

Development of CO₂ Heat Pump Hot Water System “ECO CUTE”

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1. Introduction

The market of CO₂ heat pump hot water system “ECO CUTE”, which complies with the Ministry of Economy, Trade and Industry’s CO₂ emission reduction plan, has been spreading rapidly. The new system launched in June 2006 employs Mitsubishi’s latest technologies and has been a commercial success thanks to its competitiveness. This report introduces the technologies of the compressor, heat exchanger, heat insulating material, etc. in the new system.

2. Environment of Electric Hot Water System Business

In March 2002, the “Outline for Promotion Effects to Prevent Global Warming” was established and specific countermeasures against global warming to be taken by various sectors were publicly announced by the government. Since the Kyoto Protocol came into effect in February 2005, the importance of countermeasures against global warming has grown to encompass all sectors and organizations in Japan related with energy and the environment, with the numerical targets specified for compliance.

The final energy consumed by the consumer and general household sector has increased largely, following the freight and passenger transport sector, so urgent countermeasures in these sectors are necessary. The outline mentioned above includes specific, detailed descriptions of countermeasures for the consumer sector, such as “expanding the range of application of top-runner standards”. From the trends of energy consumption by application, about 60% of energy is consumed by room heating and water heating systems in this sector.

The ratio of all-electric homes has been increasing year by year due to heavy marketing to the residential sector by electric power companies throughout the country. As a result, electric water heaters, IH cooking heaters, solar power generation systems, and the like are increasingly accepted in electricity markets. These groups of products are a key part of our all-electric strategy.

The Ministry of Economy, Trade and Industry has set a specific target of 5.2 million heat pump water heaters installed by FY2010. Both manufacturers and power companies have drawn up plans with their re-

spective policies and schemes. In addition, local governments are increasingly accepting applications by end users for grants or have established their own subsidy systems.

In this report, we discuss the technological features of the ECO CUTE heat pump water heater using environment-friendly CO₂ natural refrigerant (called HP water heater hereafter).

3. Features of ECO CUTE

ECO CUTE is a nickname commonly used by power companies and water heater manufacturers for HP electric water heaters that use natural refrigerant and are widely used in industry. Mitsubishi started to commercialize HP water heaters in FY2001, and a total of 100,000 units were actually sold from FY2001 to FY2005.

The technological features of Mitsubishi’s HP water heaters are as follows.

- (1) High-efficient heat pump system
The performance is about 3 to 4 times that of conventional heaters.
- (2) Use of environment-friendly natural refrigerant
CO₂ refrigerant, which does not destroy the ozone layer and has low global warming potential, is used.
- (3) Economical nighttime power is used.

4. Technological Features of Mitsubishi Products

Mitsubishi “diahot” has the largest share of the HP water heater market. In June 2006, we integrated the technologies of the “diahot” hot water tank with heat pump technologies used in our industry-leading air-conditioning systems, and launched new products as shown in Fig. 1 which are far superior to those of other manufacturers. The technological features of the products are described below.

- (1) High-efficiency compressor and high-efficiency heat exchanger were developed to achieve the industry-leading rating of COP4.9.
- (2) New foam insulation having 15% better insulating performance than conventional insulation material is used in the hot water tank, increasing the heat insulation capacity.



Fig. 1 Appearance of heat pump water heater ECO CUTE

4.1 High-efficiency rotary compressor

The heat pump unit serving as the heat source of the water heater uses a rotary compressor whose performance has been proved in Mitsubishi air-conditioners. The HP water heater is a high-pressure shell type rotary system using a Poki Poki Motor for the first time in the industry; its performance and quality ensure sufficient reliability of the HP water heater. The key technologies of the compressor are as follows.

- (1) Use of high-efficiency Poki Poki Motor
Mitsubishi's original Poki Poki Motor, with its high coil density and high efficiency, is used in the compressor of this water heater. Figure 2 shows the stator of the motor.



Fig.2 Appearance of Poki Poki Motor

The stator core of the Poki Poki Motor is open for coil winding, so the winding process is not spatially constrained and dead space is minimized. With a 20% higher line volume ratio (the space density of the copper coil) than conventional motors, the motor efficiency is 2% higher.

- (2) Use of wear-resistant vanes ⁽²⁾
Since CO₂ refrigerant requires a very high operating pressure (11.3 MPa), the reliability of sliding parts was expected to be vulnerable, so we coated the surface of sliding parts with super-hard DLC-Si (DLC containing silicone), thus improving reliability. The conventional nitrided vanes (for

air-conditioners) indicated low wear resistance when CO₂ refrigerant was used and failed to satisfy the required service life, so we more than doubled the load bearing characteristic and verified that the service life was sufficient.

