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Experimental Investigation of Condensation Heat Transfer in Ammonia Evaporative Condensers

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Abstract

This paper reports experimental data obtained for ammonia condensation heat transfer in an evaporative condenser. Experiments were carried out on a specially designed set-up equipped with both measuring and control devices, and a data acquisition system. Experiments were conducted for ammonia saturation temperature of 22ºC to 40ºC and condenser heat rejection rate ranging from 2000W to 6000W, during steady state condensation of ammonia. The experimental investigation aimed to determine thermal performances of the ammonia evaporative condenser under different operating conditions, namely as a function of: temperature difference between ammonia condensation and inlet air wet bulb temperature, cooling water mass flow rate and ammonia mass flow rate. Water film temperature distribution along the condenser's height has also been studied. Experimental results have been further compared to data in the open literature by authors with similar experimental investigations. The paper concluded that experimental results are in fairly good agreement with other authors work and consequently reliable. The paper also addresses the current ecological aspect implied by refrigerants, by using ammonia. Apart from its attractive thermo-physical properties, as compared to HFCs, ammonia is also an environment friendly natural refrigerant, known for its zero ozone depleting potential and zero global warming effect.

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Keywords: heat and mass transfer; evaporative condenser; ammonia.

1. Introduction

Evaporative condensers belong to a main class of heat exchangers used in refrigeration systems. As compared to other types of condensers, the evaporative condensers show a number of advantages among which it is worthwhile

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Nomenclature

h	enthalpy [J/kg]	*Greek symbols*	
$\dot{m}$	mass flow rate, [kg/s]	ε	deviation (relative error), [%]
p	pressure, [bar]	ρ	density, [kg/m^3]
P	electrical power [W]	φ	relative humidity, [%]
$\dot{m}$	mass flow rate, [kg/s]	*Subscripts*	
$\dot{Q}_k$	heat rejection rate, [W]	atm	atmosphere
r	latent heat of condensation, [J/kg]	k	condensation
t	temperature, [ºC]	NH_3	ammonia
$\dot{V}$	volumetric flow rate, [m^3/s]	p	air
x	air humidity ratio, [kg/kg]	w	water
w	velocity, [m/s]	1/2	inlet/outlet

mentioning: they reduce water pumping and chemical treatment requirements associated with cooling tower/refrigerant condenser systems; they require less coil surface and air flow to reject the same heat, in comparison with air-cooled condensers; they can operate at a lower condensing temperature than an air-cooled condenser because the condensing temperature in an air-cooled condenser is determined by the ambient dry- bulb temperature, while in evaporative condensers, heat rejection is limited by the ambient wet-bulb temperature, which is normally 8 to 14K lower than the ambient dry-bulb; they provide lower condensing temperatures than the cooling tower/water-cooled condenser because the heat and mass steps, between refrigerant and cooling water and between water and ambient air, are more efficiently combined in a single piece of equipment, allowing minimum sensible heat of the cooling water. As a consequence, evaporative condensers are the most compact for a given capacity, [1], [2].

Experimental investigations on evaporative condensers address the current issue of energy savings by assisting improved design and higher thermal performances (heat rejection rate) of these heat exchangers. The literature review performed by the authors reveals several experimental studies carried out along time by different authors on evaporative condensers that can be used as comparison data. This review includes works carried out by**:** [3] and [4].

Apart from thermal performances of the evaporative condenser of given geometrical configuration, under different operating conditions, authors also present experimental results on water film temperature distribution along the condenser's height.

2. Experimental set-up

The evaporative condenser under study is placed inside the vertical section of an insulated air loop of rectangular shape (500 x 500 mm) (Figure 1), made of galvanized steel and equipped with multiple regulating and

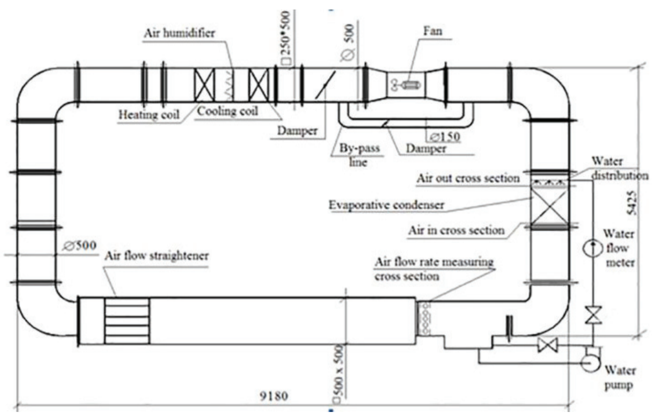

Fig. 1. Experimental set-up