

## **Experimental Investigation of Thermal Performance of Aluminum Foil Coated with Polyester in a Direct Evaporative Cooling System**

**Abbas M. Taleb \***

Researcher

Mechanical Engineering Department  
College of Engineering, University of Baghdad  
Baghdad, Iraq

E-mail: [Abas.magid@yahoo.com](mailto:Abas.magid@yahoo.com)

**Mohammed A. Nima**

Assistant Professor

Faculty of Mechanical Engineering Department  
College of Engineering, University of Baghdad  
Baghdad, Iraq

E-mail: [dralsafi@uobaghdad.edu.iq](mailto:dralsafi@uobaghdad.edu.iq)

### **ABSTRACT**

An experimental study was carried out for an evaporative cooling system in order to investigate the effect of using an aluminum pad coated with fabric polyester. In the present work, it was considered to use a new different type of cooling medium and test its performance during the change in the wet-bulb temperature and dry-bulb temperature of the supply air outside of the pad, the relative humidity of the supply air, the amount of air supplied (300-600) CFM and also the change of the amount of circulated water (1.75, 2.5, 4.5) liter per minute. A decrease in the WBT of the air was obtained, whereas the WBT of the air entering the pad was 26.5°C. In contrast, the WBT of the outside air had reached 23°C even though evaporative cooling is an adiabatic process which makes the WBT of the air that comes out of the pad is equal to the entering air WBT. The decrease in DBT is by changing the amount of air and water passing through the aluminum pad, whereas the DBT of the air entering the pad was 45°C, while the DBT of the outside air had reached 29°C. Also, an essential thing was obtained as this rise in the relative humidity of the air is very small 57%RH compared to the conventional pads, and this gives a positive impression as the air supplied from this pad has less moisture and its ability to carry moisture is much higher than that of air supplied from other pads. This gives a positive impression because the air supplied from this pad has lower humidity and its ability to hold moisture much higher than the air supplied from other traditional pads.

**Keywords:** Aluminum foil pad, evaporation cooling system, Experimental investigation.

---

\*Corresponding author

Peer review under the responsibility of University of Baghdad.

<https://doi.org/10.31026/j.eng.2021.04.01>

2520-3339 © 2019 University of Baghdad. Production and hosting by Journal of Engineering.

This is an open access article under the CC BY4 license <http://creativecommons.org/licenses/by/4.0/>.

Article received: 27/10/2020

Article accepted: 16/2/2021

Article published:1/4/2021



## دراسة تجريبية للأداء الحراري لحشوة من رقائق الألمنيوم المستخدمة في نظام التبريد التبخيري المباشر

عباس ماجد طالب  
باحث

جامعة بغداد كلية الهندسة قسم الهندسة الميكانيكية

محمد عبد الرؤوف نعمة  
استاذ مساعد

جامعة بغداد كلية الهندسة قسم الهندسة الميكانيكية

### الخلاصة

في الدراسة المختبرية تم دراسة تأثير استخدام حشوة رقائق الألمنيوم مع القماش في نظام التبريد التبخيري. حيث يتضمن هذا البحث التغير الحاصل في درجة الحرارة الرطبة والجافة للهواء الخارج من حشوة الألمنيوم وكذلك التغير الحاصل في الرطوبة النسبية للهواء الخارج ايضا بتغير كمية الهواء المجهز حيث كانت تتراوح من (300 CFM) الى (600 CFM) وكذلك تغير كمية الماء المسكوب على الحشوة حيث كانت (1.75 . 2.5 . 4.5) لتر في الدقيقة (LPM). لوحظ انخفاض في درجة الحرارة الرطبة للهواء الخارج من الحشوة. حيث كانت درجة حرارة الهواء الرطبة للهواء الداخل الى الحشوة (26.5) م° بينما كانت درجة الحرارة الرطبة للهواء الخارج من الحشوة (23) م° على الرغم من ان نظام التبريد التبخيري هو عملية ثابتة الحرارة اي ان درجة الحرارة الرطبة للهواء الخارج من الحشوة تكون مساوية لدرجة الحرارة الرطبة للهواء الداخل الى الحشوة. وكذلك لوحظ الانخفاض الحاصل في درجة الحرارة الجافة وتغير الانخفاض بتأثير كمية الهواء المارة على الحشوة ومقدار الماء المسكوب عليها حيث كانت درجة حرارة الهواء الداخلة الى الحشوة (45) م° بينما كانت درجة الحرارة الجافة للهواء الخارج من الحشوة قد وصلت الى (29) م°. ولوحظ امر مهم جدا وهو ان الارتفاع الحاصل في الرطوبة النسبية للهواء الخارج من الحشوة قليل جدا وبلغ 57% وهذا الارتفاع قليل جدا مقارنة بالحشوات التقليدية الاخرى. وهذا يعطي انطبعا إيجابيا لأن الهواء المزود من هذه الوسادة لديه رطوبة أقل وقدرته على حمل الرطوبة أعلى بكثير من الهواء المزود من الحشوات التقليدية الاخرى.

