# High-efficiency Heat Pumps

## Background and Objective

Heat pumps, such as air conditioners or water heaters, etc., are widely used to promote energy conservation and to reduce carbon emissions. The development of more efficient heat pumps with low GWP (Global Warming Potential) refrigerants and their expansion to new areas of application is needed.

CRIEPI embarked on basic research into $CO_2$ heat pumps in 1995 and finally commercialized a $CO_2$ heat pump water heater for residential use in 2001, with the pet name"Eco-cute," in conjunction with Tokyo Electric Power Company and DENSO Corporation.

In this project, we aim to evaluate the performance of the next-generation Eco-cute and to develop a more efficient version. We also assess the potential for heat pumps used in commercial and industrial sectors with low GWP refrigerants.

## Main results

### 1 Performance Evaluation of Various Types of Eco-cute Versions

We have evaluated the performance of various types of Eco-cute version, such as the conventional type, small-sized type, and cold-area type utilizing heat pump performance test facilities. In addition, in FY2011, we evaluated the system COP (daily hot water and room heating demand/daily power consumption) of the multi-function type, which had a room-heating function. In this type, the quantity and balance of hot water demand and room heating demand affect the system COP. Thus, first, the daily power consumption was divided into standby power consumption and heat pump unit power consumption. Further, heat pump unit power consumption was divided into rated power consumption, power consumption caused by high outlet water temperature, and power consumption caused by high inlet water temperature. We proposed this evaluation method (Fig. 1) and confirmed that the quantitative analysis of the system COP was possible by this method.

### 2 Development of a $CO_2$ Heat Pump for Central Heating Systems

A central heating system is widespread in cold climates. Such a system heats all rooms of a house, usually by utilizing hot water. Hokkaido Electric Power Company, SANDEN Corporation, and CRIEPI jointly developed an air heat-source $CO_2$ heat pump for a central heating system (Fig. 2). The developed heat pump, due to the modified two-stage cascade heating cycle,* can produce a high temperature of 70℃ in the hot water even in the condition of an ambient air temperature of -20°C.

### 3 Development of Small Heat Pumps for Industrial Drying

In industrial processes such as the process of drying parts after washing with water, hot air heated by an electric heater is frequently used. Thus, equipment that utilizes energy-saving heat pump technology is highly required. We have been developing a $CO_2$ heat pump air heater since FY2010 based on the technology acquired through the development of Eco-cute. In FY2011, bearing in mind commercialization, a prototype that can be operated using automatic control was designed, fabricated, and tested utilizing heat pump performance test facilities. Under the automatic control operation, a COP of about 3 and a heat output of 3 kW were achieved under the condition that the inlet and outlet air temperatures were 25°C and 100°C, respectively, and in which the heat source water temperature was 30°C (Fig. 3). This may reduce power consumption to about 1/3 compared with the conventional process (M11005).

*High-temperature side-heat pump cycle and low-temperature side-heat pump cycle are connected in series via a heat exchanger. This cycle is adopted to make a high temperature from low-temperature ambient air or to make a very low temperature.

