Status of the EAGLE Project: Coal Gas Production Technology Acceptable for Fuel Cells

2000 Gasification Technologies Conference
San Francisco, California
October 8-11, 2000

Hideo Maruyama

Shuichi Takahashi

Clean Coal Technology Center
New Energy And Industrial Technology Development Organization
JAPAN

Junichi Iritani

Hajime Miki

Electric Power Development Co., Ltd.

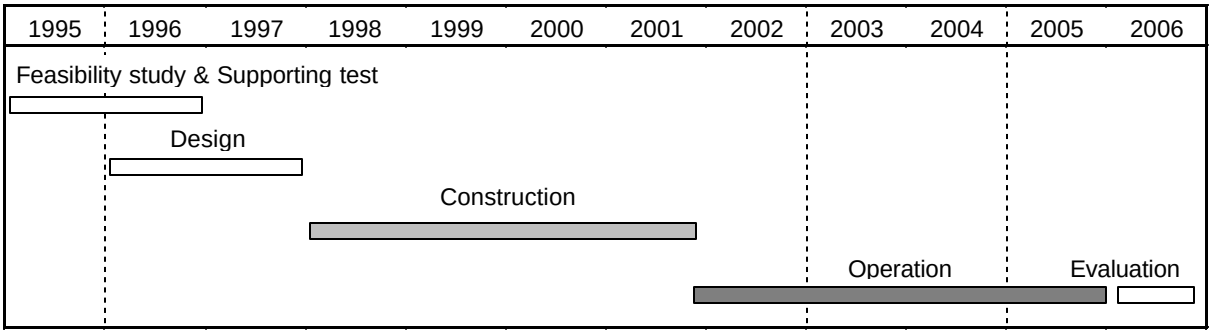
JAPAN

1. Abstract

The purpose of the EAGLE (coal Energy Application for Gas, Liquid and Electricity) project is to develop the technology to produce coal gas for fuel cells. The EAGLE has an oxygen blown, entrained flow type gasifier. The gasifier has a single chamber with a two-stage spiral flow. Oxygen is produced with an ASU (Air Separation Unit) and supplied to the gasifier. The produced coal gas is cooled in the gasifier and a syngas cooler. Impurities in the syngas are removed by water scrubbers, a COS converter and an MDEA (Methyl Die Ethanol Amine) absorber. Part of the syngas is further desulfurized by iron oxides for fuel cells.

The EAGLE project is subsidized by MITI (the Ministry of International Trade and Industry). Table 1 shows the development schedule. In 1995, an IGFC (Integrated coal Gasification Fuel Cell combined cycle) feasibility study and element tests were conducted. Following a basic design and a detailed design, civil work was started at Wakamatsu Operations & General Management Office in 1998. The pilot plant has been under construction since 1999 and it will be finished in 2001. At present, installation of the gasifier is nearly completed. The pilot tests will be started in 2002. This paper outlines the construction status of the pilot plant.

