Highly-Efficiency Heat Pump

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 on 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 2010, we won the imperial invention prize by the related patent.

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

Main results

1. Performance evaluation of various types of Eco-cute

In addition to the conventional type, various types of Eco-cute have been developed and commercialized, for example, small-sized type, multi-function type and cold area type. It is important to evaluate the performance of these equipments for considering the direction of the improvement. Thus utilizing the heat pump performance test facilities, the performance of Eco-cute for cold climates was evaluated. We have developed the method to quantify the performance degradation due to evaporator frosting and defrosting. For small-sized type, we finished the performance evaluation using the test facilities and embarked on a field test (Fig. 1) to compare the actual performance with the results obtained by using the test facilities.

2. Proposal of frost-free heat pump water heater

When an air source heat pump water heater (ASHPWH) works in frosting ambient air conditions, the average coefficient of performance (COP: water heating capacity / compressor input power) decreases significantly due to evaporator frosting and defrosting. Therefore we proposed frost-free ASHPWH system (Fig. 2). The system has a solid desiccant coated heat exchanger and a return air flow path. So it can produce hot water continuously and its average COP is estimated to be higher than that of a conventional system by 30% under the frosting ambient air conditions. This technology is also applicable to other air source heat pumps for heating, etc.

3. Development of small heat pump for industrial drying

For developing a small heat pump for drying industrial parts after washing with water, we designed and manufactured its prototype based on the technology developed for Eco-cute. The prototype uses water as heat source and CO_2 as a refrigerant. It can heat air efficiently with large temperature difference. We developed the counter flow CO_2-air heat exchanger which consists of fin and tube. The evaluation test results show that COP achieved over 3 under the condition of 3 to 4 kW air heating capacity, 25℃ inlet air temperature, 85℃ outlet air temperature, 30℃ heat source water temperature. It may reduce the power consumption to about 1 / 3 compared with the conventional process.

Fig. 1 Small-sized Eco-cute for field test
Heating capacity (max.): 10kW
Capacity of hot water tank: 185 liters
Size: 0.45m × 1.1m × 1.9m
Its footprint is about half of the conventional type.

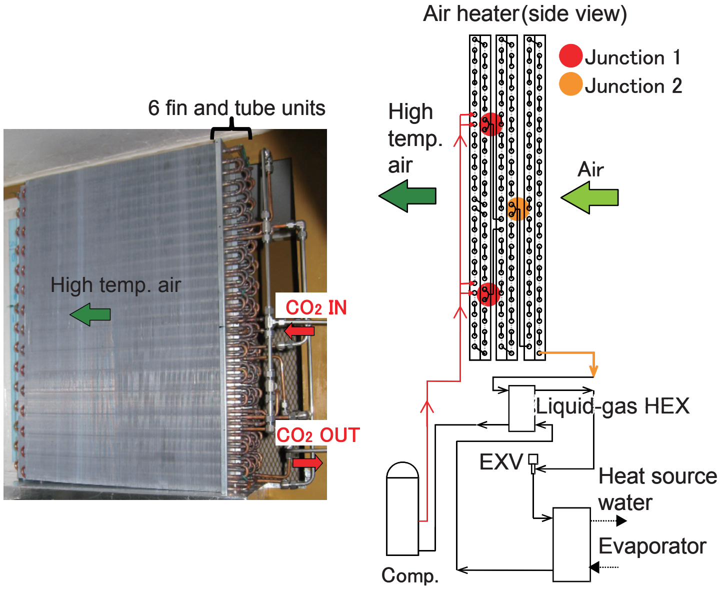
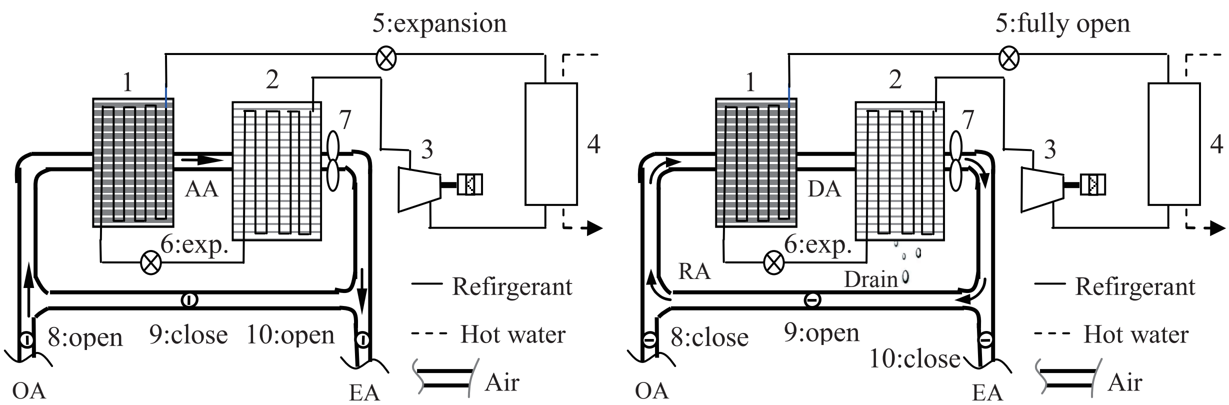


Fig. 3 Prototype of small heat pump for drying refrigerant circuit (right) and air heater (left)
Air heater is counter flow type and consists of 6 fin and tube units. First, CO_2 flows are four paths, becomes two at junction 1 and finally one at junction 2. By these flow paths, deterioration of heat transfer is prevented. Refrigerant circuit is basically the same as in Eco-cute.



(a) Adsorption mode (b) Desorption mode

1:Solid desiccant coated heat exchanger 2:Heat exchanger 3:Compressor 4:Hot water heat exchanger
5,6:Expansion valve 7:Fan 8,9,10:Damper
OA:Outer air EA:Exhaust air RA:Return air AA:Low-humidity air DA:Humid air

Fig. 2 Proposed frost-free air source heat pump water heater
This system can produce hot water continuously in the frosting ambient air conditions, with higher COP as compared with the conventional system. In this system, there are two modes of operation. In the adsorption mode, at the heat exchanger 1, the moisture of the air is absorbed and the refrigerant evaporates. Sensible heat of low-humidity air AA is used for evaporating the refrigerant at heat exchanger 2. In contrast, in the desorption mode, the water is desorbed from the adsorbent of heat exchanger 1 by the heat of the refrigerant which becomes middle temperature because of water heating at hot water heat exchanger 4, while the refrigerant evaporates by the sensible and latent heat of humid air DA and the drain is exhausted at heat exchanger 2.