**الكلمات الرئيسية:** نظام التبريد التبخيري , حشوة رقائق الألمنيوم , دراسة مختبرية .

### 1. INTRODUCTION

In air conditioning, everyone aspires to reduce the operating costs of refrigeration devices and reduce losses resulting from the high temperatures of the climate. Everyone aspires to provide an air of good quality and within comfortable conditions for humans. On this basis, it was questioned whether another one could replace the traditional pads for evaporative cooling devices with better thermal performance with less water consumption and reduced moisture in the prepared air. In order to provide this good quality of air, fresh air must be prepared for the places to be air-conditioned, such as hospitals, hotels, clubs, restaurants, etc., in addition to drawing the air inside those places. This fresh air is prepared from the outside atmosphere, where its temperature may reach 45 degrees Celsius, which requires high energy and high equipment and operation costs. So the problem is how to compensate for this air without high costs. Most places are air-conditioned using a vapor compression cycle, as we mentioned earlier, such as sports clubs, hotels, restaurants, and cafes, where we will face a big problem to compensate for the withdrawn air. Suppose the air is compensated for by evaporative cooling devices. In that case, this leads to the addition of a latent cooling load and an increase in air humidity, and therefore this negatively affects the compressive cooling devices. Many types of pad have been used in evaporating cooling to get the best performance by measuring and testing the heat and mass transfer process of various pad like (metal pad, cellulose pad, organic pad, inorganic pad, PVC pad, porous ceramic pad). (Hui and Cheung, 2009) carried out an experimental study for the working principles of a two-stage evaporative cooling system and tested its performance in the hot and humid climate of Hong Kong. System characteristics were evaluated, and local climatic factors were investigated. Furthermore, the supply air temperature, potential cooling effects, and EER were studied. A renewable evaporative cooler was achieved using a mixture of DEC and IEC with part of the process air being recycled. Results showed that the regular use of evaporative cooling systems is not allowed due to the climate conditions of high humidity. However, it can be applied to cool outdoor air and save a



large amount of energy. (Mahsa, et al., 2011) experimentally evaluated the performance of cellulosic pads made out of Kraft and neutral sulfite semi-chemical (NSSC) corrugated papers as evaporative media and comparing their performance with other cellulosic pads. A wind tunnel was used in order to evaluate the cooling efficiency and water consumption as a function of air velocity. For three different levels of air velocity (1.8, 2.25, and 2.67 m/s) and three different sizes of Kraft and NSSC Corrugated Paper (2.5, 3.5, 4.5 mm), experiments were performed in the prepared air channel. The cellulose pad is made of Kraft paper with a 2.5mm flute size. Results indicate that the cooling efficiency increase with decrease in the velocity of air and flute size of corrugated papers, furthermore, the comparison between different pads showed that the cellulosic pad which made of Kraft paper has the highest performance as its efficiency is estimated to be about 92% at 1.8m/s air velocity. (Y. M. Xuan, et al., 2012) theoretically investigated the active direct evaporative cooling system's effectiveness. As a result of the short contact period of the two fluids, insufficient humidity of the pad, and the arrival of the two fluids to a thermal equilibrium state that equals the wet bulb temperature of the supply air, it was found that the effectiveness of the wet-bulb can only be 70% -80% as the system cannot cool the supply air below the wet-bulb temperature. The wet-bulb effectiveness mainly as a function of the type and thickness of evaporative media, working climate, and supply air flow-rate. (M.M. Kulkarni, et al., 2015) evaluated the performance of a new pad material of direct evaporating cooling experimentally during summer season conditions. Two new cooling pad materials, coconut fiber clay and Khus with a thickness of 25mm to 50mm, were used one by one and compared for their performance with the evaporative coolers traditional Celdek pad material. The coconut fiber density and clay density are respectively  $1000 \text{ kg/m}^3$  and  $1650 \text{ kg/m}^3$ . Furthermore, they were mixed with specific bond material by volume proportion of 95% and 5%. Results showed that the maximum effectiveness was of coconut fiber clay. It was found to be 0.84, Khus is 0.67, and Celdek is 0.71. The cooling capacities for coconut fiber clay, Khus, and Celdek are 3.85kw, 3.80kw, and 3.2kw, respectively. Also, the comparison revealed that coconut fibers are the best in terms of effectiveness for summer conditions. (Amrat, et al., 2017) explained the thermodynamic analysis of the direct evaporative cooling system numerically by increasing the cooling media s sides. The system has advanced six geometrical configurations. The thickness of the cooling media is taken 0.15m for all the situations and configurations moreover, the effect of saturation efficiency, estimated air temperature and cooling capacity by changing the air intake velocity, and the overall flow rate of the air and heat transfer coefficient were studied with all DEC system configurations. It was observed in the results that the highest saturation efficiency was for triangle configuration is 97% . To increase the cooling capacity and reduce the consumption power under hot and dry climate experimental investigations were made by (Najim, 2017) for air-cooled split air conditioner performance, with evaporative water mist pre-cooling. By using water mist to pre-cool ambient air entering the condensers by an adiabatic cooling process that depends on the ambient air wet bulb temperature, the condensing temperature and condensing pressure will be decreased accordingly. The ambient temperature ranged from (25-52 C). The result clarify that the ECAC had an EER of 47 % higher than that of ACAC under the same and most serve hot and dry condition of 52oC and 10% relative humidity, also, ECAC operating at EER of 10.5 BTV/W .Performance analysis of a direct evaporative pad cooling system was investigated numerically by (Azzeddine, et al., 2018). The evaporative cooling system consists of Fan, a cellulose pad sheet with a thickness of 100 mm, a spray, and a water pump. The incoming air velocity is 1 m/s. The thermal properties of the wet air are found from the open-source program Cool Prop. Also, a computer program is used to determine the influence of pad thickness and frontal velocity on the system's performance. It has been found in the results that the proposed cooling system can reduce



the temperature in the hottest period with a performance coefficient higher than 80% and an average water consumption rate of more than 3.3 kg per hour. Also, the coefficient of performance decreases with increasing the thickness and frontal velocity.

On the other hand, the cooling power delivered by the system is greater than 2.3 kW. (Riffat, et al., 2018) Studied the performance of eucalyptus fiber pad experimentally and analyzed the effect of air temperature and air velocity on the material performance. A wind tunnel is used to investigate the performance of evaporative cooling by eucalyptus fibers. The air was the working fluid. The experimentations were repeated by varying two-parameters, the inlet DBT, and air velocity, with controlled RH and uniform air flow rate. The inlet air was heated with a 2 kW heater to increase the air temperature to the setpoint. The results found that fibers at low air velocity provide better performance in providing higher temperature differences. An experimental study was carried out by (Ali and Dr. Issam, 2019) to investigate the residential building's two Stage evaporative cooling using geothermal energy. The two-stage evaporative cooling system is studied. The first stage is indirect evaporative cooling (IEC), represented by two heat exchangers with the groundwater flow rate (5 L/min). The second stage is direct evaporative cooling (DEC), representing three pads with groundwater flow rates of (4.5 L/min). Results showed that the evaporative cooling efficiency of two heat exchanger stages with three pads (thickness of each pad) 3 cm (up to 167%, with a temperature difference of outside and prepared air reaching 26.2 ° C. It reaches 122.7% using (one heat exchanger with three pads) with the outside and prepared air temperature difference. It reaches 16 degrees Celsius and goes down to 84.88% and 84.36% for indirect and direct evaporative cooling, respectively.

