The Large Capacity Gas Turbine for Pressurized Fluidized Bed Combustion (PFBC) Boiler Combined Cycle Power Plant

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1. Introduction

As the global environment becomes an ever-greater issue worldwide, there is a demand for PCF plants to reduce CO2 emissions through more efficient power plants, and reduce levels of SOx, NOx, and dust in boiler exhaust through the development of new power generation systems [2] [3].

PFBC technologies have gained attention as an efficient, low-pollution technology enabling efficient use with low-grade coal. Outside Japan, 70 MW-class test and commercial power plants have been operational since the early 1990s. Japanese manufacturers are also developing power plants using PFBC technologies, and have been operating 70 to 80 MW-class test and commercial power plants since the late 1990s. Starting in 2000 to 2001, a succession of 250 and 360 MW plants – the world's highest-capacity – began commercial operation.

2. PFBC Plant Overview

A PFBC plant is a combined cycle power-generation system that turns a steam turbine by means of steam generated from a PFBC boiler installed inside a pressurized vessel, while at the same time turning a gas turbine by means of the same gas [4] [5] .

Fig. 1 provides a conceptual diagram of the PFBC plant architecture, while Table 1 lists the main specifications used for large-capacity utility power plant in Japan.

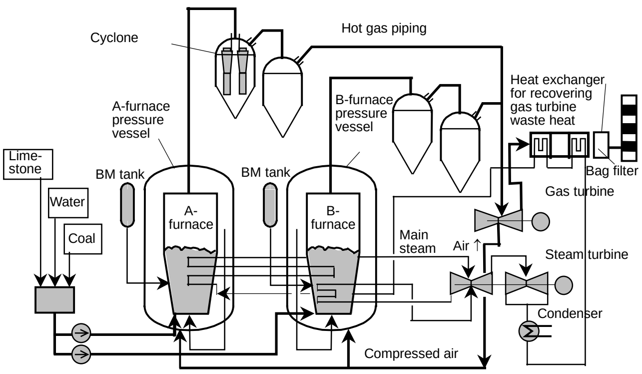

Fig.1 Conceptual diagram of PFBC system

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This paper outlines gas turbines with a focus on the 250MWPFBC plant used at the Chugoku Electric Power Company Osaki Power Station (power station 1-1 of unit 1), in which project the authors participated (see Fig. 2).

Fig.2 The Osaki power station unit 1

3. Gas Turbines

A PFBC gas-turbine has the following equipment features:

* Gas-turbine layout
* Dust filtering system
* Large gas shut-off valve
* Highly dust resistant turbine
* Gas turbine start-up system

Gas-turbine layout

Gas from the pressurized fluidized bed combustion boiler passes through headers arrayed on either side, and is led to a multi-inlet gas pass, after which it is fed to the gas turbine (see Fig. 3).

Dust collection system

A dust filtering system is installed to remove dust contained in the combustion gas from the pressurized fluidized bed combustion boiler. A total of 12 cyclone elements are arrayed in each pressure vessel. These elements serve two purposes: to remove coarse dust (primary cyclone), and to reduce abrasion to the turbine blades (secondary cyclone). The system reduces dust levels to no more than 1,000 mg/Nm3 at the turbine inlet, with a maximum particle diameter of 10 microns (see Fig. 4).

Table-1 Main specifications of 250MW PFBC plant

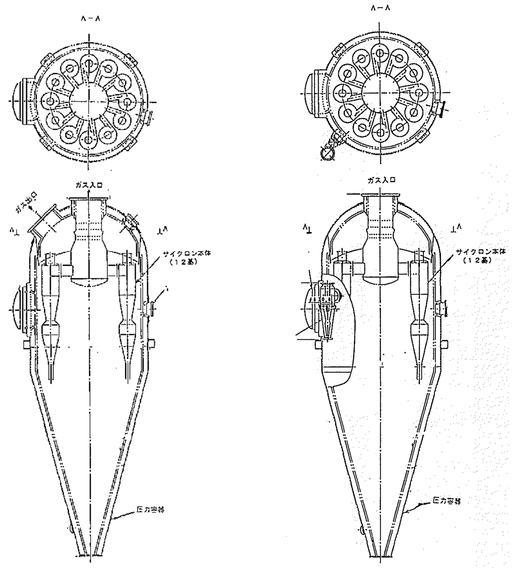
Name of facirities	Chugoku Electric Power Co. Osaki Power Station	Kyushu Electric Power Co. Karita Power Station	Hokkaido Electric Power Co. Tomato - Atsuma Power Station
Commencement of commercial operation	2000/11	2001/7	1998/3
Plant output	250MW×2	360MW	85MW
ST/GT output	215MW×2/44MW×2	290MW/75MW	73.9MW/11.1MW
Steam conditions	16.6MPa 566/593℃	24.1MPa 566/593℃	16.6MPa 566/538℃
Soot & dust removal system	Two-stage cyclone + bag filter	Two-stage cyclone + Electrostatic precipitator	Cyclone + Ceramic Filter
Desulfurization process	Desulfurization of furnace	Desulfurization of furnace	Desulfurization of furnace
Denitrification process	Catalytic + non-catalytic denitrification	Catalytic denitrification	Catalytic denitrification
Gas turbine system	Single shaft simple cycle	Twin shaft simple cycle	Single shaft simple cycle
Plant gross thermal efficiency	41.5%	42.5%	40.1%

Large gas shut-off valve

On plant startup and shutdown, it is necessary to initiate or cut off the flow of combustion air to the boiler, and the flow of gas from the boiler to the gas turbine. For this reason shut-off valves are placed on the process air supply side, and another on the gas side, and combined with a bypass valve that connects outlet of compressor and inlet of turbine. All system valves were installed on ordinary gas turbines. (See Fig. 5).

