

# Project Research — Development of a Supply/Demand Infrastructure for Next-generation Electric Power Thermal Power Generation Systems with CO<sub>2</sub> Capture

### Background and Objective

The reduction of CO<sub>2</sub> emissions in coal thermal power generation for global warming control is an important matter for electric utilities. Therefore, high-efficiency technology and biomass utilization are promoted for some power generation systems. Attention is paid to CO<sub>2</sub> Capture and Storage (CCS) as one of the effective countermeasure against global warming in recent years. In Europe and the United States, many CCS projects have been announced. However, the current CCS technology exhibits many problems, such as a significant drop

in power generation efficiency and an increase in cost.

To offer a futuristic option that solves these problems, CRIEPI has proposed a highly efficient IGCC system with CO<sub>2</sub> capture (Fig. 1). In this project, we will develop O<sub>2</sub>-CO<sub>2</sub> blown gasification technology and semiclosed GT technology.

### Main results

#### 1 Effect of Enriched CO<sub>2</sub> on Gasification Reaction Promotion in a Bench-scale Coal Gasifier\*

In an O<sub>2</sub>-CO<sub>2</sub> blown gasifier, a gasification reaction promotion by enriched CO<sub>2</sub> can be expected. On the other hand, a drop in the temperature in the gasifier is a problem because CO<sub>2</sub> has a higher molar-specific heat. CO<sub>2</sub> was used for a carrier gas component in our 3 t/day bench-scale coal gasifier, and the combustor temperature was held constant, adjusting the

oxygen concentration in the gasifying agent, to examine the gasification characteristics (Fig. 2). As a result, the carbon conversion efficiency was improved at a high CO<sub>2</sub> concentration when the temperature in the gasifier was properly maintained by adjusting the oxygen concentration in the gasification agent (M11019).

#### 2 Numerical Modeling of O<sub>2</sub>-CO<sub>2</sub> Blown Coal Gasification

An O<sub>2</sub>-CO<sub>2</sub> blown coal gasification reaction model was developed and validated to be utilized in the process of the design and optimization of a practical-scale O<sub>2</sub>-CO<sub>2</sub> blown gasifier. Modified char gasification and water-gas-shift reaction models were developed and implemented with CRIEPI's three-dimensional CFD code, which

had already been validated through air-blown gasification experiments. In comparison with the experimental results\* of the 3 t/day gasifier (Fig. 3), it was confirmed that the model presented here could capture the general feature of gasification characteristics (Fig. 4) (M11017).

#### 3 Combustion Promotion in Oxy-fuel Semiclosed Cycle Gas Turbines

The oxy-fuel IGCC (Fig. 1) employs a semiclosed-cycle gas turbine system, in which CO-rich coal gases are burnt with oxygen under stoichiometric conditions and diluted with recirculated gas turbine exhaust to adjust the combustor exhaust temperature. Since the higher combustion efficiency without supplying excess oxygen was required for the gas turbine in order to realize the high thermal efficiency of the IGCC system, the combustion promotion

was studied using numerical analyses based on reaction kinetics. As a result, it was found that, the combustion efficiency was improved with increase of the fuel oxidation rates when the dilution gas of recirculating exhaust was divided into two parts, one was supplied into a burner at a suitable gas flow rate and the other was supplied into a combustor downstream as a secondary dilution (Fig. 5) (M11004).

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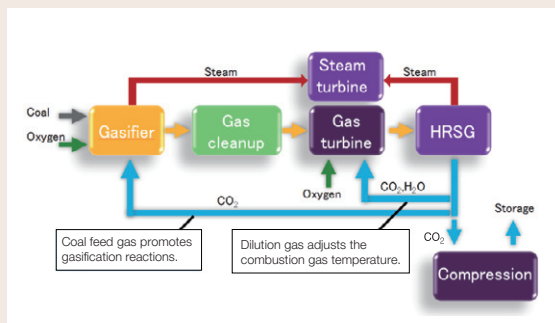


Fig. 1: Concept of a highly efficient oxy-fuel IGCC with CO<sub>2</sub> capture

This novel system consists of an O<sub>2</sub>-CO<sub>2</sub> blown gasifier and a semiclosed GT with exhaust CO<sub>2</sub> circulations. It is expected to have higher thermal efficiency (more over 40%: HHV Net) and a simpler configuration, compared with the existing IGCC with CO<sub>2</sub> capture.

