# Hitachi H-25 Gas Turbine in Oil and Gas Market

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*OVERVIEW: The Hitachi H-25 is a heavy-duty 30-MW class gas turbine. The first unit started operation in 1989 at a domestic petrochemical plant and total orders for the turbine have reached to 120 units. The H-25 is used not only in Japan but all over the world in various fields such as at power, industrial, and oil and gas plants. The oil and gas market is growing strongly but has special characteristics and extremely severe requirements including special specifications and demand for high reliability. The high performance, reliability, and flexibility of the H-25 gas turbine have helped this field grow by meeting customer demands.*

## INTRODUCTION

HIGHER performance and efficiency are an eternal theme in gas turbine applications. In addition to the technologies needed to meet these requirements, the increased awareness of global environmental problems in recent times has also led to demand for improved environmental performance.

Against this background, combined plants [consisting of a gas turbine, HRSG (heat recovery steam generator), and steam turbine] have become a standard feature of large power plants operated by electricity companies. These combined plants use bigger gas turbines powered by clean fuels [LNG (liquefied natural gas) or NG (natural gas)] to achieve high efficiency and minimum environmental impact.

On the other hand, the medium-sized gas turbine systems used at industrial plants, regional heat and power utilities, refineries and LNG plants, and elsewhere require features such as high reliability and fuel flexibility as well as high performance.

This paper discusses the characteristics of the oil and gas market and how the H-25 plays an important role in this market.

## CHARACTERISTICS OF OIL AND GAS MARKET

Key features of the oil and gas market are summarized below.

### Reliability

The most important factor in this field is reliability because the profitability of refineries and chemical plants, which are huge and complex systems, is dependent on continuous operation without plant shutdown. Therefore, only companies that have products which meet this criteria can enter this field. The company must have appropriate engineering capabilities, maintain detailed operational records, and be able to cover company liabilities, so that it is qualified by major oil companies.

In addition, after an order is received, various factory tests need to be performed to verify the reliability prior to shipment. It is common for gas turbine vendors to ship units without running tests at the factory because gas turbines are fully standardized machines and no design changes are made to the gas turbine components such as the nozzle, blades and casing. Only auxiliary systems such as the starting mechanism, lube oil system, and instrumentation are modified for specific projects. However, in the oil and gas market, running at no-load mechanical test of the gas turbine at the factory is a minimum requirement. In some cases, a load test must be performed at a vendor’s test facility. In the severest case, full load string testing is performed using the project generator and auxiliaries such as the inlet system. The purpose of this testing is to avoid trouble at the site and to prove the performance of gas turbine.

### High Performance

Only qualified companies can bid for these projects, and only the vendor who submits the most attractive proposal gets the order. A recent trend is to consider overall cost-performance. Because reliability is the most important factor, the oil and gas market has long been characterized by the use of heavy-duty machines with low firing temperatures. However, demand for higher performance has increased recently, and aero-derivative gas turbines are also used as a response to the increasing cost of fuel. The cost-performance is evaluated not only on the output and heat rate but also maintenance and other costs in relation of gas turbine operation.

### Fuel Flexibility

For environmental and performance factors, NG is the dominant fuel used in gas turbines at power utility companies. However, in the oil and gas or petrochemical fields, many types of fuel such as distillate, LPG (liquefied petroleum gas), and off-gas are used in addition to natural gas. Dual fuel systems (gas/oil, gas/gas) are also popular due to plant operation flexibility.

The most difficult fuel to use is off-gas. Off-gases are by-products from a refinery or chemical plant. This gas is cheap and, if it can be used as a fuel of gas turbine, it is beneficial to the oil company because they are a very economical fuel. However, off-gases normally include heavy gases such as propane, sometimes include corrosive elements which are difficult to handle because the component gases can vary widely.