From the previous literature, it became clear that there was a problem in controlling the amount of humidity of the prepared air. The lower the velocity of entry of the air, the better the performance of the pad.

In this paper, the influence of using an aluminum pad in improving the quality of the prepared air in terms of its low humidity and low temperature for the evaporative cooling system will be investigated. A sensible cooling load would be added to the air due to the decrease in the pad material temperature. When the evaporative cooling takes place at one section of the pad, it reduces the pad material s temperature at that section.

## 2. Experimental Apparatus

### 2.1 General Description

A wind tunnel is designed and created from iron with a thickness of 0.7mm and a cross-sectional area of (51x51) cm and 3.1 m in length to study the experimental test. A separate three-stage electric heater is used to switch the required air temperature where each stage's capacity is 1.32 kW so that the total capacity is 3.96 kW. More accurately, this capacity is sufficient to provide the required temperature during the change in ambient temperature. An axial air puller is used with a model of BDTX 310 and a type of centrifugal backward curved direct drive and 1500 rpm. The maximum amount of air processed is  $1700 \text{ m}^3/\text{h}$ , a voltage controller, is installed to control the fan velocity and in order to prepare the required amount of air. A water pump is used to circulate the water. The experimental apparatus is shown schematically in **Fig. (1)**.



## 2.2 Aluminum Foil Pad Fabrication Process

The pad used is created from aluminum foil arranged as in the heat exchanger-type fins and tube the aluminum foil used with alloy type (1100) and thickness of 0.1mm. The foil dimension is 50 cm in length, 23 cm in width. The number of foils in the pad is 95 foil. Every single foil is installed on both sides a layer of fabric from polyester as shown in **plate (a1)**.

- The textile fabric layer density used is 10 gsm (Gram per square meter) and has the same dimension as aluminum foil. The fabric layer has been applied and glued on the aluminum foil after heating the fabric's glued side by using an electric iron as shown in **plate (b1)**. After installing the cloth on both sides of the aluminum foil, the two sides are coated with (P100 Hydrophilic coating) material, which will be explained later.
- After installing the fabric layer, a number of holes were made in each foil to arrange the aluminum foils one by one. The positions of eight holes are taken accurately and distributed systematically on the aluminum foil, **Fig. (2)** and **plate (2)**.
- A metal plate with 1.8mm is used as a base, and eight holes are made in it depending on the existing ones in the aluminum foil, a toothed rod with a diameter of 6mm and 53cm length fixed in each of the eight holes **Fig (3)**. After that, sliding the aluminum foil one by one through the eight rods depending on the existing ones in the foil while maintaining a distance of 4mm between the successive foils by fixing a metal ring with a thickness of 4 mm in every single toothed rod as shown in the **plate (3)**. After each aluminum foil is located at its position, another metal plate is similar to that at the base has been fixed at the end of the toothed rods to become the pad shown in **Fig (4)**.

## 2.3 Aluminum Alloy Type 1100 Specification

Aluminum 1100 is also called Commercial Grade Aluminum, and it is an almost pure Aluminum alloy. Generally, 1100 is over 99% aluminum with less than one percent of copper, iron, manganese, silicon, titanium, vanadium, and zinc mixed in for a little extra strength. It is very light, has excellent thermal and electrical conductivity, workability, and corrosion resistance. Specifically, it has 53% of the conductivity of pure copper. However, 1100 is quite soft and therefore not used in applications that require high strength or hardness. Most frequently, it is produced in sheets, foil strips, wire, and rod. Though sheet is most common Also, 1100 aluminum is susceptible to heat variance. At temperatures ranging from 392 – 482 °F (200 – 250 °C), 1100's already lower strength decreases even further. However, at sub-zero temperatures, its strength increases. Because of this, 1100 is an ideal low-temperature alloy

