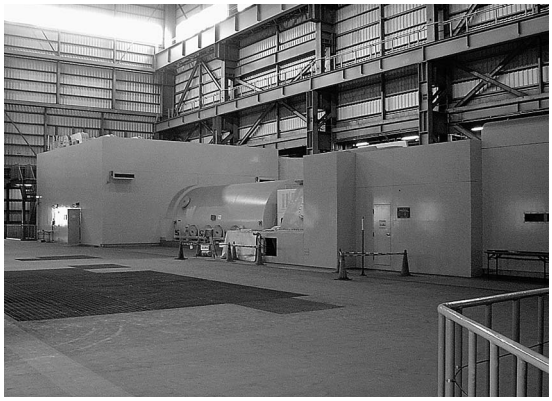

Large-Capacity, High-Efficiency BFG-Firing Combined Cycle Plant with F Series Gas Turbine

HIDEO MATSUDA*1 YUICHI OKA*1
TOYOAKI KOMORI*1 NOBUYUKI YAMAGAMI*1

Kimitsu Cooperative Thermal Power Company, Inc. Unit No. 5 is the world's first BFG-firing combined cycle plant featuring high efficiency and large capacity with F series gas turbine. Mitsubishi Heavy Industries, Ltd. (MHI) has developed and installed the principal devices including gas turbine, steam turbine, gas cooler, condenser, and distributed control system (DCS). MHI has been researching and developing BFG-firing gas turbines for many years, and has built various BFG-firing combined cycle plants with D series gas turbine. This paper introduces the latest technology established and verified for the first time in the world in this power plant.

1. Introduction

BFG is blast furnace gas, which is a fuel gas produced in quantities in the steelmaking process. For effective use of this BFG, it has been necessary to develop the technology of BFG-firing combined cycle with high efficiency and large capacity. However, as compared with natural gas used as ordinary gas turbine fuel, BFG is low in calorie and in fuel feed gas pressure, and contains many impurities in the fuel. Because of this special fuel condition, many technical problems remain to be solved in using BFG as gas turbine fuel.

MHI is a pioneer in research and development of BFG-firing gas turbines for meeting the needs of effective low-calorie fuel use, and has already constructed many BFG-firing combined cycles with D series gas turbine.

On the basis of these technical achievements, MHI has recently succeeded in developing a BFG-firing combined cycle plant with F series gas turbine for the first time in the world. This paper gives an outline of Kimitsu Cooperative Thermal Power Company, Inc. Unit No. 5 which has been in commercial operation since July 28, 2004 (an overview is shown in **Fig. 1**), and the latest technology established and verified in this power plant.

2. Outline of the plant

The main specifications of the power generation system in Kimitsu Cooperative Thermal Power Company, Inc. Unit No. 5 are given in **Table 1**, and an outline of the system is shown in **Fig. 2**.

Table 1 Main specifications of plant

Plant type	1 on 1, single shaft type
Fuel	Heat increased BFG
Plant output	300 MW
Plant efficiency	47.5 % (HHV)
Gas turbine	M701F series
Steam turbine	SRT 40.5
Gas cooler	Direct water-cooling type
Condenser	Seawater cooling type
Control device	DIASYS Netmation

