Performance Evaluation of H-25 Gas Turbine

— with Low-NO_X Combustor Installed at SaskPower's Queen Elizabeth Power Station as Part of Re-powering System —

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OVERVIEW: As concerns about global environmental problems grow, electric power plants that utilize high efficiency gas-turbine generators are being actively sought after. Accordingly, at SaskPower's Queen Elizabeth Power Station in Canada, Hitachi, Ltd. has implemented a re-powering system that combines Hitachi's H-25 gas-turbine generators with the plant's existing steam-turbine generators. This re-powering system consists of H-25 generators combined with OTSG (once-through steam generator: also known as once-through boiler). The H-25 gas-turbine generator incorporates a low-NO_x emission combustor that meets the demand for low environmental impact. The combustor is based on low-NO_x emission technology that Hitachi has accumulated during the development of low-NO_x emission combustors for large-scale gas turbines. And it was shown during the commissioning that the low-NO_x emission H-25 gas-turbine generators installed at the Queen Elizabeth Power Station produce NO_x emission at the level of 25 ppm (at 15% O_2). In addition, the performance of the turbines was demonstrated to be satisfactory; that is, trouble-free operation down to -30°C is possible, and generated gross output power and thermal efficiency easily meet the design specifications. It is thus considered that the H-25 gas-turbine generator incorporating a high-thermal-efficiency low-NO_X emission combustor will be an effective response to the growing demands for environmental-protection measures—such as prevention of global warming and reduction of NO_x emissions.

INTRODUCTION

TO address the issues of energy conservation and global warming, it is being actively sought after to increase the efficiency of gas-turbine power plants. In response to these circumstances, Hitachi, Ltd. — together with the Canadian engineering firm SNC-Lavalin Group Inc.—have implemented a re-powering system for the existing electricity-generating equipment at SaskPower's Queen Elizabeth Power Station (see Fig. 1). This re-powering system is aimed at improving the efficiency of the plant's two 66-MW boiler-fired steam turbines. It comprises the pairing of an OTSG (once-through steam generator), also known as a once-through boiler, and Hitachi's H-25 gas-turbine generator. The combustor of the gas turbine incorporates a low-emission combustor that meets the guaranteed NO_x-emission value of 25 ppm (at 15% O_2) set out in the customer specification. Commissioning of the re-powering system started in November 2001 (one turbine unit was tested per month), and in May 2002 all six turbines started commercial operation and have been operating smoothly ever since.

In the following sections, first, a brief overview of the combustor of the H-25 gas turbine is given. The results of a performance evaluation of the turbines implementation at the Queen Elizabeth Power Station are then presented.

H-25 GAS TURBINE

A total of 28 (including the six installed at the SaskPower plant and the H-15 type) of Hitachi's H-25 gas turbines — specially developed for "cogeneration" systems — have been implemented both in Japan and internationally. Each one of them is performing smoothly, and their total operating time has already surpassed 560,000 hours.

Reduction gears are set up between the turbine

Fig. 1—Re-powering System Installed at Queen Elizabeth Power Station (on the left); H-25 Gas-turbine Units (right).
The re-powering system aims to make use of the plant's existing steam-turbine generators by combining the OTSG with an H-25 gas turbine generator. The H-25 incorporates a low-NO_x combustor that produces NO_x emission at the low level of 25 ppm, which is satisfactory in terms of environmental protection.

