Lean methane- fueled gas turbine generator set

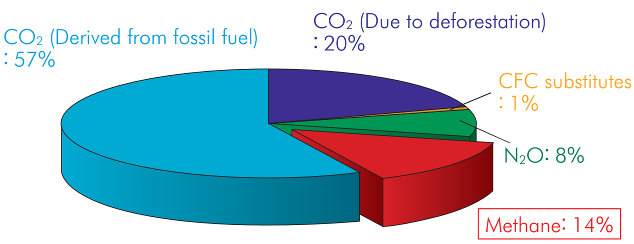
We developed, for the first time in the world, a lean methane- fueled gas turbine generator set in which ventilation air methane (VAM) obtained during the excavation of coal is used as fuel. Aiming at the reduction of greenhouse gases through large volume treatment of unused lean methane gas, which is emitted into the atmosphere from coal mines and landfill etc. around the world, and simultaneously aiming at its effective use for power generation, we are accelerating the commercialization of this system.

Preface

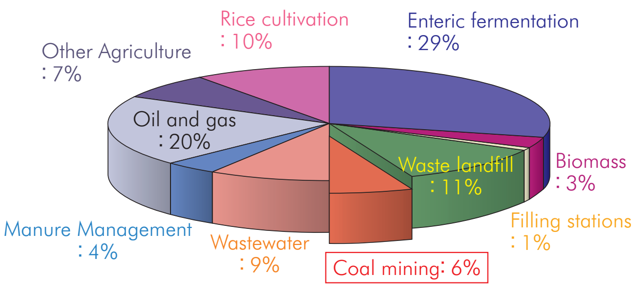
Methane gas is one of the greenhouse gases defined in the Kyoto Protocol. Its greenhouse effect is about 21 times that of carbon dioxide (CO_2), second to CO_2 in terms of environmental loading. In addition, approx. 6% of the total amount of discharged methane gas is emitted into the atmosphere from coal mines (Fig. 1).

Coal beds contain methane gas produced in the process of coal formation. It is released as coal is mined. Of the released methane gas, Coal Mine Methane (CMM) that contains 30% or more methane is used for power generation and the like. But, CMM that contains 1 to 30% methane and Ventilation Air Methane (VAM) that contains less than 1% methane are discharged into the atmosphere because there are no ways to utilize them. This VAM occupies 60 to 80% of methane gas discharged in the process of mining coal, and consequently its discharge into the atmosphere constitutes not only a waste of energy but also a cause of global warming (Fig. 2).

Against this backdrop, we are engaged in the development of gas turbines that are capable of generating electricity by using lean methane gas such as VAM as fuel.



(a) Greenhouse gas emissions of entire world (CO_2 equivalent), 2007



(b) Methane emission sources of entire world, 2010

Fig. 1 Greenhouse gas emissions and sources around the world

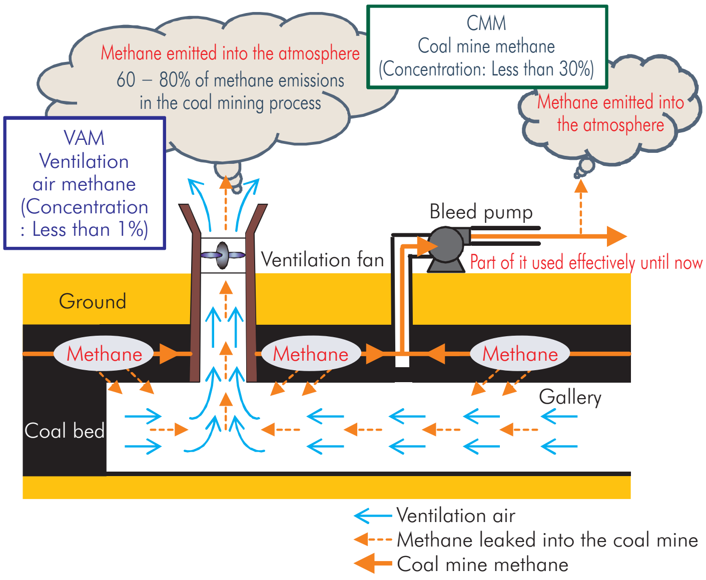


Fig. 2 Methane emitted into the atmosphere from coal mines

1 Unused lean methane treatment system

(1) Concept and configuration

Figure 3 shows the concept behind the unused lean methane treatment system proposed by us[1].

