# LOW-ELECTRIC-INPUT GAS-ENGINE HEAT PUMP AIR CONDITIONER

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## ABSTRACT

We have recently developed a gas engine heat pump air-conditioning system with a power-generating function. In this system, a high efficient generator and converter are added to a conventional GHP. This system enables highly efficient power generation by utilizing surplus capacity of the gas engine during air-conditioning. The new system achieved power generation efficiency of approximately 42-43% (in terms of Higher Heating Value). Since generated electricity is supplied to the cooling fan and pump of outdoor unit, the electric power consumption of the outdoor unit is reduced. The new system enables lower electric power consumption and running costs compared to conventional gas heat pump air-conditioners. In this paper, we show the mechanism for its high efficiency and the features of this system, and we also provide an introduction about this technology.

**Key Words:** ***gas engine, heat pump air-conditioner, power-generating function, low electric power.***

## 1 INTRODUCTION

A gas engine heat pump ("GHP" below) air-conditioner is a gas air-conditioner system where an outdoor compressor is driven by a gas engine to operate a heat pump for providing air-conditioning. The use of GHP units has been increasing every year due to the recognition of its low power consumption, low running costs, and other advantages. At the end of the fiscal year 2002, the installed capacity of GHP units in Japan totalled 8.03 million kW.

**Fig. 1. Appearance of the GHP with power generating function**

Although the GHP is an air-conditioner using gas as its primary fuel, it uses electric motors for the outdoor fan motor and cooling water pump, and so the power consumption of the GHP outdoor unit for a cooling performance of 56 kW is nearly 1 kWh.

Recently, with increasing numbers of large sites installing multiple units, the issue of GHP power consumption has become an issue that cannot be overlooked.

For this reason, SANYO Electric Co., Ltd. and OSAKA GAS Co., Ltd. jointly developed the High-Power Multi incorporating the high-efficiency power generation system. This paper describes the development of the high-efficiency power generator and high-efficiency converter and the measures implemented to reduce power consumption and cut running costs in the High-Power Multi.

## 2 PRINCIPLES

The High-Power Multi incorporates a compact 1-kW class power generator which uses an engine to drive the compressor and uses the excess power to drive the generator. In this air-conditioning system, the generated power is supplied to the fan motor and cooling water pump to reduce the power consumption of the outdoor unit.

Generally, the power generation efficiency of a 1-kW class engine power generator is said to be in the lower 20% range at most. Although this does not reach the 36.6% power generation efficiency at the power-consuming end of thermal power plants, the characteristics of GHP gas engines are used to generate power while providing air-conditioning so that only the engine output is increased without changing the engine speed for improved engine thermal efficiency. As a result, only a slight increase in gas consumption is needed for increasing the engine output volume, and it is possible to achieve a high energy usage ratio of 40% or more. Thus, compared to conventional GHP air-conditioners, this enables lower power consumption and contributes to the levelling of power demand.

Figure 2 shows the correlation between engine output, thermal efficiency, and input.

