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MATHEMATICAL MODELING OF NOVEL INDIRECT-DIRECT EVAPORATIVE COOLING UNIT

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ABSTRACT

In this study, a mathematical model has been built to simulate two stages, indirect and direct evaporative cooling units working on the principle of double (indirect/direct) effect. The evaporative unit consists of two stages; the sensible heat exchanger and the cooling tower composing the indirect evaporative cooling, which represents the first stage, where as the direct evaporative cooler represents the second stage. The modeling results show the wet-bulb effectiveness is (1.185) at 45°C system inlet dry-bulb temperature, 5 g/kg humidity ratio, 35% air extraction rate, 0.1 L/s water flow rate and 0.425m^3/s inlet air volumetric flow rate. A maximum COP of (14.88) is recorded at these above conditions. In addition, it is shown that the predicted results of system COP is much higher than the measured by (6%) to (10%) at the same performance circumstances.

Keywords: inlet dry bulb temperature, vapour compression cycle, extraction ratio.

1. INTRODUCTION

Many countries suffer from the problem of high dry bulb temperatures in summer season that carries the burdens of high power demand of air condition equipment's. A substantial percentage of power burdens can be resolved by employing the evaporative cooling technique. The effectiveness of evaporative cooling is depending on the advantage of the large difference between the dry-bulb temperature and the wet-bulb temperature, which can be used positively in evaporative cooling systems. Iraq is one of these countries that have a desert climate and characterized by summer high dry-bulb temperature and dryness. Also, along the summer period that could spans for seven months from April to October, the day time often exceeds 49 C° with an average daily temperature over 37C° [1], in most of summer season. As a result, a large amount of power is consumed for air-conditioning (A/C) purposes. This indirect evaporative cooling technique is pledging to evolve in the next few decades owing to its elevated efficiency in a broad range of thermal applications, and faint consumption of energy [2].

The cooling performance of an indirect evaporative technique has been investigated by many researches. Navon and Arkin [3] studied the capability of using indirect-direct evaporative cooling for residential uses in desert areas of Palestine. The system showed the ability of providing a higher level of thermal convenience wherever the external humidity is around 80%. Generally speaking, the evaporative cooling can be considered as an applicable and appealing passive cooling technique for variant atmospheric conditions, where as great endeavors has been put in for developing and upgrading the effectiveness and applicability of such systems. Furthermore, there have been respectable environmental and economic profits in utilizing the traditional air conditioning systems owing to the persistent augmentation in its thermal efficiency. El-Dessouky [4] developed a membrane air dryer coupled with a conventional direct-indirect evaporative cooler. It was found that the drier takes off the humidity from the entering flowing air, and the air could be cooled to a minimum temperature by employing a subsequent evaporative cooler. They results showed that a reasonable cooling performance can be achieved by using such a system. It was also shown that when combining this system with mechanical vapor compression system, exemplary thermal conditions may be reached, e.g. about 50% electricity savings are obtained. Gomez [5] developed an evaporative cooling unit made of a ceramic, which works as a semi-indirect cooler. The water that is cooled in a cooling tower is passed from the annulus passage of the ceramic tubes. Whereas, the air entering from outside passes during the central zone. On the other hand, the chilled water is evaporated due to its flowing over the ceramic pores. Such a system allows indoor air recirculation that is not possible to be occurred in the traditional evaporative cooling units. Using of such system was experimentally verified and (5-12)°C temperatures drop was obtained under various conditions.

Jain [6] developed and investigated an evaporative cooler working under two-stages. The researcher attempted to augment the thermal efficiency of cooling unit to be working under higher humidity and lower air-conditioning temperature; such a cooling system could provide necessary comfort even with the high outside humidity. An evaluation for the cooling system was performed in terms of thermal efficiency, temperature reduction, and effectiveness of using a two-stage evaporative cooling technique over single evaporation. The results showed that the efficiency of a single evaporation is ranging between (85-90) %. However, the effectiveness of utilizing a two-stage method through a single evaporation was found to be ranging between (1.1-1.2). Riangvilaikul and Kumar [7] developed and investigated experimentally an unfamiliar dew point evaporative cooling device for cooling the ventilation air sensibly. A good comparison between their numerical and