Composed of a catalyst combustion-type "gas turbine generator set" and a catalyst combustion-type "lean methane purifying unit" that operates on the waste heat from the gas turbine, this system is capable of simultaneously processing ultra-lean methane gas like VAM that cannot be processed by ordinary means, and generating power. Fig. 4 shows the system configuration and Table 1 the design performance characteristics.

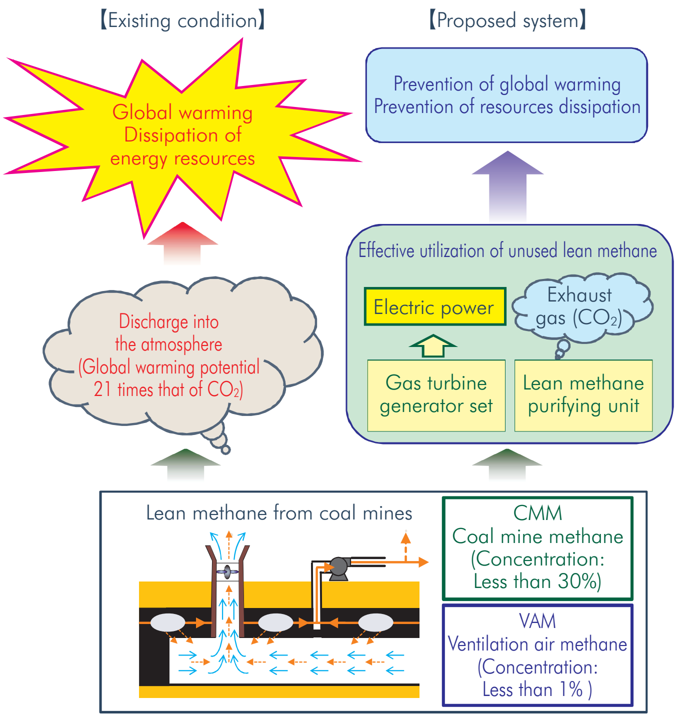


Fig. 3 Concept behind treatment system for unused lean methane

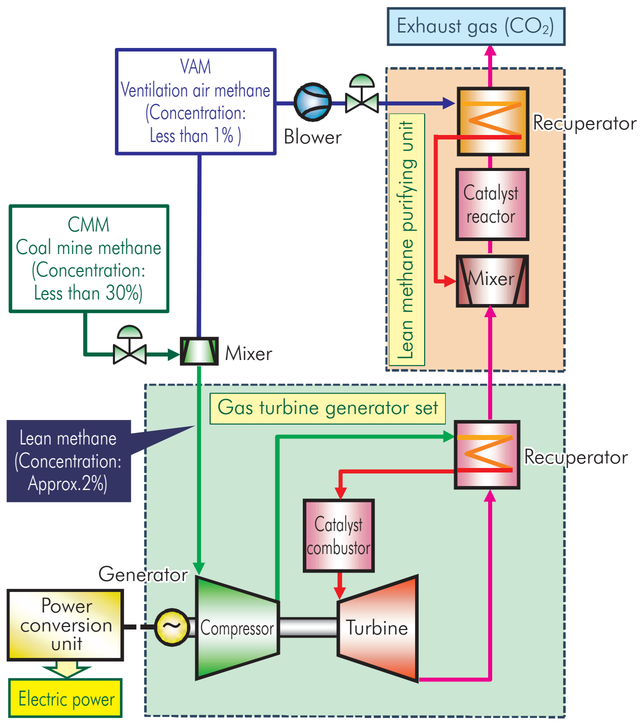


Fig. 4 Configuration of system

Table 1 Design performance of system

Generator unit	Generator end output (kW)*1)	800
	Quantity of VAM and CMM treated (Nm^3/h)	22,000
	Reduction in greenhouse gas (t-CO_2/year)*2)*3)	48,000
Purifying unit	Quantity of VAM treated (Nm^3/h)	38,000
	Reduction in greenhouse gas (t-CO_2/year)*2)*3)	20,000
Total reduction in greenhouse gas (t-CO_2/year)*3)		68,000

*1) Output under conditions of 15°C, 1 atm, and 0 m elevation
*2) Methane concentration supposed to be 0.5% for VAM and 30% for CMM
*3) For one-year operation at an availability factor of 97%

(2) Principle

In the catalyst combustion "gas turbine generator set", a mixture of a large amount of VAM that is discharged unused into the atmosphere and CMM (with a methane concentration of 2%) is drawn in as engine intake, compressed, and heated to the catalyst reaction starting temperature by a recuperator, and then is burned in the catalyst combustor. The high-temperature high-pressure gas thus obtained is used to rotate the turbine, thereby driving the generator.

The high-temperature exhaust gas from the generator set has still a high level of energy, and by using this energy, the catalyst combustion type "lean methane purifying unit" oxidizes the VAM. Through this process, greenhouse gas emissions are further reduced. The lean methane purifying unit is composed of an exhaust mixer, a catalyst reactor, and a heat exchanger. The VAM, which is