Characteristics and Applications of Hitachi H-25 Gas Turbine

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OVERVIEW: More than 100 orders have been placed for Hitachi H-25 gas turbines from both Japan and various other countries, because of their exceptionally high reliability and efficiency in their class. In addition, they can be used for a wide range of applications, from power and general industrial use to utilization in oil and gas fields. The H-25 is characterized as being heavy-duty, highly reliable, and applicable to cogeneration and combined cycle operations, resulting in higher operational efficiency of the entire system, for which it is highly acclaimed. In one recent application where the worksite was located far from the power supply system, several H-25 gas turbines were used to form an island operation system that was not linked to the main power system. In another application, an H-25 gas turbine was used as a power supply for driving a motor, instead of the mechanical drive system usually based on a small gas turbine. Such applications have been adopted due to the high reliability of the H-25 gas turbine. Hitachi, Ltd. has continued to enhance its H-25 gas turbine as a type of power supply equipment, and thus has contributed to the fields in which it has been used.

INTRODUCTION

THE H-25 gas turbine is an open, simple-cycle, single shaft gas turbine of the 30-MW class.

The H-25 gas turbine offers the following characteristics:

(1) It is heavy-duty, highly reliable, and ideally suited for continuous operation.

(2) The system start-up time when used in a simple gas turbine cycle is between 15 and 20 min from ignition to reaching the rated load, and thus shorter than that in conventional steam power generation. It is therefore applicable for DSS (daily start-up and shut-down) and peak applications.

(3) Based on modern turbine cooling and compressor technologies, the H-25 achieves the highest level of thermal efficiencies in the heavy-duty 30-MW class. It is also one of the models that has achieved the highest level of efficiency as a cogeneration system combined

Fig. 1—H-25 Gas Turbine and General Overview of Sakhalin II Project in Russia.
Hitachi delivered four H-25 gas turbine generation equipment units to the Sakhalin Energy Investment Co., Ltd., for use in a land-side plant that processes gas and oil extracted from the seabed off the eastern shore of Sakhalin Island in Russia.

with an HRSG (heat recovery steam generator) and a combined cycle equipped with a steam turbine.

(4) The use of a horizontally split casing and a multi-can combustor ensures its high maintainability, and enables the on-site replacement of hot gas path parts.

(5) The adoption of various combustor technologies makes the system adaptable for use of light oil, LNG (natural gas), LPG (liquefied petroleum gas), and other fuels. Moreover, the application of a wet/dry low-NO_x combustor enables low- NO_x environmental measures to be taken.

For fuel diversification technology, Hitachi is actively committed to using off-gas, COG (coke oven gas), coal gas, dimethyl ether, and other special fuels. The rest of this report describes H-25 gas turbine's history, specifications, and examples of its applications (see Fig. 1).

HISTORY OF H-25 GAS TURBINE

In 1988, the first H-25 unit was completed and delivered to the Tokuyama Oil Refinery of Idemitsu Kosan Co., Ltd.

Then in 1990, Hitachi delivered the first H-15 unit — a scaled down model — to the Research Union for Integrated Coal Gasification Combined Cycle, and thus expanded its scope of applications.

For about a decade after delivery of its first unit, the H-25 has been mainly used for cogeneration applications in domestic petrochemical companies. Based on its proven capabilities and track record during that period, Hitachi delivered the first unit for overseas use to South Korea in 2000. Since then, many more units have been delivered to various parts of the world (see Fig. 2).

The 20th anniversary of the first H-25 unit ever being delivered will happen this year (2008). Given its widely recognized high performance and reliability, the unit has received more than 100 cumulative orders, with more than 70 units now in commercial operation.

Moreover, the total operation time of these turbines largely exceeds 1.4 million hours. As illustrated in Fig. 2, the product continues to run steadily worldwide.

