Gas Energy Recovery Radial Turbine Generator System

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Gas energy recovery systems generate power from the pressure difference of gas. The systems are eco-friendly with reduced CO_2 emissions. An increasing number of them are being used around the world, Kobe Steel's radial turbines playing a key role. This paper introduces the energy recovery system based on the company's unique turbine technology. Also included are the company's activities aimed at the future expansion.

Introduction

In autumn 2008, Keiyo Gas Co., Ltd. introduced a system for recovering gas energy to generate electric power. The system employs a generator with a radial turbine developed by Kobe Steel. The turbine effectively utilizes the energy of adiabatic expansion, an unprecedented exploitation of energy, as a cold source to generate power without combustion.

This paper introduces Kobe Steel's radial turbine which plays a key role in the power generation system. Also included in this paper are the company's activities aimed at the future expansion.

1. Gas energy recovery system for power generation

City gas in Japan mainly consists of liquefied natural gas (LNG). The natural gas is mined and liquefied at gas fields overseas before being imported in dedicated tankers. The imported LNG is temporarily stored in the tanks of LNG terminals located in the country's coastal areas. This stored LNG is vaporized using a heat transfer fluid, such as seawater, adjusted for its calorific value and mixed with odorant before being supplied as city gas to consumers. To deliver the city gas over a wide area, each gas company supplies the gas through high-pressure [note)] pipelines to regional governor stations. Each governor station reduces the gas pressure to an intermediate pressure [note)] and stores it in a spherical gasholder (**Fig. 1**). The gas is then delivered through a network of intermediate pressure pipelines to local governors, where the pressure is adjusted to a level required by consumers.

A gas energy recovery system utilizes the energy released during this pressure reduction, the energy of adiabatic expansion, for rotating an expander turbine to generate electric power. **Fig. 2** depicts the flow of the power generation system. As shown, the expander turbine can be configured in two patterns. In the first pattern, the expander turbine is placed between a high-pressure line and an intermediate pressure line A (i.e., in the upstream of the spherical gasholder). In the second pattern, the turbine is placed between intermediate pressure line A and another intermediate pressure line B (i.e., in the downstream of the spherical gasholder). This system has a simple construction compared with other systems used, for example, for thermal power generation. In addition, the system generates power without combustion, emits much less CO_2 and is more environmentally friendly.

When recovering pressure energy using an expander turbine, however, a significant temperature drop occurs at the turbine outlet. The temperature

[note)] The term "high pressure" refers to the pressures of 1.0MPaG or higher. The term "interediate pressure A" refers to pressures of 0.3MPaG or higher and lower than 1.0MPaG. The term "intermediate pressure B" refers to pressures between 0.1MPaG and than 0.3MPaG. The term "low pressure" indicates gas pressure lower than 0.1MPaG. Gas is supplied to typical users, such as households, at a low pressure, while it may be supplied at an intermediate pressure, A or B, to commercial-scale utility customers.