### Special Specifications

Projects in this market often involve special specifications. Typical examples are the API (American Petroleum Institute) standards, a set of usual standards in the petrochemical industry. These standards include not just the main API 616 standard (Gas Turbines for the Petroleum, Chemical, and Gas Industry Services). All the related API standards for lube oil systems, gears, heat exchangers, pumps, and similar are referred to in the specifications. One of the purposes of these high-grade requirements is to achieve the highest level of reliability. It is very important to comply with these specifications. In addition to the API specifications, special specifications used by major oil companies, such as the DEP (Design and Engineering Practice) of Royal Dutch Shell (Shell) standards, are also used. These extensive standards impose very severe requirements.

## HISTORY OF H-25 GAS TURBINE

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

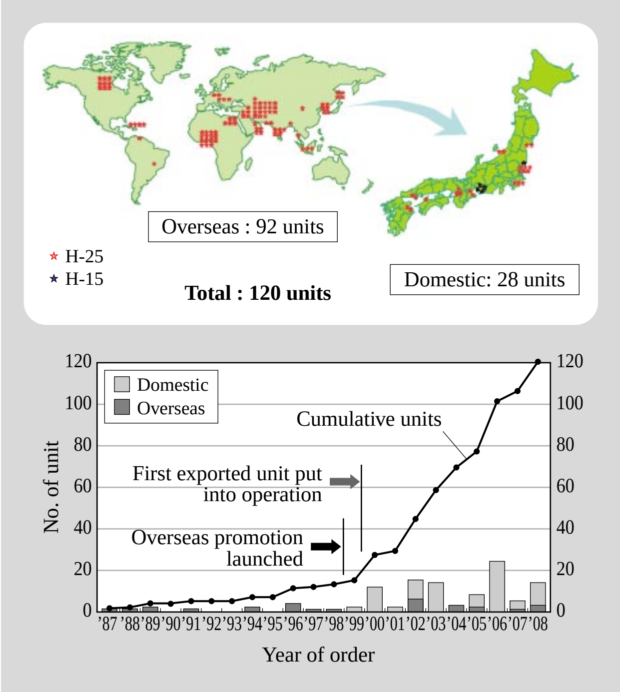



*Fig. 1—H-25 Gas Turbine Order Records.*
*The graph shows deliveries of H-25 gas turbines in Japan and overseas. H-25 gas turbines have been operating reliably in various different environments ranging from the extreme cold of Russia (–48°C) to the intense heat of Iraq (54°C)*

TABLE 1. H-25 Users
*The table shows breakdown of H-25 users.*

| | |
|---|---|
| Oil and gas | 60 |
| Electric companies and IPPs | 45 |
| Other industries | 8 |
| Regional heat and power | 4 |
| Research and development | 3 |
| Total | 120 units |

IPPs: independent power products

During the first decade after the delivery of the first unit, the H-25 has been mainly used in cogeneration plants at domestic petrochemical companies. Based on its proven capabilities and its track record during that period, Hitachi delivered the first unit for overseas use to the Republic of Korea in 2000. Since then, order volumes have grown rapidly with total international orders reaching 120 this year (see Fig. 1). The figures include five H-15 turbines. The H-15 is a scaled down model of the H-25.

Table 1 shows the industries where the H-25 turbines are used. As shown in the table, the oil and

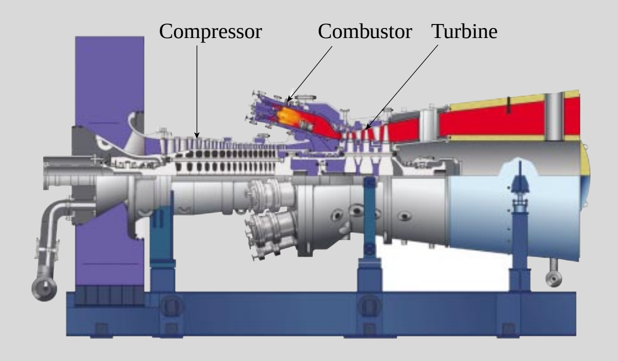



*Fig. 2—H-25 Cross Section.*
*H-25 gas turbine has simple structure which consists of three main parts, compressor, combustor and turbine.*

TABLE 2. H-25 Structural Features
The table shows specifications of main components.

| Component | Design |
|---|---|
| Compressor | • 17-stage axial type<br>• Pressure ratio: 14.7 |
| Turbine | • 3-stage impulse type<br>• Air cooled 1st and 2nd stage nozzle and bucket<br>• TBC on 1st bucket |
| Combustor | • Reverse flow type<br>• Conventional type or dry low $NO_x$ type<br>• Slot cooling<br>• TBC on transition piece |

TBC: thermal barrier coating

gas industry represents the largest market.