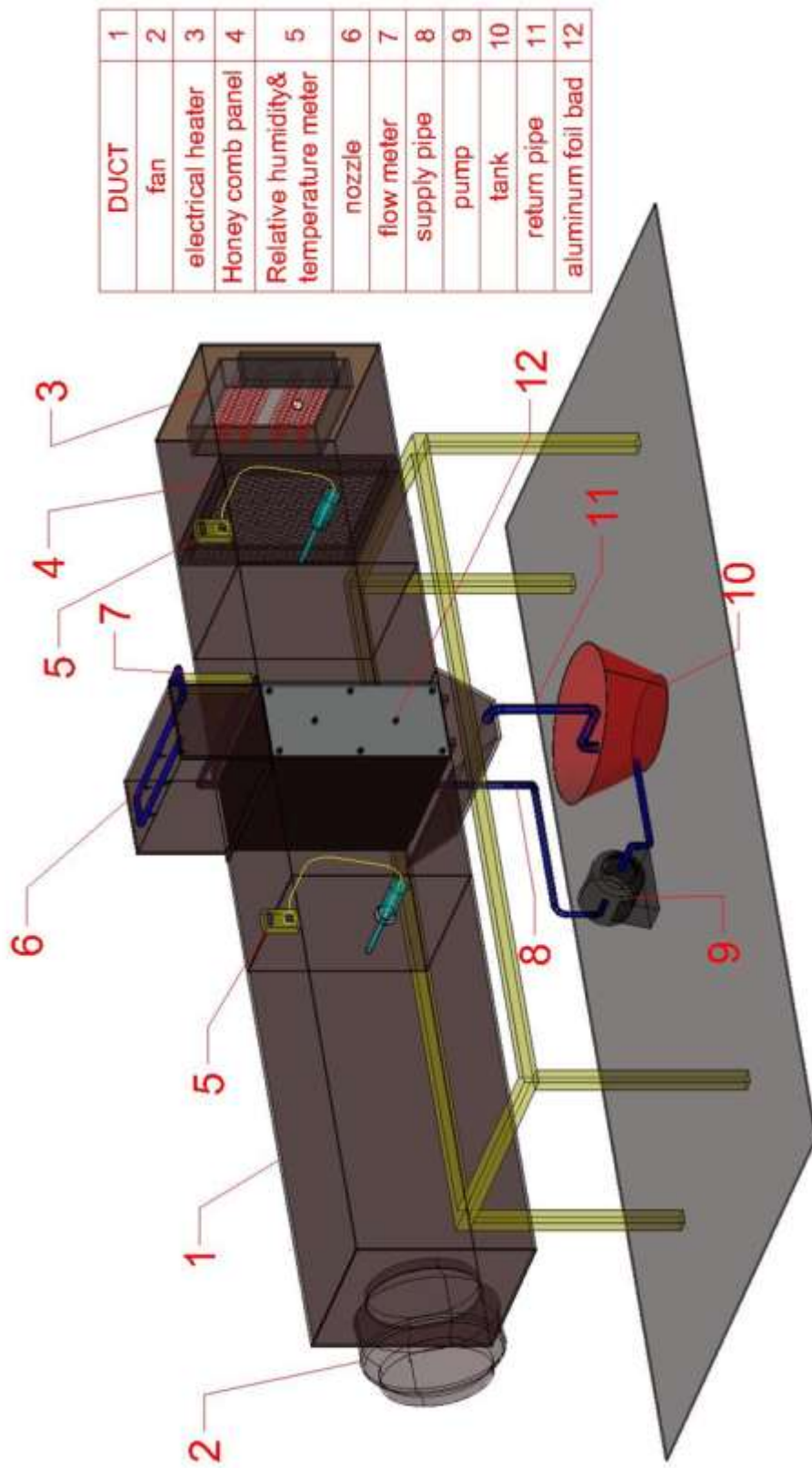


Figure1. Schematic drawing of the experimental apparatus.



### 2.4 P100 Hydrophilic coating Specification

P100 is a patent-pending coating with superior hydrophilic properties, which can be applied to most surfaces and materials. P100 can be used for several applications but is developed for single-use diagnostic consumables based on capillary microfluidics. The hydrophilic coating (water contact angle  $\sim 10^\circ$ ), long functional life, fast, simple and flexible coating process, coating tolerant to storage without temperature and humidity control, excellent adhesion to most materials, high optical clarity, fragile coating, biocompatible, safe solvent chemistry, finally FDA approved ingredients are the P100 coating features. The coating process is carried out using a spray gun, and all the surface of the foil on which the cloth layer is installed is painted and left to dry at room temperature in a short time. This is one of the advantages of the coating.



**Plate. (a1)** Install the layers of fabric .



**Plate. (b1).** Ironing the fabric with thermal glue.

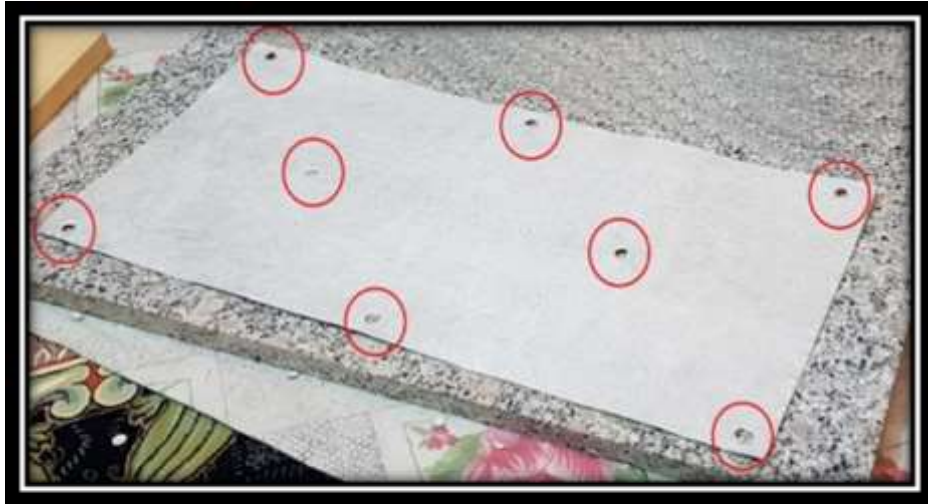


Plate. (2) The positions of eight holes on the Aluminum foil.

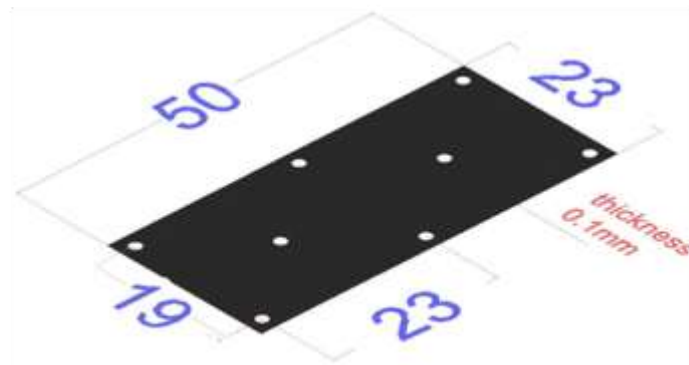


Figure 2. The positions of eight holes on the Aluminum foil (dimension in cm).

