Trigeneration Gas Turbine System (Electricity, Heat, and Water Purification)

Mutsumi Horitsugi
Shunichi Kuba, Dr. Eng.
Shigeo Hatamiya, Dr. Eng.

OVERVIEW: Hitachi's H-25 gas turbine is widely used in a variety of different countries for electricity generation and cogeneration. With the aim of expanding its scope of application further, Hitachi has been studying its use for "trigeneration", which involves the production of electric power, heat, and water. In addition to its features of reliability and suitability for continuous operation, this takes advantage of the H-25's ability to burn a number of different types of fuel. The supply of water, whether it be for domestic or industrial use, is an important part of the infrastructure of society. It is also a major issue for energy resource developments, including oil and gas production. In addition to their use for CSG production and to augment extraction of heavy oil, trigeneration systems powered by gas turbines also represent a new type of system that takes account of environmental protection.

INTRODUCTION

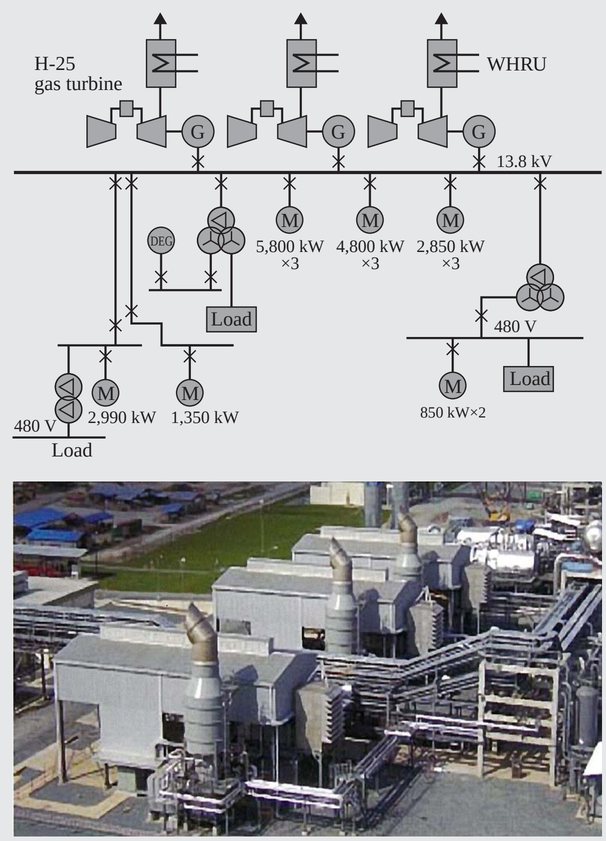
IN addition to having a fundamental role in our way of life, water is also a crucial resource for many industries. For applications such as electric power generation and cogeneration, water is needed for use as boiler make-up water (water used to make up for losses in the water recovery process), a use that requires good-quality fresh water. Unfortunately, the world is suffering from fresh water shortages, and in some places where water is available its quality is inadequate for use as make-up water. Even in this case, however, good quality fresh water can be manufactured by using the electric power and heat produced by a gas turbine, and this expands the scope of production activities.

This article describes a future-oriented trigeneration system for use in the production of heavy oil and CSG (coal seam gas), resources that are currently being developed and for which reserves are estimated to be several times as much as for conventional oil and gas.

GAS TURBINE COGENERATION SYSTEM

A single H-25 gas turbine can generate approximately 30 MW of electric power, and a cogeneration system can be configured by using the heat from its exhaust gas to produce steam or as some other type of heat source.

As an example, Fig. 1 shows the gas turbine cogeneration system at the Betara project of PetroChina Co., Ltd. in the Republic of Indonesia. Natural gas is produced by separating the gas and liquid carried via pipelines from several dozen nearby gas wells. The heat in the high-temperature exhaust gas from the H-25 gas turbine is used to regenerate the adsorption



WHRU: waste heat recovery unit G: generator M: motor
DEG: diesel engine generator

Fig. 1—Gas Turbine Cogeneration System.
Photograph and block diagram of the Betara project of PetroChina Co., Ltd. in the Republic of Indonesia.

agent for the dryer which removes the moisture from the process gas. The pipeline compressors constitute the main load at the site, and the overall system operation was enhanced by adopting electric motors to drive these compressors using electric power generated by the H-25 in place of the mechanical-drive gas turbine used in the past.

