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Investigating the Effects of Air Bubbles Injection Technique on the Cooling Time of Warm Drinking Water

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ABSTRACT

This paper deliberates experimentally the inspiration of capacity flow rate of air bubbles inserted on the time period of a water cooler container with 30 liters of regular water initially at 37 °C. Four various volume flow rates of the injected air were used in the experiments (Qa=0.5; 1.0; 1.5 and 2.0 LPM). The air was injected into the water basin from the bottom as small air bubbles with an average diameter of (0.1 mm) via a spiral sparger made of silicon tube with (1400) holes and 0.1 mm hole diameter. In addition, four air pressures (P=2, 3, 4, and 5 bar) were used in the experiments. Consequences exhibited that the time required to cool down the water temperature (about 5 °C) was much smaller with injecting air bubbles than that of without injecting air bubbles (using the traditional cooling method). This consequence was more pronounced with amassed the volume airstream of the inserted air bubbles. The escalation the air volume flow rate, the quicker reduction the water cooling. Also, it was found that the pressure of the injected air bubbles had only a minor impact on the cooling process. Furthermore, the heat transfer and the cost of the cooling process with and without injecting air bubbles were studied. The heat transfer convection coefficient correlated of Nu was investigated to be increased with rising the volume flow rate of the injected air bubbles. Similarly, the cost of cooling down a specific amount of water was noticed to be decreased with increasing the injected air bubbles., The calculations illustrated that small air bubbles motility amount have a very significant guidance on time. The possibility of reaching the end of the cooling process can be achieved quicker as air flow rate amount is increased. It was clear how much electricity is saved using air bubble inoculation technique.

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1. Introduction

Air vaccination ways that are used to inject tiny air bubbles addicted to the liquid lead to yield tiny air bubbles inside the liquid. Exchanger. Number of the tiny bubbles, the sparger configurations, and the bulk of the dumps (orifices) which used these tiny air bubbles be based on the system which is enhanced with tiny bubbles injection. About to the production of tiny air bubbles, due to the impact of buoyancy force, the tiny air bubbles move vertically through the liquid [1,2]. The natural behaviour of air bubbles can enhance the convection heat transfer by minimize the layer of thermal boundary layer [1-3].

The air injection technology was achieved through extensive scientific studies, including what was done by the researcher Dizaji *et al.,* [4] in 2015 to augment the parameter of thermal features performance of heat exchangers like a shell and tube with coiled shape using water as the working liquid [3-5]. They elaborated the behaviour of tiny air bubbles blueness on the; thermal units' number "NTU" and the heat effectiveness "ε" inside the column heat exchanger [6,7]. Moosavi *et al.,* [5] spotted experimentally that the amount of inoculated tiny air privileged the pipe side confirmation to less heat convection transfer augment than the air injection into the shell side of the serpentine coiled exchanger. Panahi [6] scrutinized experimentally the guidance of tiny bubbles of air injection on the Nusselt number (Nu) for the same shell and tube used by Dizaji [8,9]. The experimental statistics specified that the Nusselt number was augment by about (50 – 32) %. Khorasani and Dadvand [7] located experimentally that the number of heat unit has amended by (1.3-4.3) times, the exergy disadvantage has enlarged from (1.8-14.2) times, and the heat effectiveness was about 0.815 due to bubbles injection though a horizontal shell and tube. Pourhedayat *et al.,* [8] detected the heat effectiveness, exergy demolition and the Nussle number were enlarged by about (45 – 57) %, and 30% respectively with reason to the small bubbles' injection in an upright shell and double pipe heat h\exchanger [10]. Hasan *et al.,* [11] investigated experimentally the influence of injection air bubble size on thermal performance and studied the furtherance of thermal performance of spiral tube inside shell take advantage air injection routine [12-14].

2. Experimental Part

2.1 Materials and Device

In experimental part, there are some rigs were used such as compressor, condenser, evaporator, capillary tube, helical tube evaporator, sensors, plastic sparger.