## FEATURES OF H-25 GAS TURBINE

### Design Philosophy and Structural Features

The H-25 is a 30 MW class heavy-duty, single-shaft gas turbine with horizontal split casings. Fig. 2 shows a cross section of the H-25.

Heavy-duty gas turbines are developed primarily for industrial use and have the following advantages over aero-derivative gas turbines.
(1) Continuous operation (reliability)
(2) Ease of maintenance (site maintenance)
(3) Fuel flexibility

A heavy-duty gas turbine consists of three parts: a compressor, a turbine, and a combustor. Table 2 lists the characteristics of each component.

Fig. 3 shows the cross section of a typical LNC (low $NO_x$ combustor). The total number of LNC units delivered has already reached 40. The latest LNC technology used in the H-25 achieves performance of 18.7 ppmvd @ 15% $O_2$ available.

Fig. 4 shows the 1st stage bucket with TBC (thermal barrier coating) and its theory of operation. Use of a ceramic coating with high heat resistance on the substrate (base metal) means the surface temperature of the substrate is lower than when TBC is not used. It is estimated that use of TBC reduces the temperature by more than 50°C. This increases the reliability of the material for the same level of firing temperature. It can also provide higher efficiency because the firing temperature can be increased while still keeping the substrate at the same temperature.

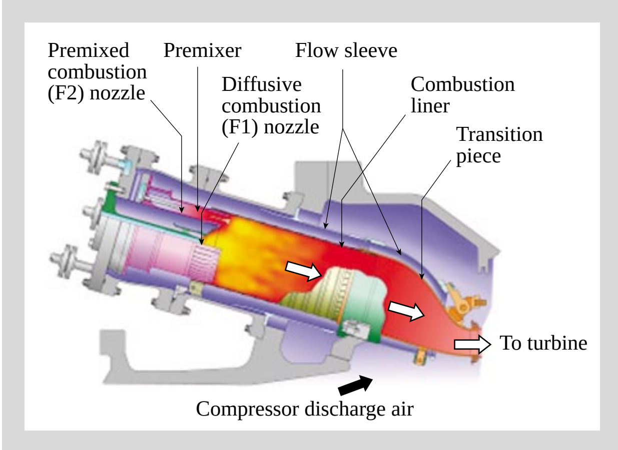
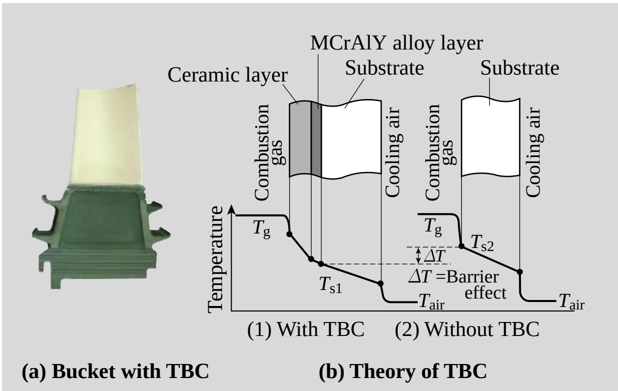



*Fig. 3—LNC Cross Section.*
*LNC (low NOx combustor) consists of diffusive combustion (F1) and premixed combustion (F2) nozzles.*




$T_g$: combustion gas temperature
$T_{s1}$, $T_{s2}$: Surface temperature of substrate
$T_{air}$: cooling air temperature

*Fig. 4—TBC Technology for H-25 Gas Turbines.*
*By appling TBC on bucket, temperature of the substrate will be decreased, and its reliability will increase.*

### Special Features

The H-25 has the following special characteristics.