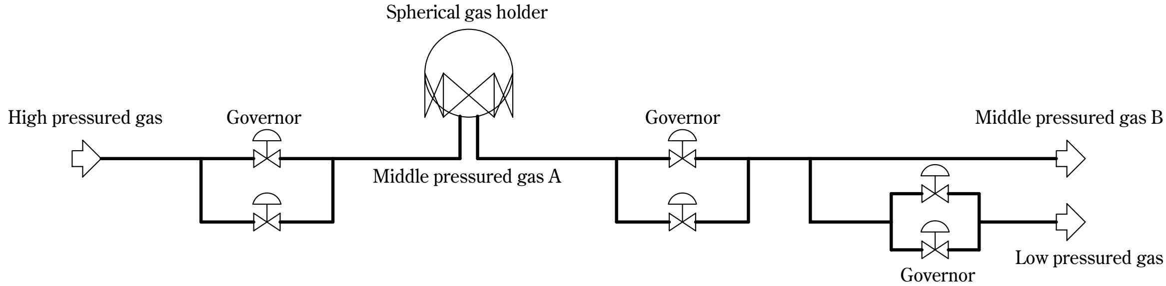

Fig. 1 General flow of gas supply

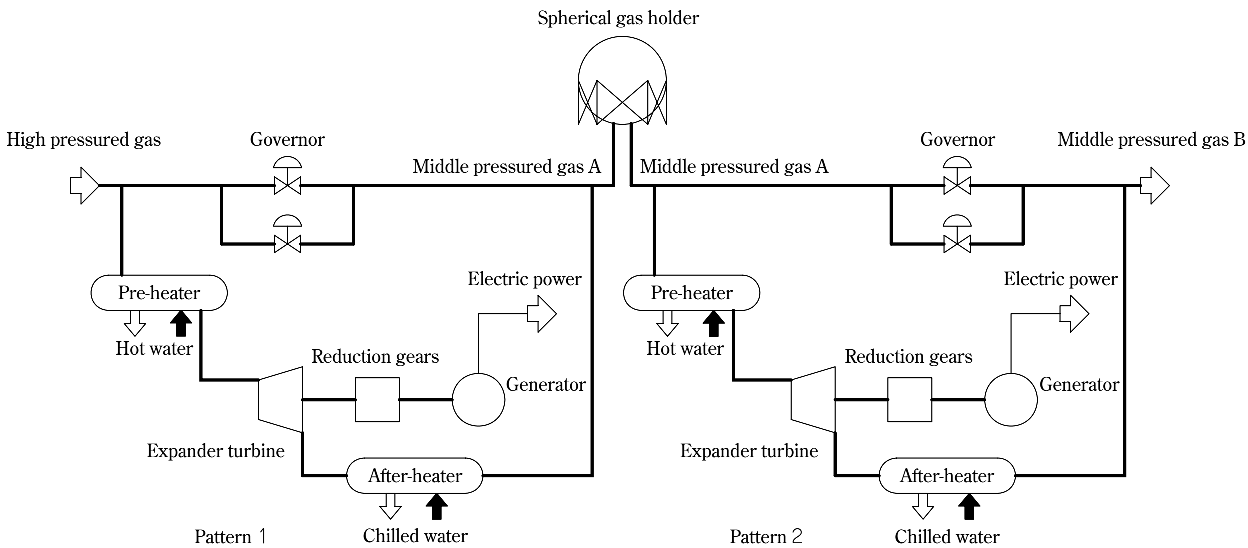

Fig. 2 System flow of gas energy recovery system

drop is partly attributable to the Joule-Thompson effect, which occurs any time when the pressure is reduced from high to low. An expander turbine, however, decreases the temperature more significantly with its characteristically large energy drop. On the other hand, the law stipulates the temperature of city gas must be higher than 0℃ when supplied to end users. Thus the gas must be heated during the energy recovery. As shown in Fig. 2, two methods are available for heating the gas namely,

(A) a preheater method in which, for example, a hot-water boiler heats the gas before it enters the turbine and

(B) an afterheater method in which an afterheater controls gas temperature using cold heat recovery at the turbine outlet or low temperature heat exhausted from neighboring facilities.

Most conventional governor stations, without any expander turbine, use similar heaters before and after the pressure reduction to compensate for the energy drop caused by the adiabatic expansion. These heaters can be the source of CO_2 emissions. In this respect, the new system emits slightly more CO_2 due to the additional amount of fuel consumed to compensate for its characteristic energy drop. But this emission is regarded as negligibly small considering the amount of power generated. It is to be noted that the pressure adjustment from intermediate pressure A to intermediate pressure B may not require any heater.

A terminal or station can employ either or both of the two methods, depending on user needs. The new gas energy recovery system offers various alternatives for the effective use of energy. This versatility of options is one of the features of the system.

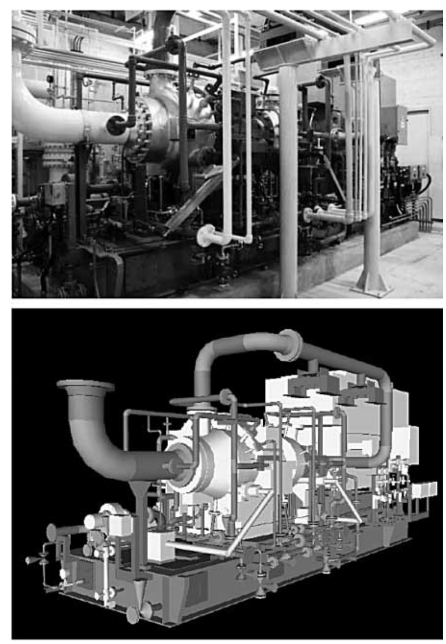

Fig. 3 Photo of gas energy recovery turbine unit and 3D-CAD drawing

1.1 Features of system delivered to Keiyo Gas Co., Ltd.

In 2008, Kobe Steel delivered a radial turbine generator to Keiyo Gas Co., Ltd. **Fig. 3** shows a near view and a 3D-CAD image of the generator, and **Fig. 4** depicts its system flow. **Table 1** summarizes the specifications of the generator. The generator delivered to Keiyo Gas Co., Ltd. has an expander turbine on the bypass line of the governor that adjusts the high pressure to intermediate pressure A. This is an example of the aforementioned first pattern. According to local news [1], the system is to