2.2 Methods

The specifications of the cooler water system are illustrated in Table 1. The water basin is a cylindrical basin with 30 litters of water covered from outside by helical tube evaporator. Figure 1 demonstrations a graphic diagram of the investigate. The experimental rig consists of a compressor, condenser, evaporator, and capillary tube. The temperature allocation along the cooler basin were measured by 16 K-Type calibrated thermocouples (RS Component Ltd, Northants, UK) connected to a data logger via extension wires for display the measured temperature directly on a PC. The thermocouples are distributed as 8 sensors immersed in the water basin and 8 sensors measure the water basin surface. The bubbles injected into the cooler basin was via a plastic sparger as shown by Figure 2 which consists of 1400 holes and 0.1 mm hole size. This sparger was newly designed and manufactured and installed at 30mm from the bottom of the water basin. Finally, the rate of volume flow of the injected air was calculated by a rota-meter.

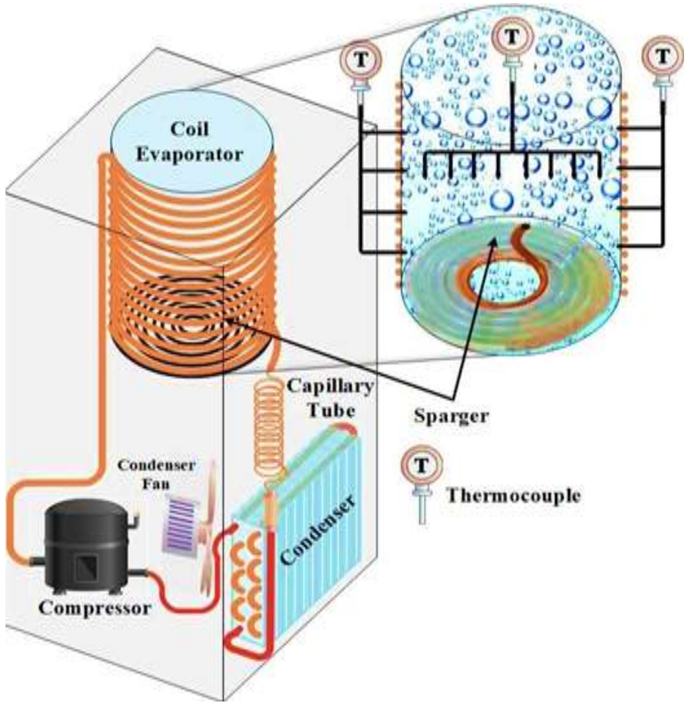

Fig. 1. Experimental rig contents

Table 1
Specifications of the water cooling system

Type	Water Cooler
Tank Capacity	30 Liters
Voltage, HZ	220-240, 50 HZ
Refrigerant Type	R134a
AMP	3.8
Dimensions	53*40*131 (W*D*H), cm
PH	1

3. Results

This investigational work was concluded inside the laboratory of the technical institute of Najaf in April, over the official working days, below the environment temperature domain of nearly (34-38) °C. The experiments were started with the planning of the experimental device by proving the water level, Figure 2. thermocouples, compressor and electric power supply. Once all was sorted out probably, the rate of volume air flow of the injected bubbles is selected by adjusting the Rota-meter.

