Conversion to Biogas-Fueled Engines
-- Rotary Engines –

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1. Introduction

Hiroshima Gas Company's Technical Research Laboratory was completed in July 2001. From the outset, we wished to develop and introduce a cogeneration system (CGS) that would make the most of locally available technologies. With the technical assistance of a local automaker, we therefore decided to demonstrate the performance of a rotary engine-mounted CGS in December 2002. The engine operated with 13A(*) gas for a total of 5,500 hours and the operating performance of the rotary engine proved satisfactory. At the same laboratory we had also been working on an environment-related research theme, participating in an industry-government-academia collaboration project on dry methane fermentation. Accordingly, we ran the rotary-engine CGS with biofuel with the aim of effectively using surplus methane. This prompted a local automobile manufacturer to invite us to jointly develop a rotary-engine CGS with biofuel, and so we developed a prototype system. This paper presents the prototype system.

Photo 1. Appearance of RE-CGS

Photo 2. Rotary 13B

2. Significance of Operating the System with Biogas

(1) Trends in the Gas Industry

The Japan Gas Association is encouraging the use of biogas in sewage treatment plants and in the food industry. Specific applications include (a) the advanced use of biogas in CGS systems and (b) the use of untapped biomass for new purposes.

(2) Use of Digestion Gas at Sewage Treatment Plants

The Current Situation of Biogas Uses

A large amount of digestion gas is combusted as surplus gas and little progress has been made in using digestion gas effectively. Energy should be derived from digestion gas to help reduce CO_2.

The Current Situation of Power Generating Installations

Less than 7% of about 300 digestors at sewage treatment plants are equipped with power generating facilities, about half of which can produce only about 60 m^3 of gas per hour. In terms of generating capacity, 30-50kW-class power generating installations are needed.

3. Development Aims

After considering the situations stated above, and taking the geological conditions and simplification of facilities into account, we set the following three development targets:

- Generating capacity of 35 kW
- Biogas-fueled engines
- Capable of dealing with methane concentration of more than 50%

4. Preliminary Tests for Conversion to Biogas-Fueled Engines

(1) Characteristics of Rotary Engines

Rotary engines have the following characteristics:

- Any types of fuel can be used as the rotary engine can operate with hydrogen.
- The rotary engine has a simple construction and has fewer parts than the reciprocal engine. As there are no air intake and exhaust valves that may cause trouble, the rotary engine may be suitable for biogas.
- The engine is small, light and yet produces high output.

(2) Specifications of the Testing Machine

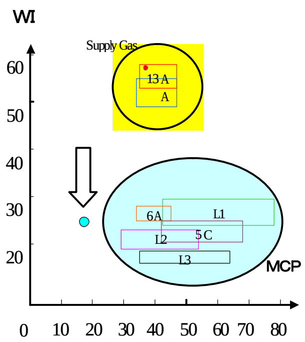
Preliminary tests were carried out with the initial testing machine shown in Table 1 using synthetic biogas.

Engine Type	Rotary Engine 13B
Total engine displacement	1,308 cc (654×2 rotors)
Engine speed	1,800 rpm
Compression ratio ε	11
Generating capacity(13A)	20 kW

Table 1. Specifications of the RE-CGS (13A) Initial Testing Machine

(3) Combustibility of Biogas

Table 2 shows an example of the combustibility of digestion gas generated at sewage treatment plants. WI falls under the low-calorie group, and because its combustion speed is very low, it is rather hard to burn.



CH_4	58.7 %vol
CO_2	38.7 %vol
O_2	0.1 %vol
N_2	0.3 %vol
Calorific value	24.0 MJ/m^3

Table 2. Example of the Composition and Combustibility of Digestion Gas at Sewage Treatment Plants

(4) Composition of Synthetic Biogas

Because biogas was unavailable, a device capable of mixing CH_4 and CO_2 in a certain proportion was used to generate synthetic biogas for the tests.

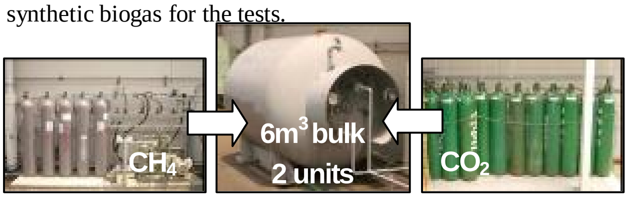
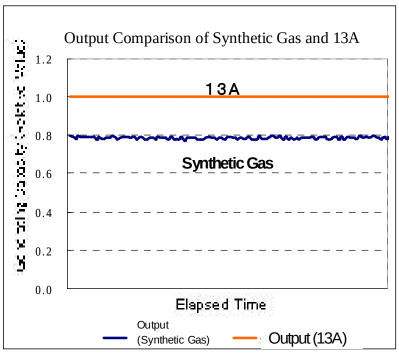


