

Introduction of Micro Combined Heat and Power Generation Unit for Residential Use

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ABSTRACT

The Micro-cogeneration unit (MCHP1.0) for residential use has been developed. The unit produces both hot water and electricity. This process is carried out in an extremely efficient manner. By fueling the system with cleaner burning natural gas, carbon-dioxide emissions can be further reduced. Electrical power from the units can be connected to the electricity grid. The Honda MCHP1.0 has reached 85% (LHV) of total energy efficiency, has a 380 mm width of enclosure, and a 46 dB (A)/1 m operating noise level due to advanced small engine technology and inverter generator technology accumulated in Honda's power equipment business. The unit is the smallest commercialized cogeneration unit.

1. Introduction

There is an increase in efforts across a range of sectors to reduce energy consumption and to utilize new forms of energy in response to global environmental issues. In striving to achieve the targeted reduction in CO₂ emissions by 2010 (6% less compared to 1990), which was proposed at the 1994 Kyoto Protocol Symposium (COP3), a range of measures are being explored by the industry, the social, and the transportation sectors. Nevertheless, the current restriction levels pose an extremely tough challenge.

Of particular note, is the dramatic rapid increase in energy consumption among residences, which is now a major cause of the overall increase in energy consumption.

A law in Japan concerning the rational use of energy has

been established for addressing the efficient consumption of energy in residences. This law is based on the so-called top runner method, which is the principle of adopting the most efficient energy consumption levels achieved by specific electronic products such as TVs, air conditioners, automobiles and so forth. In addition, housing and construction design have adopted principles of lower energy consumption to help reduce the level of energy consumed through air conditioning and heating systems. Still, in spite of these improvements, changing lifestyle patterns and a greater number of home electric appliances have led to a continued increase in energy consumption.

In addressing the supply of energy, the shift toward cleaner fuels that emit less CO₂ as well as continual improvements in energy consumption efficiency are both

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essential to achieving the targeted emission levels. Cogeneration systems supply both heat and electric energy and by 2010 the total power production from cogeneration systems is expected to reach approximately 10 GW. These cogeneration systems are expected to make increased inroads in addressing the requirements for reduced levels of energy consumption.

Cogeneration systems have, until recently, been used in large-scale facilities such as factories, hotels and retail shops. However, with the recent revision of the Electricity Utility Industry Law, gas engine generators with a maximum power of less than 10 kW are treated as small electric equipment. This deregulation has led to an increased impetus in the development of micro-cogeneration units.

The Micro Combined Heat and Power Generation System described in this report is an energy supply system for residential use designed and achieved through joint development participation. The micro-cogeneration unit was developed by Honda while the combined hot water storage tank and supplementary boiler sub units were developed jointly by a city gas company, along with some manufacturers of hot-water supply systems. This report introduces the main features of the micro-cogeneration unit.

The micro-cogeneration unit is the world's first system to adopt electric interconnection sine wave inverter technology⁽¹⁾.

2. Development Concept

The following requirement conditions were focussed on in the development of the unit.

- (1) Must be able to minimize efficiency loss of city gas supplies while maintaining balanced environmental conditions.
 - Effective use of such a direct source of energy
 - Reduce CO₂ and nitrogen oxide (NO_x) emissions
- (2) Must be able to be set up in a typical residential environment
 - A compact packaging
 - Low noise
 - High quality power supply
 - Connection to hot water supply and heating systems
- (3) Must be able to integrate the various subsystem standards.
 - Meet standards of the Japan Gas Appliances Inspection Association
 - Simplify discussion with electric power companies regarding Electric Interconnection. (Meet guidelines of electric interconnection technology requirements in the future.)
 - Conform to Fire Prevention Standards

3. Specifications and Features

3.1. System Configuration and Specifications

Figure 1 shows the micro-cogeneration system layout in a residential setting. The system is set up outside the house. The power generated by the micro-cogenerator is consumed by the various electric products used in the house via the distribution panel. Heat produced along with the electricity is used first to warm water in hot water storage. Then it is used efficiently for hot water supply, floor heating and dehumidification in the bathroom.