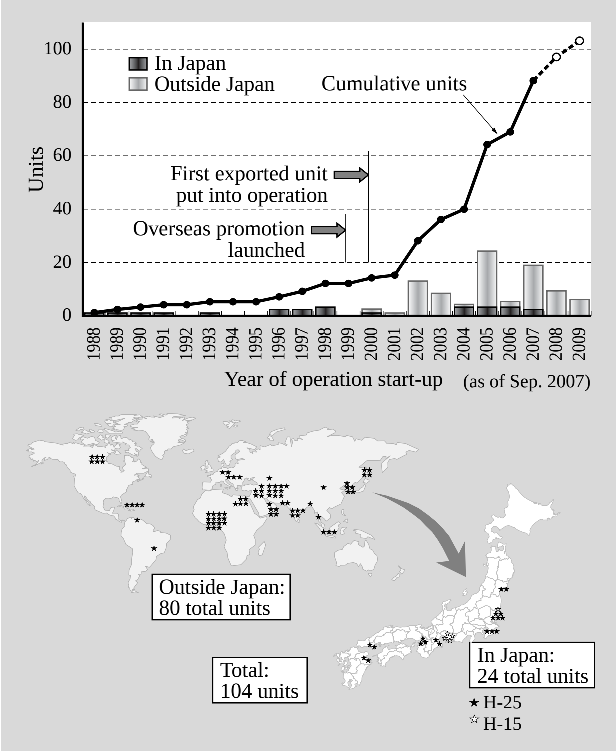


Fig. 2—H-25 Gas Turbines Previously Delivered.
These are the H-25 gas turbines delivered both domestically and abroad. H-25 gas turbines have been steadily running in various environments ranging from the extreme cold in Russia (–48°C) to the intense heat of Iraq (54°C).

PERFORMANCE AND EQUIPMENT COMPOSITION OF H-25 GAS TURBINE

Performance of H-25 Gas Turbine

Fig. 3 (a) shows the performance of the H-25 and H-15 under ISO (International Organization for Standardization) conditions. The H-25 achieves an output of 31 MW and a gross thermal efficiency of 34.8% LHV (lower heating value) when fired with natural gas.

This performance is remarkable for a heavy-duty gas turbine of the 30-MW class. When combined with a steam turbine, the system offers the highest level of combined cycle efficiency — a gross thermal efficiency of 50% LHV or more.

Equipment Composition of H-25 Gas Turbine

Fig. 3 (b) shows the equipment composition and performance of the H-25 gas turbine. The turbine can be roughly divided into 17 axial flow compressors, 10 cannular combustors, and three stage turbines.

The bearings have a forced lubricating system. The journal bearings are No. 1 on the turbine side and No. 2 on the compressor side, while the thrust bearings are on the compressor side. These are tilting pad bearings.

The casing is horizontally split for both the compressor and turbine sides, while the support is designed to absorb thermal elongation.

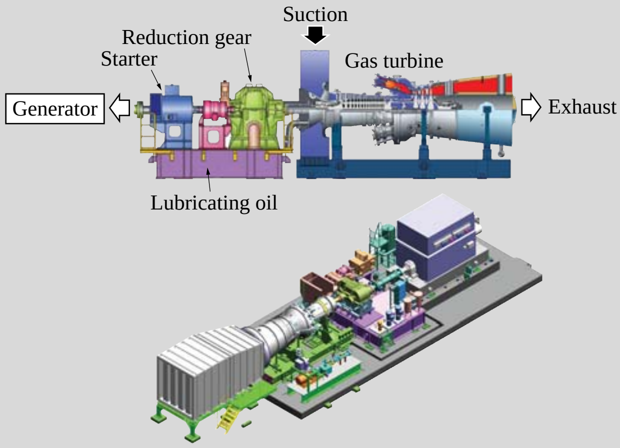
In terms of exhaust, a side exhaust was previously the mainstream. However, in recent years, the axial

Item	Unit	H-25		H-15	
Fuel		Natural gas	Heavy oil A	Natural gas	Heavy oil A
Output	MW	31.0	30.0	16.9	16.0
Gross power generation efficiency (LHV)	%	34.8	33.6	34.3	32.6
Airflow at compressor inlet	kg/s	92.4	92.4	52.0	52.0
Exhaust temperature	°C	564	564	564	564

Conditions
ISO conditions (atmospheric temperature of 15°C, relative humidity of 60%)
Suction pressure loss: 0.87 kPa (3.5 inchH_2O)
Exhaust pressure loss: 0.62 kPa (2.5 inchH_2O)

(a)

LHV: lower heating value



(b)

Fig. 3—Composition and Performance of H-25 Gas Turbine.
These are the turbines performance under ISO conditions that achieve a heavy-duty high reliability and a high efficiency of 34.8% (a), and an overview of the equipment and layout composition of H-25 gas turbine (b) . This creates a compact and flexible equipment layout composition.

flow exhaust has also been used to increase efficiency. The axial flow type is designed so that the front shaft of the compressor is connected to a reduction gear equipped with an accessory gear. The start-up motor is then connected to the generator. The lubricating oil tank is either installed separately as an off-base skid or arranged compactly, also functioning as the basis for the reduction gear as shown in Fig. 3 (b).