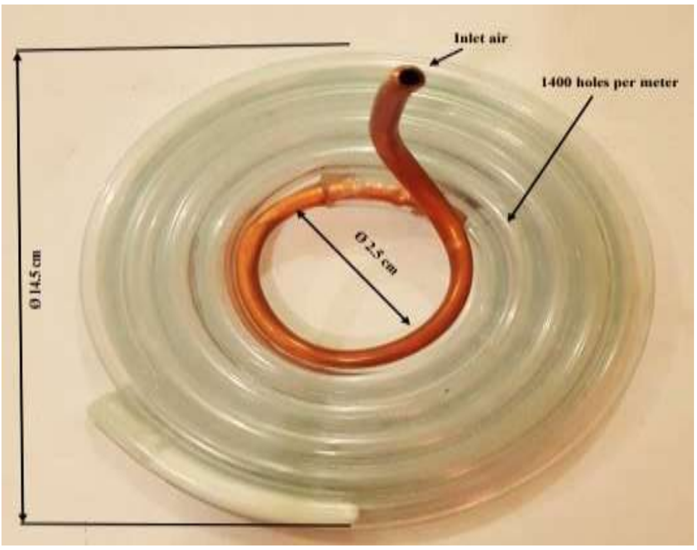

Fig. 2. Shape of the artificial sparger

4. Discussion

The inspiration of bubble injection on the temperature of the water inside the water basin is studied experimentally under varying air flow rates and an initial water temperature of 37 ℃. To visualize the behavior of air bubbles rising inside the water basin, Figure 3 shows the turbulence effect caused by rising the air bubble inside the water basin with many rates of volume air flow. It's clearly shown that the influence of increasing the rate of volume air flow caused additional turbulence effect [11,15,16]. Adding that, air bubbles caused to augment in the heat exchanger between the water particles and the water basin surface.

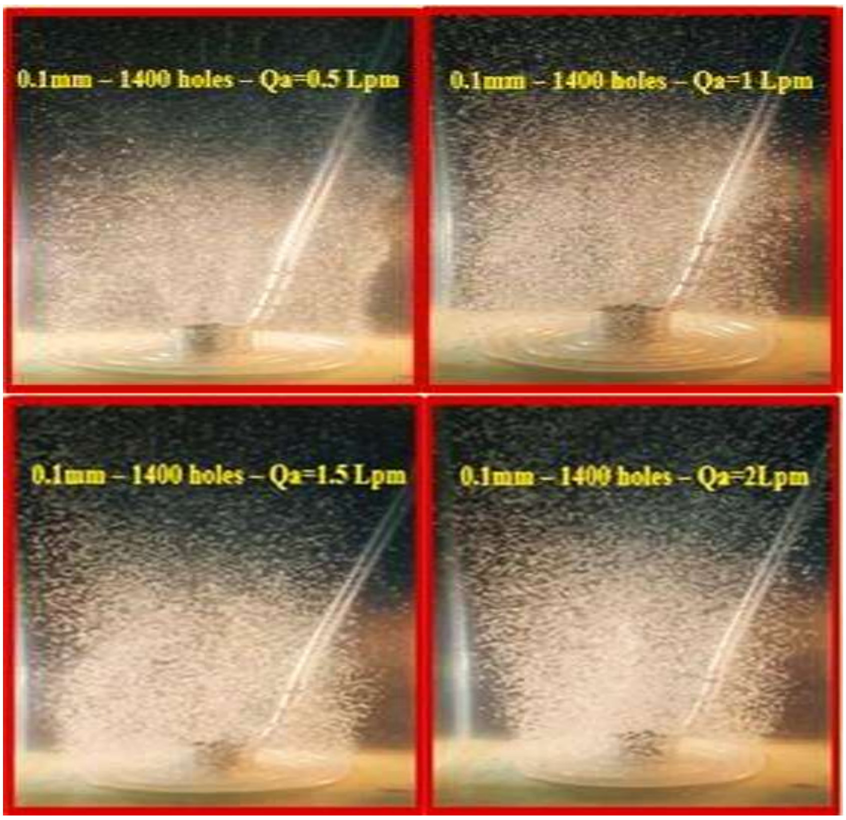

Fig. 3. Sparger inside water basin with different air pressures

Figure 4 demonstrations the stimulus of variation the air pressure on time to complete the experimental procedure. It is clearly shown that from Figure 4 that the different in the air pressure has a visible guidance on the time; the higher amount of the injected bubbles, the lower the time to complete the experimental procedure. It is also remarkable that it has a more outstanding guidance when it is 0.5 LPM.