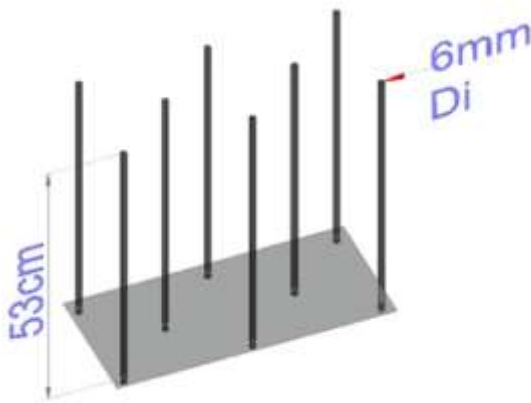
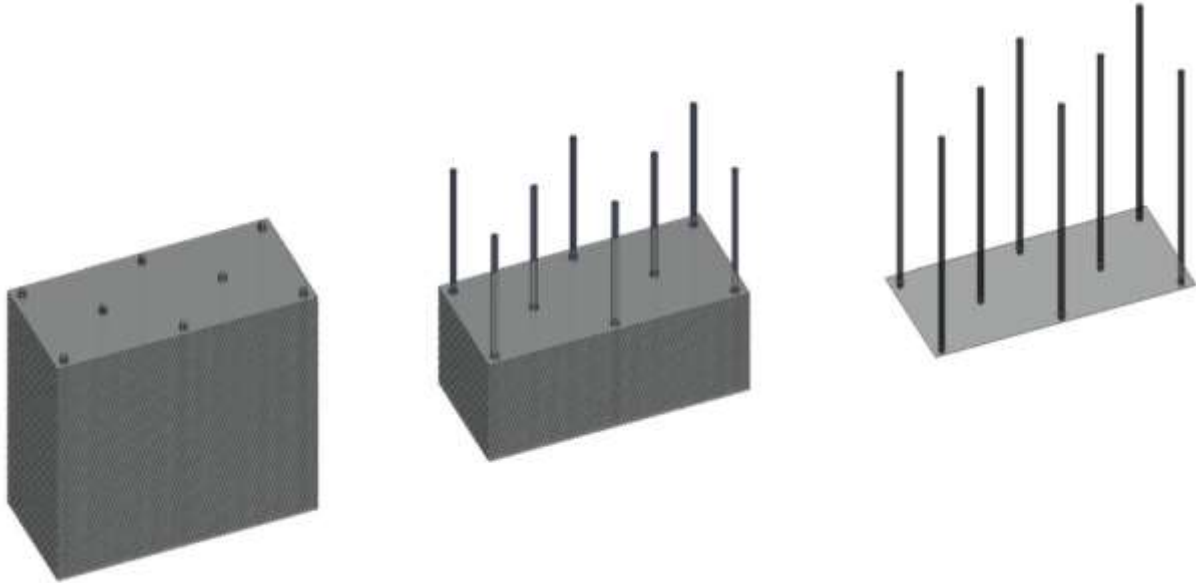


Figure 3. Toothed rod.



Plate. (3) Metal ring.





**Figure 4.** Aluminum foil pad .

### 3. EXPERIMENTAL PROCEDURE

In this research, the experiments are repeated with varying parameters to study their effect on the outlet dry bulb, wet bulb temperature, relative humidity, and the water evaporation amount. These parameters are:

1. Inlet dry-bulb temperature°C.
2. The flow water amount on the pad (LPM).
3. Air flow rate (CFM).

The following procedure is followed for experimentation:

1. The blower is switched on to pull the outside air through the wind tunnel and permeate the aluminum pad for varying air. The amount of air is changed by changing the blower rotational speed using regulator voltage; the range of airflow rate is 300 to 600 CFM and increases at a rate of 50 CFM.
2. The water pump is switched on to circulate the water and supply the aluminum pad with ten nozzles places above the pad. the amount of supplied water is controlled by using a valve connected with the water flow meter, and the supplied water amount is three values (1.75, 2.5, and 4.5 LPM)
3. The electrical heater with three-stage is switched on to control the dry-bulb temperature of the inlet air manually.
4. In order to take a reading, start the water pump and set the amount of water flowing into the filling and start with 1.75 liters per minute with this value of water fixed. The air quantity is set from 300 to 400 CFM at a rate of 50 CFM increment. The results are taken for each rate of increase after the passage of 15 minutes to run for the system to stabilize. The results to be taken are the dry temperature, the relative humidity of the inlet air, the dry temperature, and the outlet air's relative humidity from the pad. This process is repeated for other quantities of water.



#### 4. RESULTS AND DISCUSSION

In this paper, a summary and practical results will be presented and analyzed using an aluminum pad on which fabric cloth is installed in evaporative cooling. The resultant from the practical study will be present and analyzed which includes the change in the WBT and DBT of the air outside of the pad, the change in the relative humidity of the outside air, the change in the amount of air supplied and the cooling capacity of the pad and its change by changing the characteristics of the prepared air. The investigated parameters in the present experimental work are listed in **Table (1)**. A total of 21 test runs were carried out to cover all the investigated parameters in the experimental part of the present work. When the required data is recorded at the end of each run, data analysis is performed to presents the physical relationships between the investigated parameters.

##### 4.1 Decrease of Supply Air Temperature with Change Air and Water Flowrate

The values of the wet-bulb temperature and the dry bulb temperature of the air passing through the aluminum pad, as shown in **Fig. (5)** and **Fig. (6)**, change after increasing the 50 CFM for each amount of water, which ranges between 1.75, 2.5 and 4.5 liters per minute and the air volume from 300 to 600 CFM.

