# Highly-Efficiency Heat Pump

## Background and Objective

Heat pumps, such as air-conditioners or water heaters, etc. are widely used as a measure 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.

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

In this project, we evaluate the performance of next generation Eco-cute and develop a more efficient one. Also we assess the potential for heat pumps used in commercial and industrial sector with low GWP refrigerants.

## Main results

### 1. Establishment of the performance evaluation technology for Eco-cute

Eco-cute produces hot water using inexpensive night electricity and stores produced hot water in a tank. It is a heat storage system and its performance depends on daily hot water demands. The evaluation of consecutive three-day operation has been prescribed in Japan Refrigeration and Air Conditioning Industry Association standards. But the more long-term performance evaluation is needed because of the daily change of hot water demands. Setting up the heat pump performance test facilities (Fig. 1) and evaluating the performance of many kinds of Eco-cute, the CRIEPI established the performance evaluation technology, which consists of the technologies to keep air temperature and humidity settings in the chamber in which Eco-cute is installed and to set different daily hot water demands automatically and accurately over a consecutive 30-day operation period. Using the technology, small sized new types of Eco-cute were evaluated and knowledge about the operation patterns to consider the future direction of performance improvement was acquired.

### 2. Performance improvement of Eco-cute in winter conditions

To improve the efficiency of Eco-cute in winter conditions, which has a significant impact on its annual efficiency, evaporative heat transfer tubes for $CO_2$ refrigerant were investigated experimentally. The result showed that a tube with triangle fin and a tube with slim high fin were excellent (Fig. 2) [M09011]. Also, the study was started to solve the frost problems of outdoor heat exchanger in winter. The wind tunnel for evaporator test was installed to quantify heat pump performance degradation due to frosting and defrosting of outdoor heat exchanger and to develop heat transfer tubes, heat exchangers and heat pump systems with frost resistant and easy defrosting (Fig. 3).

### 3. Development trends of heat pumps with low GWP refrigerants

To evaluate low GWP refrigerants potential, the development trends of heat pumps with natural refrigerants such as water and $CO_2$ and with low GWP Freon were investigated and the challenges were summarized. The CRIEPI will conduct research and development of heat pumps with water and $CO_2$ as a refrigerant for residential room heating, commercial room cooling and heating and industrial high temperature process heating.