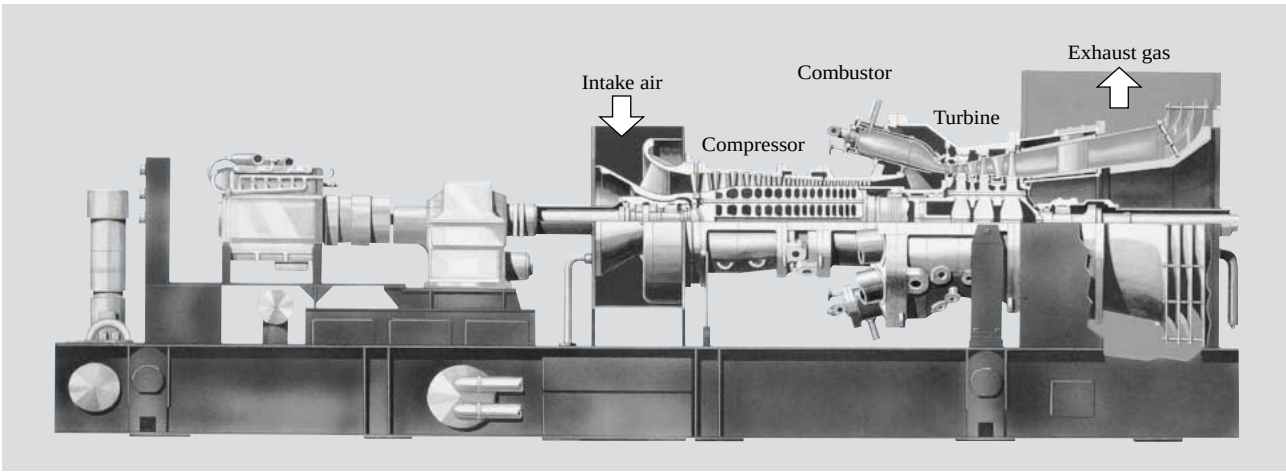

Fig. 2—Cross Section of H-25 Gas Turbine.
Single-axis configuration consists of a 17-stage axial-flow compressor, a three-stage axial-flow turbine, and a 10-compartment combustor.

generators so that, at the rated revolution speed of 7,280 rpm, a frequency of 50 or 60 Hz can be produced. And the IGV (inlet guide vane) of the turbine's compressor is a swing-wing type aimed at improving the performance of this section in the case of both cogeneration and combined-cycle-generation systems. The cross-sectional structure of the H-25 gas turbine is shown in Fig. 2, and its specifications are listed in Table 1.

COMBUSTOR OF H-25 GAS TURBINE

On the subject of the combustor of the H-25 gas turbine, as well as a standard combustor, the low-NO_x emission combustor can be chosen for single-fuel gas firing. The specifications of the combustors are listed

TABLE 1. Specifications of H-25 Gas-turbine Generator.
Listed performance values for power-generation operation at 15°C; intake pressure: 88.9 mmH_2O; exhaust gas pressure: 63.5 mmH_2O.

Parameter	Specification	
Fuel	Natural gas	Light oil
Power output (MW)	26.9	26.3
Heat efficiency (%)	33.2	32.6
Rated revolution speed (rpm)	7,280	
Intake flow rate (kg/s)	88	
Exhaust gas temperature (°C)	555	
Pressure ratio	14.7	
Compressor	17-stage axial-flow type	
Turbine	Three-stage axial-flow type	
Combustor	Multi-compartment type (10 compartments)	

Combustor type	Form	Possible fuels		NO_x reduction
		Gaseous	Liquid	
Standard combustor	Single-gas fired Oil fired Oil-gas mixed fired Two-gases mixed fired	LNG Natural gas Town gas Offgas	Light oil Fuel oil A Naphtha Methanol LCO	Steam/water injection
Low-NO_x combustor	Single-gas fired	LNG Natural gas Town gas	—	Dry type

TABLE 2. Specifications of Combustors.
The standard combustor can use a wide variety of fuels. In the case of single-gas fired, the low-NO_x combustor can be chosen.

LNG: liquefied natural gas
LCO: light cycle oil

in Table 2.

Standard Combustor

The standard combustor can handle a wide variety of fuels. In addition, by using water and steam injection in this type of combustor, NO_x emissions can be reduced.

Low-NO_x Combustor

From the viewpoint of environmental protection, the demand for a low-NO_x emission combustor even for small- and medium-sized gas turbines is on the rise. Accordingly, Hitachi developed the low-NO_x combustor for the H-25 turbine by building on the low-NO_x technology accumulated up to now. This low-NO_x combustor, whose structure is shown in Fig. 3, is operated by single-fuel gas firing with most type of fuels (excluding particular gases).

