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Performance analysis of novel dew point evaporative cooler with shell and tube design through different air-water flow configurations

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ABSTRACT

The complex design of a dew point evaporative cooler (DPEC) is the largest impediment to the globalization of such a high-performance system. Therefore, in this paper, we introduce a new design for the DPEC which eliminates the complexity barrier and significantly improves the system's performance. The new design consists of one shell and a bank of tubes. The single shell works as a working channel, while the tubes work as primary channels. A solid mathematical model has been developed which can predict the system's performance with high accuracy, as it was validated against three experimental studies. Throughout the analysis, the energy and thermal performances of the current model has been compared to the conventional DPEC with flat plate design for two air-water flow configurations, namely, parallel and counter air-water flow configurations. It was found that, under a wide range of operational and geometrical conditions, the new cooler consistently outperformed the flat plate type cooler by producing colder air by about 3.1 °C and improving energy efficiency by about 12.2 %. Meanwhile, the parallel air-water flow configuration produced much colder water than the counter configuration, accounting for 15.76 °C (140 %) colder.

1. Introduction

Over the years, evaporative cooling, in general, has been considered as one of the most consistent and relible sources of cooling in buildings and industries owing to its simplicity, low-cost, and ease of access. Besides, compared to space cooling refrigeration systems (SCRSs), it lacks hydrofluorocarbon coolants that have been banned over the past decades. Such working fluids must be pressurized and de-pressurized to transport heat from one zone to another and produce cooling. This process consumes a high amount of electrical energy that eventually contributes to the global warming phenomenon through the emission of greenhouse gases [1,2]. In 2022 alone, the SCRSs approximately accounted for 17 % of overall electricity consumption and 8 % of overall greenhouse gas emissions worldwide [3]. In consequence, the SCRSs result in high electricity bills, high initial and maintenance costs, and severe environmental damage [4,5]. Therefore, the environmentally friendly characteristics of the evaporative coolers led many researchers to study such a system and attempt to improve its performance through many approaches [6–11]. The limitation of high humidity content and wet bulb temperature of product air are two of the common impediments of the direct evaporative coolers [12,13]. However, in 2003, a group of researchers [14] was able to overcome these impediments and boost the system's performance by introducing a new heat and mass exchanger (HMX) with novel design from which the air was cooled toward the inlet air's dew point temperature, yet keeping the humidity ratio unchanged. This system was named the Maisotsenko cycle (M-cycle). It distinguished from direct evaporative cooler by precooling the air within the cooler inside the primary channel before diverting to the working channel.

Since the first innovation, the performance of such a system has been continuously improving through the endeavors of many researchers, and it came with other names such as dew point and regenerative evaporative coolers. Such studies include experimental-based, computational-based, and combined studies, each contemplating a different aspect, i.e., geometrical investigation, air-flow configurations, mathematical approaches, weather assessment, and structural material. Xu et al. [15] employed a corrugated shape plate as a new design for the

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