INTERNATIONAL JOURNAL OF REFRIGERATION 66 (2016) 21–31

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/ijrefrig

Consolidated experimental heat and mass transfer database for a reduced scale evaporative condenser

Ivoni Carlos Acunha Junior [a], *Paulo Smith-Schneider* [b,*]

[a] *Department of Refrigeration, Federal Education, Science and Technology Institute of Rio Grande do Sul – IFRS, Rio Grande, Brazil*

[b] *Mechanical Engineering Department, Federal University of Rio Grande do Sul – UFRGS, Porto Alegre, Brazil*

ARTICLE INFO

Article history:
Received 18 June 2013
Received in revised form 24 November 2015
Accepted 18 December 2015
Available online 17 February 2016

Keywords:
Evaporative condenser
ANSI/ASHRAE 64–1995 standard
Condenser bench scale prototype
Experimental artificial neural network
Design of experiments

ABSTRACT

This work reports an experimental investigation on the heat and mass transfer phenomena observed in a reduced scale evaporative condenser, operated under laboratory controlled conditions. Experimental results are organized on sequences of consolidated samples, ready to be used for analysis and simulation by researches on refrigeration and transport phenomena. Heat rejection is kept constant for each of the 40 samples as a function of the inlet air temperature, volumetric flow rate and the spray water mass flow rate. The inlet wet bulb temperature showed to be the most significant parameter, leading to a predictive model of the mean rejected heat, with a correlation coefficient R^2 of 79.3%, and a maximum error of 13.28%.

Base de données expérimentales consolidées de transfert de chaleur et de masse pour un condenseur évaporatif à échelle réduite

Mots clés : Condenseur évaporatif ; Norme ANSI/ASHRAE 64-1995 ; Prototype d'essai d'un condenseur ; Réseau neuronal artificiel expérimental ; Conception d'expériences

* *Corresponding author.* Federal University of Rio Grande do Sul, Rua Sarmento Leite, 425, 90050-170, Porto Alegre, RS, Brazil. Tel.: 0 (+55) 51 33 08 39 31; Fax: 0 (+55) 51 33 08 32 22.

E-mail address: pss@mecanica.ufrgs.br (P. Smith-Schneider).

http://dx.doi.org/10.1016/j.ijrefrig.2015.12.006

Nomenclature

a	variable output
A	electrical current [A]
EC	evaporative condenser
i	enthalpy [kJ kg^{-1}]
$\dot{m}$	mass flow rate [kg s^{-1}]
P	gauge pressure [barg] or absolute pressure [bara]
$\dot{q}$	heat transfer rate [W]
$\dot{q}_{\Delta}$	modified heat transfer rate [W]
$\bar{q}$	mean rejected heat [W]
T	temperature [°C]
u	measurement uncertainty
V	electrical tension [V]
$\dot{V}$	volumetric flow rate [m^3 s^{-1}]
W	humidity ratio [kg$_W$kg$_{DA}$$^{-1}$]
Xi	independent parameters
x	vapor quality
Y	measured quantities

Greek symbols

Δ	variation or deviation
ε	effectiveness
ρ	density [kg m^{-3}]

Subscripts

air	air
cond	condensation
DA	dry air
DB	dry bulb
Hw	hot water
in	inlet
out	outlet
r	refrigerant fluid
sat	saturation
Sw	spray water
w	water
WB	wet bulb

1. Introduction

Condensation of refrigerant fluids on large scale systems are a relevant technical and scientific topic as high performance equipments can strongly impact capital and operational costs. Although more sophisticated than single phase condensers, evaporative condensers appear as an option due to their higher heat transfer capacity per unit area. Modeling evaporative condenser brings an extra effort due to the water and air biphasic flow at its external side. Advanced and more realistic correlations are useful tools for accessing its operation conditions and energy performance.

One of the first and more relevant works on evaporative condensers was developed by Parker and Treybal (1961), whose transport correlations were studied by several researches and are still used nowadays. They pointed out that the water temperature profile must be considered along its flow.

Many subsequent works (Mizushina et al. (1967), Leidenfrost and Korenic (1982), Bykov et al. (1984), Dreyer and Erens (1990) focused on the determination of heat and mass transfer correlations, together with performance estimation. Zalewski and Gryglaszewski (1997) introduced the air wet bulb temperature as a parameter for these correlations. Halasz (1998) proposed a dimensionless model for any kind of system operating with evaporative cooling, with good agreement to experiment data for regular operational conditions.

Qureshi and Zubair (2006a) introduced the effect of external tube incrustation on the heat transfer performance. In a further work, the same authors (Qureshi and Zubair 2006b) identified by sensitivity analysis that the condensation temperature is the most relevant parameter for evaporative condensers, and its behavior was not sensible to the water to air flow ratio. Their model also took into account the effect of the inlet air relative humidity on the condensation temperature and therefore, on the equipment performance. Evaporative condensers and cooling towers were analyzed by the same authors (Qureshi and Zubair 2007) following a second law approach, showing that their efficiency, and consequently the exergy destruction, was inversely proportional to both the condensation temperature and the refrigerant flow rate.

Studies on cooling towers can be useful to understand similar phenomena observed on evaporative condensers. Facão (1999) performed an experimental study on a 10 kW direct contact cooling tower, finding similar results to Parker and Treybal (1961) and Niitsu et al. (1967). Rezaei et al. (2010) developed an experimental approach for dry and wet cooling towers, validated afterwards by computational simulation.

Literature review showed that reliable data from the behavior of evaporative condensers can help build predictive models and new heat and mass transfer correlations. The present work reports the laboratorial investigation on a reduced scale evaporative condenser under controlled conditions. A set of experimental data sequences on steady state regime was consolidated and ready to be used by other researchers on the field of refrigeration and transport phenomena.

2. Experimental setup

An experimental laboratorial rig was assembled to perform controlled tests (Fig. 1), following the ANSI/ASHRAE 64–1995 standard, based on a calorimetric essay methodology at controlled environmental conditions.

The rig center device is a reduced scale evaporative condenser, followed by a set of auxiliary equipments sized in accordance to the evaporative condenser geometrical and capacity. R-22 was chosen as the refrigerant fluid due to its less toxicity, when compared to R-717, often used on industrial applications.

Four main streams can be identified on that figure: the refrigerant stream (continuous bold line), the spray water stream (dot line), the air (continuous line) and finally an auxiliary heat source stream (dashed line). Following the refrigerant fluid stream, one can identify its path across the evaporative con-