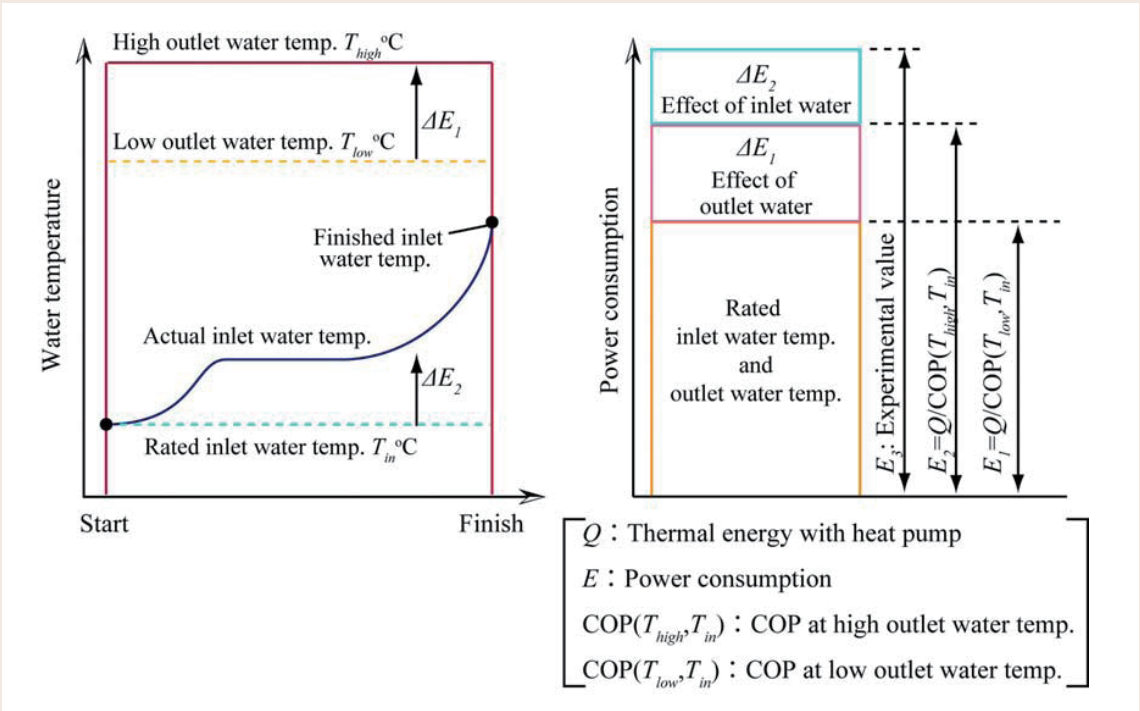


Fig. 1: Proposal of the evaluation method for Eco-cute

The figure shows schematically the increase of heat pump unit power consumption from start to finish for water heating (thermal storage). The heat pump unit power consumption at the rated inlet water temperature and the low outlet water temperature is the smallest (*E1*, rated power consumption). However, in actual operation, the outlet water temperature becomes high to ensure the storage of heat needed. Further, due to the influence of hot water remaining in the hot water tank, the actual inlet water temperature becomes high. Because of these, heat pump unit power consumption is increased (△*E1*, △*E2*). A quantitative analysis of the system COP can be done by evaluating each of these effects. The proposed evaluation method can also be applied to various types of Eco-cute.

Fig. 2: Prototype of the $CO_2$ heat pump for a central heating system tested at heat pump performance test facilities

Size: 828 (width) × 283 (depth) × 1,280 (height) mm
The prototype was tested utilizing the test facilities. We have developed a method of defrost control.

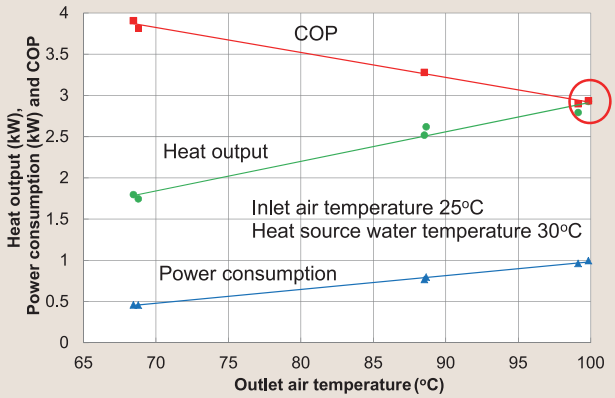


Fig. 3: Test results of the prototype for a small heat pump for industrial drying

In Figure 3, the horizontal axis shows the outlet air temperature and the vertical axis shows heat output, power consumption, and COP. Even if a high temperature of 100°C hot air was produced, a COP of about 3 was obtained (red circle in the figure).