environmental sciences proceedings

Proceeding Paper

Test Bench for Complete Characterization of Evaporative Cooling Pads †

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† Presented at the Innovations-Sustainability-Modernity-Openness Conference (ISMO'22), Bialystok, Poland, 26–27 May 2022.

Abstract: Nowadays, we can find many studies about evaporative cooling pads, but a uniform methodology does not exist for experimental tests, and many factors are less studied. Our goal is to design and build a versatile experimental facility that enables the characterization of these pads under different operating conditions: airflow (velocity), relative humidity, temperature, pad thickness, pad material and water distribution system. The test bench will permit the use of different water distributors and any type of pad material with three different thickness.

Keywords: experimental facility; direct evaporative cooling; pad thickness; pad material; water distribution system

Citation: Tejero-González, A.; Boubkari, A.; Simón-Caicoya, M.; Sánchez-Noriega, E.A. Test Bench for Complete Characterization of Evaporative Cooling Pads. *Environ. Sci. Proc.* **2022**, *18*, 8. https://doi.org/10.3390/environsciproc2022018008

Academic Editors: Iwona Skoczko, Dorota Anna Krawczyk and Ewa Szatyłowicz

Published: 30 August 2022

1. Introduction

The evaporative cooling of air is a natural phenomenon that occurs when water evaporates within it, absorbing the latent heat of vaporization and yielding a reduction in air sensible heat. This can be enhanced through larger contact between air and water, which can be implemented by wetting porous surfaces or by water spraying. If cool and humidified air is directly supplied to the target space, we call it direct evaporative cooling (DEC). This technique is widely used in outdoor spaces [1], but also in large spaces where the increased relative humidity has a limited effect, such as industrial [2], greenhouse [3], and intensive farming [4] facilities.

For a proper assessment of the application of DEC from wetted surfaces, it is necessary to characterize in detail the behavior of the different pads available, either as new designs and prototypes or commercial pads. The present work briefly reviews the existing literature and analyses the main influence factors and the key operating parameters. Once identified, a test bench is designed and conceived to implement any type of evaporative cooling pad in terms of material and geometrical characteristics, as well as different water distribution systems.

2. Key Factors in Direct Evaporative Cooling Pad Operation

There are several factors known to affect the operation of evaporative cooling pads notably. For instance, hot and dry climates are accepted to be the most favorable conditions [5]. However, air psychrometric conditions are usually measured in the experiments, but not controlled. Most research focuses on the effect of dry bulb temperature, but not on air humidity. On the contrary, many studies measure and control the airflow or air velocity supplied to the pad, relating it the saturation effectiveness, pressure drop, and water consumption. Concerning waterflow rate, its effect on the pressure drop and the saturation effectiveness is negligible if it is enough to maintain the pad completely wetted. Finally, the pad material, configuration, its thickness, and other geometric characteristics are also decisive to the system's operation [6].

The existing literature provides a great number of results derived from the characterization of different DEC pads made of a variety of materials with different geometric characteristics [7]. However, the description of the pad characteristics is usually incomplete, making the comparison and extrapolation of results difficult [6]. Moreover, many works measure but do not control the operating factors, and many parameters of relevance for DEC pad applications, such as transient operation, risk of water entrainment, and material decay, are not studied. Next, the design and construction of a test bench for a complete characterization of any DEC pad is described.

3. Design and Construction of the Test Bench

The main target of this work is the design of an experimental setup that allows the characterization of the pads under different controlled operating conditions: air flow (velocity); air psychrometric conditions (dry bulb temperature and relative humidity); pad thickness; pad material; water distribution system.

The designed test bench permits the use of three types of water distributors, any type of pad material, and three different thicknesses, controlling the waterflow rate. It is then connected to an air handling unit that permits the total control of the airflow rate and the psychrometric conditions.