Table 1 Development Schedule



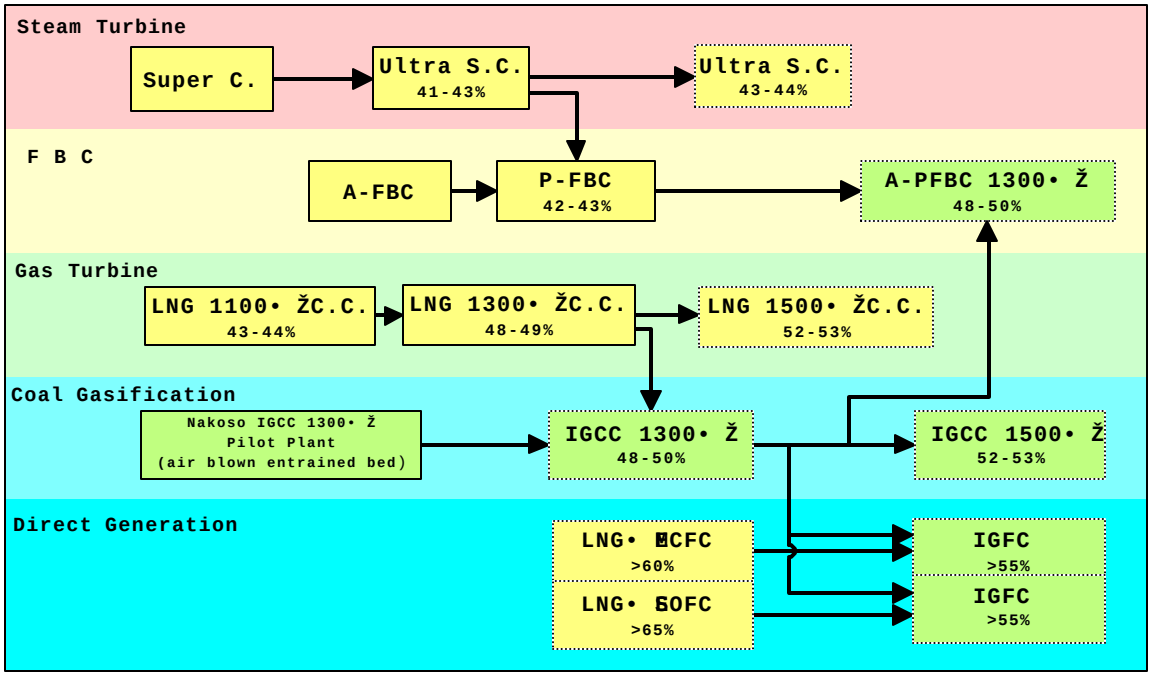
2. Introduction

In Japan, coal fired thermal power is expected to continue to play an important role as a base power together with nuclear power in the 21st century. In order to increase the coal utilization, it is important to develop various technologies, including the use of various kinds of coal, the clean use of coal for environmental protection, and the high efficiency use of coal to prevent the increase of the earth's temperature.

Table 2 shows high-efficiency coal power generation technology systematically. The efficiency of power generation using a boiler is approximately forty percent. The efficiency is improved by the Integrated coal Gasification Combined Cycle (IGCC) system which consists of a gasifier, gas turbine and steam turbine etc. For greater improvement, fuel cells are added to the IGCC system. We call this the Integrated coal Gasification Fuel Cell combined cycle (IGFC) system. The efficiency of IGFC exceeds fifty percent. In addition to its high efficiency, emissions of NOx, SOx, and dust are far less than the other systems.

In 1995, the IGFC feasibility study was conducted. From the results of the study, we concluded that an oxygen-blown gasifier would be suitable for IGFC and the net thermal efficiency of IGFC with an oxygen-blown gasifier would be 53% or more. Therefore the EAGLE (coal Energy Application for Gas, Liquid and Electricity) project was planned as a pilot plant with a 150 tons per day oxygen-blown gasifier.

Table 2 High-efficiency Coal Power Generation Technology



: Technology not yet put into practice

: Gross thermal efficiency

3. Outline of the Pilot Plant

3.1 Objectives of the EAGLE Project

The EAGLE (coal Energy Application for Gas, Liquid and Electricity) project has been started to develop the technologies for IGFC (Integrated coal Gasification Fuel Cell combined cycle). Therefore the purpose of this project is to establish the technologies required for IGFC, which are technologies for optimum coal gasification and syngas clean-up for fuel cells. Table 3 shows the specific objectives of the EAGLE project. The target performance for syngas clean-up technology has been decided in consideration of the acceptable level for fuel cells.

Table 3 Objectives of EAGLE Pilot Plant

Coal Gasification Capability	
Carbon Conversion	> 98%
Higher Heating Value of gas	> 10,000KJ/m^3N
Gas clean-up Capability	
Sulfur Compound	< 1ppm
Halogen Compound	< 1ppm
Ammonia Compound	< 1ppm
Scrubbing Capability	1mg/m^3N
Obtaining gasification data for over 5 type of coal	
Obtaining design data about 10 times that of test plant	

3.2 System of the EAGLE Pilot Plant

The EAGLE Pilot Plant is composed of a coal gasification unit, syngas clean-up unit, air separation unit and gas turbine unit, as shown in Figure 1.