supplied by means of a blower, is pre-heated by heat exchange between the heat exchanger and exhaust gas. The pre-heated VAM is mixed evenly with the exhaust gas from the generator set in the exhaust mixer and sent to the catalyst reactor, and the methane content in the gaseous mixture is oxidized by catalyst reaction. After this, the exhaust gas from the catalyst reactor is discharged into the atmosphere through the heat exchanger.

(3) Features

The features of this system are described here.

- VAM and low-concentration CMM, for which no means of utilization has been available, can be used for power generation; this allows the consumption of good-quality fuels (natural gas, oil, and coal) to be reduced.
- This system reduces greenhouse gas emissions while generating power.
- This system does not produce nitrogen oxides (NOx).
- The use of lean methane (approx. 2%) outside the flammable range (5 – 15%) increases safety.
- The system can be finished into a compact transportable size.

2 Outline of the applicable technologies

Table 2 shows the equipment specifications of a gas turbine generator set. In addition, an outline of the technologies applicable to each element is given below.

(1) Gas turbine

Forming the core of this system, the catalyst combustion gas turbine is optimized to meet the catalyst combustion and regeneration cycle specifications on the basis of the M1A-01 1,000 kW class gas turbines developed and marketed by us.

Table 2 Equipment specifications of gas turbine generator set

Section	Item	Type and specification
Gas turbine	Type	Regenerative cycle, single-shaft type
	Compressor	Two-stage centrifugal type
	Combustor	Single-can catalyst combustor
	Turbine	Three-stage axial type (All stages not cooled)
Engine equipment	Starting combustor	Single-can diffusion combustor
	Recuperator	Plate fin type
	Reduction gearbox	Two-stage planetary type
Power electronics equipment	Generator	Induction generator (Serving also as the starter)
	Power conversion unit	Inverter-Converter type