Figure 2 shows an external view of the micro-cogeneration unit consisting of a gas engine, electric

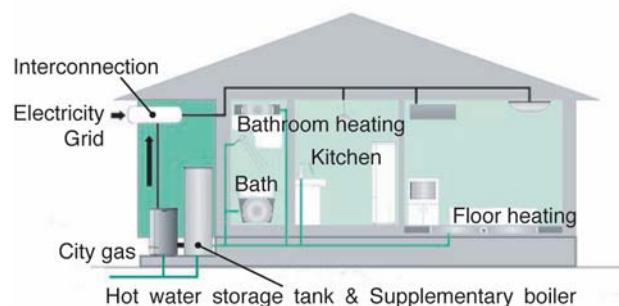


Fig. 1 General view of micro-cogeneration system

generator, heat exchanger and electric interconnection inverter. Table 1 lists the unit's specifications.



Fig. 2 External view of micro-cogeneration unit

Table 1 Specifications

Output	Electricity	1Φ3W 200V/100V 50/60Hz 1 kW
	Heat	3.25 kW
Power supply		Grid connection by inverter
Heat recovery		80°C Hot water
Efficiencies (LHV)	Electricity	20%
	Heat	65%
Dimensions (LxWxH)		635 × 380 × 940 mm
Weight(kg)		81
Noise		46dB(A)
NOx		Max 60 ppm
Engine	Type	Liquid cooled 4-stroke OHV vertical single cylinder
	Displacement	163 cm ³
Starting system		Starter generator

3.2. Differences with Conventional Micro Electric Generators

The micro-cogeneration unit differs significantly from conventional micro electric generators with its combined interconnected electricity grid. The power produced by the micro-cogeneration unit is synchronized to the frequency of the electricity grid and is supplied to the house, monitoring potential voltage trouble and power failure occurrences. Also, heat loss that would normally occur in typical micro engine generators is recovered by the engine coolant and converted to heating water in the hot water storage tank and supplementary boiler. The heat of exhausted gas including latent heat is also recovered by a heat exchanger unit shown in Fig. 6. Figure 3 shows the internal layout of the micro-cogeneration unit.

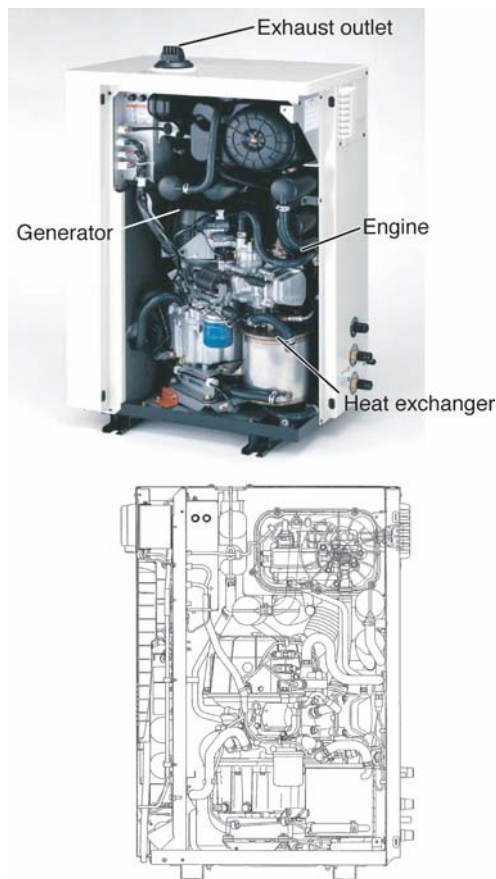


Fig. 3 Layout of micro-cogeneration unit

4. Technological Achievements

4.1. Effective Use of Primary Energy and Low Emissions

Usually, when power is supplied by electric power companies, there is a significant line of distance between the source of power generation and the areas where the power is in demand. Heat energy generated along with electricity cannot be used and is inevitably lost. After the transmitted energy loss is deducted, usable energy would account for an energy utilization ratio of 39%. On the other hand, as the micro-cogeneration unit generates power in the house, the heat can be used efficiently for heating water. Figure 4