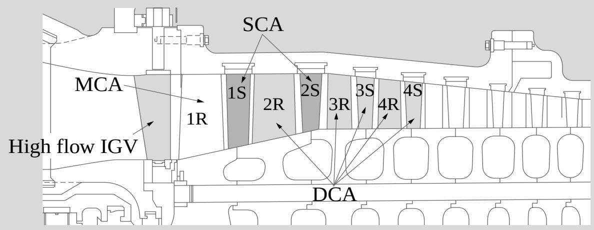
COMPRESSOR

Compressor Application Technology

The axial compressor for the H-25 gas turbine has 17 stages and a pressure ratio of 15. The compressor is equipped with an IGV (inlet guide vane) at the inlet, and its hydraulic drive allows it to control the airflow.

The front stages of the compressor entail a high Mach number. A supercritical arc blade, multiple circular arc blade, and double circular arc blade are applied to control any loss, as shown in Fig. 4. The rotor and stator blades are made of 12Cr-Nb steel and 12Cr steel, and given a corrosion-proof coating.

The system is designed so that 6-stage and 13-stage air extractions are used to discharge air to prevent from a rotating stall during start-up. In particular, the 6-stage air extraction is used to seal the bearings and cool the exhaust frame, while the 13-stage air extraction cools the second and third stage turbine nozzles.



SCA: supercritical arc blade
MCA: multiple circular arc blade
DCA: double circular arc blade
IGV: inlet guide vane
S: stator
R: rotor

Fig. 4—Compressor Technology for H-25 Gas Turbine.
These are the types of compressor blades used for the H-25 gas turbine.