**High reliability**

More than 70 units are now in commercial operation, and the total operating time of these turbines exceeds 1.4 million hours. A project to research the reliability of continuously operating H-25s in Japan was carried out in 2006. Three units with an operating time in excess of 100,000 hours were selected. Table 3 summarizes the reported results. The RF (reliability factor) is calculated in accordance with ISO3977-9. The results in the table demonstrate the extremely high reliability of the H-25.

**Fuel flexibility**

Table 4 lists the fuels used in the H-25. The table indicates the importance of fuel flexibility in this market. The fuels used include natural gas, distillate, and LPG. The difference of 44 between the total number of H-25 turbines in service and the number of different fuels used indicates the number of dual fuel units. One important fuel is off-gas generated as a by-product at oil and gas plants. If it can be used in the gas turbine, off-gas is a very cheap fuel source. On the other hand, the content of the off-gas can vary widely and may include corrosive substances or drains. It is very difficult to handle such a fuel and use it as a suitable auxiliary fuel system that incorporates a gas fuel booster system. The engineering capability to do this is the key technology.

**High level of engineering capability**

As mentioned in "CHARACTERISTICS OF OIL AND GAS MARKET," gas turbines often require special specifications such as API and major oil company specifications. Hitachi can supply the best solutions to these requirements. In addition, the gas turbines used at oil and gas plants are normally purchased through engineering companies such as M.W. Kellogg Limited (Kellogg), Toyo Engineering Corporation (TEC), JGC Corporation (JGC), and Chiyoda Corporation (Chiyoda). These engineering companies are familiar with these severe specifications and require considerable engineering documentation to verify quality at both the quotation stage and during the project stages after the order has been made. Satisfying these demands requires the highest level of engineering capabilities. That is a reason why Hitachi has been able to supply H-25s successfully to Kellogg, TEC, JGC, Chiyoda and in addition major oil companies such as Shell and Petrobras Brasil.

TABLE 3. H-25 Reliability Record
The table shows extremely high H-25 reliability.

| | Operating hour | RF |
|---|---|---|
| Unit A | 126,886 h (As of Aug. 2004) | 99.69 % |
| Unit B | 120,767 h (As of Aug. 2004) | 99.88 % |
| Unit C | 105,234 h (As of Dec. 2003) | 99.88 % |

RF: reliability factor

TABLE 4. Types of Fuel
The table shows fuels used for H-25 gas turbines. 44 units have dual fuel system.

| | |
|---|---|
| Natural gas | 94 units |
| Distillate oil | 46 |
| Off gas | 15 |
| LPG | 6 |
| Kerosene | 3 |
| Coke gas (low calorie gas) | 2 |
| Total | 166 |

LPG: liquefied petroleum gas

TABLE 5. H-25 Performance
The table shows H-25 performance at ISO conditions.

| Item | Unit | Natural gas | Distillate oil |
|---|---|---|---|
| Output | MW | 31 | 30 |
| Gross efficiency (LHV) | % | 34.8 | 33.6 |
| Airflow | kg/s | 92.4 | 92.4 |
| Exhaust temperature | °C | 564 | 564 |

LHV: lower heating value

### Performance

Based on modern materials, coatings, cooling and aerodynamics technologies, the H-25 has the highest thermal efficiency of any heavy-duty 30 MW class gas turbines. The efficiency of the H-25 enables cogeneration plants and combined plants to run at maximum efficiency.

Table 5 shows the performance of the H-25. The H-25 achieves an output of 31 MW and gross thermal efficiency of 34.8 % LHV (lower heating value) when fired with natural gas. This performance is remarkably high for a heavy duty gas turbine in this range. It allows cogeneration plants and combined plants to run at higher efficiency. In a combined cycle plant, a gross thermal efficiency of 50 % or more is possible.

