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# Proposal of an eco-friendly high-performance air-conditioning system part 2. Application of evapo-transpiration condenser to residential air-conditioning system

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ABSTRACT

Improving performance of existing air-conditioning system and minimizing its environmental effect are requested from global environmental issues. A new air-conditioning system using evapo-transpiration condenser has been proposed. Evapo-transpiration condenser is a condenser that uses transpiration by keeping condenser surface wet and water evaporation enhancing heat-transfer rate. In this paper, a prototype of the new system is tested and compared with the existing system in summer weather of Japan. Hourly-average condenser-temperature is achieved to be 5–10 °C reduction compared to that of the air-cooled condenser. Without any optimization in system operation, up to more than 30% hourly integral power consumption is saved at ambient temperature below 31 °C from this prototype. Besides, temperature of outlet-air from outdoor-unit is nearly the same as ambient temperature, while its relative humidity is slightly higher. Special maintenance is not necessary for the new evapo-transpiration condenser.


# Proposition de système de conditionnement d’air hautement performant et écologique. Partie 2. Application du condenseur à évapotranspiration à un système de conditionnement d’air résidentiel

*Mots clés :* conditionnement d’air ; chaleur récupérée ; économies d’énergie ; îlot de chaleur ; condenseur à évapotranspiration

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## 1. Introduction

Air-cooled condenser is popularly used in small-scale air-conditioning system due to its advantages of convenient size and easy maintenance. However, it consumes high energy in summer weather, which causes a peak-load in electricity demand from July to September in Japan (Aoshima, 2010). Moreover, air-cooled outdoor unit releases exhaust-heat to the surrounding, which makes the temperature outside of buildings to increase and higher indoor cooling demand requires simultaneously. It also causes heat-island problem.

Some attempts have been done by using water vaporization instead of sensible heat of air to cool condenser. Most of them are using a water-cooled condenser accompanied with a cooling tower or combining two of them in an evaporative condenser in order to reduce condenser temperature, which can result in reducing pressure ratio between condenser and evaporator. Those are mostly used in medium or large scale air conditioning systems.

A conventional evaporative condenser, in which water is pumped to spray directly to condenser coil, has been in commercial for outdoor unit of split air-conditioning system (Ken Nittler, 2007). According to the company reports, their product provides a compliance saving of 39% of the cooling for statewide California weather. Because of direct contact of water and heat-transfer surface, condenser coil may suffer from mineral deposit which can decrease the performance. In order to avoid this problem, as well as expense for water treatment system, in direct evaporative cooling process has been applied to pre-cool air before entering condenser coil by using cellulose media pad wetted by pumped water. A 8.8-kW split air-conditioning system was investigated by Goswami et al. (1993) in Florida weather. The results show that about 20% of electric energy was saved. Using the same principle, Hajidavalloo (2007) applied for a window-air-conditioner in dry and high temperature area. The experimental results showed that thermodynamic characteristics of new system decreases about 16% power consumption and Coefficient of Performance (COP) increases about 55% at outdoor dry-bulb temperature of 45–46 °C.

Cellulose pad has also been used in water-cooled condenser of residential split air-conditioner of 3.5-kW cooling capacity in study of Hu and Huang (2005). A 98-W pump was used in the cooling tower. Steady state COP of this system is said to improve from 3.0 to 3.5.

Another innovative design of evaporatively-cooled condenser for residential-size heat pump system was found in the study of Hwang et al. (2001). The condenser is immersed in a cooling water tank, which is cooled by the rotating disks driven by a motor. The experimental results after optimizing short-tube length, amount of refrigerant charged and rotating speed showed that COP increases by 11–22%.

From the above improvement for small-scale air conditioning system, either additional power, i.e., disk motor, pump, is required; or the size of the unit is not considered.

In previous study, conventional air-cooled air-conditioning system has revealed its high condenser and compressor temperatures compared with those of a testing air-conditioning system that uses water-cooled condenser. In addition, conventional outdoor-unit releases exhause-heat, creating an uncomfortable space outside of buildings. Besides, an experiment of evapo-tranpiration heat-exchanger has been tested and confirmed its high performance compared with conventional air-cooled condenser.

In this study, we applied the evapo-transpiration heat exchanger to condenser of a residential air-conditioning system.

- We confirm temperatures achieved at condenser and compressor of the new outdoor-unit in the range of outdoor-temperature of 27–35 °C of summer weather in Tokyo region, Japan.
- Integral power consumption of the prototype system is compared with conventional system.
- Outlet air from new outdoor-unit is also compared with that of air-cooled unit.

## 2. Experiment

An existing split commercial air-conditioning system using R410A as refrigerant, nominal cooling capacity of 2.5 kW and manufacturer COP of 5.68 is used as baseline system. This conventional system has air-cooled condenser in outdoor unit. In this experiment, a new air-conditioning system is modified from the existing system by using new evapo-transpiration condenser. An actual view from the back side of outdoor unit is taken as in Fig. 1.

Sketch of new condenser is shown in Fig. 2, which includes: top water tank, copper tube covered by porous ceramics heat-exchanger and a bottom water tank. Water is spread automatically to horizontal direction by hydrophilic property of porous ceramics and flows downward vertically by gravity. As a result, ceramics surface is always kept wet. Air-flow by fan crosses this wet surface, enhancing evaporation. Remaining water that does not evaporate is collected in the bottom tank. The flow-rate of water is controlled manually by a valve to keep it comparable with rate of evaporation on ceramics surface. For this reason, collecting water in the bottom tank is negligible.

In previous study, we have used a small 13W-pump to circulate water from bottom tank to the first row of heat-

Fig. 1 – Actual new outdoor-unit (from the back side).