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INTEGRATION OF CARBONATE FUEL CELLS WITH ADVANCED COAL GASIFICATION SYSTEMS

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INTRODUCTION

Carbonate fuel cells have attributes which make them ideally suited to operate on coal-derived fuel gas; they can convert the methane, hydrogen, and carbon monoxide present in coal derived fuel gas directly to electricity, are not subject to thermodynamic cycle limits as are heat engines, and operate at temperatures compatible with coal gasifiers. Some new opportunities for improved efficiency have been identified in integrated coal gasification/carbonate fuel cells which take advantage of low temperature catalytic coal gasification producing a methane-rich fuel gas, and the internal methane reforming capabilities of Energy Research Corporation's carbonate fuel cells.

The improved efficiency would be obtained by recycling waste heat and spent fuel from a carbonate fuel cell anode back to a low temperature catalytic gasifier. This would virtually eliminate the energy release within the gasifier (normally obtained by combustion) which is needed to maintain gasifier temperature and drive the gasification reactions. By selecting the appropriate operating conditions and catalyst in the gasifier, methane formation is maximized to improve gasification efficiency and to take advantage of the heat management aspects of the internal reforming carbonate fuel cell. These advanced integrated gasification/carbonate fuel cell systems are projected to have better efficiencies than gasification/carbonate fuel cell systems employing conventional gasification, and also competing non-fuel cell systems. These improved efficiencies would be accompanied by a corresponding reduction in impact on the environment as well.

Three conceptual 200 MW advanced integrated gasification/carbonate fuel cell systems are presented which are results from system studies conducted under DOE/METC sponsorship by Energy Research Corporation in conjunction with Fluor Daniel and the University of North Dakota/Energy & Environmental Research Center. Heat rates of 6377-6748 Btu/kWh (Efficiencies of 50.6% - 53.5% HHV) have been projected for these conceptual systems, which are based on catalytic gasification. Standard low-temperature gas cleanup is compared with hot gas cleanup, and operation with recoverable and disposable catalysts is also compared. Results of experimental testing at the University of North Dakota/Energy & Environmental Research Center evaluating the gasification catalysts used in the three system cases are presented.

SYSTEM STUDIES

The system configuration shown in Figure 1 was selected based on a comparison of two approaches. One based on a high hydrogen producing gasification system, and one based on a high methane producing system. The high methane producing gasification system was found to result in higher efficiencies and lower projected costs and was therefore selected(1).

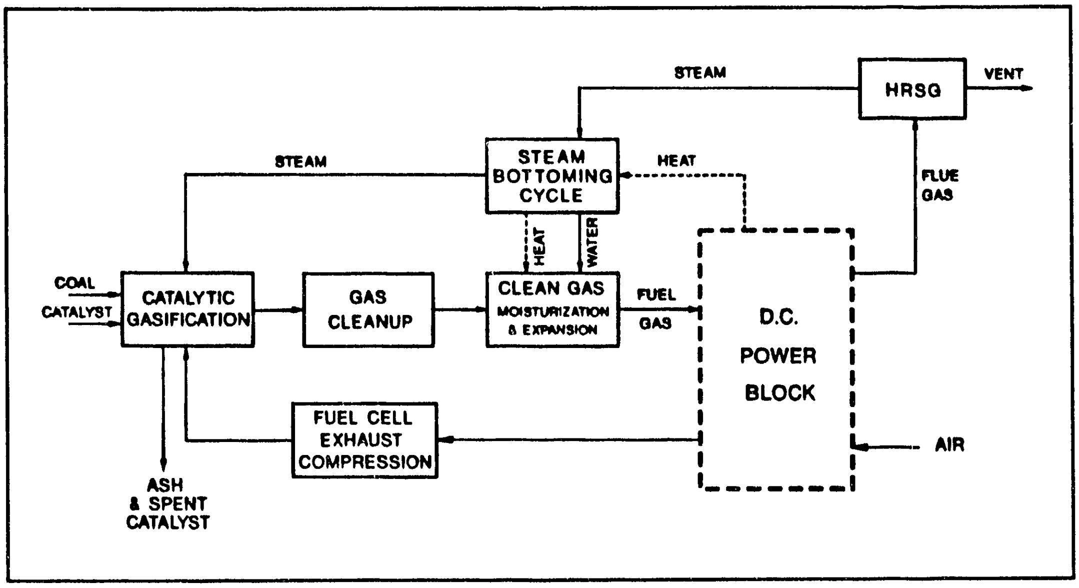

Figure 1 ADVANCED GASIFICATION CARBONATE FUEL CELL SYSTEM CONFIGURATION

Fuel gas is produced by low temperature catalytic gasification of coal requiring steam and hydrogen which is recovered from the spent fuel leaving the fuel cell anode. An oxygen plant is not required for this system. Gas cleanup can be carried out either hot or cold followed by fuel gas expansion which recovers energy for power generation. A moisturization step is provided if cold cleanup is used to prevent carbon formation. Steam and heat from the steam bottoming cycle is used for this purpose.