Highly dust resistant turbine

The gas turbine is designed in accordance with the exhaust-gas volume using a boiler for the existing F7EA gas turbine. Since the boiler produces exhaust gas at a lower temperature than standard turbines (about 850$^{deg\text{-}c}$), the cooling air and seal air in each part is reduced, and changed the turbine blade profile to set pressure of combustion gas properly. Additionally, the specifications of the blade coating were changed, in order to resist erosion due to dust contained in the high-temperature gas. (See Fig. 6)



Primary cyclone　　Secondary cyclone

Fig. 4 Cross section of cyclone-type dust collector

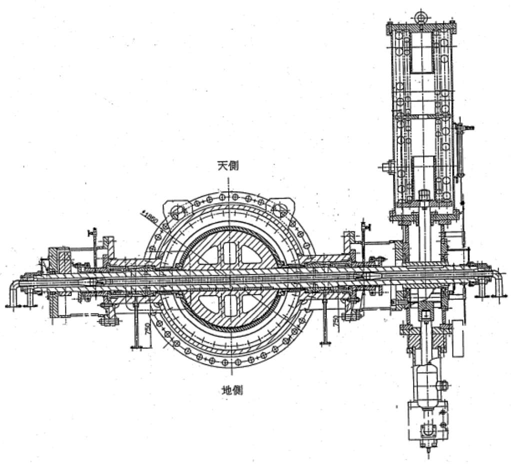


Fig. 5 Cross section of gas shut-off valve

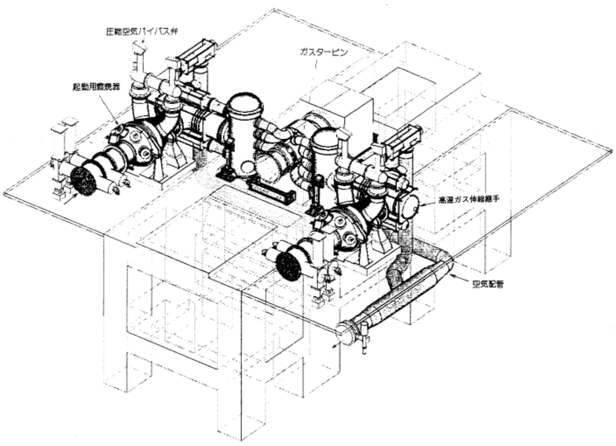


Fig. 3 Bird view of gas turbine facilities

Fig. 6 **Gas turbine first stage nozzle assembly**

Gas turbine startup system

An electric startup motor and gas-turbine startup combustor are used together to start the gas turbine.

The outline of startup procedure is as follows. 1)Start like a standard gas turbine by the electric starter motor. 2)Accelerate till rated speed using startup combustor. 3)Parallel in to the electric power system. 4)Startup combustor is extinguished. It becomes motoring operation at first until the load of the plant goes up to high.

4. Operating Conditions

The 250-MW PFBC plant delivered by Hitachi Ltd. for the Chugoku Electric Power Company Osaki Power Station was jointly developed using the 4 MW_{th} test facility at the Chugoku Electric Thermal Power Generation Technology Center.

Construction of the plant began in November 1995. Performance tests of the plant carried out during test operation have confirmed approximately 10% better efficiency than PCF plants with the same output scale. (see Table-2).

Table-2 The Osaki PFBC plant performance

Item		Planned value	Measured value
Plant gross thermal efficiency		41.5%	Above 42%
Desulfurization	SOx concentration at flue inlet	76ppm	7.1ppm
	Desulfurization efficiency	>90%	97.7%
Denitrification	Efficiency of non-catalytic denitrification	37%	38.0%
	Efficiency of catalytic denitrification	85%	88.3%
	NOx concentration at flue inlet	<19ppm	14.4ppm
Soot & dust removal	Cyclone efficiency	97.1%	97.2%
	Concentration at gas turbine inlet	≤1000mg/m^3 N	≤533mg/m^3 N
	Concentration at bag filter outlet	≤9mg/m^3N	≤3.5mg/m^3 N

to improve environmental performance as well, and levels The dust collector, cyclones, and other facilities work well of SOx, NOx, and dust all meet planned values. and it has been in commercial operation since November 2000. As of November 2003, it has undergone an inspection for the first time.

350-MW PFBC plant delivered to the Kyushu Electric Karita Power Plant [7] by IHI/Toshiba/Alstom power has been operating commercially since July 2001.

85-MW PFBC plant delivered to the Hokkaido Electric Tomakomai Higashi Azuma Power Plant [6] by Mitsubishi has been operating commercially since March 1998.

5. Conclusions

This paper has showcased PFBC gas turbines, with a focus on major equipment. Power plants constructed in Japan are operating well. A future task will be to build up an operating track record, improve them operationally (including expanding the types of coal that can be used), and confirm the long-term reliability of plants featuring PFBC systems.

In the future, it is expected that further developments in gas-turbine utilization technologies and related equipment, based on a favorable track record for pressurized fluidized bed combustion power plant systems, will meet the needs of society.

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