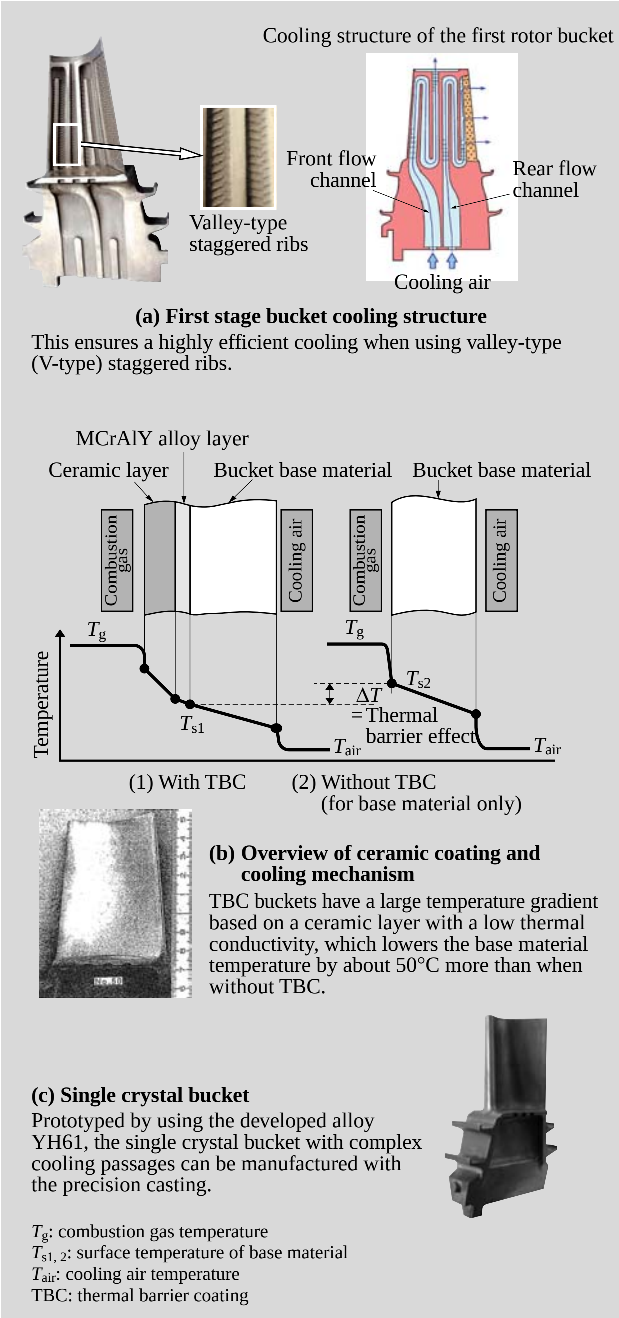
TURBINE

Turbine Application Technology

The H-25 turbine consists of three impulse stages. As illustrated in Fig. 5 (a), the first stage bucket is designed as a multi-pass cooling bucket, with staggered ribs developed by Hitachi to increase the cooling efficiency.

The turbine buckets are made of nickel-base alloys that have extremely high temperature strengths. The first stage turbine bucket has a TBC (thermal barrier coating), as illustrated in Fig. 5 (b), to cool the metal surfaces of the bucket.

The combination of impingement cooling, film cooling, and pin fin cooling are applied for the first



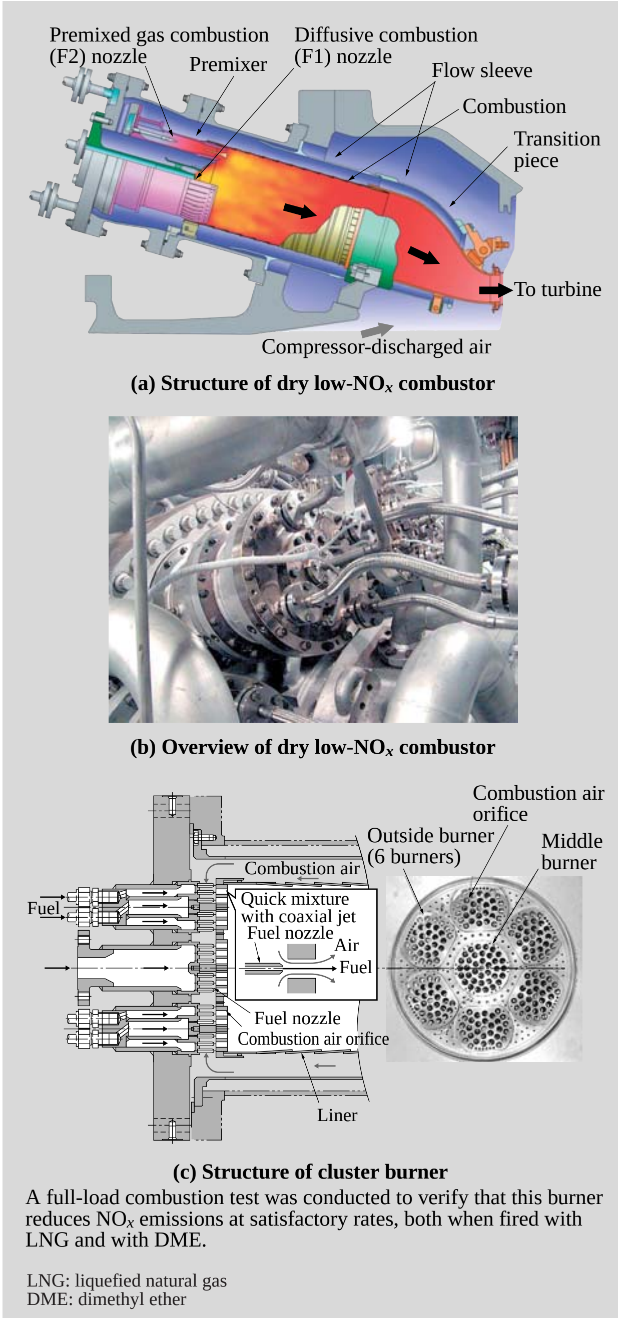
(a) First stage bucket cooling structure
This ensures a highly efficient cooling when using valley-type (V-type) staggered ribs.

