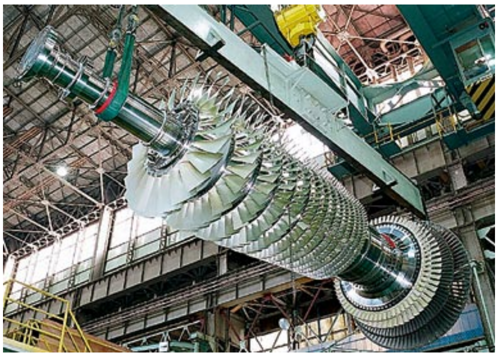

# Development of High Efficiency Gas Turbine Combined Cycle Power Plant

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*The reduction of carbon dioxide ($CO_2$) to prevent global warming has become a serious issue for power plants. Since power plants account for one third of the total $CO_2$ emissions, improvements in their efficiency will greatly contribute to the reduction of $CO_2$ emissions. This paper focuses on the gas turbine combined cycle power plant, and introduces the approaches for the improvement of its efficiency.*

## 1. Introduction

Methods of $CO_2$ reduction to prevent global warming can be divided into two types: reduction of $CO_2$ emissions and recovery of $CO_2$.

Over the last one or two years $CO_2$ recovery has been studied for a combined system of hydrogen gas turbine combined cycle and EOR (enhanced oil recovery), where petroleum coke is gasified and the gas is shifted by reforming to $CO_2$ and hydrogen.

It is well-known that power plants are responsible for one third of the total $CO_2$ emissions. Improving the heat efficiency of a power plant by introducing a high-efficiency gas turbine combined plant with an advanced gas turbine leads directly to the reduction of $CO_2$ emissions, and is therefore an effective means of $CO_2$ reduction.

This paper reports the gas turbine combined cycle plant to reduce $CO_2$ emissions, and describes its future prospects of high efficiency.

## 2. Transition of the heat efficiency of combined cycle plant and $CO_2$ reduction

Thermal power plants are broadly divided into two types: the conventional type with a combination of a boiler and steam turbine and the combined cycle type which consists of a gas turbine and a steam turbine that uses high-temperature steam obtained through heat recovery from the gas turbine exhaust gas.

Unlike a conventional thermal power plant, a combined cycle power plant was adopted for power generation in Japan for the first time in 1984 in Unit No. 3 at Higashi Niigata Thermal Power Station of Tohoku Electric Power Co., Inc., where a D-type gas turbine with an inlet temperature of 1,100°C was adopted.

With the rise in turbine inlet temperature, a 1,300°C class F-type gas turbine was developed, followed by a 1,500°C class G-type gas turbine (see **Fig. 1**). The state-of-the-art G-type gas turbine combined plant has an efficiency exceeding 59% (LHV base) and 53% (HHV base). **Figure 2** shows a comparison between the combined cycle power plant and a conventional thermal power plant, while **Fig. 3** shows the transition of reductions in $CO_2$ emissions per kWh due to improvement of efficiency.

**Fig. 1 G-type combined cycle plant**
Unit 4-2 at Higashi Niigata Thermal Power Station of Tohoku Electric Power Co., Inc.

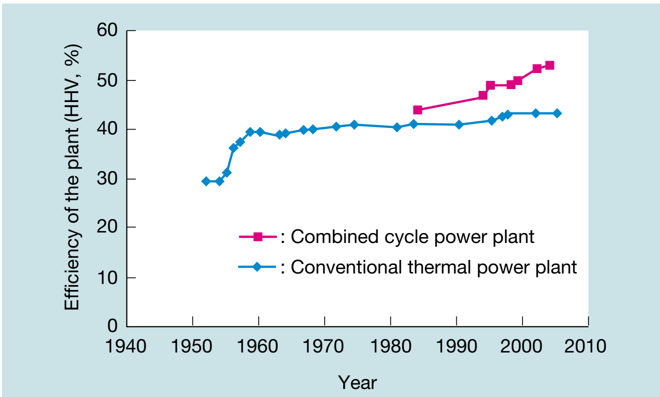


**Fig. 2 Transition of plant efficiency of conventional type thermal power plant and combined cycle power plant :**
Adapted from Improvement of Efficiency of Thermal Power Plant, '3. Gas Turbine,' Thermal Power and Nuclear Power Plant Vol. 54 No. 10 (2003) p. 1176.