4.2 High-efficiency water-to-refrigerant heat exchanger

In addition to the compressor, this water heater system features Mitsubishi's new technology for heat exchangers. In the water-to-refrigerant heat exchanger (also referred to as gas cooler in water heaters) which heats water for hot-water supply to users, we used a newly developed "twist & spiral gas cooler". As shown in Fig. 3, the heat exchanger uses a twisted pipe with three lines of spiral grooves for a water pipe, which are prepared by a twisting method. A refrigerant pipe (thin pipe) is wound around the twisted pipe and connected to each other by zinc-free soldering for heat conduction. This arrangement increases the contact surfaces on both pipes, thus increasing the heat transfer area. The continuous spiral grooves in the twisted pipe accelerate the turbulence effect in the water and also help reduce pressure loss in the heat exchanger. Furthermore, three pipes are wound around the three spiral grooves in parallel to reduce the pressure loss in the refrigerant.

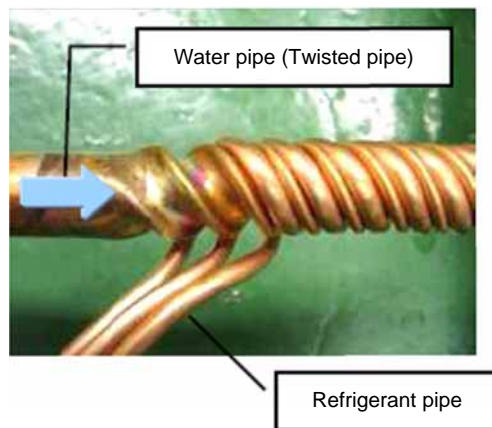


Fig. 3 Appearance of water-to-refrigerant heat exchanger

Since pressure loss is minimum in both the water pipe and refrigerant pipe, the efficiency of the compressor and heat transfer efficiency are improved, and the input to the circulation pump can be reduced.

The features of the heat exchanger are described below.

Figure 4 compares the heat transfer efficiency between Mitsubishi's twisted-pipe type heat exchanger and other types of heat exchangers. The figure clearly indicates that the twisted-pipe type has a far higher (more than double) heat transfer efficiency.

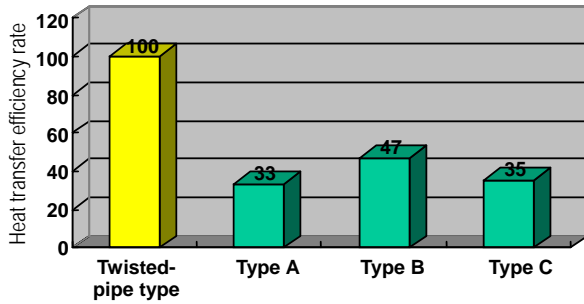


Fig. 4 Heat transfer efficiency per unit length of water pipe

4.3 Improvement of heat insulation of tank unit

The insulation material of the hot-water tank unit of this water heater is reinforced. Figure 5 shows the appearances of both conventional insulation material and the reinforced insulation material. The conventional insulation material (Fig. 5(a)), glass wool, was wrapped around the stainless steel tank. With the new water heater, molded foamed polystyrene (PS) is configured to match the exterior shape of the tank to improve adhesion between the insulation material and the tank.

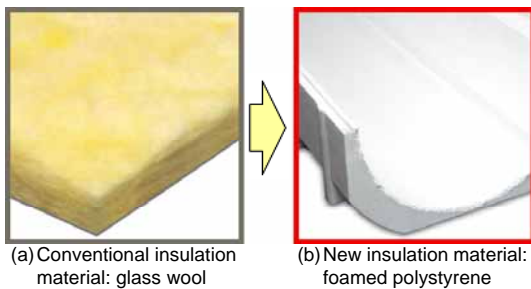


Fig. 5 Appearance of insulation material

As shown in Table 1, the thermal conductivity of the new heat insulation material is lower than that of the conventional material. In addition, the insulation structure is designed to increase the insulation of the connection pipe on the tank and controlled heat radiation by providing a gap between the insulation material and the housing covering the insulation material. As a result, the total heat insulation efficiency of the tank unit is improved such that the temperature inside the tank is reduced by approx. 15% over a certain period.

Table 1 Thermal conductivity of insulation material

	Glass wool for conventional specification	Foamed polystyrene for new specification
Thermal conductivity W/mK	0.038	0.034

5. Future Developments

With the HP water heater market rapidly expanding, the JIS for home-use HP water heaters will come into effect in April 2008. The details of the standard are currently being discussed.

The new JIS standard will change the evaluation reference from conventional “rating of COP (coefficient of performance)” to “actual operating efficiency of equipment” on annual basis, the same as for air-conditioners. This suggests key points for future technological development.

Since FY2006, manufacturers have been conducting joint studies with NEDO (New Energy and Industrial Technology Development Organization), and are likely to launch new products from next year based on the results.

We must continuously develop technologies to meet the changing performance evaluation criteria, improve the functionality of each system, expand the product range, and meet the need for energy saving measures.

6. Conclusions

Mitsubishi will strive to expand the sales of new products and continue to develop energy-saving plant facilities.

7. References

- (1) H. Maeyama et al.: Development of Rotary Compressor for CO₂ Heat Pump Water Heater, Mitsubishi Advance
- (2) H. Nakahide et al.: Technology for Controlling the Wear on the Top of Vanes Used for CO₂ Refrigerant Rotary Compressor, Mitsubishi Advance