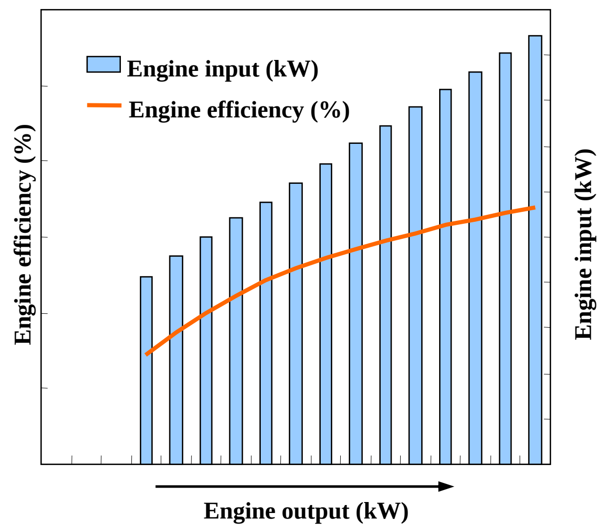


**Fig. 2. Correlation between engine output and efficiency**

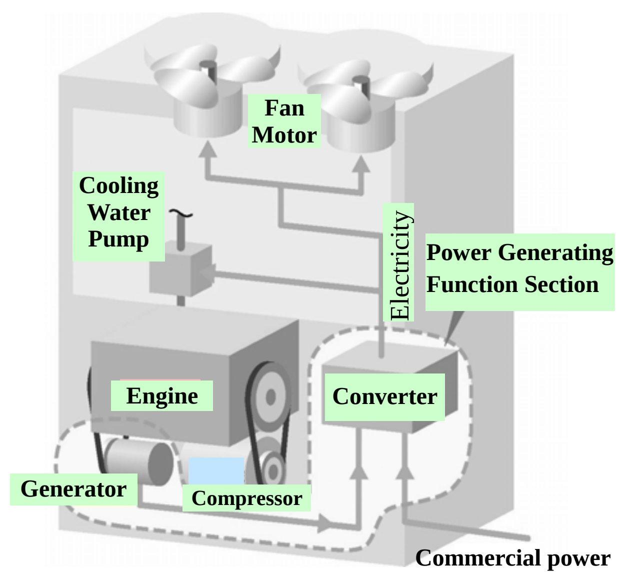


**Fig. 3. Structure of the GHP with power -generating function**

## 3 SYSTEM CONFIGURATION

Figure 3 shows a schematic diagram of the outdoor unit of High-Power Multi. In this system, a power generator and converter are added to a conventional GHP air-conditioner. The converter converts the high-frequency AC power generated by the power generator to DC power, the inverter converts this power to a frequency corresponding to the required speed, and then this power is supplied to the fan and pump. This system is constantly backed up by commercial power, and any shortages in generated power are automatically made up using commercial power.

## 4 MAIN SPECIFICATIONS

There are currently three types of systems: 56 kW, 45 kW, and 35.5 kW. The main specifications of the Standard Multi and High-Power Multi for the primary model, the 56 kW systems, are shown in Table 1.

**Table 1. Specification of the previous model and the GHP with power-generating function(60Hz)**

| | | Previous Model | GHP with Power Generating Function |
|---|---|---|---|
| Cooling Capacity | kW | 56 | ← |
| Heating Capacity | kW | 67 | ← |
| Power Source | - | 3-phase | ← |
| Power (Cooling Mode) | kW | 0.99 | 0.08 (0.99*) |
| Power (Heating Mode) | kW | 1.07 | 0.09 (1.07*) |
| Starting current | A | 30 | ← |
| Gas Consumption (Cooling Mode) | kW | 43.5 | 45.7 (43.5*) |
| Gas Consumption (Heating Mode) | kW | 46 | 48.3 (46.0*) |
| Generator | kW | - | 2 |
| Generator Type | - | - | Permanent Magnet Type |
| Dimensions | mm | W1735 D1000 H2208 | ← |
| Weight | kg | 930 | 945 |
| Noise | dB(A) | 58 | ← |

*; Electricity is not generated

A view of the internal structure is shown in Fig. 4, and the area around the generator is shown in Fig. 5. A pulley for a belt is attached to the flywheel side of the engine, and this belt is then used to drive the power generator.

The compressor on the other hand, is driven by a belt on the opposite side of the generator in the same way as conventional compressors.

Once the engine is driven, the power generator is driven together with the compressor, and power starts to be supplied. The power supplied from the power generator is AC, and it is supplied at a frequency four times the engine speed. However, since the engine speed control is based upon the air-conditioning load, the frequency and voltage cannot be fixed, and this frequency cannot be used as power without conversion. Therefore, a converter is used to convert the irregular frequency power to DC, and then after voltage adjustment, it is supplied to the DC power input of an inverter for driving the DC motor.