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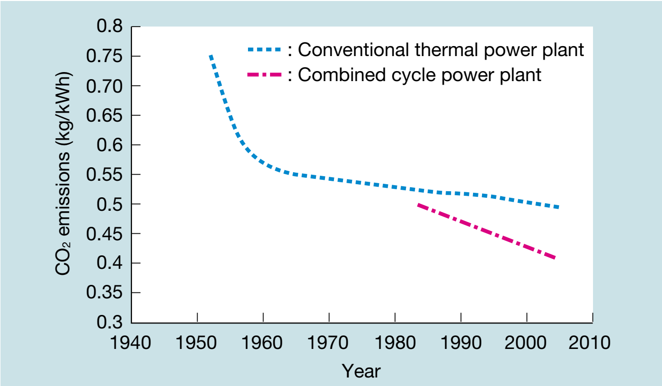


**Fig. 3 Transition of "$CO_2$ emission reduction"**
Indicates the $CO_2$ emissions converted to emissions from natural gas firing conventional thermal power/combined cycle power plants

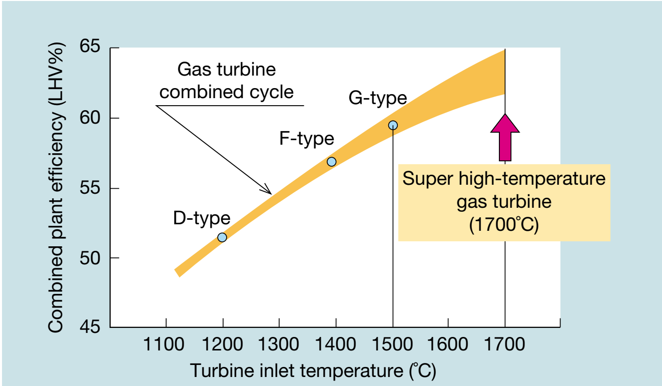


**Fig. 4 Turbine inlet temperature and combined plant efficiency**

The $CO_2$ emissions have consistently been reduced since 1950, but because of the slowdown of the improvement in efficiency, the amount of $CO_2$ reduction in conventional thermal power plants is not so much compared with the combined plant.

On the contrary, because of the drastic improvements made in the efficiency of the combined cycle plant, the $CO_2$ emissions have been greatly reduced and are expected to be further reduced in the future due to improvement of efficiency.

## 3. Outline of 1,700°C class high-efficiency gas turbine

As mentioned above, it is necessary to raise the cycle temperature in order to improve the efficiency of the combined cycle plant. **Figure 4** shows the relationship between the maximum cycle temperature (gas turbine inlet temperature) and efficiency.

The efficiency of the combined cycle plant with a 1,700°C class gas turbine with its inlet temperature improved to 1,700°C compared with the F-type and G-type with inlet temperatures of 1,500°C has reached the level of 62% - 65% (LHV base), and is expected to stand at a higher level than the efficiency of the conventional combined cycle plant.

The design concept of 1,700°C class gas turbine is shown in **Fig. 5**.

Mitsubishi Heavy Industries, Ltd. (MHI) has joined the development program of the 1,700°C class gas turbine, a national project, which requires six component technologies (combustor, cooling technology, heat-resisting materials, heat-shielding coating, turbine aerodynamics and compressor aerodynamics).

For realization of the 1,700°C class gas turbine with an inlet temperature far higher than the latest 1,500°C gas turbine,