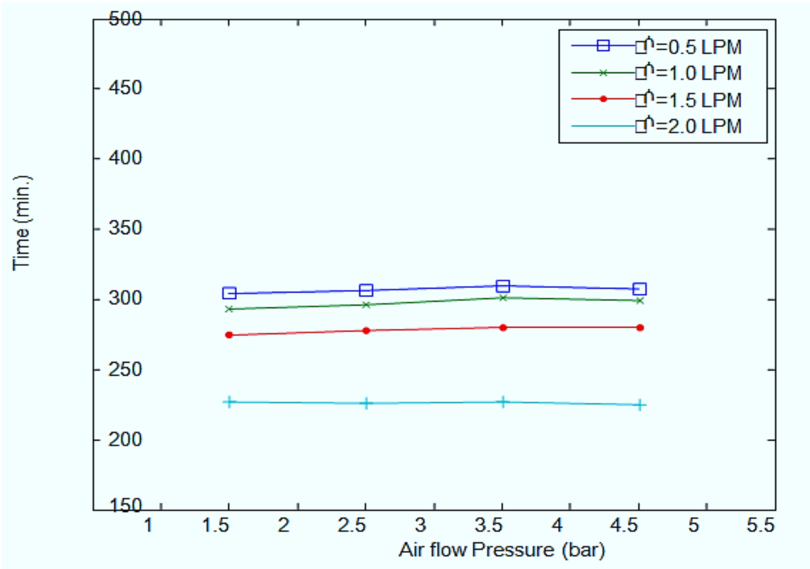

Fig. 4. Inspiration of variation air flow pressure on time to complete the experimental procedure at different airflow rates

Figure 5 and Figure 6 demonstrate the transient activities of the temperature for waterside and water basin surface side temperature to many volume flow rates of air side. Figures appeared the laboratories matrix that was preserved directly by the data-logger device used through the tests. Therefore, while the initial temperature of the water remains unchanged through the test, an immediate fluctuation in the temperature over the water basin is closer after the experimental start. The distribution of the water temperature in the basin and basin superficial along the water basin rise set to decrease directly after bubbles injection from the basin side. Adding that, these decreases of the water temperature are progressed with the boost of the airflow rate (0.5, 1, 1.5, and 2.0 LPM) while realizing it the steady state terms to the test end. This could be established by that nature of bubbles movement because the bouncy impose effects from the variation in the density between water and air, leading to augment the thermal combination of the working liquid inside the basin which sustains temperature variation at its a suitable plane [17-19]. This variation shows to an augment in the heat transfer between the warm water inside the basin and the cold surface water basin and therefore decreases the water temperature inside the water basin.