(b) Overview of ceramic coating and cooling mechanism
TBC buckets have a large temperature gradient based on a ceramic layer with a low thermal conductivity, which lowers the base material temperature by about 50°C more than when without TBC.

(c) Single crystal bucket
Prototyped by using the developed alloy YH61, the single crystal bucket with complex cooling passages can be manufactured with the precision casting.

T_g: combustion gas temperature
$T_{s1,2}$: surface temperature of base material
T_{air}: cooling air temperature
TBC: thermal barrier coating

Fig. 5—Turbine Technology for H-25 Gas Turbine.
These are the technologies used for turbine cooling, coating, and materials of the H-25 gas turbine.



(a) Structure of dry low-NO_x combustor

(b) Overview of dry low-NO_x combustor

(c) Structure of cluster burner
A full-load combustion test was conducted to verify that this burner reduces NO_x emissions at satisfactory rates, both when fired with LNG and with DME.

LNG: liquefied natural gas
DME: dimethyl ether

Fig. 6—Combustor Technology in H-25 Gas Turbine.
This is the technology used for the low-NOx combustor and cluster burner in the H-25 gas turbine.

stage turbine nozzle. The material used in this nozzle is a Co-based alloy that is highly resistant to high-temperature corrosion.

The above-mentioned technology is used to reduce cooling air and thereby increase the thermal efficiency (see Fig. 6).

The prototype of the single crystal bucket shown in Fig. 5 (c) has been completed to improve the thermal efficiency.

COMBUSTOR

Combustor Application Technology

The H-25 is equipped with 10 cannular combustors connected by cross fire tubes. This structure makes the system highly maintainable.

Possible fuel options are the combustion of gas or oil, a dual fuel of gas and oil, or a dual combustion of gas and gas.

Among the possible methods of reducing NO_x

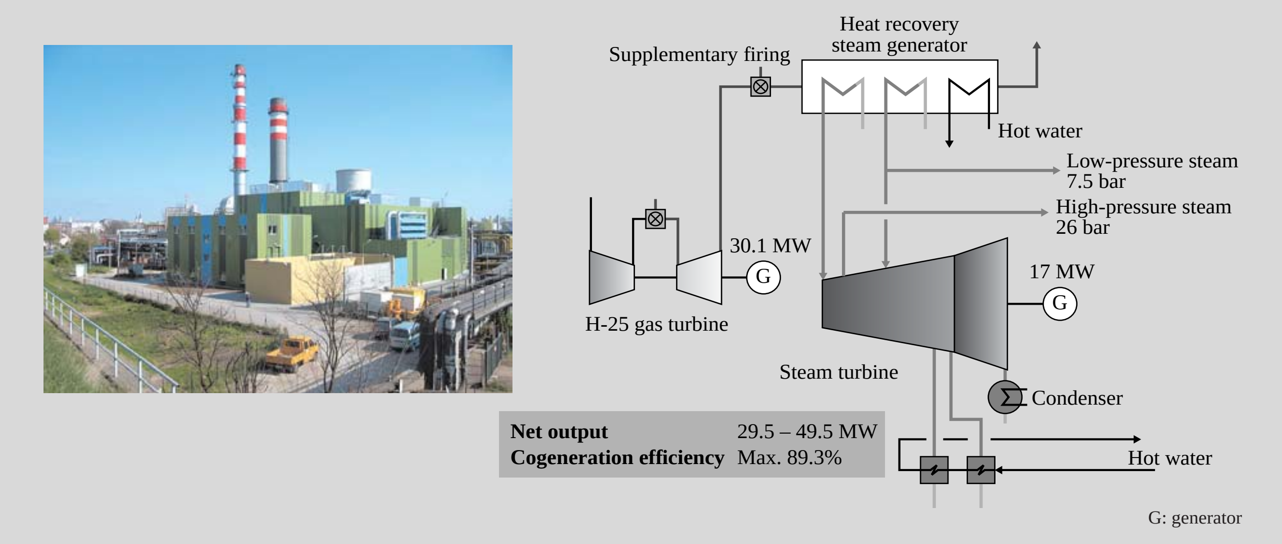


Fig. 7—NYKCE Project in Hungary by E.ON Hungaria.
An overview of the project and its system configuration are shown. The power plant is connected to the grid and supplies heat and power to nearby factories and district heating.

emissions are a water injection (wet) method and a steam injection method. The dry method can use a low-NO_x combustor developed by Hitachi, illustrated in Figs. 6 (a) and (b), that achieves 25 ppm (dry) or less in 15% oxygen during a base load operation with natural gas.