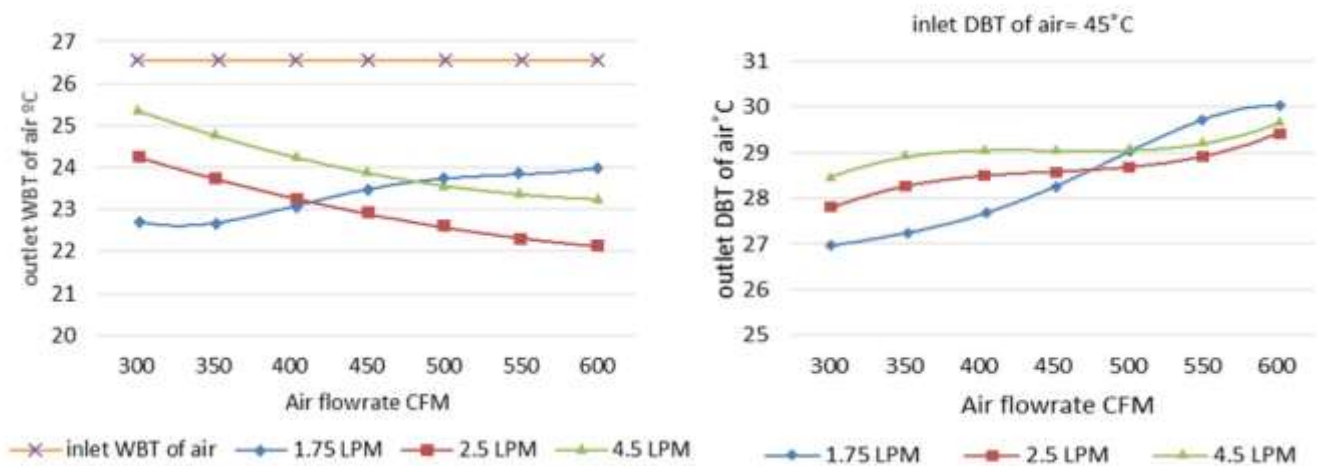
It is obtained in **Fig. (5)** A decrease in the WBT of the air, despite the fact that the evaporative cooling is an adiabatic process that makes the WBT of the air that comes out of the pad is equal to the entering air WBT. The nature of the pad used and made of aluminum foil caused this kind of behavior. It is found that there is a sensible cooling added to the air due to the decrease in the pad material temperature. Due to the high heat conductivity property of the aluminum material, the incoming air is cooled as a result of colliding with the pad and losing part of its heat as well as exchanging its heat with the circulating water, which makes the aluminum foil pad the best among all the pads used in evaporative cooling devices. The sensible reduction in the air temperature through the pad is similar to the in-direct evaporation cooling effect. This process does not observe in conventional evaporative cooling systems. It is also noticed in **Fig. (5)** that when the amount of water spilled is 1.75, and the amount of airflow is low, the WBT of air is low, and vice versa when the amount of air increases, the WBT of air begins to rise compared to the WBT of air when the amount of water poured is 2.5 and 4.5 with the same amount of flow air, the reason for this rise is the occurrence evaporative cooling, it takes place at one section of the pad and reduce the temperature of pad material at that section. . But the high conductivity property of aluminum contributes to cooling the air as well as the circulation water, as the temperature of the pad gradually decreases. Also, when the pad is moistened with water, the water spreads very quickly because the fabric covering each sheet inside the pad is of the type that allows the rapid spread of water. All of the above mentioned above is to clarify the superiority of the aluminum pad in evaporative cooling systems. It has been observed that the evaporation rate increases as the amount of incoming air increase with the decrease in the amount of circulation water, thus obtaining air with high humidity in addition to not reducing the air temperature to the required degree. More precisely, heating the pad due to the hot air inlet and the small amount of circulating water leads to an increase in the outlet air's wet bulb temperature. In **Fig. (6)**, the decrease in DBT by changing the amount of air and water passing through the aluminum pad. This decrease is that the effect of evaporative cooling will cool the air in addition to the sensible cooling obtained from aluminum foil, which is not available in conventional pads. With the amount of water at 1.75 LPM, an increase in the air temperature is found when the air amount increases, as in **Fig. (6)**. This increase is because the cooling effect resulting from the water evaporation process is insufficient to reduce the air temperature to the required level and the hot air passing through the aluminum pad performs



its role. **Fig. (7)**, the psychrometric chart, shows the difference between the process of cooling the air in the case of the use of conventional pads and in the case of the use of the aluminum pad, which is explained by the same characteristics of the entering air. Where the process from A to B represents the conventional evaporative cooling system, where it is an adiabatic process in which there is no change in the enthalpy and WBT of air, but the process from E to C represents the use of an aluminum foil pad is not adiabatic, where the sensible heat load lost by the air does not equal the latent load added to it as a result of evaporation, and this is due to the nature of the pad used. As the pad is moistened with water, the last will evaporate in certain parts of the packing, and the fact that the pad is made of aluminum foil with high conductivity will cause a heat transfer to occur resulting from the evaporation to all parts of the pad by not requiring the presence of evaporation in those parts so that the air DBT will decrease as a result of it passing through the cold aluminum foils without any evaporation of water. That is, it will substantially decrease the DBT of air without adding any latent load to the air, on the other side, the temperature of the circulated water decreases after water passes over the cold aluminum pad thus the evaporation rate decreases and that will contribute to the cooling process greatly as well as the evaporation of the water after exchanging its heat with the inlet air. Finally, the latent load added to the air is much less than the latent load added when using the other conventional pads.