Photo 3. The Synthetic Biogas-Making Device

(5) Preliminary Tests

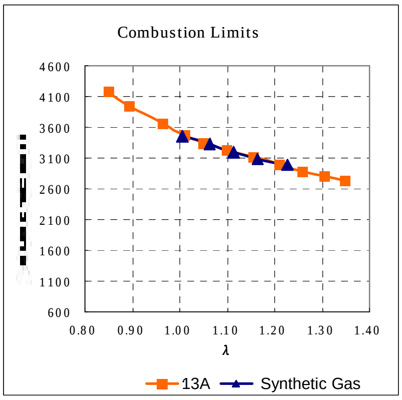
Using the synthetic biogas (CH_4: 50%; CO_2: 40%), the testing machine shown in Table 1 was operated and its performance (was) examined. Although the generating capacity decreased by nearly 20%, the machine operated normally by adjusting the air ratio and ignition timing.

Graph 1 shows the generating capacity in a steady state.



Graph 1. Operation of the Initial Testing Machine with Synthetic Biogas (Generating Capacity)

The combustion range of synthetic biogas was found to be narrower than that of 13A, as shown in Graph 2.



Graph 2. Operation of the Initial Testing Machine with Synthetic Biogas (Combustion Range)

From these observations, we concluded that the machine can operate with biogas provided the engine is adjusted to a certain combustion range.

5. Final Tests for Conversion to Biogas-Fueled Engines

(1) Remodeling of the Initial Testing Machine

In order to increase the generating capacity (on the 13A basis) to 40–50 kW, the initial testing machine was remodeled as follows:

- The engine speed was raised from 1,800 rpm to 3,600 rpm.
- Gas mixer nozzles were expanded.

(2) Operating Adjustments after Remodeling

Confirmation of the Generating Capacity

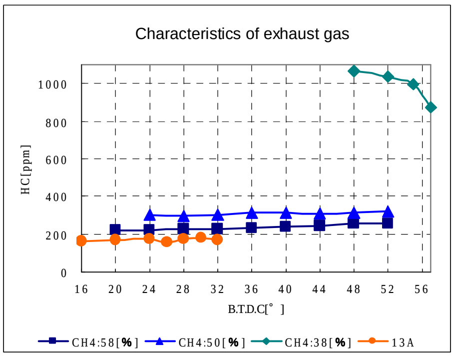
Because the generating capacity was no more than half of the expected level, the causes were investigated and it was found that the fuel supply was less than that required by the engine. The gas pressure at the inlet of a gas mixer was unusually low, so the bore of the pipe at the inlet was increased and final tests were carried out.

(3) Determination of Optimum Combusting Conditions

Ignition timing and air ratio were adjusted to find the optimum combusting conditions and the highest point.

Adjustment of Ignition Timing

Good combustion was achieved by advancing the ignition timing as the concentration of methane in the synthetic biogas decreased. It was also confirmed that the machine can operate with the methane concentration of 50%.



Graph 3. Characteristics of Exhaust Gas with Adjustment of Ignition Timing

(4) Results

The maximum generating output and the steady combustion range were examined with due consideration of the adjusted ignition timing. The following results were obtained:

- The maximum generating output reached nearly 35 kW with the methane concentration of 50–60%.
- The air ratio was adjusted to around 1.

The above results were incorporated into the prototype machine used for pilot operation at a sewage treatment plant.

6. Evaluation of the Prototype Machine

The prototype system was installed at this laboratory in mid July 2006. After being adjusted in a trial run, the prototype system was shipped successfully to the neighboring sewage treatment plant.

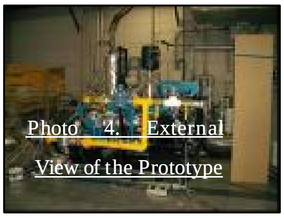


Photo 4. External View of the Prototype

7. Conclusion

We will increase the generating capacity of the system, study the feedback from field operation data, and improve the prototype system for steady operation.

Finally, we sincerely thank the local automobile manufacturer for providing technical support from the outset of introducing the rotary-engine CGS system.

(*)13A：Based on differences of calorific value and combustion speed, city gas is classified into seven groups in Japan: 13A, 12A, 6A, 5C, L1, L2, and L3. In the terms for each group, numerals are approximately equivalent to one-thousandth of the Wobbe index, and the letters indicate the combustion speed (A - slow, B - medium, and C - fast).