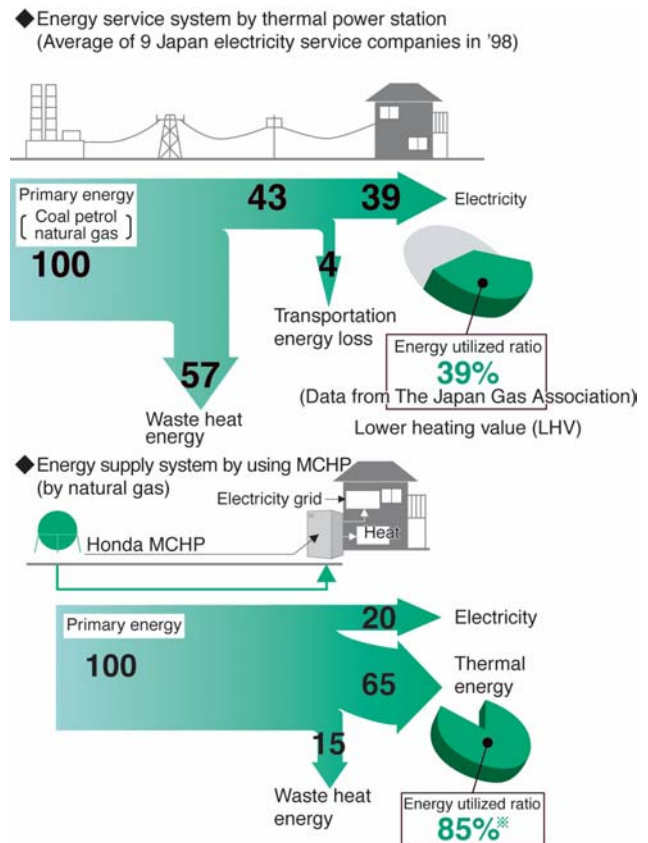


Fig. 4 Comparison of total energy efficiency

provides a comparative illustration of energy utilization ratio between conventional energy supply systems and the micro-cogeneration system.

The efficiency of power production at 1 kW of power output is 20%. The overall rate of efficiency, which is equal to (power output + amount of heat recovery) / gas supplied energy, reaches 85% of the lower heating value (LHV) standard. Figure 5 shows the multi-pole sine wave generator used in the micro-cogeneration unit.

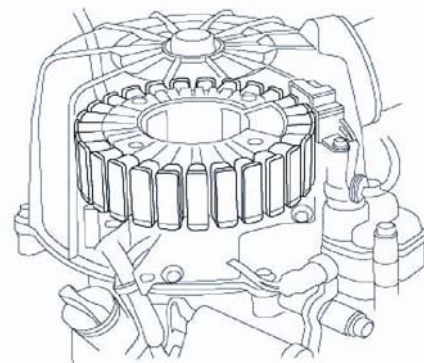


Fig. 5 Generator unit (27 pole)

The heat is recovered up to 65% of the LHV by using a heat exchanger unit, which is capable of recovering both sensible and latent heat. Figure 6 provides a structural representation of the heat exchanger unit.

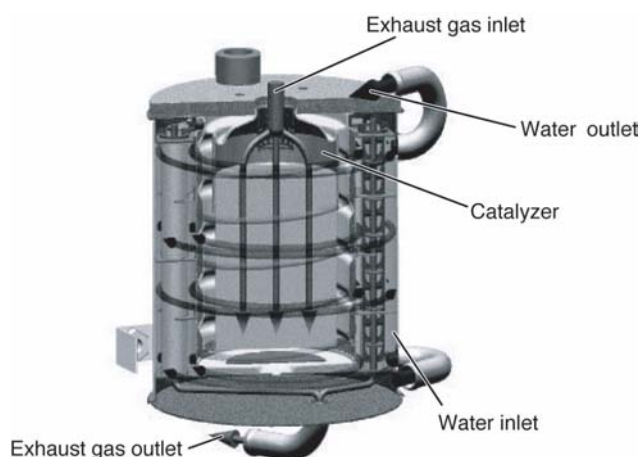


Fig. 6 Heat exchanger with a built-in catalyzer

The temperature of the engine coolant through which heat recovery is delivered ranges between 75°C and 80°C. The hot water storage tank and supplementary boiler unit can produce hot water, which is achieved through heat conversion from the engine coolant with clean water. For supplementary terminals using heated water, such as floor heating or bathroom dehumidifier, existing commercial products can be used without modification.