FUTURE-ORIENTED TRIGENERATION SYSTEM

Application for Heavy Oil Recovery Using Steam Injection

As for crude oil, around 20-40% of reserves are produced by primary and secondary collection. The ratio of high viscosity oil in an underground well gradually tends to increase. Old oil fields are suffering from dwindling production due to falling pressure levels. While large reserves of heavy oil have been confirmed in several parts of the world, processing this oil is difficult.

As heating oil to increase its temperature also reduces its viscosity, this process can be used to recover more oil from wells with declining production volumes, and is called EOR (enhanced oil recovery). The most common heat source is steam, which can be produced by a H-25 cogeneration system.

There are two types of steam injection. CSS (cyclic steam stimulation), also known as the “huff and puff method,” works cyclically by injecting steam into a well for a fixed period of time and then sealing off the well for several days before extracting the heavy oil. The SAGD (steam assisted gravity drainage) method uses a pair of upper and lower horizontal wells, with steam being injected into the upper well so that oil can be continuously extracted from the lower well (see Fig. 2). The SAGD method creates a saturated steam region around the upper well. The temperature in this region rises, reducing the viscosity of the oil such that it flows by gravity toward the lower well where the oil can be continuously extracted. SAGD has greater efficiency than other types of steam injection and, when production runs smoothly, can recover from 50% to 70% of the reserves.

Steam injection requires good quality feedwater for the boiler. Although water can be taken from the sea or from a river or lake, a treatment facility is usually required for production make-up water. In addition, how to supply local residents with drinking water becomes an important problem if the level of environmental pollution of the water source deteriorates. Hitachi can offer a trigeneration system that can supply electric power, heat, and water to create an effective and environmentally conscious EOR system. In addition to supplying the electric power required by the oil field, the system can also help satisfy demand for drinking water.

Fig. 3 shows an overview of the trigeneration system. Electric power is generated by a gas turbine and steam is produced by an HRSG (heat recovery steam generator). In addition to injection into oil wells, this steam is also used as a heat source for an MED (multi-effect distillation) water purification system. Fresh water produced by the MED system is supplied to the community for drinking water as well as to the boiler.

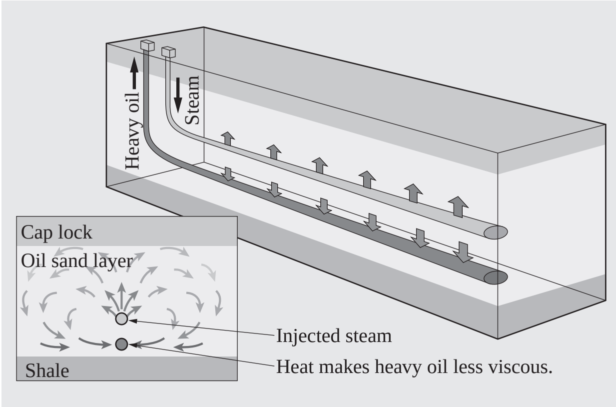


Fig. 2—Overview of SAGD Method for Heavy Oil Extraction.
The diagram shows how the SAGD method extracts heavy oil.

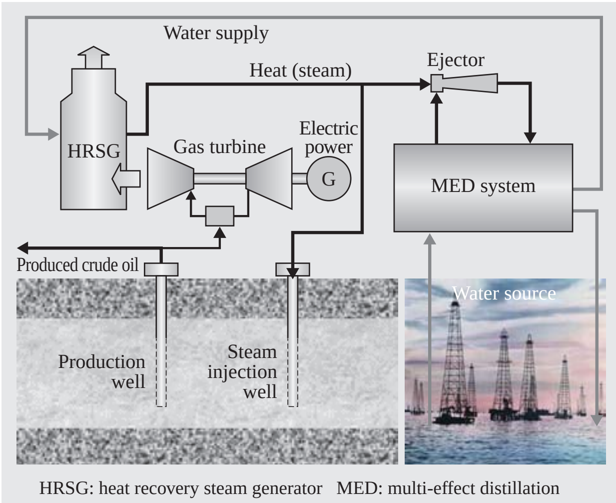


Fig. 3—Trigeneration System Producing Electric Power, Heat, and Water.
The trigeneration system uses a gas turbine to generate electric power and a heat recovery steam generator to produce steam which is used for injection into oil wells and for production of fresh water.