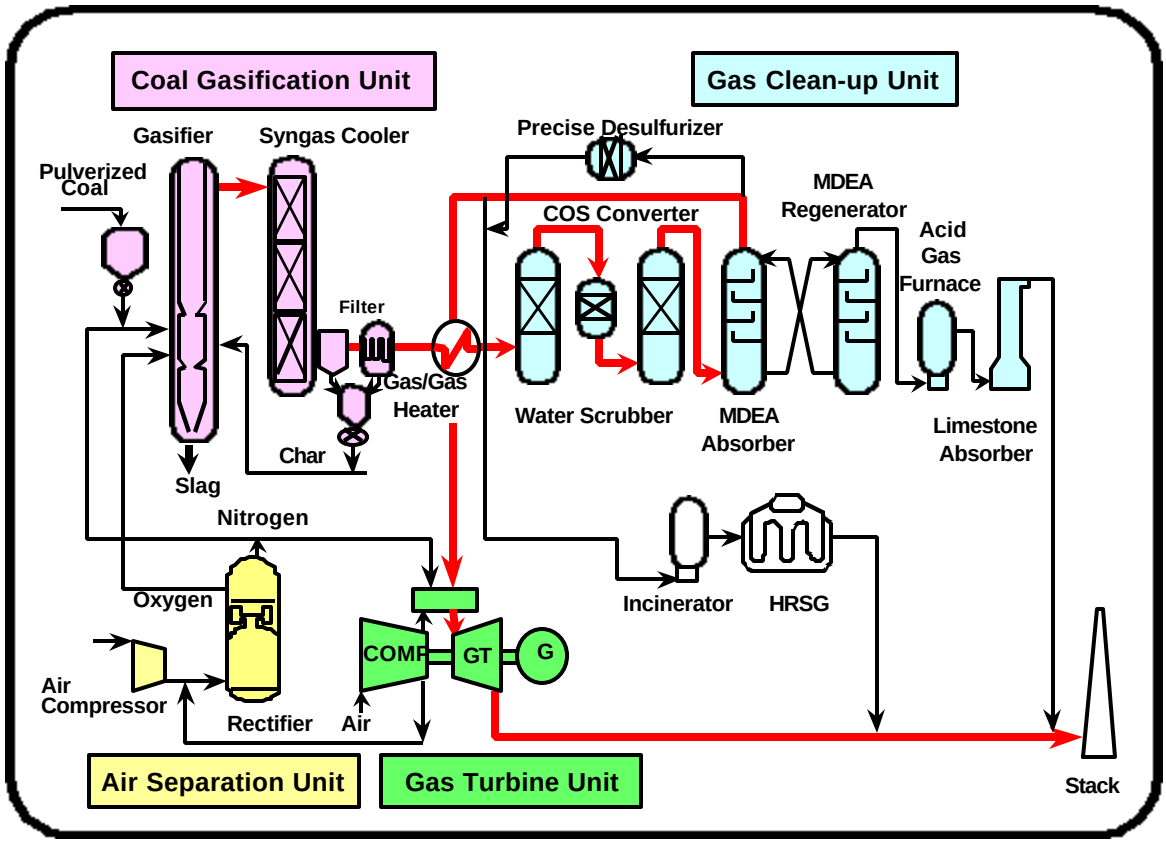


Figure 1 Flow Diagram of the EAGLE Pilot Plant

The gasifier of the EAGLE pilot plant is an oxygen-blown entrained-flow type. Pulverized coal is transported by nitrogen to the gasifier, where it reacts with a gasifying agent (95 percent oxygen) at 2.5 MPa and is converted into a fuel gas. Oxygen is produced by cryogenic air separation in the ASU (Air Separation Unit). Meanwhile, molten ash is discharged from the bottom of the gasifier into a water quench. The high-temperature syngas exits the gasifier and is forwarded to a gas clean-up unit after heat is recovered by passing it through a syngas cooler, lowering it to 450°C. Char in the syngas is removed by a cyclone and a filter, and transported by nitrogen to the gasifier.

Syngas must be cleaned in order to meet the fuel cells' strict tolerance. Impurities such as halogens, sulfur and so on in the syngas are removed by a water scrubber and an MDEA (Methyl Die Ethanol Amine) absorber, and the syngas is finely desulfurized through the use of iron oxide. Acid gas removed by the MDEA absorber burns to sulfur oxide in a furnace and the sulfur is recovered as gypsum through the use of a limestone absorber.

Cleaned syngas goes to the gas turbine where it combusts to generate electricity. Generated electricity is consumed as auxiliary power for the pilot plant. The plant is also designed so that compressed air from the gas turbine can be supplied to the air separation unit.