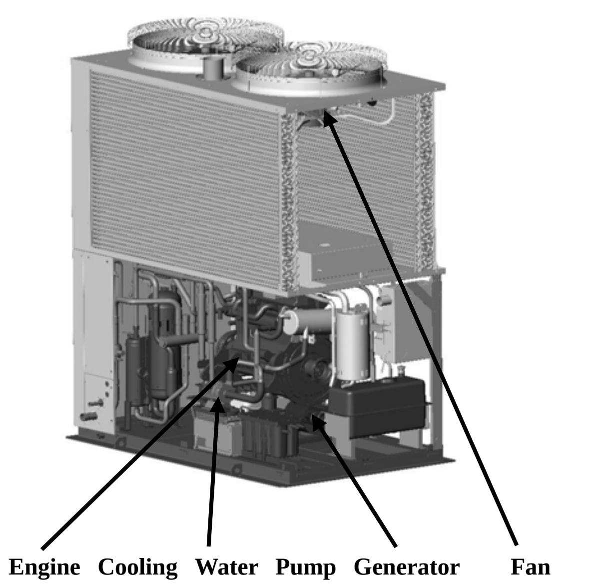


**Fig. 4. Internal view of the GHP with power -generating function**

The area around the converter board is shown in Fig. 6. The converter board is installed under a conventional air-conditioning control board.

## 5 FEATURES

### 5.1 Lowest Power Consumption in the Air-Conditioning Industry

The conventional GHP features a low power consumption of about 1/10 of electric heat pumps in the same class. The new High-Power Multi, however, when operated at a cooling performance of 56 kW, has a low power consumption of less than 100 W, which is about 1/200 of an electric heat pump.

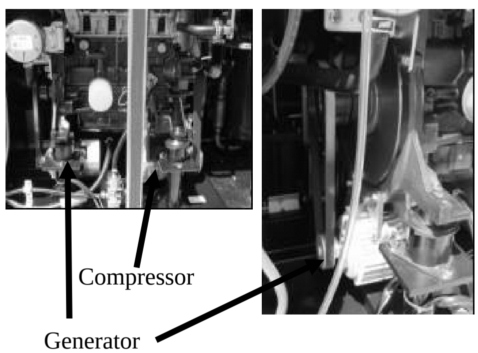


**Fig. 5. Generator and its vicinity**

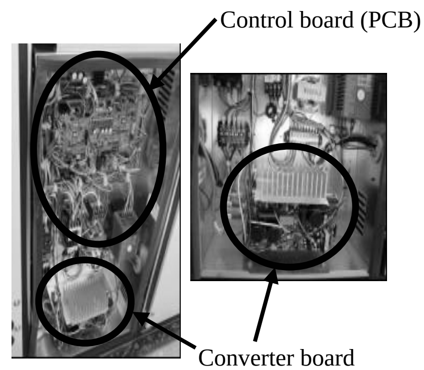


**Fig. 6. PCB and converter**

Whereas conventional models at a cooling performance of 56 kW consume 990 W of power at cooling, the High-Power Multi consumes only 80 W for power savings of about 900 W.

### 5.2 High-efficiency Power Generation Surpassing even Large Power Generators

Since power is generated using excess power from the gas engine, the engine is operated under a higher load, and the engine's thermal efficiency is improved. As a result, the energy usage rate (defined by the formula below) under the cooling rated conditions and heating rated conditions is approximately 42 to 43% (Higher Heating Value) for realizing a high energy usage rate that exceeds even large power generators.

$$\text{Energy usage rate} = \frac{\text{Generated power (kW)}}{\text{Additional gas consumed by power generation (kW)}}$$

### 5.3 Same Ease of Operation as Conventional Models

No changes have been made from conventional models in terms of the connected indoor units, air-conditioning performance or dimensions of the outdoor units, ease of installation, ease of construction, maintenance periods, or other factors. Also, if commercial power is needed due to a shortage of generated power, a DC coupling that does not require a coupling protective device is used to automatically divert commercial power to meet any shortage of power. This enables the system to provide the same reliability as conventional models.

## 6 TECHNICAL DEVELOPMENT

### 6.1 Development of High-efficiency Power Generator

The structure of the developed power generator is shown in Fig. 7, and the specifications are shown in Table 2.

Using the basic technology in SANYO Electric's high-efficiency DC motors for air-conditioners, a high-efficiency, permanent magnet-type brushless power generator was developed that uses a belt driving system to provide both vibration resistance and durability.

A cooling fan is located on the opposite side from the pulley for driving the power generator, and it is used for the forced air-cooling system. Since this is a permanent magnet-type system, the casing has an airtight structure for preventing any effect from dust. Heat-dissipating fans are located around the casing perimeter, and this enables a high rated power generation efficiency of 95%.