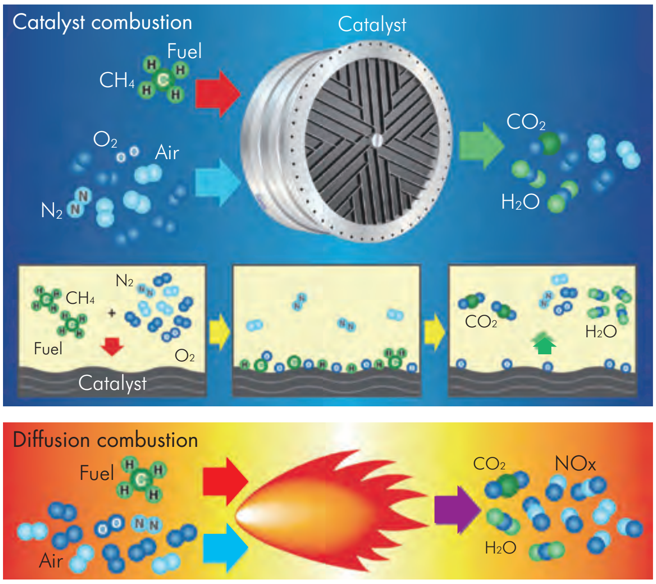


Fig. 5 Comparison between catalyst combustion and normal (diffusion) combustion

(2) Catalyst combustor

The "catalyst combustion technology" indispensable to the system adsorbs oxygen in the air and methane into the catalyst surface and burns (oxidizing) them by means of the strong oxidizing action of the catalyst. This system allows ultra-lean methane gas, which cannot be burned in normal flame combustion, to be burned at low temperatures without generating nitrogen oxides (NOx), a cause of atmospheric pollution, at all. In contrast to this, a normal combustor not only needs a mixture gas in a flammable concentration range (5 – 15%) but also produces a large amount of NOx because the mixture gas of air and fuel burns with a flame at a high temperature. Fig. 5 shows a comparison between catalyst combustion and normal combustion (diffusion combustion) in a conceptual illustration.

We are the world's only manufacturer that has commercialized catalyst combustion type gas turbines, in the form of the M1A-13X ultra-low NOx gas turbines, by converting catalyst combustion technology for development (Fig. 6).

(3) Recuperator

The recuperator requires high temperature efficiency and durability as well as a compact size. With these requirements taken into consideration, a plate fin type recuperator, which had been proven with Kawasaki's S7A 600 kW class regenerative gas turbines, was adopted (Fig. 7).