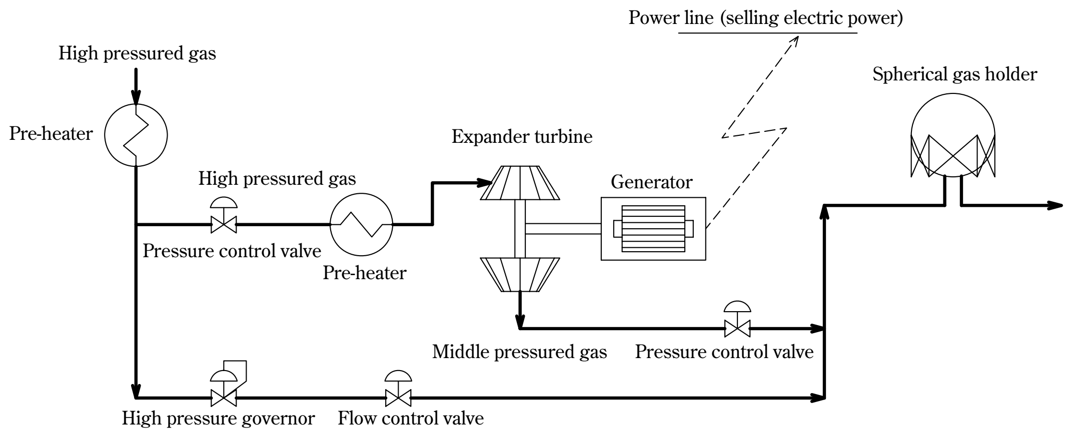

Fig. 4 Flow of gas power generating system for Keiyo Gas Co., Ltd.

Table 1 Specifications of gas energy recovery turbine unit for Keiyo Gas

Item	Spec.	Note
Stage	2	GRT250+GRT310
Gas flow (Nm^3/h)	30,000	10,000～30,000 variable operation
Turbine inlet		
Pressure (MPaG)	3.9	
Temperature (℃)	83	
Size	150A(6B)	
Turbine outlet		
Pressure (MPaG)	0.9	
Temperature (℃)	6	
Size	250A(10B)	
Rated power (kW)	830	@Terminal
Unit size (m)	6.5×2.6×2.2	Seal gas unit is separately installed
Unit Weight (kg)	25,200	Seal gas unit is not included

generate a peak power of 830kW and an annual power of 4.4 million kWh. This amount of electricity is sufficient to support about one thousand households for a year. The generator reduces the CO_2 emissions by 1,500 tonnes/year compared with a case in which the electricity would have been purchased. The system adopts the aforementioned preheater because the governor station where the generator is installed has neither a user of cold heat, nor a supplier of surplus heat in the neighborhood. According to certain announcements [2), 3)], the electricity generated at each governor station is sold to power producers and suppliers (PPS), in addition to being consumed in-house. In general, in-house consumption is the most economical way of using the generated power, as it decreases the bill to power companies by the amount that would have been paid without the self-generated power. However, there is no user for the self-generated power in many cases.

Until recently, Japanese gas companies had introduced fewer energy recovery systems than foreign companies. One reason is that regulations prevented the gas companies from using self-generated power other than for their in-house consumption. Thus, energy recovery was feasible only for large gas terminals that consume large amounts of electricity.

The recent deregulation of the Electricity Business Act has enabled entities to sell their self-generated power to power product suppliers (PPSs) and other power companies in addition to consuming it in-house. As a result, a governor station with a small in-house consumption can afford to introduce a gas energy recovery system for self-generation. In addition, government now provides certain subsidies for newly installed equipment that utilizes unused energy and reduces CO_2 emissions. The bounty system is expected to promote the introduction of the energy recovery system described in this paper.

1.2 Features of Kobe Steel's expander turbine

1.2.1 High efficiency

In general, turbines are either the axial flow type or radial flow type. Kobe Steel employs a radial turbine based on the impeller technology developed for the company's centrifugal compressors. The major advantage of the turbine is a high efficiency in converting pressure energy into external power [4) - 6)].

1.2.2 Excellent partial load performance

City gas companies control the supply of gas in accordance with the consumption. This affects the amount of gas passing through the turbines. Average households, major consumers of gas, consume a larger amount of gas in the morning and evening of each day for activities such as cooking, air-conditioning and bathing. Less Gas is consumed early in the morning and late in the evening. More gas is consumed during the winter months than during the summer months each year. Thus, the gas flow is constantly subject to change during the day and throughout the year. This requires turbines for gas energy recovery to have wide operation ranges and superb partial-load efficiency.

Turbine efficiency depends on the gas flow rate and declines significantly when the flow rate falls lower than the design point. This is because decreased gas flow changes the rate and angle of the flow from the turbine nozzle into the turbine runner, making it difficult to keep the flow optimized at the design point. A variable nozzle resolves this issue by adjusting nozzle angle in accordance with the change of flow from the nozzle into the runner. The nozzle can adjust the rate and angle of the gas flow in a wide range and keep it in the most suitable condition.