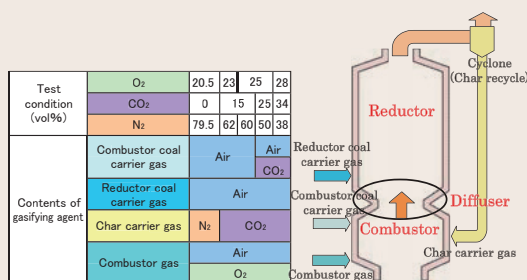


Fig. 2: Gasification testing conditions and the CO<sub>2</sub> feeding method

CO<sub>2</sub> was used for coal and/or char carrier gas in a combustor, and the O<sub>2</sub> supplied to the combustor was adjusted, maintaining the air ratio so that the combustor temperature became constant.

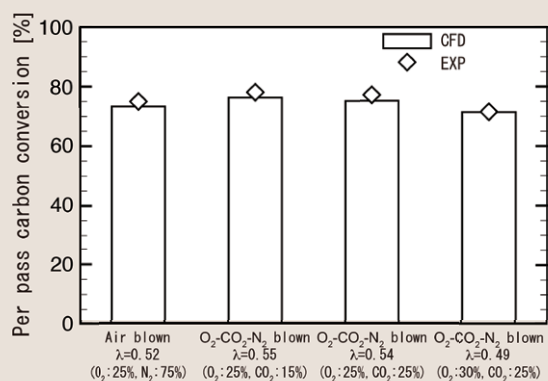


Fig. 3: Comparison of model results with experiments in the 3 t/day gasifier

The presented model could accurately estimate the gasification characteristics.

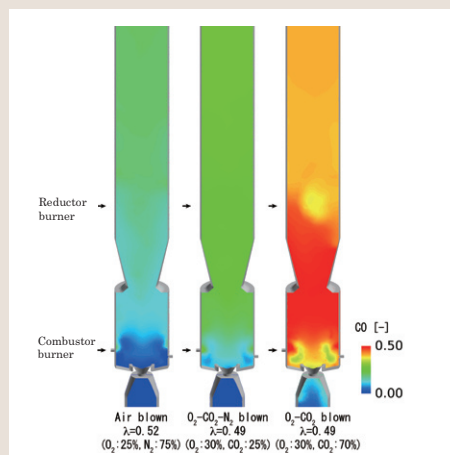


Fig. 4: Distributions of CO concentration  
CO concentration in the O<sub>2</sub>-CO<sub>2</sub> blown condition drastically increased at high CO<sub>2</sub> concentration in the gasifying agent.

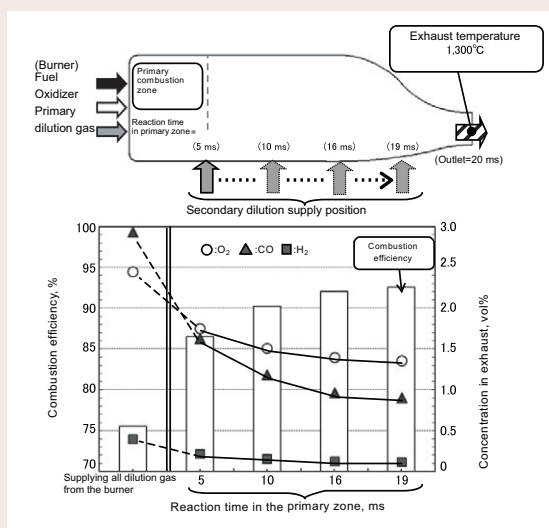


Fig. 5: Combustion promotion by dilution gas streamwise splitting

The combustion efficiency could be improved both by adjusting the primary dilution gas/fuel molar ratio to approximately 3 and by supplying the secondary dilution downstream to maintain the combustibility in the primary combustion zone.