Application to Water Treatment for CSG Production

Conventional natural gas is produced from oil and gas fields located in comparatively shallow sedimentary layers. However, attention in recent years has turned toward shale gas and tight sand gas, two types of unconventional natural gas. CSG is natural gas that has been absorbed into coal or that is present in small fissures and fractures in coal. It exists in large quantities in Australia. The gas is widely distributed throughout the coal seams in the Great Artesian Basin. Here, the pressure exerted by underground water has caused gas to be absorbed into coal seams. Accordingly, when a well is drilled to access this gas, it also produces large quantities of water as a by-product. This water contains salt at concentrations between 200 and 10,000 ppm which, although less than the 35,000 ppm in seawater, is still enough to impair the growth of plants and animals. Because this salty water cannot just be discharged into the environment, the conventional way of dealing with it has been to let it collect in shallow ponds where it can evaporate by sunlight.

Nevertheless, this requires the evaporation ponds to have a large surface area and, because of concerns that the remaining salt must be dealt with to prevent it from contaminating the environment, use of this method of reducing the volume of by-product water by discharging it into evaporation ponds has been restricted. Instead, use of RO (reverse osmosis) membrane system technology for seawater desalination plants has recently been investigated. However, because the water production performance of RO membrane systems decreases as the salt concentration increases, this results in more expensive equipment costs and greater power consumption. Therefore, these systems have been used to reduce the volume of by-product water by only around one-half to one-third or less.

To meet these challenges, Hitachi has proposed a hybrid water purification system that combines an H-25 gas turbine with RO membrane and MED systems. The MED system, which is driven by waste heat from the gas turbine, further increases the salt concentration and reduces the volume of water that has been partially concentrated by the RO system,