Cryogenic air separation is introduced to the ASU (Air Separation Unit) in consideration of oxygen purity and yielding capacity. Surplus nitrogen produced in the ASU is supplied to the gas turbine to reduce NOx.

Table 4 shows the specifications of the EAGLE pilot plant's equipment.

Table 4 EAGLE Pilot Plant Specifications

Coal gasification	Oxygen-blown entrained-flow gasifier (two-stage tangential flow type)
Coal feed	150 tons per day
Gasification pressure	2.5 MPa
Gas clean-up	Cold gas clean-up using MDEA
Syngas volume	14,600 m^3 N/h (MDEA absorber outlet)
Sulfur recovery	Limestone-gypsum wet scrubbing
Air separation	Pressurized cryogenic separation
Oxygen production	4,300 m^3 N/h
Oxygen concentration	95 vol %
Air feed	20,000 m^3 N/h
Air feed pressure	1.12 MPa
Gas turbine power	8,000 kW

3.3 Features and Structure of the Gasifier

High concentrations of H_2 and CO and a high calorific value for the syngas are suitable in the application of a coal-gasifier for use with fuel cells. This project has thus employed a dry feed oxygen-blown entrained-flow gasifier. Figure2 shows the characteristics of the EAGLE project gasifier. The gasifier has the following features:

(1) Upper and lower burners are installed tangentially to the cylindrical gasifier sidewall. A spiral flow can occur from the upper stage down to the lower stage, thus making particle residence times much longer than that of a gas stream. This allows high efficiency gasification.

(2) Changing the feed rate of oxygen to each stage can control the gasifier's temperature profile. At the upper stage, activated char is formed in lean oxygen conditions. At the lower stage, ash without carbon is fused in rich oxygen conditions. This system makes it possible to obtain both high gasification efficiency and stable operation.

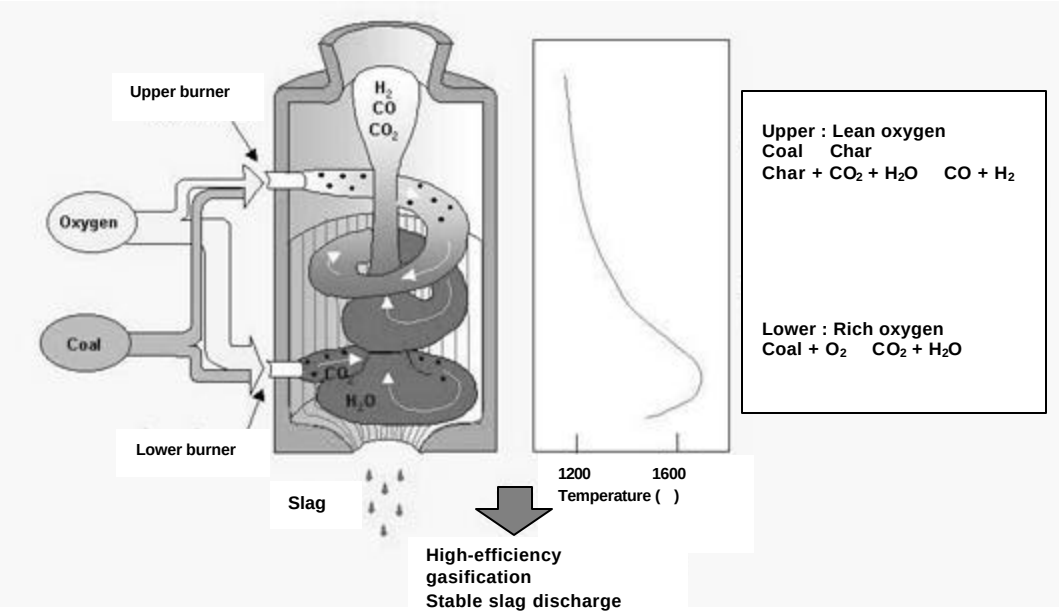


Figure 2 Characteristics of the gasifier

3.4 Gas clean-up

This project employs cold gas clean-up in order to satisfy the tolerance limits of fuel cells. Syngas at a temperature of approximately 400°C exits from the char-filter and is heat-exchanged at the Gas/Gas Heater (GGH). Impurities such as halogens and ammonium are removed in a water scrubber, and the gas is then desulfurized in an absorber. Here, this project employs MDEA (Methyl Die Ethanol Amine) as the sorbent. Since MDEA has low absorptivity for carbonyl sulfide (COS), COS must be converted into H_2S in a COS converter in advance. The clean syngas, which exits the MDEA absorber at approximately 40°C, is heated to approximately 200°C by a steam heater and the GGH and supplied to the gas turbine. Part of the clean syngas is sent to the precise desulfurizer, where it is further desulfurized down to the tolerance limit of the fuel cells or less. Figure3 shows flow diagram of gas clean-up unit.