## EXAMPLE APPLICATIONS IN OIL AND GAS INDUSTRY

### Sakhalin II Project in Russia

This is a well-known big project (see Fig. 5). Not only is the equipment exposed to severe environmental

*Fig. 5—H-25 Gas Turbines in Sakhalin II Project in Russia.*
*Hitachi delivered four H-25 gas turbines 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.*

*Fig. 6—Overview of Damietta H-25 Plant in Egypt.*
*Hitachi delivered five H-25 gas turbine generator sets to Damietta LNG plant through Kellogg, an engineering company.*

conditions, but it must also comply with the most severe Shell specifications. The minimum ambient temperature reaches –48°C. In order to endure such severe conditions, material selection and systematic design were carefully done. The facility has four sets of H-25 gas turbines and heat recovery units in total. All of these use dry low $NO_x$ combustors. Also, two of the sets are dual fuel (gas and oil) units to increase operational flexibility.

## Damietta Plant in Egypt

This plant is located in a hot desert area. Hitachi received an order for five H-25 sets from the well-known Kellogg engineering company (see Fig. 6). The order specified the API specifications and special measures for dealing with the sandy conditions were required.

*Fig. 7—Overview of Betara H-25 Plant.*
*Hitachi delivered three H-25 gas turbine generator sets to Betara plant in Indonesia.*

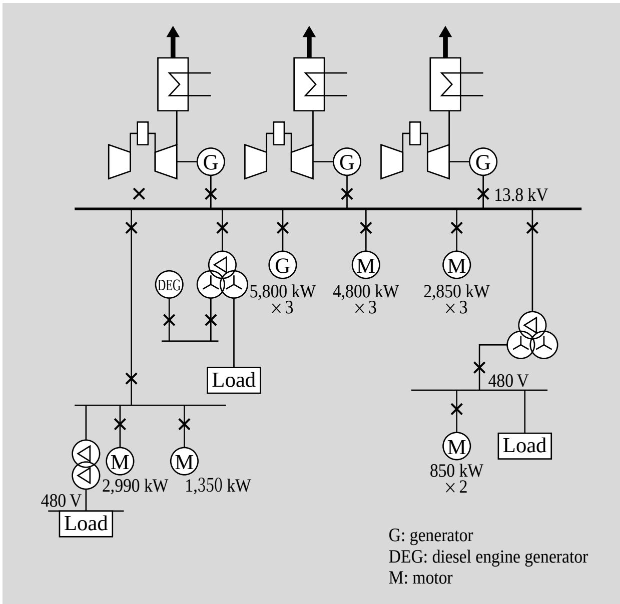



*Fig. 8—Electrical System of Betara H-25 Plant.*
*Three H-25 gas turbines are connected to 13.8 kV line and supply electricity to the motors for gas compressors.*

## Betara Project in Indonesia

This is an example of using the H-25 in a gas booster compressor plant (see Figs. 7 and 8).

Hitachi received an order for three H-25 sets from Petrochina International Jabung. This plant receives gas and liquid from tens of nearby gas fields, then separates the liquid from gas to produce refined natural gas. The plant requires hot gas to recondition the molecular sieve of the drier which removes water from the processed gas and uses exhaust heat from the H-25. Each of the three H-25 units is equipped with a

WHRU (waste heat recovery unit) that treats the processed gas and uses it for reconditioning the molecular sieve. The refined natural gas produced by the plant is carried by pipeline for use as city gas or fuel for power generation, while the separated hydrocarbon liquid is sent to another plant for separation and refining into LPG for export.

Standard practice in gas compression plants has been to use mechanically driven gas turbines with two shafts. A special feature of this plant, however, is that H-25s which drive generators and motor-driven compressors are used instead of mechanically driven gas turbines with two shafts. This system was selected for reasons of total plant availability and maintenance cost. Such a system is only made possible by use of the highly reliable H-25.

## CONCLUSIONS

This paper has introduced the Hitachi H-25 gas turbine and explained how the H-25 gas turbine has played an important role in the oil and gas market. The increase in the number of turbines delivered since 2000 when overseas promotion first started is remarkable. The number has reached 110 units out of a total of 120 units. We believe this is because the reliability and high performance of the H-25 have become recognized in the market, especially in the oil and gas market. We would like to contribute to growing the oil and gas market through endless efforts to achieve higher reliability and performance.

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