Heat, power output and the heat-electricity ratio, which is equal to heat output/power output, are all taken into account for system operation. The system operates according to heat demand while the amount of electricity generated is subsidiary. The engine operation time is adjusted depending on domestic heat demand. The system enables efficient use of any heat recovered from the engine.

The daily heat requirement and duration of heat use are calculated for the hot water storage tank and supplementary boiler unit. The calculation is then used to determine the start time and run duration of the micro-cogeneration unit. In effect, the system conducts a learning control routine to extract the most efficient level of energy consumption by running the units mainly when the radiation heat loss from hot water storage is low and electric loading is high. The remote controller for the supplementary boiler unit displays the current amount of stored hot water and power being consumed. The remote controller also incorporates a navigation function to enable scheduling of bathing time for the most effective energy consumption.

Regarding the emission, the internal exhaust gas heat exchanger discussed above has a three-way catalyst for controlling exhaust emissions and uses an O₂-feedback controller to enable fuel consumption at a stoichiometric air-fuel ratio to attain levels of NO_x ≤ 20 ppm, CO ≤ 100 ppm.

4.2. Compact Packaging Suitable for Typical Residential Space Layouts

The micro-cogeneration unit incorporates numerous design controls in a compact size suitable to the general home environment. Installation floor space and compact format are of particular merit, especially from the viewpoint of the limited residential space conditions in Japan. A large volume oil tank along with a vertical engine has been incorporated in a unified layout design to enable the smallest possible floor space. Figure 7 shows the vertical engine layout with a multi-pole generator in comparison with a conventional generator. The vertical engine design

contributes to the unit's reduced footprint size and facilitates installation in the smallest of locations. The multi-pole sine wave inverter generator has been designed without a fly wheel and has achieved a compact format approximately 1/2 the size and weight of a conventional generator. When starting, the generator acts as a starter motor for the engine by introducing net electricity (starter-generator). This configuration has eliminated the need for heavy and large independent starter motors. Figure 8 shows a comparison of the planar dimensions for an installed micro-cogeneration unit and other installed domestic appliances. The micro-cogeneration unit incorporates a smart compact design suitable for installation in typical residential environments.

When the system is started, the starter generator transmits power to the generator and initiates engine operation.

