Applied Thermal Engineering 69 (2014) 1–10

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

Experimental optimization of the thermal performance of a dry and adiabatic fluid cooler

Manuel Lucas [a,*], Pedro Martínez [a], Clemente G. Cutillas [a], Pedro Juan Martínez [a], Javier Ruiz [a], Antonio S. Kaiser [b], Blas Zamora [b]

[a] Department of Mechanical Engineering and Energy, Universidad Miguel Hernández, Avda. de la Universidad, s/n, 03202 Elche, Spain
[b] Department of Thermal and Fluids Engineering, Universidad Politécnica de Cartagena (Campus Muralla del Mar), Dr. Fleming, s/n, 30202 Cartagena, Spain

HIGHLIGHTS

- The efficiency of evaporative section decreases with increasing velocity of air flow.
- The global heat transfer coefficient and the area (UA) increases by increasing the air velocity.
- The effect of heat transfer is dominant compared to what happens in the evaporative section.
- The beneficial effect of evaporative section increases with decreasing relative humidity and increasing ambient temperature.

ARTICLE INFO

Article history:
Received 12 July 2013
Accepted 15 April 2014
Available online 24 April 2014

Keywords:
Adiabatic cooler
Cooling tower
Legionella
Evaporative cooling

ABSTRACT

The energy and environmental implications of a refrigeration cycle are largely conditioned by the choice of the condensing system. The dry and adiabatic fluid cooler works as a standard fluid dry cooler enhancing its capacity with adiabatic pre-cooling of the air intake. The objective of this study was to experimentally optimize the thermal performance of a dry and adiabatic fluid cooler. The experimental study has shown how the efficiency of the evaporative section decreases when air flow velocity increases. With respect to the product of the global heat transfer coefficient and the area (UA), we have seen how it increases by increasing the air velocity through the outside of the pipes and when the water flow inside increases. A model has been set to search for the optimal operating velocity. The average and maximum differences between the modeling and experimental outlet water temperatures are 0.30 °C and 0.92 °C respectively. The effect of ambient temperature and relative humidity on the outlet water temperature is also shown. For an ambient temperature of 30 °C and 50% relative humidity, the outlet water temperature of the dry and adiabatic fluid cooler is 7.5 °C lower than a dry system.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Air conditioning systems are used more and more frequently in buildings due to the improvement of both the quality of life and comfort levels in current societies. Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the energy efficiency performance of buildings affirms that more than 40% of the final energy consumption in the European Community is demanded by the residential sector and the tertiary sector. In addition, this directive points out the importance that the European Union attaches to energy savings in the tertiary sector, where air conditioning systems have clearly contributed to increase the power demanded by this sector.

Indeed, the installed capacity of air conditioning systems has caused an increase in the peak demand of electricity during the summer period in countries like Spain, with a similar value to the peak demand in winter [1]. Moreover, the current trend to replace the condensed water systems for air-cooled systems in centralized facilities has increased this fact. For reference, the appropriate range for the use of water for condensation in refrigeration equipment can be set between 120 and 5000 kW, and within that range they are competing with the possibility of using air cooled up to 1500 kW [2].

A fundamental difference between the water-cooled and air condensation systems is that the former uses lower levels of temperature in the refrigeration system, so, thereby maintaining the

* Corresponding author. Tel.: +34 966 65 88 87; fax: +34 966 65 89 79.
E-mail address: mlucas@umh.es (M. Lucas).

http://dx.doi.org/10.1016/j.applthermaleng.2014.04.033
1359-4311/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