The types of fuel used in the H-25 and H-15 include natural gas, off-gas, coal gas, kerosene, light distillate oil, A-heavy oil and cracked kerosene.

Hitachi developed the cluster burner illustrated in Fig. 6 (c) that burns dimethyl ether, and evaluated its feasible combustion performance by conducting a full load test. This combustion system allows for faster premixing in a shorter distance than conventional premixing burners, making it applicable for high-burning velocity fuels and capable of reducing NO_x emissions.

EXAMPLES OF H-25 GAS TURBINE APPLICATIONS

Application for Power Utilities

The following is an example of the application of these turbines for power utilities. An H-25 was put into operation in 2007 in the NYKCE project in Hungary that was undertaken by E.ON Hungaria, Ltd. The turbine used for this project was Hitachi's fifth unit delivered to Europe.

As shown in the system diagram in Fig. 7, the project is a multi-shaft, combined cycle plant consisting of an H-25 gas turbine, a heat recovery steam generator with supplementary burner, and a steam turbine.

The net combined output was between 29.5–49.5 MW. This plant uses the H-25 gas turbine exhaust gas energy to provide hot water for the district heating, and 26-bar high pressure and 7.5-bar low pressure steam for the industrial customers. Therefore this plant is a highly efficient cogeneration system whose cogeneration efficiency is 89.3% LHV.

To protect the inlet filter of the gas turbine against icing, the plant uses hot air from the ventilation outlet of the gas turbine enclosure.

Low- NO_x combustors are used to achieve 25 ppm (dry) or less in 15% oxygen during base load operations.

Application 1 for Petrochemical Company (Example-1)

The following information is a summary of the information from the Betara Project of PetroChina International Jabung Ltd. in Indonesia as our example for turbine use in a petrochemical projects (see Fig. 8).

This project is being undertaken in the jungles of Sumatra Island in the Republic of Indonesia, and therefore, is far away from the main Indonesian power system (50 Hz). Based on the evaluation of high reliability of H-25 gas turbine, three sets are used as the power supply at the project site and run in the "island operations." To scale down the pumps and equipment and reduce the total system costs, the plant