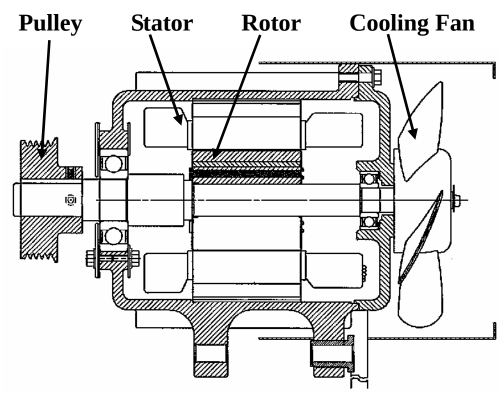


**Fig. 7. Structure of the generator**

**Table 2. Specification of the generator**

| Item | Unit | Specification |
|---|---|---|
| Rated Speed | min-1 | 4,400 |
| Power Source | － | 3-phase |
| Rated Output | W | 2,000 |
| Rated Current | A | 4.7 |
| Rated Voltage | V | 240 |
| Rated Efficiency | % | 95 |
| Range of Rotational | min-1 | 1,500 － 4,800 |
| Number of Poles | － | 4 |
| Insulation | － | Class E |
| Magnetic Field | － | Permanent Magnet |

### 6.2 Development of AC/DC Converter

To convert the three-phase power supplied from the power generator to DC for sending to the inverter, power conditioner technology for photovoltaic generation was used to develop a converter with a high conversion efficiency of more than 96%.

The power supply circuitry is shown in Fig. 8. The generated power is supplied to two fan motors and a cooling water pump, and this power is all consumed in the GHP outdoor unit.

Since the fan motor is controlled according to the air-conditioning load, the power load also varies, but the power does not back-flow to the commercial power since it is DC coupled.

Since the usage of generated power is given priority over power from commercial sources, the output voltage from the converter is controlled to a voltage higher than the commercial power voltage

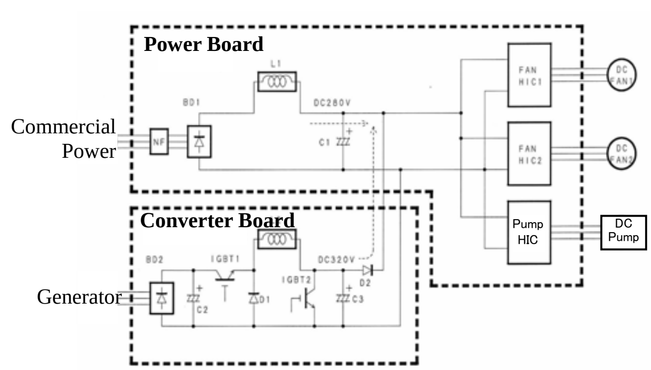


**Fig. 8. System configuration**

(280 V DC) after DC conversion. However, if the engine speed slows down due to a reduction in air-conditioning load, and the power supplied from the power generator is not enough, then the output voltage from the converter will drop, and the shortfall of power will automatically be supplied from commercial power.

### 6.3 System Development

The power generator is used effectively at the position opposite from the air-conditioning compressor where space is available. Since engine output is achieved using belt driving, no significant structural modifications are needed from conventional models.

Conventional technology such as air-conditioning motors and photovoltaic generation converters are also used to realize a product that provides reliability without significant increases in cost.

## 7 CONCLUSION

The gas heat pump air conditioning system with power-generating function is very beneficial to society. This system not only realizes higher power-generating efficiency than thermal power plants, but also offers the advantages of energy saving and thereby reduction of operating costs to customers, since it is a co-generation system which effectively uses engine exhaust heat for space heating.

In Japan, the number of gas heat pump air conditioning systems sold annually has already reached the 40,000-unit mark. Installation of a 1-kW generator in all such models would lead to a 40,000-kW annual increase in the co-generation installed capacity. For reference, although the installed capacity of less than 10 kW co-generation systems has been increasing every year in this country, the figure for the previous fiscal year was only 2,000 kW or so.

In the future, we will further develop innovative concepts such as the combination of an air-conditioner and generator for optimization of generating capacity, to add new products to our line-up.