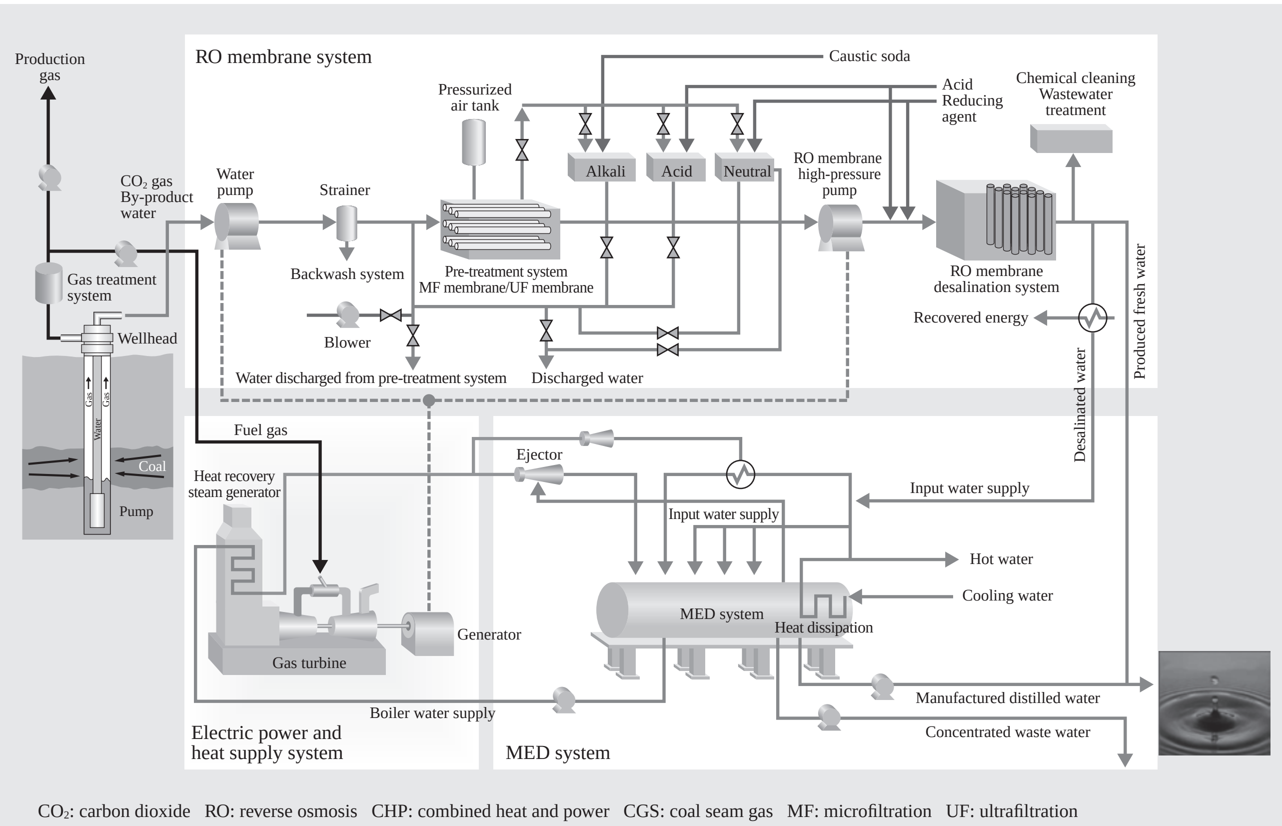


Fig. 4—Example Configuration of Hybrid Trigeneration System.
Overview of a hybrid trigeneration system in which partially concentrated brine from an RO membrane system is further concentrated by an MED system that uses waste heat from a gas turbine.

either reducing the amount of by-product water to 1/10th or less of its initial volume or subjecting it to further volume reduction and concentration so that the amount of by-product water discharged is reduced to zero.

Fig. 4 shows an example configuration for a hybrid trigeneration system made up of a gas turbine and RO membrane and MED systems. Because the osmotic pressure is less when the concentration of salt is lower, the RO membrane system can operate with a lower pressure and consume less energy under these conditions. However, the efficiency of fresh water production falls and the power consumption increases as the salt concentration rises. The MED system, on the other hand, which works by distillation and uses heat energy, is suitable for treating water with a high salt concentration. Accordingly, a system configuration that minimizes energy consumption can be achieved by combining the two types of system.

Fig. 5 shows examples of the calculated energy consumption for the overall system, taking into account the power required to drive the gas compressors that pump the produced natural gas along the pipeline, as well as the gas turbine and the RO membrane and MED systems. The figures show how the energy consumption can be minimized by appropriately balancing the operations of the RO membrane and MED systems.

Use of this future-oriented trigeneration system not only allows fresh water produced from by-product water to be supplied for irrigation or other industrial uses, it also provides a system that can convert water into electric power. The gas turbine uses air as its working medium and its power generation output and efficiency can be improved by mixing in steam. While use of a STIG (steam injection gas turbine), in which steam is injected into the combustor and turbine, can increase output by approximately 20%, the AHAT (advanced humid air turbine), which injects humid air around the compressor stage, is expected to achieve output and efficiency gains in excess of 50%.

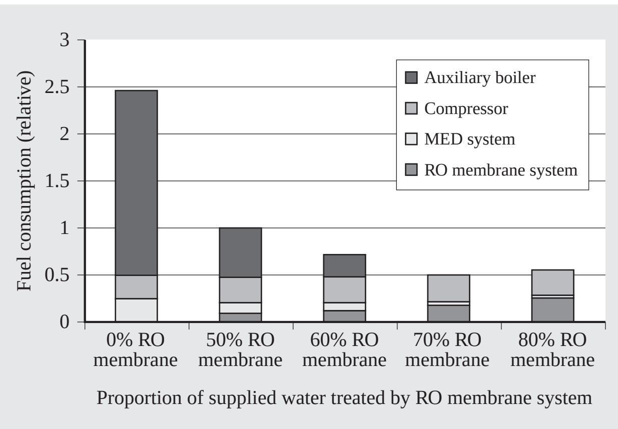


Fig. 5—Optimization of Hybrid System.
The graph shows examples of the overall energy consumption calculated for different combinations of RO membrane and MED system operation.