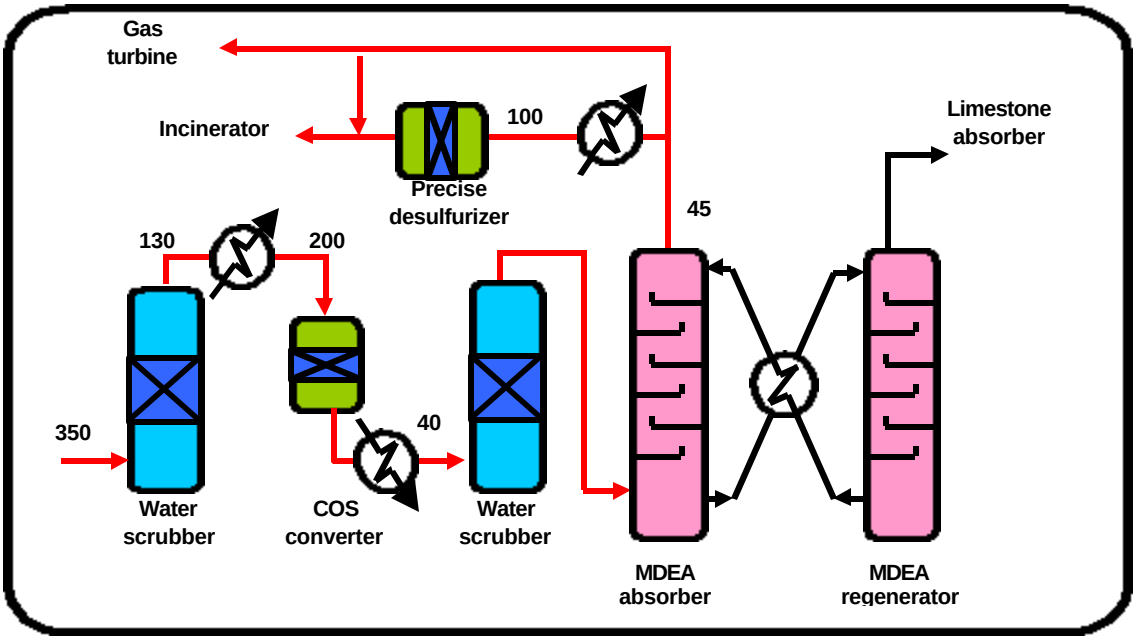


Figure 3 Flow Diagram of Gas Clean-up Unit

4. Construction of the Pilot Plant

At the test site, the Wakamatsu Operations & General Management Office, Electric Power Development Co., Ltd., in Fukuoka Prefecture, the mechanical foundation work was started in August 1998 for the main facilities of the pilot plant, that is, the coal gasification and gas clean-up units. The building foundation work and the steel frame construction work were also started for the operation and compressor rooms. The gasifier and the syngas cooler were delivered in September 1999, and their installation work is nearly completed.

Figures 4 to 6 show the status of the site as of the end of July 2000 and Figure 7 shows the gasifier installation September 1999. Figure 8 shows the conceptual drawing of the EAGLE project at its completion. A test run is scheduled to be started in 2002 and a three-year running study in 2003.