Clean fuel gas enters the D.C. Power Block shown in Figure 2 where it is partially consumed in the anode. Spent fuel leaving the anode is shifted prior to entering a Hydrogen Transfer Device (HTD) which separates hydrogen for recycle to the gasifier. The HTD is based on phosphoric acid fuel cell technology being tested at Energy Research Corporation. Spent fuel gas lean in hydrogen leaves the HTD and enters a catalytic burner which combusts any remaining hydrogen, CO, or CH_4 with excess air. The products of combustion enter the cathode side of the fuel cell where CO_2 and O_2 are partially consumed by the fuel cell cathode reaction. The cathode exhaust goes to the Heat Recovery Steam Generator (HRSG) where steam is produced for use by the gasifier, moisturization step, and the bottoming cycle.

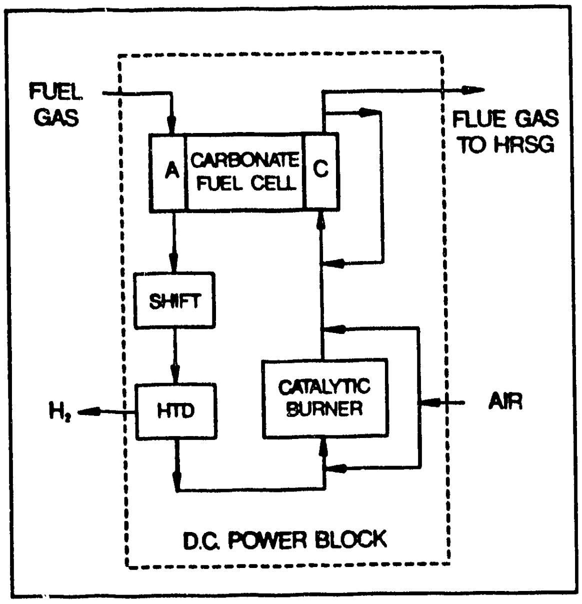

Figure 2 D.C. POWER BLOCK

Three system cases were evaluated based on the system configuration described above as shown in Table I. One case was based on a K_2CO_3 recoverable gasification catalyst with a cold gas cleanup system.

Table I ADVANCED GASIFICATION CARBONATE FUEL CELL SYSTEM HEAT RATE COMPARISON

CASE NUMBER	1	2	3
GAS CLEANUP TECHNOLOGY	COLD	COLD	HOT
CATALYST	K_2CO_3	$CaCO_3$	$CaCO_3$+Fe
GASIFIER DATA			
TEMPERATURE (°F)	1200	1200	1200
PRESSURE (psia)	750	750	750
RAW GAS CH_4 (mol%)	17.0	14.9	14.9
HEAT RATE, HHV (Btu/kWh)	6606	6748	6377
EFFICIENCY, HHV (%)	51.7	50.6	53.5

Another was based on an alternate disposable catalyst using $CaCO_3$ as a gasification catalyst with cold gas cleanup. A third case was based on a disposable gasification catalyst using $CaCO_3$ + Fe with a hot gas cleanup system. Heat rates of 6377 - 6748 Btu/kWh (HHV) were estimated for these systems with the hot cleanup system producing the lowest heat rate.

EXPERIMENTAL TESTING

Experimental testing was conducted to evaluate the gasification catalysts used as a basis for the three system study cases. Reactivity of catalyzed Illinois no. 6 char was compared based on TGA tests as shown in Figure 3. The alternate catalysts were shown to have significantly lower activity in the same order of magnitude as assumed in the system study cases.

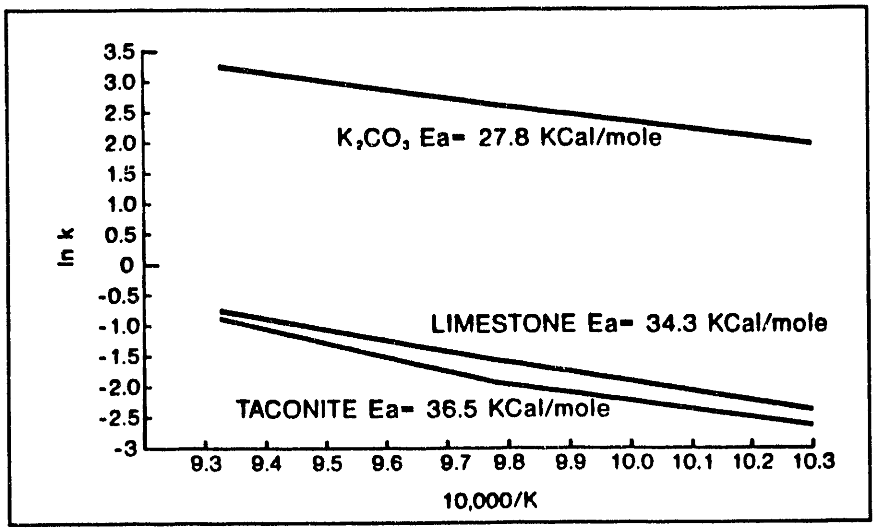

Figure 3 REACTIVITY OF ILLINOIS NO. 6 CHAR

CONCLUSIONS

Advanced gasification carbonate fuel cell systems based on catalytic gasification offer the potential of higher efficiencies compared to conventional systems. Additional development and testing is required to realize this potential.

REFERENCES

1. G. Steinfeld, W.B. Hauserman, A. Lee, S.J. Meyers, "Design of Gasifiers to Optimize Fuel Cell Systems" Proceedings of the Eleventh Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting, Aug. 1991.

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