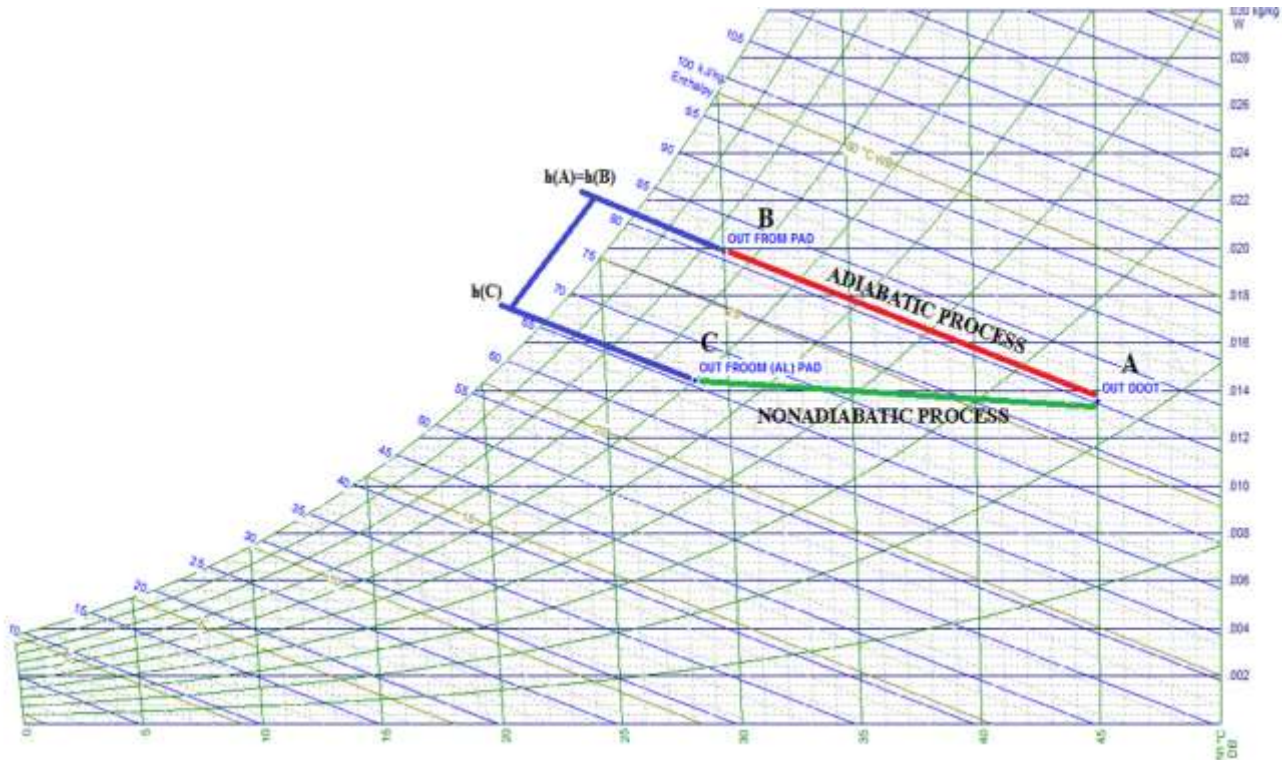
**Table. 1** Range of the Investigated Parameters

Parameters	Unit	Range of Values
		Experimental
Inlet DBT of Air	°C	45
Inlet WBT of Air	°C	26.5
Air Flow Rate	CFM	300-600
Water Flow Rate	LPM	1.75-4.5
Inlet Relative humidity	%	23



**Figure 5.** Variation of outlet WBT of air with the air flow rate for different water amount.

**Figure 6.** Variation of the outlet DBT of air with the air flow rate for different water amount.



**Figure 7.** The difference between the process of cooling the air in the case of the use of conventional pads (A-B), and in the case of the use of aluminum pad (A-C)

#### 4.2 Change in Relative Humidity Between in and out Air with Changing the amount of Air and Water

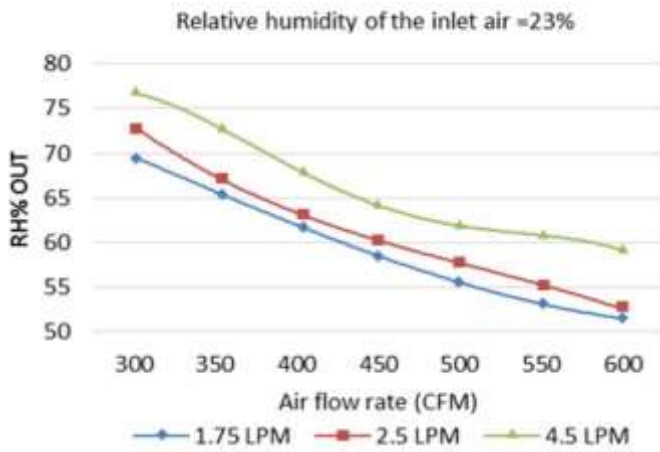
**Fig. (8)** Shows the rise in the relative humidity of the air coming out of the aluminum pad and its change by changing the amount of air and water passing through the pad.

From **Fig. (8)** obtained the decrease in the relative humidity of the outgoing air by increasing the amount of air passing through the pad and the constant water amount. The explanation for this is that the rate of increase in the amount of evaporated water due to the increase in the amount of air passing through the pad is relatively low compared to the increase in the amount of air, as shown in **Fig. (9)**.

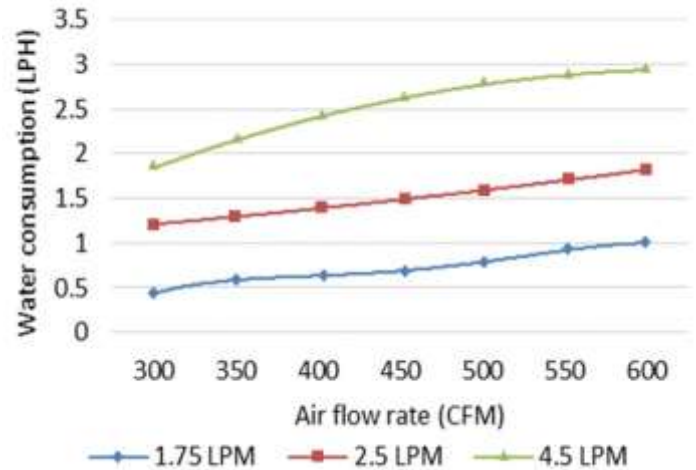
**Fig. (8)** shows an essential thing as this rise in the relative humidity of the air is tiny compared to the conventional pads, and this gives a positive impression as the air supplied from this pad has less moisture and its ability to carry moisture is much higher than that of air supplied from other pads. The reason for this little rise in relative humidity is that a portion not a little of the air passing through the pad decreases its temperature due to the sensible cooling gained when passing on cold aluminum foil, so its ability to evaporate this water decreases from one side, while the other side is that the water itself acquires a coolness perceived by the foils cold aluminum. This, in turn, reduces the evaporation of water, which explains the reason for the low relative humidity of the outside air. When observing the relative humidity values of the outgoing air in **Fig. (8)**, it is found that all these values are close or equal to the recommended relative humidity in air-conditioned and inhabited places, and in turn, this thing will open wide doors for us in the application and use of this pad in different cooling systems .