The system delivered to Keiyo Gas Co., Ltd. accommodates a gas flow ranging from 10,000 to 30,000Nm^3/h. This wide operation range and high efficiency are important for encouraging the use of the generator system.

1.2.3 High reliability

Kobe Steel developed a turbine-generator for cold power generation in the late 1970s. This was the beginning of the company's history of special turbine-generators recovering pressure energy from city gas and LNG. Cold power generation systems generate electricity from the cold heat of LNG. Such a system vaporizes LNG by a heat exchanger using seawater for example and recovers the pressure energy associated with the volume expansion using a turbine. This has led to the development of the pressure energy recovery system described previously. The newly delivered system also ensures high safety and reliability using the Kobe Steel's shaft-seal technology to prevent the flammable and explosive fluid from leaking from the rotary feedthrough. Kobe Steel acquired this shaft-seal technology over years of developing centrifugal compressors.

1.2.4 High durability

A prior art example of the gas energy recovery system is found in the cold power generator at the Senboku No. 2 plant of Osaka Gas Co., Ltd. The company put Kobe Steel's first machine into service in 1979 and its second machine in 1982. The Himeji terminal of Osaka Gas Co., Ltd. inaugurated a Kobe Steel machine in 1987. Remarkably, the first machine has been in service for around thirty years, demonstrating its durability.

2. Future activities

The gas energy recovery system meets the market need for power generation utilizing unused energy. The generation system is being widely used, as the electric power business has been deregulated and more effort is being made to reduce CO_2 emissions and prevent global warming.

The following section describes the technical challenges and Kobe Steel's recent efforts.

2.1 Technical challenges

2.1.1 Operation with small gas flow

As described above, the generator at Keiyo Gas Co., Ltd. operates at 10,000 to 30,000Nm^3/h. The generators, such as the one installed at Keiyo Gas Co., Ltd., may be feasible only in heavily populated urban areas where enough gas flows can be secured. However, conditions as favorable as those found at Keiyo Gas Co., Ltd. are rare in this country, and there are terminals with gas flows of less than 10,000Nm^3/h. Now many small to medium sized gas companies plan to introduce gas energy recovery systems as a part of their climate change mitigation programs. A small or medium-sized city gas company may generate less electricity and needs a system adapted for small-scale operations. Such a generator must balance the saved energy that would have been bought, the energy used by the preheater for heating, and the cold and/or waste energy utilized by the afterheater. In addition, a smaller system tends to have an increased equipment cost per unit output. This requires a less capital-intensive system with less costly components such as turbines.

When the gas flow becomes extremely small, a turbine starts to work as an electric motor, consuming, instead of generating, power. This actuates a reverse power relay and shuts off the turbine generator.

Thus a continuously running system that works cooperatively with the mains power must be considered. Such a continuous system is disconnected from the mains power and keeps its turbine in idle when the system cannot generate enough power. The system is connected back to the mains power when the gas flow is recovered.

2.1.2 Shaft seal system

Kobe Steel's standard specification calls for nitrogen for the shaft seal of the turbines; however, most governor stations do not have nitrogen equipment. The shaft seal may alternatively employ a large amount of air; however, governor stations are likely to have compressors that lack the capacities or air quality (dew point) needed. This often necessitates the addition or upgrade replacement of compressors and decreases the advantage of the generator system.

Therefore, it is desirable to develop a new shaft seal that consumes less nitrogen or air, while securing the high performance of the current design.

2.2 Kobe Steel's effort to promote widespread use

The following are required to promote the widespread use of the generator system.

- Reduced running cost

A new technology is required for reducing utility consumption, particularly the consumptions of nitrogen and/or air for the shaft seal, as well as the initial cost of the turbine generator.

- Control technology for stable operation with a small gas flow.

The newly adopted variable nozzle has improved partial load performance; however, control technologies remain to be improved. This includes preventing reverse power for small gas flow and achieving continuous operation regardless of whether the generator is connected to the mains power or not.

Conclusions

There are about one thousand governor stations and spherical gasholders dotted around the country. They are of various sizes and are connected, for example, to high pressure pipelines or to natural gas pipelines. These stations and gasholders provide a potential market for the gas energy recovery system. The market will increase with the expanding network of city gas pipelines and the addition of governor stations and spherical gasholders. A huge market may exist in overseas pipeline stations. Kobe Steel's radial turbines have been well recognized in the market for their high performance.

Kobe Steel will keep ahead in resolving technical issues, such as downsizing, cost reduction and performance improvement, to establish a competitive position. The company will strive to continue development and make a positive contribution to reducing global warming.

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