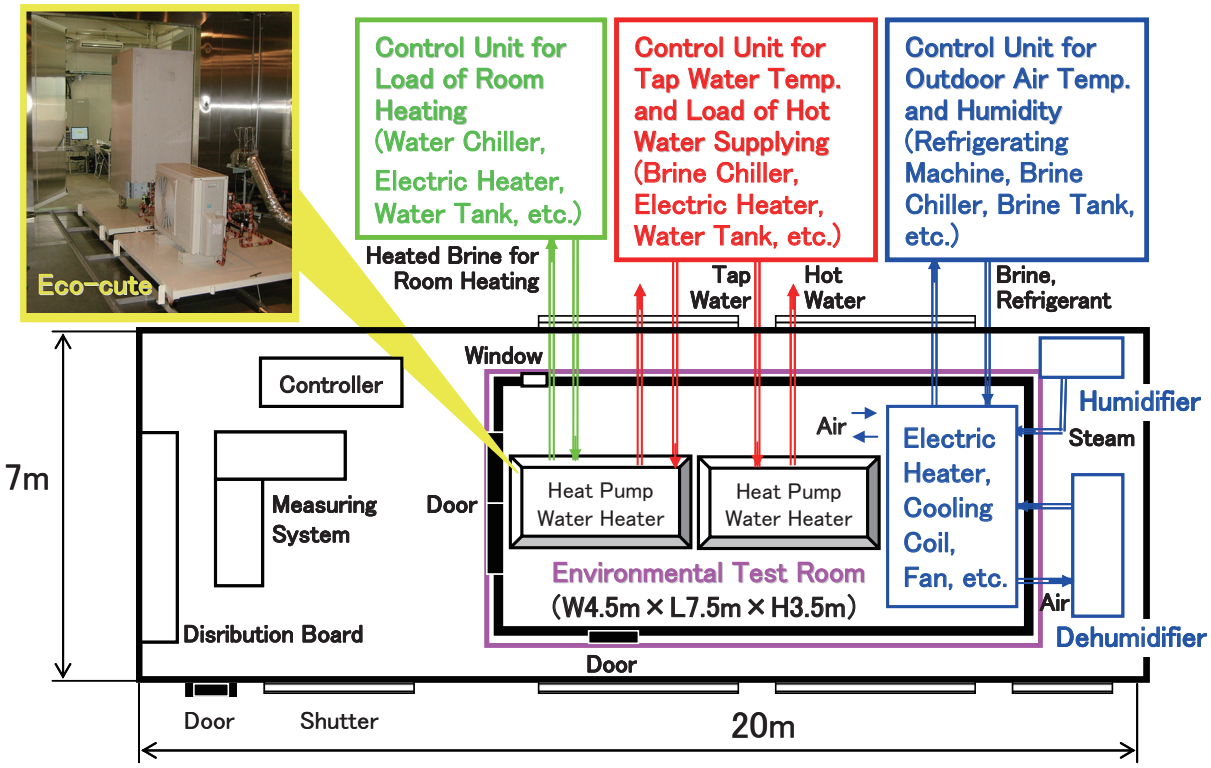
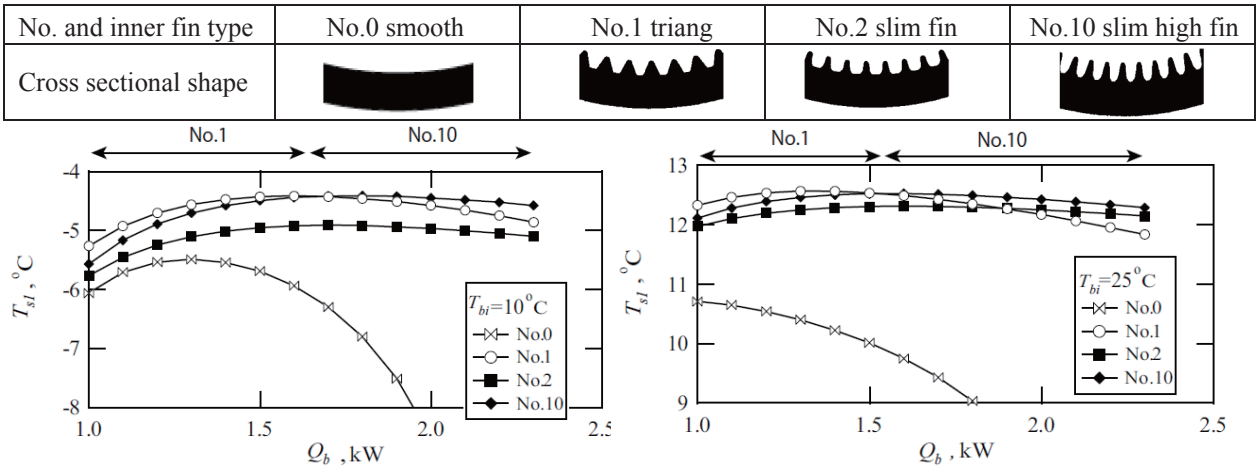



**Fig. 1 Heat pump performance evaluation test facilities**

This test facility evaluates the performance of heat pump water heaters under the various conditions of outdoor air temperature and humidity, tap water temperature and hot water demand.




**(a) Heat source brine temp. Tbi 10℃** **(b) Heat source temp. Tbi 25℃**

**Fig. 2 Investigation of evaporative heat transfer tube best suited to $CO_2$ refrigerant**

In the figures, horizontal axis *Qb* and vertical axis *Ts1* indicate respectively heat flow and saturation temperature of $CO_2$ at the tube exit. Higher value of *Ts1* means more efficient tube for $CO_2$. The result shows that a tube with the triangle fin (No.1) in low *Qb* and a tube with slim high fin (No.10) in high *Qb* are excellent.

**Fig. 3 Wind tunnel for evaporator test**

The wind tunnel was installed in the environmental test room shown in Fig 1. Evaporators and heat pump systems with frost resistance and easy defrosting will be developed using this tunnel.