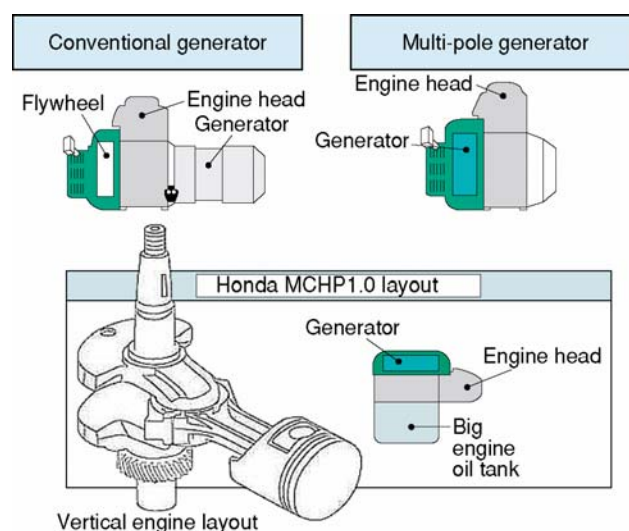


Fig. 7 Comparison of layout

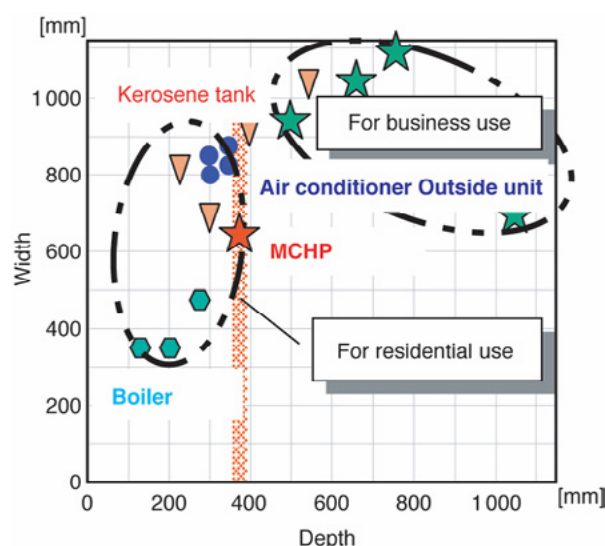


Fig. 8 Comparison of installed planar dimension

4.3. Noise Reduction

Potential noise sources are engine intake air and exhaust noise, ventilation noise inside the unit, engine combustion noise and mechanical noises. A multistage intake and exhaust silencer has been fitted to moderate engine intake air and

exhaust noise. Similarly, a silencer has also been fitted to reduce ventilation noise within the unit. To reduce overall internal noises including engine-generated noise, the inner walls of the unit have been covered with sound insulator.

These sound reduction measures have enabled a reduction in noise level to 46 dB (A) / 1 m (measurements conducted according to JIS GHP standards) during rated operation conditions and have attained low noise levels such as that for outdoor air-conditioners. Figure 9 shows a comparison of noise levels evaluated for the micro-cogeneration unit and other appliances.

The previously discussed multi-pole generator enables a silent start without engagement.

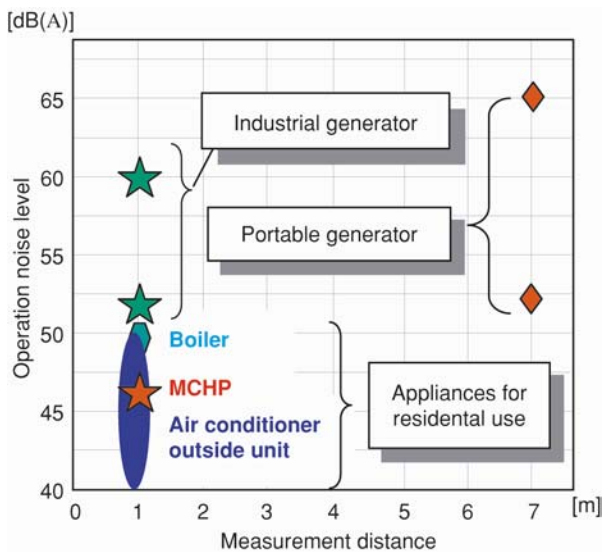


Fig. 9 Comparison of noise level

5. Summary

The newly developed micro-cogeneration unit is the world's first model for residential use that has successfully achieved an environmentally friendlier application by optimizing the saving of primary energy.

- (1) The sine-wave inverter generator and exhaust gas heat exchanger used in the unit have enabled an overall efficiency of 85% LHV ((power output + amount of heat recovery) / gas supplied energy.)
- (2) The sine wave inverter generator, which avoids the use of a fly wheel, a vertical engine and starter generator contribute to reducing the overall weight and size of the unit, highly suitable for residential use.
- (3) Mechanical noise and internal noises such as engine intake and exhaust noise, etc. have been reduced to a maximum operating noise level of 46 dB (A) / 1 m making the system ideally suited to residential application. This has been achieved by adopting a multistage silencer and by covering the entire inner surface of the unit with sound insulator.

6. Acknowledgements

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The issue of efficient energy consumption and reduced levels of CO₂ emissions are topics of concern shared on a global scale. In designing the co-generation system, although the principles of compactness and application to residential use were conceived at an early stage, these were not readily attained due to various technical issues and a range of social constraints.

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