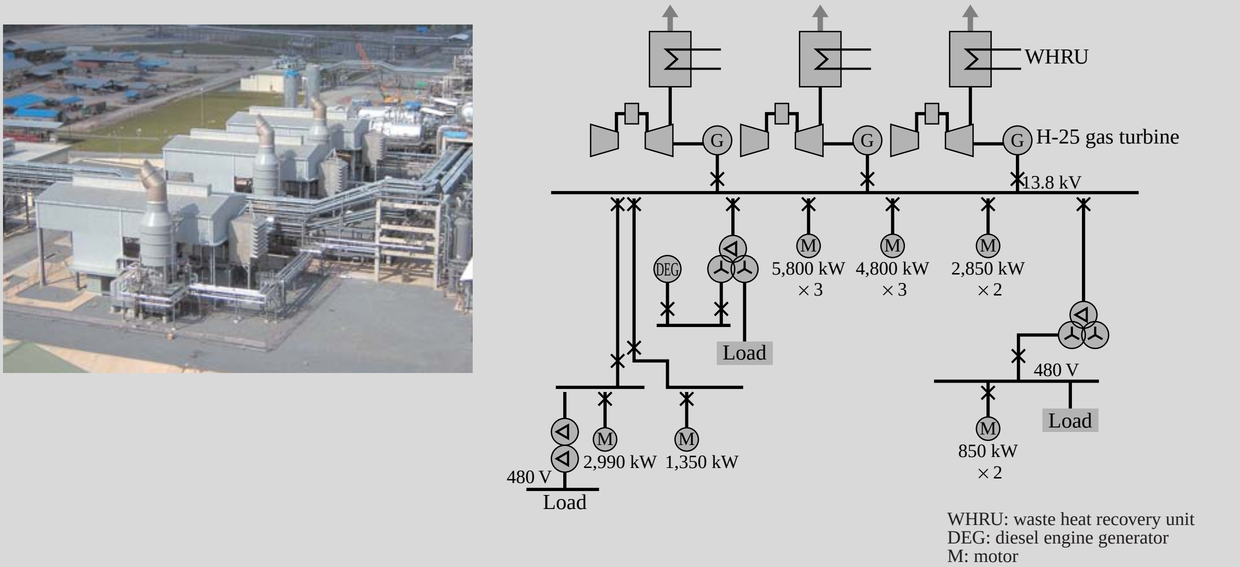


Fig. 8—Betara Project at PetroChina International Jabung Ltd., Indonesia.
An overview of the project and its system configuration are shown.
This plant receives gas and liquid from tens of nearby gas fields, separates the liquid from the gas, and thus produces refined natural gas. The plant requires hot gas to recondition the molecular sieve of the drier for removing water from the processed gas and thus uses exhaust heat from the H-25. Each of the three H-25 units comes equipped with a WHRU that heats the processed gas and uses it for reconditioning the molecular sieve. Refined natural gas is sent out by pipeline as city gas or fuel gas for power generation, while the separated hydrocarbon liquid is sent to another plant for separation and refining into LPG to be exported.

is designed to operate at a frequency of 60 Hz. This site incorporates three 5,800-kW compressors, two 4,800-kW compressors, one 2,990-kW compressor, and many other compressors. In conventional practice, the normal method has been to provide mechanical drive gas turbines for the drive compressors. However, gas turbines require the periodic replacement of spare parts, such as the hot gas path parts. When the compressors are being driven by a lot of mechanical drive gas turbines, a large number of spare parts are required. However, serious consideration was given to an easy operation and layout, less maintenance, reducing the cost for keeping spare parts, the cost-cutting effects of facilities, and other advantages, and the entire system was then made more operable by concentrating the power supply on the H-25 and replacing all the compressors with motor-driven models.

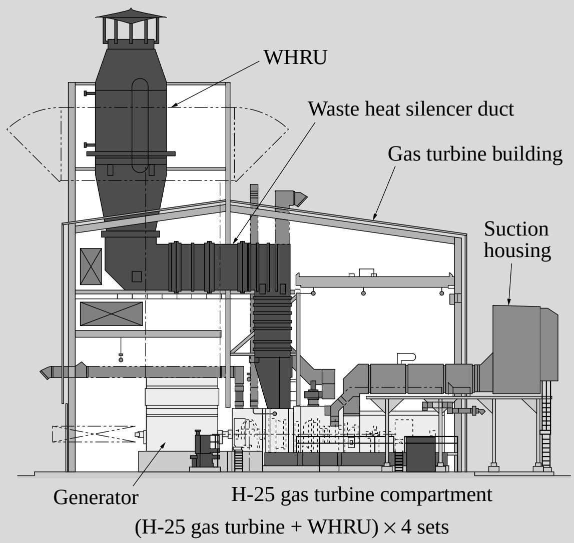


Fig. 9—Sakhalin II Project, Russia.
The internal layout of the H-25 gas turbine building is shown.

Application 2 for Petrochemical Company (Example-2)

Fig. 9 shows a cross-sectional view of the H-25 layout plan inside the building for Sakhalin II, as shown on the first page of this article. This project is an example of our turbines application in a cold environment where the ambient temperature is –48°C. The indoor equipment is comprised of a total of four

H-25 gas turbines including the waste heat recovery units. To increase the operability, two of the four units consist of gas-fuel, dry low-NO_x combustors; the other two consist of dual gas/oil fuel, dry low-NO_x combustors.

CONCLUSIONS

We have discussed the characteristics and typical applications of the H-25 gas turbine. Since the Third Conference of Parties to the United Nations Framework Convention on Climate Change (COP3) in 1997, various efforts have been made to reduce greenhouse gas emissions. Power plants based on fossil fuels are projected to find higher need for highly efficient gas turbine combined cycles, cogeneration systems, and similar systems. The need for cogeneration systems based on such a medium-capacity gas turbine as the H-25, in addition to the conventional, large gas turbine power plants, is increasing. Hitachi intends to continue working towards developing even higher levels of performance and reliability in its H-25 gas turbine.

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