3.1. Test Bench Operation Principles and Components Required

A test bench for the characterization of evaporative cooling pads must allow a certain waterflow to circulate and be distributed upon the pad, while air is driven crossflow. A water tank is thus required, whose water level is supplied from the mains. When the system starts operating, a recirculation pump supplies water to an upper distributor. From there, water flows down through the corrugated pad. Water is partially absorbed by the pad and the remaining water flows down to the lower tank. As air flows through the pad, it becomes more humid and cooled due to the partial evaporation of the water contained in the porous pad material.

The basic components are thus a lower water tank, water pump and pipes, an upper distributor, a pad case, and air connections.

3.2. Design of the Test Bench

For the design of the test bench, the following data are needed:

- Height and width of the pads, as well as thicknesses to be studied, to determine the dimensions of the case and the air connections;
- The volume required for the water tank, depending on the waterflows to be characterized and the water volume absorbed by the pads;
- The pump power and flow rate;
- The types of water distributors to be characterized to determine the gap between the pads and the box for the upper installation.

The pads to be tested were 825 mm in height and 622 mm long, and could be of three different thicknesses: 50/100/200 mm.

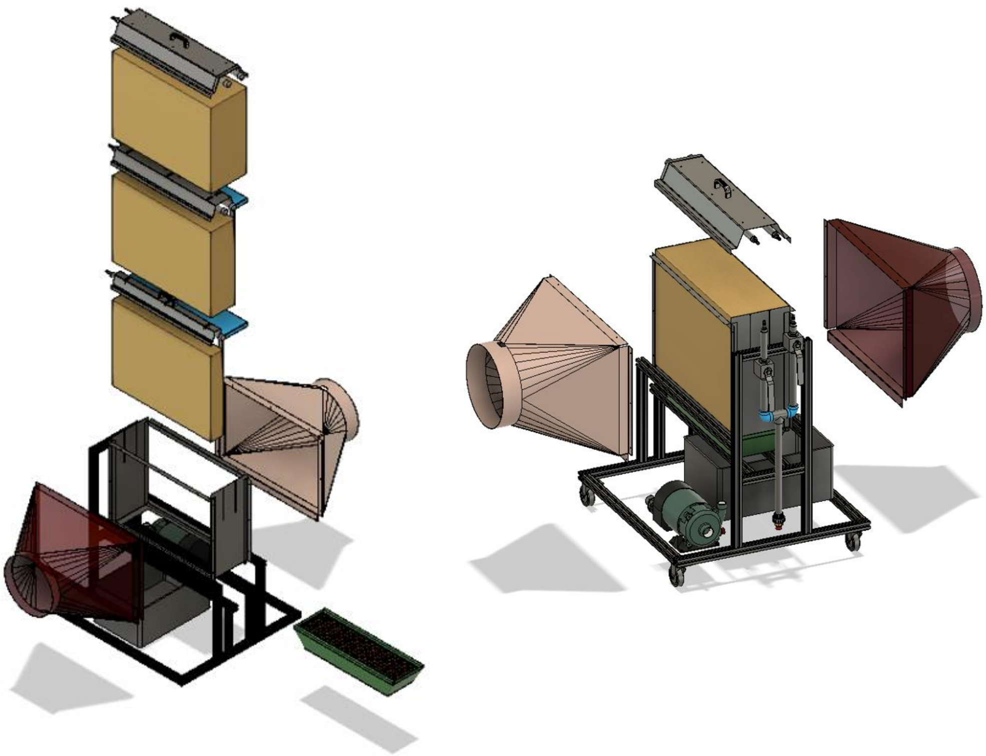
The test bench is designed to allow an easy substitution of tested pads.

The dimensions of the tank that collects the water from the pads are calculated based on the measurement of how much water is absorbed by the pad. Cellulose corrugated pads are considered as a reference for this calculation, given their high porosity. The average measured water mass absorbed by a 825 $\times$ 622 $\times$ 100 mm corrugated cellulose pad for five tests was 3.95 kg, with a standard deviation of 0.06 kg.

The water pump is chosen according to the following flow rates to be tested:

- 6.2 L/min for 1 m pad length and 100 mm pad thickness;
- 9.9 L/min for 1 m pad length and 150 mm pad thickness.

