

# 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 problem for the electric utilities. Therefore, the high-efficiency technology and biomass utilization are promoted in the power generation systems. CO<sub>2</sub> Capture and Storage (CCS) receives attention as an effective global warming control measure in recent years. In Europe and the United States, many plans of CCS project have been announced. However, current CCS technology has many problems such as significant reduction of power generation efficiency and high cost.

To offer the futuristic option that solves these problems, CRIEPI has proposed highly efficient IGCC system with CO<sub>2</sub> capture (Fig. 1). In this project, we evaluate the feasibility of this system, the development issues for practical use, and advance the development of the elemental technology.

## Main results

### 1. Effect of enriched CO<sub>2</sub> on the gasification reaction promotion by using bench scale gasifier\*<sup>1</sup>

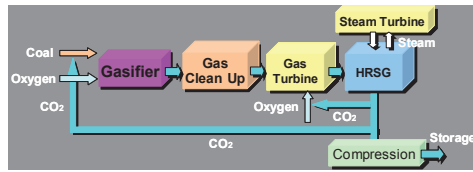
In oxygen-CO<sub>2</sub> blown gasifier of this system, gasification reaction promotion by enriched CO<sub>2</sub> can be expected. Then, in order to clarify the influence of CO<sub>2</sub> supplied to the gasifier on the gasification characteristics, the gasification tests that used CO<sub>2</sub> for a part of the coal transportation gas were done based on the oxygen enriched air blown gasification with 3tons/day coal research gasifier set up in CRIEPI (Fig. 2). As a result, when the CO<sub>2</sub> concentration increased, the decrease in the gasifier temperature was caused from the high molar heat of CO<sub>2</sub>. However, the char product rate decreased, and it was clarified that char gasification reaction was promoted by CO<sub>2</sub> enriched (Fig. 3) [M10016].

### 2. Clarification of soot production and reaction behavior in coal gasification condition

By using this gasifier, the high CO<sub>2</sub> partial pressure promotes char gasification reaction and a great improvement of the carbon conversion ratio is expected. In coal pyrolysis, char is produced and also soot which has lower reactivity than char can be produced. However, soot production and reaction behavior in gasifier had not been clarified because char and soot are mixed together and it is difficult to separate or quantify them\*<sup>2</sup>. In this study, a novel and reliable soot quantitative method using a laser diffraction particle size analyzer was developed. Coal gasification experiments were performed using a pressurized drop tube furnace (PDTF) and it was found that the yield of soot with low gasification reactivity hardly decreased while char was promptly consumed by CO<sub>2</sub> gasification. As a result, the carbon conversion rapidly increased initially but almost became constant at latter term. Hence, it is required to consider control of the soot generation (Fig. 4) [M10017].

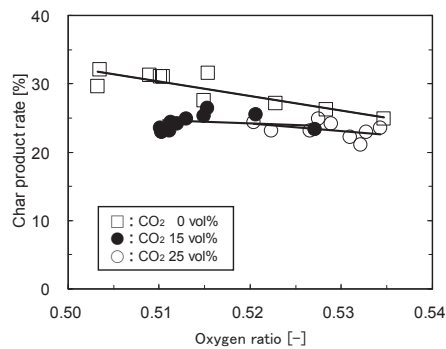
### 3. Development of a means to retard carbon deposition in dry gas desulfurization process\*<sup>1</sup>

Because the CO concentration in the coal derived gas of the power generation system is extremely high (around 60 vol%), there is degradation in the performance of the desulfurization process\*<sup>3</sup>. It is important to establish the procedure to retard carbon deposition in the plant. Steam, CO<sub>2</sub>, and recirculated exhaust gas were selected as candidate gas supply that is effective to suppress carbon deposition in the plant (Fig. 1). They were evaluated from the viewpoints of necessary amount of gas, additional heat and power, as well as effect on the desulfurization performance. The results confirmed that the most suitable gas supply is the recirculated exhaust gas (Table 1) [M10012].



