: F-class H_2 Operation experience.

		Wabash, US	Tampa, US	Singapore	Delaware, US
Turbine		7FA	7FA	2x6FA	2x6FA
H_2	(% Vol)	24.8	37.2	44.5	32.0
CO	(% Vol)	39.5	46.6	35.4	49.5
CH_4	(% Vol)	1.5	0.1	0.5	0.1
CO_2	(% Vol)	9.3	13.3	17.9	15.8
N_2+Ar	(% Vol)	2.3	2.5	1.4	2.2
H_2O	(% Vol)	22.7	0.3	0.1	0.4
LHV	BTU/ft^3	209	253	241	248
	kJ/m^3	8,224	9,962	9,477	9,768
T_{fuel} F/C		570/ 300	700/ 371	350/ 177	570/ 299
H_2/CO Ratio		0.63	0.80	1.26	0.65
Diluent		Steam	N_2	Steam	H_2O/ N_2
Equiv BTU/ft^3		150	118	116	150
	kJ/m^3	5,910	4,649	4,600	5,910

Several small modifications of existing Gas Turbines, designed for natural gas, have been applied to account for the higher mass flow of syngas fuel with diluents.

Those hardware changes, including Combustion system, Hot Gas Path and general features have been implemented in the F-class Gas Turbine platform for GE´s 6F, 7F and 9F Syngas products. As a validation tool, the large tests facilities in Greenville, South Carolilna, provide full pressure, temperature, and flow conditions, as such replicating engine conditions. They also allow for a wide range of fuel blending capability for H2, N2, CO, CO2, and H2O, and to monitor dynamics, emissions, ignition, under full and part load characterization. Figure 2

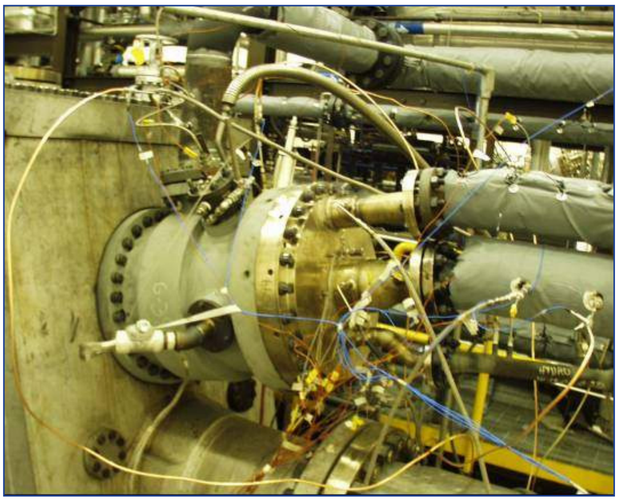


Figure 2: Syngas Test cell for full-scale equipment development.

This results in high fuel flexibility to allow for capabilities with hydrogen fuels for a wide range of carbon capture application, ranging from straight syngas combustion up to 90% CCS.

Since increasing firing temperature and cycle operating pressure are the principle drivers for improving Gas Turbine Combined Cycle and IGCC plant efficiencies, GE continues to drive technology enhancements with the latest F-class Gas Turbines designs. Successful operating experience, combined with continuous R&D efforts, provide efficient solutions for syngas and H2 fuels required by the carbon-constrained generation environment.

It is expected that policy makers will consent to tighten Carbon Dioxide emissions on a global basis in the near future and General Electric has meanwhile advanced the IGCC plant concept to take into considerations the lessons learnt from recent project activity, including the currently ongoing construction of the largest IGCC plant at Duke Energy, with over 620MW electric generation capacity.