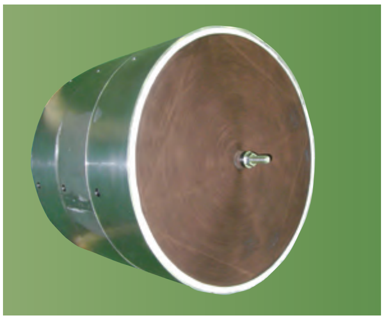


Fig. 6 Catalyst combustor core

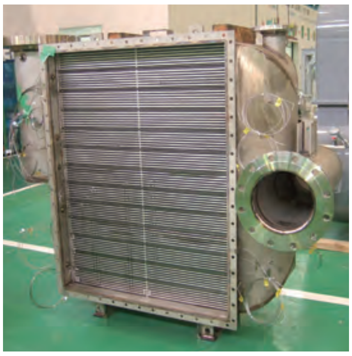


Fig. 7 Plate-fin-type recuperator

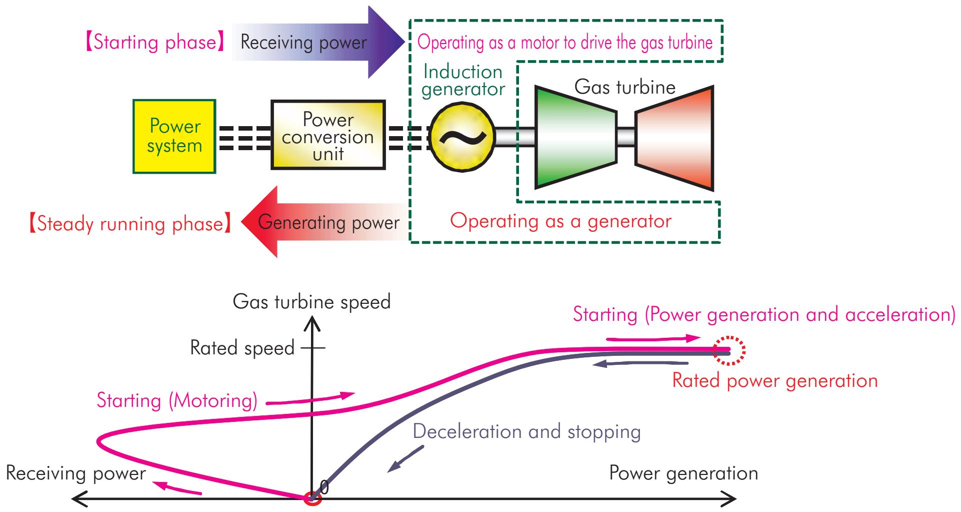


Fig. 8 Image of equipment operation in starting phase and steady running phase

(4) Power conversion unit

When igniting the catalyst combustor in the starting phase, this system must shift to a warming-up state and power generation at a slow gas turbine speed. For this reason, an induction generator with variable speed control using a power conversion unit developed by us is used. Fig. 8 shows a conceptual view of operation of the devices in starting phase and in steady running phase.

(5) Control technology

In addition to ordinary control sequences, control logic for starting and stopping and controlling methane concentration variation were newly designed. This has made it possible to materialize a system that takes into consideration stability when starting and stopping, and the protection and safety of equipment, such as the catalyst, against the variation in methane concentration in VAM and CMM.

3 In-house demonstration test

(1) Demonstration test unit

The demonstration test was conducted in-house using a demonstration test unit (Fig. 9) and a demonstration test facility (Fig. 10). With no VAM-like lean methane available in the in-house demonstration test, air was taken in and Fuel gas was injected into the mixer to simulate lean methane.

(2) Result of the demonstration test

The starting, loading, and other tests conducted confirmed that the system is capable of operating stably under automatic control in all stages from startup to loaded operation, and that the desired performance characteristics (reduction in greenhouse gas: 48,000 t-CO_2/year; rated output: 800 kW) can be obtained. Fig. 11 shows an example of test results.

Fig. 9 Demonstration test unit

Fig. 10 Demonstration test facility

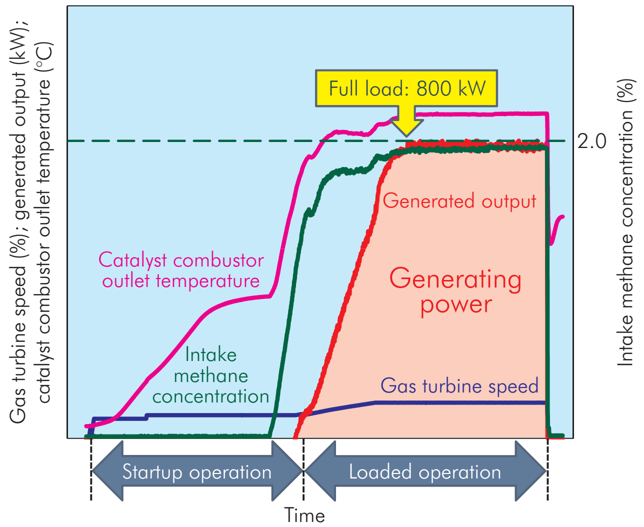


Fig. 11 Example of results of demonstration tests

Concluding remarks

We will verify the reliability and durability of "lean methane-fueled gas turbine generator sets," and then put them into mass-production. After this step, we plan to sell them to coal mines in Australia and China where VAM emissions are large and to waste landfill sites in the United States and other countries where lean methane gas is emitted in great amounts.

This product will aid the fight against global warming by processing lean methane gas emitted into the atmosphere (greenhouse gas) and utilizing it for power generation, thus contributing to the future of the global environment.

Reference

1) Patent No. 2009258561 (PCT/JP2009/060595): Lean fuel sucking gas turbine system

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