The combustion method combines efficient premix combustion, which lowers NO_x emission, and a stable diffusion combustion. The diffusion burner is located at the core of the combustor, and the premix burner is located around its periphery in the form of a ring. To ensure stable combustion, the diffusion burner is a swirler type, and it functions as the main burner when revolution speed increases. Moreover, under high-loading operation, the premix burner functions as an pilot flame. Fuel and air are premixed inside the premix burner, and a bluff-body type flame stabilizer located at the premix-burner outlet forms a stabilized premixed flame downstream. This premix combustion with a bluff-body type flame stabilizer attains high combustion stability and outstanding characteristics concerning reduced NO_x emission and loading operation. Under high-loading operation, NO_x emission can be reduced by increasing the amount of premixed combustion.

PERFORMANCE OF H-25 GAS TURBINE IMPLEMENTED AT THE QUEEN ELIZABETH POWER STATION

System Overview

The re-powering system installed at the Queen Elizabeth Power Station improves plant efficiency

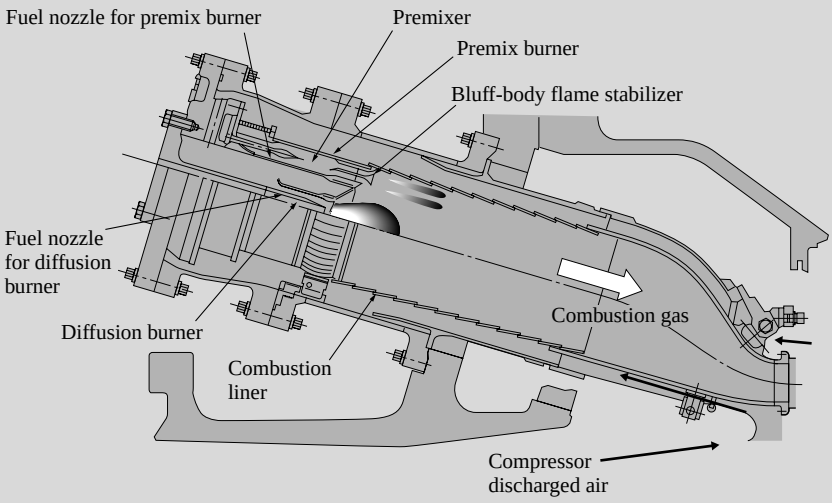

Fig. 3—Structure of Low-NO_x Combustor Incorporated in H-25 Gas-turbine Generator.
A bluff-body type flame stabilizer is incorporated for a stable premixed flame.

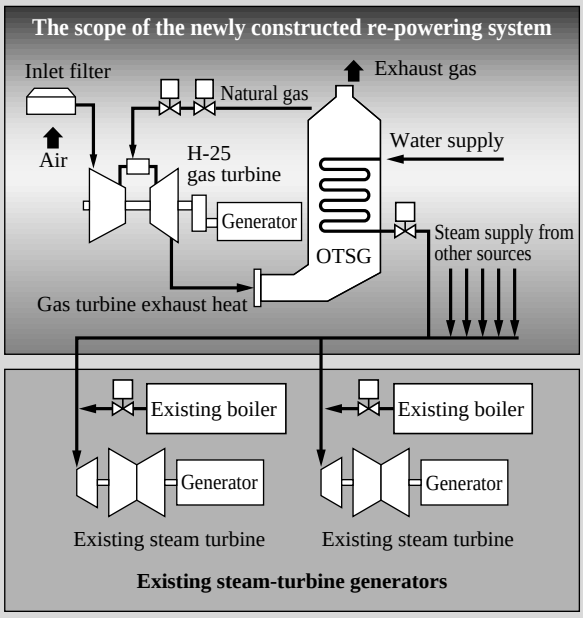

Fig. 4—Schematic of Re-powering System.
Six H-25 gas-turbine units are combined with the existing steam-turbine generators.

through combined operation with the existing boiler-fired steam-turbine units. As shown in the schematic of the re-powering set up in Fig. 4, the H-25 gas-turbine unit and the OTSG (manufactured by SNC-Lavalin Group Inc.) are configured so that the exhaust heat produced by the H-25 is transferred into the OTSG. This heat generates steam that is used to drive the existing steam turbines.

Operating Performance of H-25 Gas Turbine

Operation characteristics

The Queen Elizabeth Power Station is located at a latitude of 52 degrees north and an elevation of 501 meters. In wintertime, the temperature at this location can fall to as low as -30°C. The measured output power during the testing of a H-25 gas turbine is plotted against atmospheric temperature in Fig. 5. Since the commissioning was performed during the winter, the temperature at the turbine's compressor occasionally reached -30°C. However, such low temperature presented no problems to the operation of the H-25 gas turbines. It is clear from the figure that the specification for the power output is satisfied and a high level of operation reliability is achieved. Note that at temperatures below -15°C, the power output is limited by constant load control.