**Fig. 1 Concept of high efficient IGCC with CO<sub>2</sub> Capture**

This system consists of O<sub>2</sub>-CO<sub>2</sub> blown gasifier and O<sub>2</sub> combustion closed GT with exhaust CO<sub>2</sub> circulation. It is expected to have higher thermal efficiency (more than (over) 40% : HHV Net) and the system simplification, compared with the existing IGCC with CO<sub>2</sub> capture.



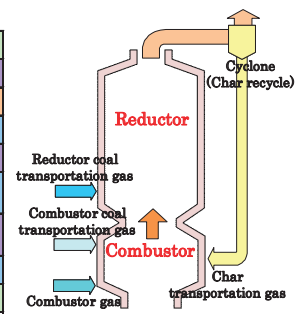
**Fig. 3 Relation between oxygen ratio and char product rate at the change of CO<sub>2</sub> concentration of gasifying agent**

When the CO<sub>2</sub> concentration increased, the char gasification reaction was promoted and the char product rate decreased.

Testing condition (vol%)	O <sub>2</sub>	25	25	25
	CO <sub>2</sub>	0	15	25
	N <sub>2</sub>	75	60	50

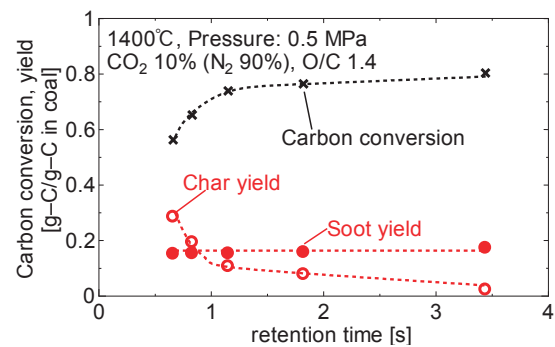
  

Contents of gasifying agent	Combustor coal transportation gas	Air	Air	Air
	Reductor coal transportation gas	Air	Air	Air
	Char transportation gas	N <sub>2</sub>	CO <sub>2</sub>	CO <sub>2</sub>
	Combustor gas	Air	Air	Air



**Fig. 2 Gasification testing condition and CO<sub>2</sub> supplying method**

The oxygen concentration of gasifying agent was always 25vol% and CO<sub>2</sub> was used for char and combustor coal transportation gas.



**Fig. 4 Progress of gasification reaction in high temperature gasification by CO<sub>2</sub>**

The carbon conversion almost became constant at latter term because soot with low gasification reactivity hardly decreased.

**Table 1 Comparison of the evaluated gas supply for retardation of carbon deposition**

(◎, superior, ○, adequate, ▲, inferior)

Gas supply	Steam	CO <sub>2</sub>	Recirculated exhaust gas
Retarding effect of carbon deposition	◎large	▲small	○moderate
Necessary amount of gas (Ratio of additional gas <sup>†1</sup> [-])	◎small (1.0)	▲large (3.1)	○moderate (2.3)
Consumption of heat and power (Ratio of heat and power consumption <sup>†2</sup> [-])	▲large (1.0)	○moderate (0.7)	◎small (0.2)
Effect on desulfurization performance	▲large	◎small	◎small
Conclusive evaluation	○	▲	◎

† 1: ratio of the additional gas amount to the steam

† 2: ratio of heat and power for the gas addition to the heat consumption of steam

\* 1 : This work was supported by New Energy and Industrial Technology Development Organization (NEDO).

\* 2 : In coal pyrolysis, at first, solid char composed of carbon and ash and volatile matter are produced. After that, soot, which has lower gasification reactivity than char, is produced through volatile matter decomposition. However, soot production and reaction behavior in gasifier has not been clarified.

\* 3: Boudouard reaction ( $2CO \rightarrow C + CO_2$ ) is dominant reaction of carbon deposition. Thus, a smaller ratio of partial pressure ( $KB = \frac{PCO_2}{(PCO)_2}$ ) will enhance the reaction through the higher partial pressure of CO [M09015].