Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 85 (2016) 461 – 471

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO - YRC 2015, 18-20 November 2015, Bucharest, Romania

A review of indirect evaporative cooling technology

Bogdan Porumb[a], Paula Ungureşan[a], Lucian Fechete Tutunaru[a], Alexandru Şerban[b], Mugur Bălan[a*]

[a] *Technical University of Cluj-Napoca, Bd. Muncii 103-105, Cluj-Napoca, 400641, Romania*
[b] *"Transilvania" University of Braşov, Str. Universităţii 1, Braşov 500068, Romania*

Abstract

The paper presents actual knowledge concerning the indirect evaporative cooling (IEC). This cooling technology is promising to develop in the near future due to its very low energy consumption and high efficiency in its range of applications. The review is presenting in details: theory, working principles, flow and construction. The IEC equipment and technology is suitable in different air conditioning applications: commercial, industrial, residential or data centres. The IEC technology is completely environmental friendly and has very low global warming impact. The single disadvantage of IEC is the water consumption.

Peer-review under responsibility of the organizing committee EENVIRO 2015
Keywords: Indirect evaporative cooling, regenerative cooling, dew point cooling, Maisotsenko cycle, energy efficiency

1. Introduction

The evaporative cooling (EC) technology is based on heat and mass transfer between air and cooling water. Direct evaporative cooling (DEC) is based on *mechanical and thermal contact* between air and water, while indirect evaporative cooling (IEC) is based on heat and mass transfer between two streams of air, separated by a *heat transfer surface* with a dry side where only air is cooling and a wet side where both air and water are cooling.

Both DEC and IEC are characterised by very high energy efficiency but also by significant water consumption rates.

* Corresponding author. Tel.: +4-026-440-1670; fax: +4-026-441-5490.
E-mail address: mugur.balan@termo.utcluj.ro.

Peer-review under responsibility of the organizing committee EENVIRO 2015
doi:10.1016/j.egypro.2015.12.228

In the case of IEC technology, on the dry side of the heat transfer surface (dry surface), is flowing the primary (or product) air that is cooling down. On the wet side of the heat transfer surface (wet surface), is flowing the secondary (or working) air in mixture with water.

The goal of this study is to present from both qualitative and quantitative point of view, the available scientific information concerning different aspects related to the IEC: construction principles, flow schemes and working processes.

2. Theory

2.1. Direct evaporative cooling (DEC)

The working principle scheme of the DEC equipment and a simplified flow scheme are presented in figure 1. The warm inlet air (1) enters in a pad which is sprayed with water at the wet bulb (WB) temperature of the inlet air. The heat transfer is realised from the warm air to the cold water. The heat is transferred by the air stream as sensible heat and is absorbed by the water as latent heat. Corresponding to the value of latent heat, a part of the water is evaporated being embedded by diffusion into the flowing air, increasing the moisture content of this air. The temperature of the outlet air (2) decreases due to the sensible heat transferred by the air, but the enthalpy of the outlet air will be the same with the enthalpy of inlet air as effect of the latent heat recovered into the air as moisture.

The working process of the DEC equipment is presented in the psychrometric chart in figure 2.

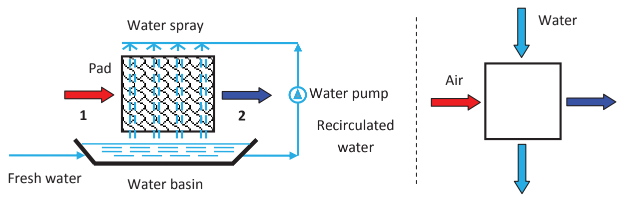

Fig. 1. Working principle scheme and simplified flow scheme of the DEC

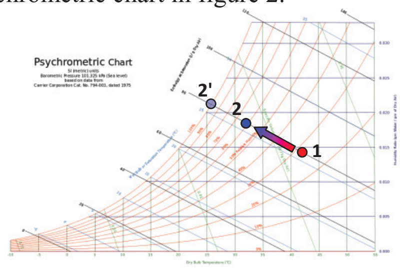

Fig. 2. The working process of the DEC

The working process (1-2) is realized at constant enthalpy as it can be observed on the chart. At limit, the cooling process could continue until the state of saturation (2').

The main advantage of DEC is represented by the very simple construction of the equipment. The main disadvantage of the DEC is represented by the increasing of the air moisture content which may be undesirable for certain applications.

2.2. Indirect evaporative cooling (IEC)

The working principle scheme of the IEC equipment [2], [3], [7], [11], [12], [15], [17], [18], [22], [24], [26], [30-33] is presented in the left side of figure 3. The warm primary (or product) air (1) is flowing inside the dry channels and transfers heat through the heat surface to the wet channels. At outlet, the primary (or product) air (2) will have a lower temperature as at inlet, due to the transferred heat. The secondary (working) air (3) is flowing inside the wet channels together with the water. The behaviour of the air and water in the wet channel is similar with the DEC process. The water temperature is the WB temperature of the secondary air. The heat transferred through the surface between the dry and wet channels is absorbed by the water as latent heat and a corresponding part of the water is evaporated being embedded by diffusion into the secondary air, increasing the moisture content of this air.

If the secondary air arrives at the saturation state, after this stage forward the heat from the primary air is split as latent heat absorbed by the water and as sensible heat absorbed by the secondary air. Thus, the temperature of the secondary air at the outlet (4) can be one of the following:

a. Lower than the WB temperature of the secondary air at the inlet (no saturation);

b. Equal with the WB temperature of the secondary air at the inlet (saturation is reached at the outlet);