As for the performance of the individual gas turbines, their gross output power and thermal efficiency were shown to satisfy the customer specifications.

NO_x emission characteristics of low-NO_x combustor

The commissioning results concerning the NO_x emission characteristics of the low-NO_x combustor at a rated load are plotted against atmospheric temperature in Fig. 6. This figure shows that at each measurement temperature, the measured NO_x emission value is below the customer specification of 25 ppm (at 15% O_2). This means that this combustor can achieve 25-ppm class emission combustion.

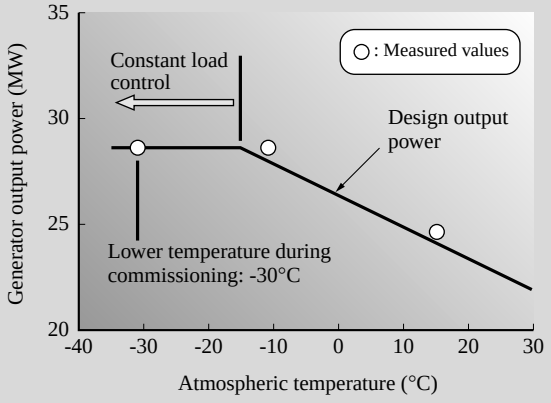

Fig. 5—Power-output Characteristics of H-25 Gas Turbine.
Problem-free operation is even possible at atmospheric temperature of -30°C.

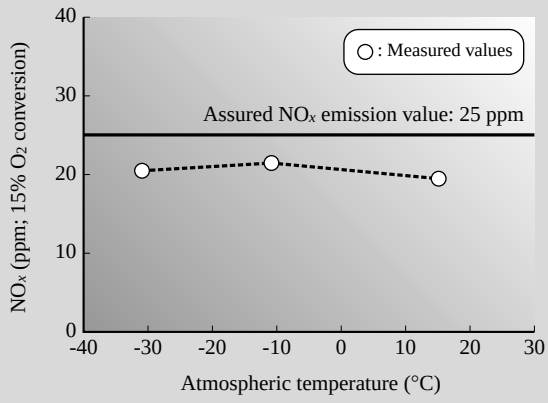

Fig. 6—NO_x Emission Characteristics of H-25 Gas Turbine.
NO_x emission value is less than 25 ppm (at 15% O_2).

Commercial operation and preliminary performance evaluation

Commissioning of the six H-25 low-NO_x combustor gas turbines began in November 2001, and they have been running trouble-free since then. Initial inspections of the units were carried out in sequence from October 2002, and the inspection results revealed no damage to the combustors or gas turbines. These satisfactory results affirm the reliability of the H-25 hardware. From now on, the installed H-25 gas turbines will be maintained under the terms of our long-term operation maintenance contract.

CONCLUSIONS

This paper first described the specifications of Hitachi's H-25 gas turbine and its low-NO_x combustor. It then presented the performance results concerning the operational performance of six H-25 generator units installed at SaskPower's Queen Elizabeth Power Station.

The performance evaluation at the Queen Elizabeth Power Station demonstrated the outstanding operation and performance characteristics of the H-25 gas turbine and its incorporated low-NO_x combustor. In the future, with further improvements in efficiency and environmental protection in mind, Hitachi will continue to develop market-leading gas turbines and low-NO_x combustors.

REFERENCES

(1) N. Horii et al., "Hitachi H-25 High-efficiency Gas Turbine — Current Status and Future Applications," *Hitachi Hyoron* **81**, pp. 187-190 (Feb. 1999) in Japanese.
(2) S. Takihana et al., "The Latest High-efficiency Gas Turbine," *Hitachi Hyoron* **72**, pp. 527-534 (June 1990) in Japanese.
(3) Y. Kinoshita, "Technical Trends in Low-emission Combustors for Gas Turbines," *Report of the Gas Turbine Society of Japan*, **29**, 6, pp. 447-452 (Nov. 2001) in Japanese.

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