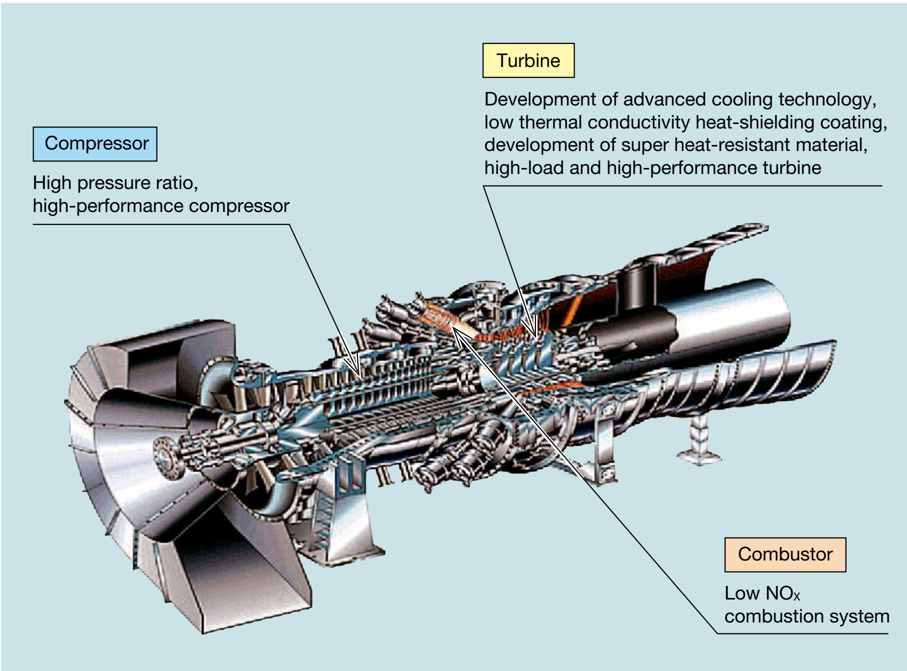


**Fig. 5 Design concept of 1,700°C class gas turbine**

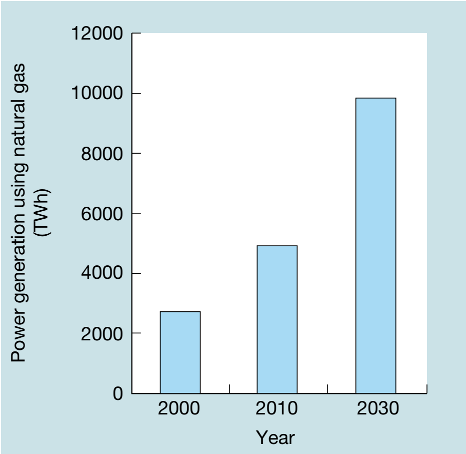


**Fig. 6 Estimated power generation using natural gas**
Adapted from IEA World Energy Outlook

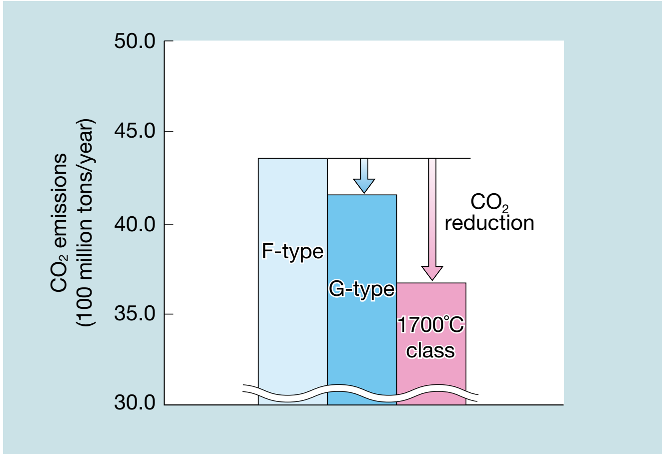


**Fig. 7 Estimated $CO_2$ emissions due to power generation at natural gas firing combined cycle plant**
Indicates emission rate per 10,000 TWh.

the basic design of high performance compressor, low $NO_X$ combustor and turbine capable of withstanding the 1,700°C inlet temperature is under development.

## 4. $CO_2$ reduction due to high-efficiency gas turbine combined cycle plant

The world's gross power generation amounted to 15,000 T (tera) Wh in 2000, and is estimated to exceed 20,000 TWh in 2010 and 30,000 TWh in 2030.

It is estimated that the power generation due to natural gas, the main fuel of power generation equipment, will be 5,000 TWh in 2010 and double to about 10,000 TWh in 2030 (see **Fig. 6**).

Supposing it is planned that all of the power generation (10,000 TWh) for 2030 will use natural gas firing high-efficiency gas turbine combined cycle G-type or 1,700°C class turbines, the $CO_2$ reduction due to fuel reduction because of the efficiency difference from the F type turbine will amount to 200 million tons for G-type turbines and approximately 500 - 700 million tons for 1,700°C class turbines (see **Fig. 7**).

In view of the present total annual $CO_2$ emissions of approximately 1.3 billion tons in Japan, this figure shows a remarkable progress in $CO_2$ reduction.

Thus, it is considered that the large $CO_2$ reduction for high-efficiency gas turbine combined cycle plants is possible before the implementation of $CO_2$ recovery and reservoir systems.

## 5. Conclusion

Gas turbine combined cycle power plants mainly using MHI D, F and G-type gas turbines are currently in operation in large numbers, and there are many under construction or planned both in Japan and abroad. The development and introduction of this new technology responds to the need for the effective utilization of energy and countermeasures against global warming, thus contributing greatly to society. MHI is determined to continue efforts to develop new technology as a pioneer company in this field.

### References


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