Figure 4 Status of Construction (1)

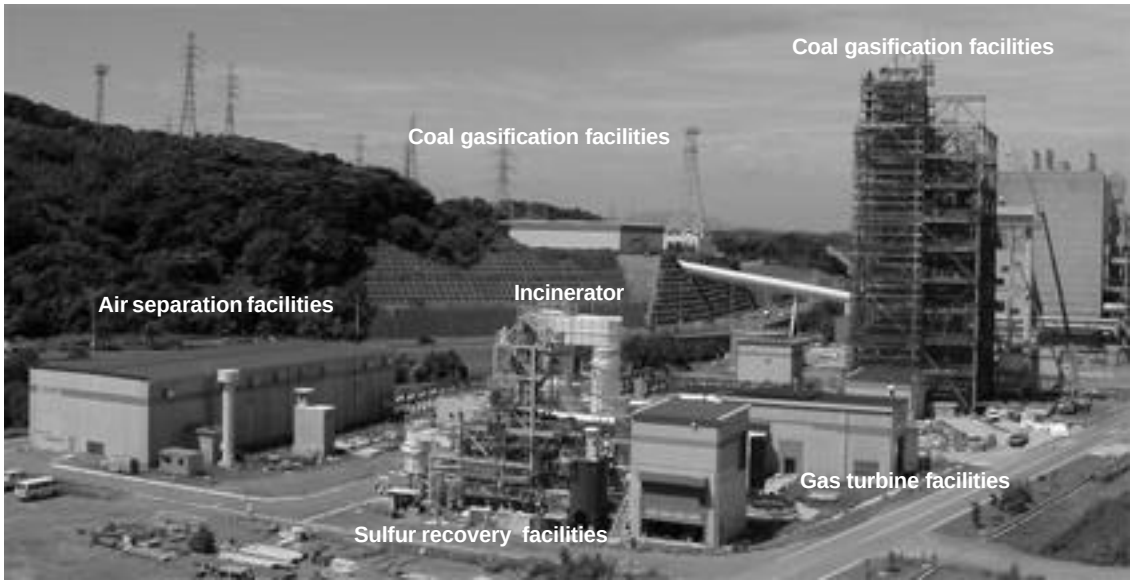


Figure 5 Status of Construction (2)

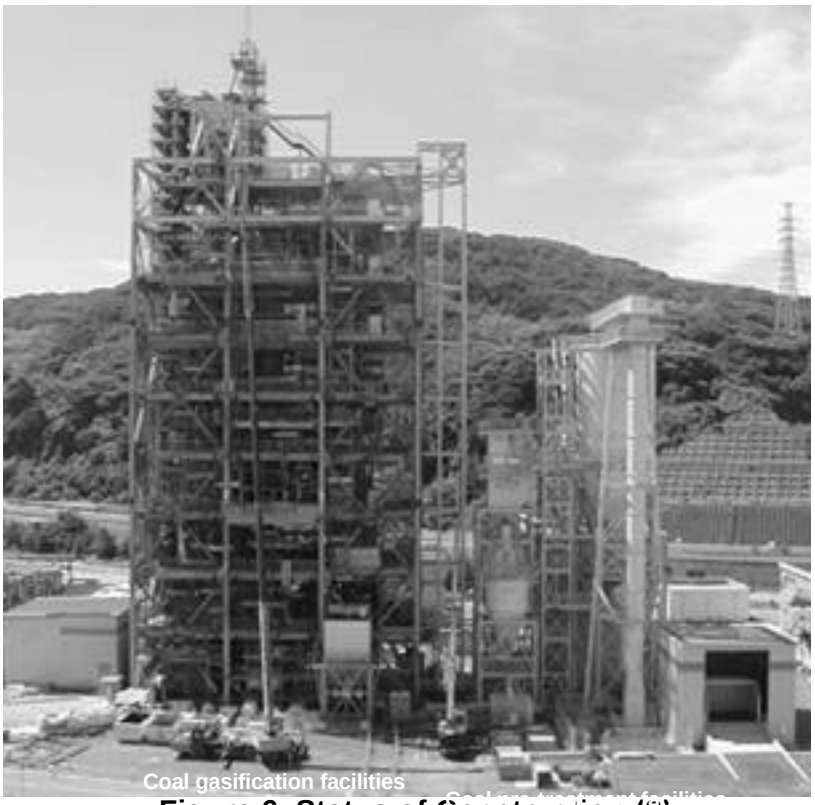


Figure 6 Status of Construction (3)

Figure 7 The Gasifier Installation (September,1999)