The design of the test bench was performed with software Fusion 360. Figure 1 shows exploded views of the design for the three possible pad thicknesses with the corresponding upper structure to adjust the distributors, and a global view for a 300 mm thick pad.



(**a**) (**b**)

Figure 1. Exploded view of the test bench (**a**) with the three possible pad thickness and (**b**) a 300 mm thick pad.

Finally, Figure 2 shows the built test bench, equipped with the upper structure designed for the characterization of 100 mm thick pads and connected to the AHU.

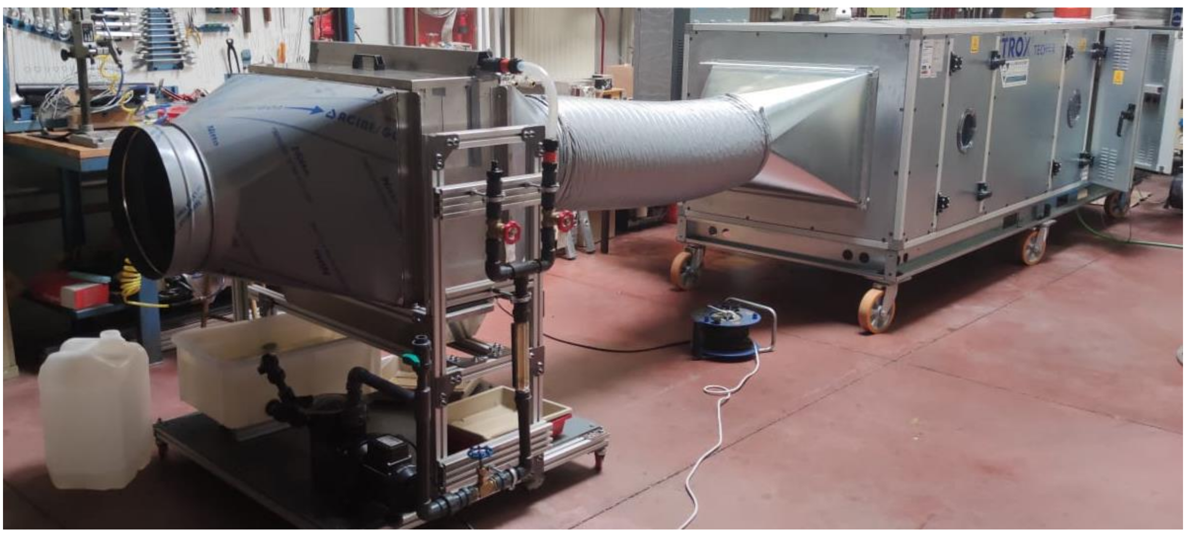


Figure 2. View of the test bench from both sides.

Finally, an air handling unit is used to reproduce the desired air velocity, dry bulb temperature, and relative humidity, enabling the performance of the tests under controlled conditions. Measuring equipment is selected to register the variables needed for the calculation of the target operating parameters: pressure drop, saturation effectiveness, and cooling capacity, among others.

4. Conclusions

Direct evaporative cooling pads are widely studied in the literature, but many key operating factors are simply measured and not controlled due to limitations in the experimental setups. Moreover, they are scarcely studied in terms of material decay, risk of water entrainment, or transient operation. The present study aimed to design a test bench that enables a complete characterization of any pad type in terms of material and thickness, as well as different water distribution systems, with total control of the airflow and water flow rates supplied and air psychrometric conditions.

The proposed test bench enables a complete characterization for any pad type (material and thickness) and different water distribution systems, under controlled waterflow and airflow rates supplied and air psychrometric conditions.

Author Contributions: Conceptualization, A.T.-G. and A.B.; methodology, A.B., E.A.S.-N. and M.S.-C.; investigation, A.B., M.S.-C. and E.A.S.-N.; writing—original draft preparation, A.B.; writing—review and editing, A.T.-G.; visualization, E.A.S.-N.; supervision, A.T.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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