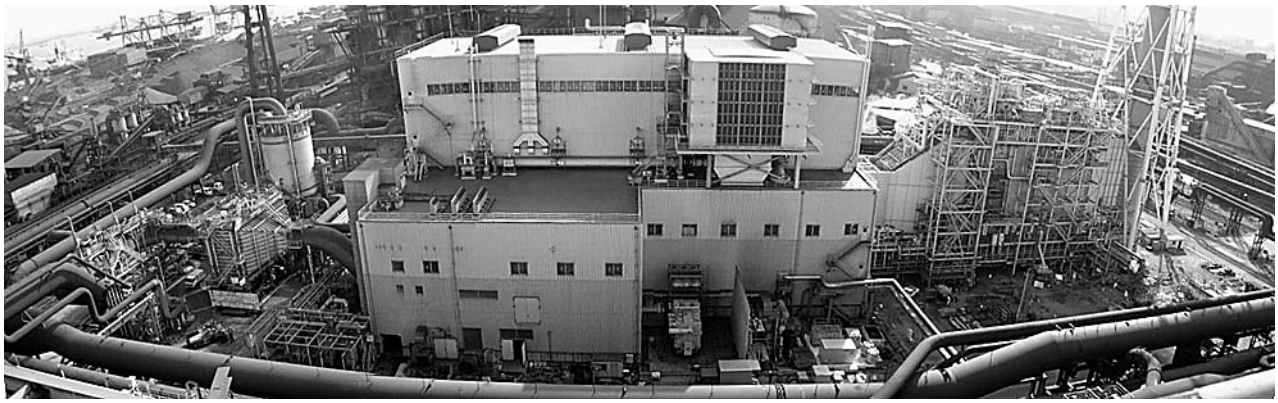

Fig. 1 Overview

*1 Power Systems Headquarters

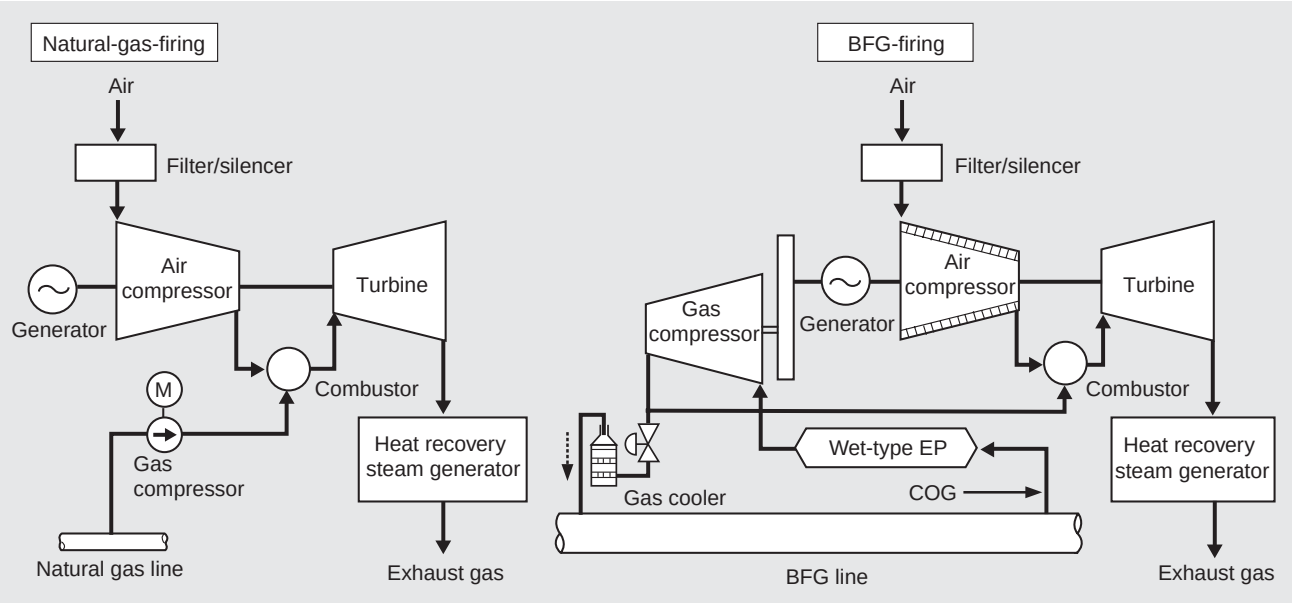

Fig. 2 Outline of plant system

In Fig. 2, a natural-gas-firing system is shown together in order to clarify the features of the BFG-firing system. MHI has installed a BFG-firing M701F series gas turbine at a turbine inlet temperature of 1 300°C, single-casing down exhaust steam turbine, gas cooler, condenser and distributed control system (DCS).

As shown in Fig. 2, when BFG is mixed with COG (cokes oven gas), its calorific value is increased up to 4 400 kJ/m^3-N dry (LHV). The BFG is supplied to the gas turbine after being boosted by a gas compressor coupling a shafting system of gas turbine, generator and steam turbine, and step-up gear.

3. New gas turbine technology

A sectional view of the BFG-firing F series gas turbine is shown in **Fig. 3**.

3.1 Combustion unit

As compared with liquefied natural gas (LNG) generally used as gas turbine fuel, BFG generated in a blast furnace is lower in fuel heat generation capacity, slower in burning velocity because of high rate of inert gas such as nitrogen and carbon dioxide, and has a narrower flammability limit.

In spite of these combustion characteristics, in order to obtain an optimum fuel-to-air ratio for realizing a high combustion efficiency in the entire operating range, the multican type with air bypass valve is employed, as in the case of dry low NOx combustors (**Fig. 4**). Further, flammability is improved by mixing the high calorie gas of COG into BFG by flow rate control to increase the calorific value, and a turbine inlet temperature of 1 300°C is achieved, the highest in the world record for a BFG combustor.