A	heat transfer area (m^2)
A_V	surface area of water droplets per unit volume of tower ($m^2\ m^{-3}$)
$c_{p,a}$	specific heat at constant pressure of moist air ($J\ kg_a^{-1}\ K^{-1}$)
$c_{p,w}$	specific heat at constant pressure of water ($J\ kg_w^{-1}\ K^{-1}$)
C	air velocity ($m\ s^{-1}$)
C_{min}	minimum value of the heat capacity rate between C_w and C_a ($J\ s^{-1}\ K^{-1}$)
C_r	heat rate capacity ratio, C_{min}/C_{max}
DAFC	dry and adiabatic fluid cooler
DFC	dry fluid cooler
e	thickness of the tube wall (m)
f	friction factor
F	correction factor
h	enthalpy of moist air ($J\ kg_a^{-1}$)
h_C	convective heat transfer coefficient of air ($W\ m^{-2}\ K^{-1}$)
h_D	convective mass transfer coefficient ($kg_a\ m^{-2}\ s^{-1}$)
h_f	specific enthalpy of saturated liquid water ($J\ kg_w^{-1}$)
$h_{f,w}$	specific enthalpy of water evaluated at T_w ($J\ kg_w^{-1}$)
h_g	specific enthalpy of saturated water vapor ($J\ kg_w^{-1}$)
$h_{g,T}$	specific enthalpy of saturated water vapor at T ($J\ kg_w^{-1}$)
$h_{g,w}$	specific enthalpy of saturated water vapor at T_w ($J\ kg_w^{-1}$)
$h^0{}_g$	specific enthalpy of saturated water vapor evaluated at 0 °C ($J\ kg_w^{-1}$)
$h_{fg,w}$	change of phase enthalpy($h_{fg,w} = h_{g,w} - h_{f,w)}$ ($J\ kg_w^{-1}$)
h	local heat transfer coefficient of the heat exchanger ($W\ m^{-2}\ K^{-1}$)
j	Colburn factor, $Nu/Re_{Dc}\ Pr^{1/3}$
k	thermal conductivity ($W\ m^{-1}\ K^{-1}$)
Le	Lewis number $Le = h_C/h_D c_{pa}$
$\dot{m}_a$	mass flow rate of dry air ($kg_a\ s^{-1}$)
$\dot{m}_w$	mass flow rate of water ($kg_a\ s^{-1}$)
NTU	number of transfer units
Nu	Nusselt number
Pr	Prandtl number
Q	total heat transfer (W)
R	thermal resistance ($K\ W^{-1}$)
Re	Reynolds number
T	dry bulb temperature of moist air (K)
T_{wb}	wet bulb temperature of moist air (K)
T_w	water temperature (K)
TC	tower characteristic
U	global coefficient of heat transfer ($W\ m^{-2}\ K^{-1}$)
UA	overall conductance of the heat exchanger ($W\ K^{-1}$)
V	volume of tower (m^3)
W	humidity ratio of moist air ($kg_w\ kg_a^{-1}$)
$W_{s,w}$	humidity ratio of saturated moist air evaluated at t_w ($kg_w\ kg_a^{-1}$)

Greeks symbols

ε	heat exchanger effectiveness
δ	thickness of the filling material (m)
δ_f	thickness of the fins (m)
η	fin efficiency
ΔT_m	log mean temperature difference (K)

Subscripts

a	moist air
f	fin
i	water-side of the heat exchanger
o	air-side of the heat exchanger
w	water
1	inlet
2	outlet

other operating conditions, energy consumption and cost equipment performance is lower. The effect of increasing the condensation temperature on the power absorbed by the compressor can be from 1.8 to 4% per degree Celsius [3], depending on the cycle under consideration and the refrigerant used. The worst energy efficiency of air-condensed systems is associated with the increase in CO_2 emissions to the atmosphere.

Cooling towers are equipment devices commonly used to dissipate heat from water-cooled refrigeration, air conditioning and industrial processes. The principle of operation is based on distributing or spraying water over a heat-transfer surface across or through which a stream of air is passing [4]. As a result, water droplets are incorporated in the air stream and, depending on the velocity of the air, will be carried out of the unit. This is known as drift and it is independent of water lost through evaporation.

Cooling tower drift is objectionable for several reasons [5]: firstly, because it represents an emission of chemicals or microorganisms to the atmosphere; secondly, corrosion problems can affect equipment, piping and structural steel, and can be the source of the electrical system's failure. In the case of cooling towers, undoubtedly, the most well known pathogens are the multiple species of bacteria collectively known as Legionella. These bacteria tend to thrive at the range of water temperatures frequently found in these cooling systems. Hence, workers or other people near a cooling tower may be exposed to drift, may inhale aerosols containing the Legionella bacteria, and may become infected with the illness. Several Legionella outbreaks have been related to cooling towers [6].

In Spain, some local Governments tend to restrict the installation of cooling towers due to numerous severe outbreaks of Legionella [7]. The local government of the city of Murcia has forbidden the installation of cooling towers in the metropolitan area [8]. The regional government of Valencia has used public funds [9] to replace cooling towers with a safer alternative: standard dry coolers. Following this tendency, some companies, commercial building owners with large air conditioning systems (thousands of kilowatts), have replaced cooling towers with dry coolers. This is for human health and energy efficiency and sustainability purposes.

The answer that the market has come up with due to the administrative pressure exerted on the cooling towers is the search for alternatives to dissipate heat from industrial plants, refrigeration and air conditioning. Today, air-cooled heat exchangers are the commercial alternatives proposed to replace cooling towers. They have a clear advantage from a public health approach, since they are non-risk installations. However, from an energy point of view, power consumption and cost of operation are increased. Besides, and as mentioned before, their energy efficiency is lower and they have higher CO_2 emissions to the atmosphere.

In addition to traditional solutions – such as condensation from cooling towers, evaporative condensers and air condensers – commercially hybrid devices are emerging as an alternative. These hybrid systems seek a trade-off between environmental impact and energy consumption. Yang et al. [10] investigated how water mist evaporative pre-cooling can be applied to air-cooled chillers to improve the chillers' efficiency. The experimental results showed

Download English Version:

https://daneshyari.com/en/article/7049028

Download Persian Version:

https://daneshyari.com/article/7049028

Daneshyari.com