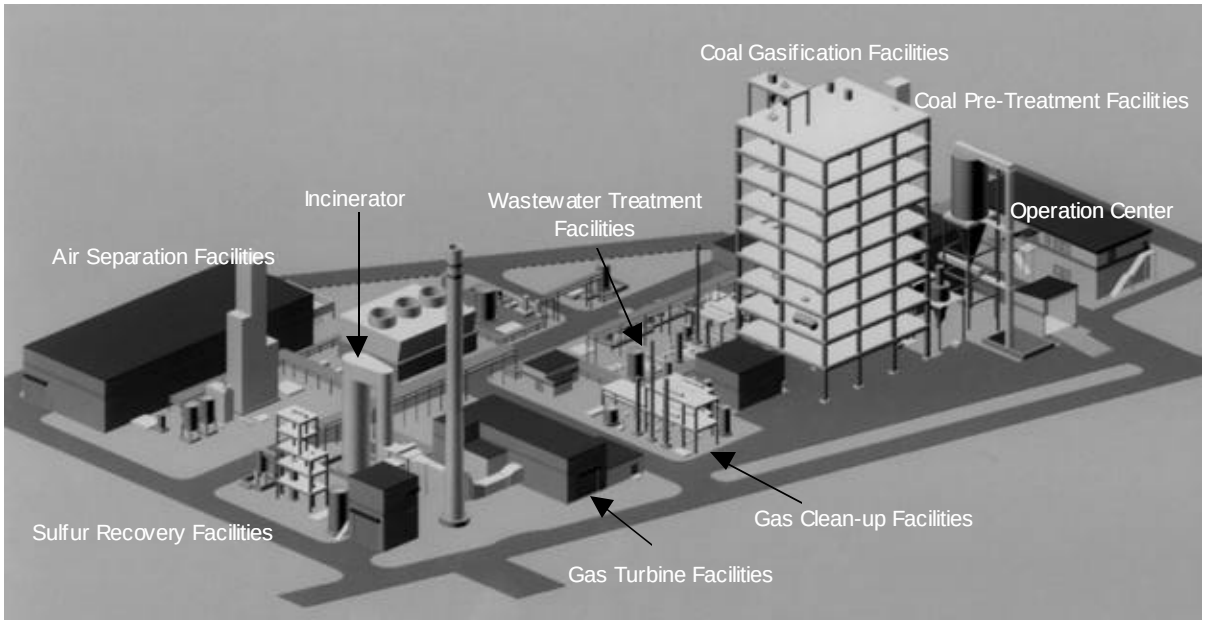


Figure 8 Conceptual drawing

5. <Informative> Development Status for Fuel Cells

The Electric Power Development Co., Ltd. is promoting the self-development of "Solid Oxide Fuel Cells (SOFC)" in collaboration with Mitsubishi Heavy Industries, Ltd. We have consecutively developed an atmospheric 1 kW SOFC module, an atmospheric 10 kW module, and a pressurized 1 kW module. In December 1998, we succeeded in achieving continuous 7,000-hour power generation with the pressurized 10 kW SOFC module, becoming the first in the world to do so. Test runs of the modified pressurized 10 kW module will be started in October 2000. The objective of these tests is to verify one of the important items for establishing the 100 kW module, "Fuel internal-reforming technology".

The EAGLE project contains the "Precise Desulfurizer" for fuel cells. When the test run is underway and the coal gasification gas supply becomes available in 2002, a demonstration test will be proposed for the "Integrated Coal Gasification Fuel Cells Combined-cycle Power Generation System (IGFC)", depending on the status of development of MCFC and SOFC technologies. It can be said that the coal utilizing ultra-high efficiency power generation technology will soon be realized.

6. Summary

As a result of the IGFC feasibility study, we concluded that an oxygen-blown gasifier would be suitable for IGFC, and that the net thermal efficiency of IGFC would be 53 percent or more. A pilot plant with a capacity of 150 tons per day will be equipped with a coal gasification unit, gas clean-up unit, air separation unit, and gas turbine unit (outside the range of the subsidy). The pilot plant, which was designed to implement experiments on a total coal gasification system for fuel cells, is now under construction. Operation is scheduled to commence in 2002. We look forward to obtaining results in which coal gasification technology for fuel cells is put into practical use.

This project is being conducted as a national project by our company under entrustment from the New Energy Industrial Technology Development Organization (NEDO). We would like to express our deep appreciation for the support and guidance we have received from all concerned parties, including the Agency of Natural Resources and Energy of MITI.