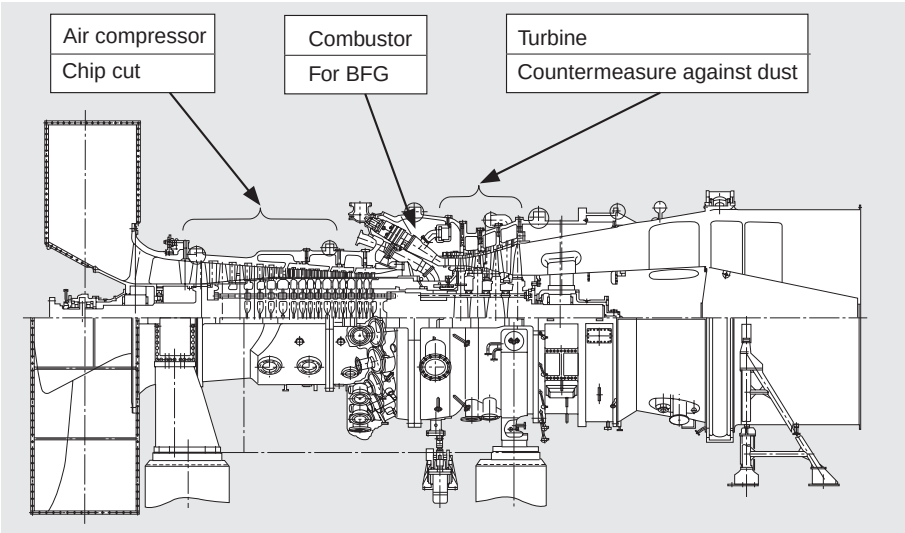

Fig. 3 Sectional view of BFG firing F series gas turbine

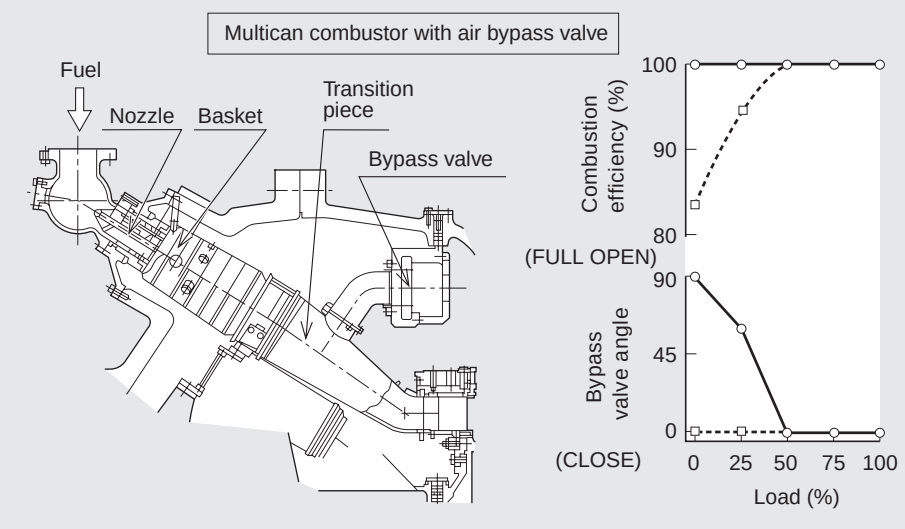

Fig. 4 Multican combustor with air bypass valve

3.2 Air compressor and turbine

At a constant temperature of the turbine inlet, by low-calorie firing, the fuel amount is greater as compared with ordinary high calorie fuel firing, and the turbine passing combustion gas amount increases. In conventional low-calorie gas firing machines using blast furnace gas or the like, the air compressor is smaller in size as compared with standard machines, and the air intake is decreased to control the turbine passing flow rate to the level of standard machines, so that a standard cascade can be employed in the turbine cascade.

However, BFG contains a higher level of dust than LNG, and degradation and clogging can be expected. The system reliability is improved because dust particles are removed by the installation of a wet-type electrostatic precipitator (EP) on the BFG supply side.

4. Conclusions

Kimitsu Cooperative Thermal Power Company, Inc. Unit No. 5, which started commercial operation in July 2004, is described together with an outline of the plant and new technology. This power plant has achieved an efficiency in the 48 percent range (HHV) in performance tests, and is continuing stable commercial operation at present.

This power generation plant based on the new technology is being planned overseas at present, and many plants are scheduled for construction both in Japan and overseas. This technical development is reportedly contributing much to society by satisfying the needs of effective use of energy and environmental impact reduction. Henceforth, MHI is determined to promote technical development further in order to play the role of pioneer in this field.


Hideo Matsuda


Yuichi Oka


Toyoaki Komori


Nobuyuki Yamagami