A Thesis for the Degree of Ph.D. in Engineering

A Study on an Eco-friendly and High-performance Cooling System using Evapo-transpiration

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Thesis Abstract

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Thesis Summary

According to International Energy Agency, buildings contribute nearly about 40% total world energy consumption. Most of the consumption is used during their operational phase, especially for air conditioning, which causes peak-load in electricity demand in summer. Urban heat island recently has become a big issue for human's lives. Tokyo temperature has increased about 3.5°C in the past one hundred years, while global temperature increases about 0.7 °C.

Recognizing that heat released from outdoor unit of the air conditioning is one of the causes of heat island in the city, the objective of the study is to create a cooling system that does not exhaust heat to the environment. From the thermodynamic viewpoint, temperature is free from energy conservation. As the leaves of trees, they can keep the temperature or even make the air cooler while absorbing solar insolation, by evapo-transpiration. Learning from that phenomenon, an air-conditioning system that not only cools the indoor space but also can create comfortable space outdoor by using evapo-transpiration is proposed in this study. With the fact that latent heat of water vaporization gives high potential of cooling capacity, e.g., 1 g water evaporation in 1 second can absorb about 2.43 kW heat at a temperature of 30°C, it is expected that exhaust air from outdoor unit can reach to wet-bulb temperature, which is lower than that of ambient or dry-bulb temperature by 7°C at dry-bulb temperature of 30°C and the relative humidity of 50%.

Evapo-transpiration is applied to the condenser in the outdoor unit of the air conditioning system. Proposed condenser is copper-tubing covered by porous ceramics with tiny open holes, which can automatically spread water by the capillary phenomenon. The heat transfer coefficient is higher than that of the conventional air-cooled condenser from 3.5 up to 10 times. In addition, it also helps to reduce the condensing temperature; in consequence, reduce the work for compressor and energy consumption for air conditioning.

Experiments of an existing air conditioning system using air-cooled condenser, an air conditioning system with water-cooled condenser, and an air conditioning system with the proposed evapo-transpiration condenser have been done. Existing system is used as a baseline; while air conditioning system with water-cooled condenser is used to test the ability to reduce condenser temperature; and finally, the proposed system is to confirm the possibility of apply evapo-transpiration principle to air-conditioning system.

The result confirms that condenser temperature is reduced to ambient air from the water-cooled condenser. From simulation result, it is expected that any system, which has condenser temperature near to outdoor temperature, can increase its Coefficient of Performance (COP) up to 30 %.

For the prototype air conditioning system with evapo-transpiration condenser, it shows that the air outlet from the outdoor unit has almost the same temperature as that of the outdoor air. Since there is no spray of water in the system and the air just passes the wet surface of ceramics, the relative humidity of the outlet air is just slightly higher than that of the ambient, at an average of 5%. Therefore, the proposed outdoor unit does not release any heat to the environment. Hence, the problem of heat island can be reduced.

In addition, for the energy consumption at the specific case of experiment, the proposed system was confirmed to reduce the energy consumption up to 30 %. Last but not least, water condensed indoor can be utilized to cool the condenser outdoor.

In conclusion, the study has figured out the originality to create an air-conditioning system which can cool a space without release higher heat to the environment. The proposed system can help to reduce urban heat island problem by using the evapo-transpiration phenomenon. Moreover, it is also confirmed the possibility to save energy consumption using the proposed system compared to conventional air conditioning system.