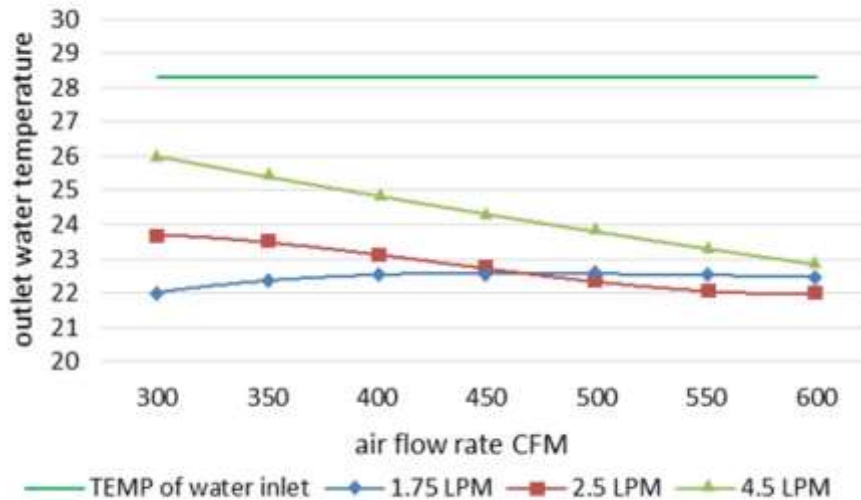
When observing **Fig. (9)** for the amount of evaporated water as the device is working with different quantities of air and water, it is observed that the amount of evaporated water is tiny, which is a positive point in terms of the amount of water drainage that is achieved by this pad compared to the other pads. In addition, it is observed in **Fig. (10)** the rapid decrease in the water temperature that coming out of the pad. This gives an essential perception that the water temperature will decrease not only by the effect of evaporative cooling but will be cooled by gaining a sensible coldness from aluminum foil, and as the device continues to work, this water will be a cooling medium that raises of device efficiency.



**Figure 8.** Variation of outlet relative humidity of air with the air flow rate for different water amount.



**Figure 9.** Variation of the water consumption with the air flow rate for different water amount.



**Figure 10.** Variation of outlet water temperature with the air flow rate for different water amount.



## 5. CONCLUSIONS

The experiments conducted to test the performance of the aluminum foil pad inside a wind tunnel led to the conclusion that the aluminum foil pad was the best in terms of thermal performance and a small amount of circulating fluid consumption. Process (a-c) in Fig. (7) illustrates the aluminum pad's ability to effectively reduce the wet-bulb temperature of the outlet air. The high thermal conductivity of the aluminum material was the characteristic feature of the aluminum foil filling. As it contributed to cooling the pillow and reducing the temperature of the recycling water after it passed through the pillow, which led to a decrease in the evaporation rate of water, thus reducing water consumption as shown in Fig. (9), as well as reducing the amount of moisture in the prepared air to 57% as shown in Fig. (8). The DBT of the air coming out of the pad reached 28 ° C, as shown in Fig.(6) so that the air that is prepared with its low relative humidity and low temperature allows it to be used as a fresh air device that prepares buildings and places that use compressive cooling devices without adding loads of the latent hardware.

## ABBREVIATIONS

LPM	Liter per minute.
CFM	Cubic foot per minute.
Gsm	Gram per square meter.
Rpm	Revolution per minute.
WBT	Wet bulb temperature.
DBT	Dry bulb temperature.
%RH	Relative humidity.

## REFERENCES

- Riffat S, Gan G, and Aydın D, 2018. Experimental study of the potential of eucalyptus fibers for evaporative cooling.
- Mahsa Barzegar, Mohammad Layeghi, Ghanbar Ebrahimi, Yahya Hamzeh, and Manouchehr Khorasani, 2011. Experimental evaluation of the performances of cellulosic pads made out of Kraft and NSSC corrugated papers as evaporative media, Energy Conversion and Management 54 (2012) 24–29, 25 September.
- M.M. Kulkarni, K.N. Vijaykumar, N.A. Jadhav, M.J. Bhor, and S.S., Shinde, 2015. Experimental Performance Evaluation of new cooling pad material for direct evaporating cooling for Pune summer conditions, International Journal of Engineering Trends and Technology (IJETT) – Volume22 Number 6
- Azzeddine Laknizi, Mustapha Mahdaoui, Abdelatif Ben Abdellah, Kamal Anoune, Mohamed Bakhouya, and Hassan Ezbakhe, 2018. Performance analysis and optimal parameters of a direct evaporative pad cooling system under the climate conditions of Morocco, Abdelmalek Essaâdi University – Tangier, Morocco .



- Hui, S. C. M., and Cheung, W. Y., 2009. Two-stage evaporative cooling systems in hot and humid climate, in
- Proceedings of the Tianjin-Hong Kong Joint Symposium, Tianjin, China, pp. 64-76.
- Y. M. Xuan, F. Xiao, X. F. Niu, X. Huang, and S. W. Wang, 2012. Research and application of evaporative cooling in China: A review (I) – research, Renewable and Sustainable Energy Reviews, vol. 16, pp. 3535-3546,
- Amrat Kumar Dhamneya, S. P. S. Rajput, and Alok Singh, 2003. Thermodynamic performance analysis of direct evaporative cooling system for increased heat and mass transfer area, Maulana Azad National Institute of Technology, Bhopal 46, India
- Najim Abid Jassim, 2017. Performance Enhancement of an Air Cooled Air Conditioner With Evaporative Water Mist Pre-cooling, Journal of Engineering Research and Applications, Vol. 23, No. 1, pp. 48–62.
- Ali Hammoodi Mahdi Alhosainy, and Issam Mohammed Ali Aljubury, 2019. Two Stage Evaporative Cooling of Residential Building Using Geothermal Energy, Journal of Engineering Mechanical and Energy Engineering, Vol. 25, No. 4, pp. 29–44.