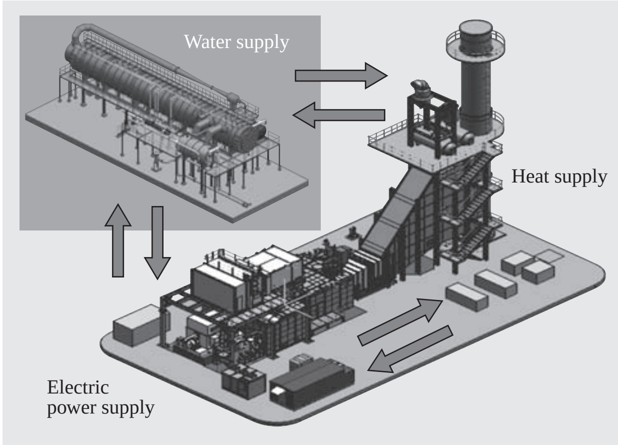


Fig. 6—Interrelation between Electric Power, Heat, and Water Supply in Trigeneration System.
Since injecting steam into a gas turbine increases its power generation output and efficiency, the trigeneration system has flexible operation that can respond to demand for electric power, heat, and water.

Since the water used for humid air gas turbines such as this should ideally be purified water with a very low level of impurities, the distilled water produced by the MED system is an ideal water source for a gas turbine. The proposed trigeneration system not only supplies electric power, heat, and fresh water, it also has the flexibility to rebalance production of these three outputs as operating conditions require (see Fig. 6).

CONCLUSIONS

This article has described a future-oriented trigeneration system for the oil and gas industry which uses a H-25 gas turbine.

By utilizing its core technologies and solution technologies and by bringing together its capabilities in the electric power and social and industrial infrastructure sectors, Hitachi is able to respond to a variety of customer needs, including securing water resources and water-related environmental protection outside Japan. Hitachi aims to contribute to society through technology in the future by further engaging in technical development.

ACKNOWLEDGMENTS

The engineering of the trigeneration system described in this article was undertaken using part of the funding provided by the "Subsidies for Cost of Refining Technology and Other Measures for Oil-producing Nations (Industrial Cooperation and Other Activities with Oil-producing Nations)" of the Ministry of Economy, Trade and Industry. We would like to take this opportunity to express our thanks for this support.

REFERENCES

(1) T. Miyazaki et al., "Solutions for Oil & Gas Industries under Expansion of Investment Taking Account of Environmental Conservation," Hitachi Review **59**, pp. 149–158 (Oct. 2010).
(2) O. Arai et al., "Characteristics and Applications of Hitachi H-25 Gas Turbine," Hitachi Review **57**, pp. 273–279 (Oct. 2008).

ABOUT THE AUTHORS

Mutsumi Horitsugi
Joined Hitachi, Ltd. from Arabian Oil Co., Ltd. in 2000, and now works at the Power Systems Sales Management Division, Power Systems Company. He is currently engaged in strategy formulation for the power supply business and overseas sales of gas turbine systems.

Shunichi Kuba, Dr. Eng.
Joined Hitachi, Ltd. in 1979, and now works at the Turbine Design Department, Hitachi Works, Power Systems Company. He is currently engaged in the design and overseas sales of gas turbines. Dr. Kuba is a member of The Japan Society of Mechanical Engineers (JSME) and Gas Turbine Society of Japan.

Shigeo Hatamiya, Dr. Eng.
Joined Hitachi, Ltd. in 1985, and now works at the Energy and Environment Research Center, Hitachi Research Laboratory. He is currently engaged in the research and development of gas turbine power generation system. Dr. Hatamiya is a member of JSME and Gas Turbine Society of Japan.