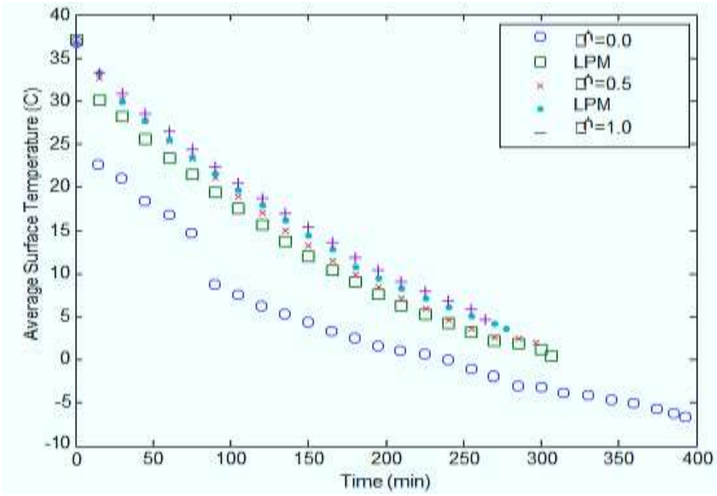

Fig. 5. Surface water basin temperature with time at different airflow rates

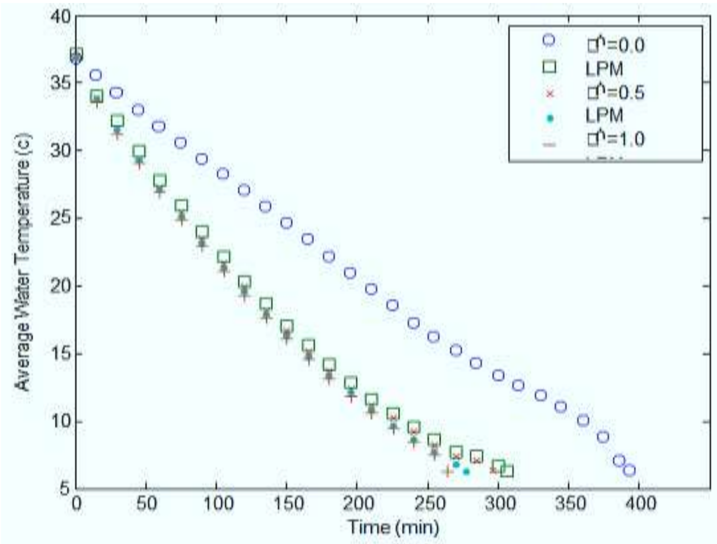

Fig. 6. Water Basin Temperature with Time at Different Airflow Rates

4.1 Energy Saving

Table 2 refers to the amount of cost for one operation to cool the water according to the price of electricity in Iraq which is 0.041 U.S. Dollars per KWh for business and the power consumed by the water cooling system is about 0.85 KW.

Table 2
Amount of cost for one operation

$\dot{V}$, LPM	Time to complete cooling operation, h	Cost*, $
0	6.63	0.231056
0.5	5.25	0.182963
1.0	4.95	0.172508
1.5	4.56	0.158916
2.0	3.8	0.13243

*Cost for one operation = (Amount of energy)(Unit cost of energy)

Table 2 shows the cost of electricity consumed by one cooling system or one cooling device and knowing that any work or sit businesses contain dozens of water cooling systems. There is a justification for using air bubble injection system reduce the energy consumption.

4.2 Heat Transfer

Consider a water as fluid inside water basin of volume *V*, mass *m*, surface area *As*, specific heat *Cp*, initially at a uniform temperature *Ti* and density ρ. At time *t* = 0, the water is placed inside basin, and heat transfer between the water and its surfaces, with an instantaneous heat transfer convection coefficient *h (t)*.

During time period *dt*, the water temperature in basin declines by a differential quantity *dT.* The balance of energy of the water for the time period *dt* can be written as

$$(\text{Heat transfer from the water during dt}) = (\text{The decrease in energy of water during dt}) \tag{1}$$

or

$$h(t)\ as\ (Ts, i{+}1 - Tw, i{+}1)\ \Delta t = m\ Cp, i{+}1\ (Tw, i - Tw, i{+}1) \tag{2}$$

where

Ts is the water basin surface temperature, °C
Tw is water temperature inside basin, °C
i, i+1 is the time increment

The instantaneous Nusselt number can be written as

$$Nu(t) = h(t)Dh/kw, i{+}1 \tag{3}$$

where

Dh is the hydraulic diameter and kw water conductivity. The initial temperature of water Ti at time = 0 and the final water temperature Tf after the end of the cooling process are constant and become 34.5 °C and 6.3 °C respectively.

Define temperature ratio or dimensionless temperature θ as a ration which twitch from (1) at *t* = 0 and become (0) at the end of the cooling process,

$$\theta = Tw(t) - Tf/Ti - Tf \tag{4}$$

Figure 7 shows the stimulus of prompt convection heat transfer coefficient with time at different volume air flow injected from sparger inside water basin. It is clearly shown that, the maximum instantaneous convection heat transfer coefficient occurred at the preliminary cooling process beginning due to decreasing temperature different (Tw–Ts) then its reductions during cooling process [20,21]. Also, increases volume air flow rate caused water turbulence inside the water basin which increases the prompt convection heat transfer convection coefficient h(t).

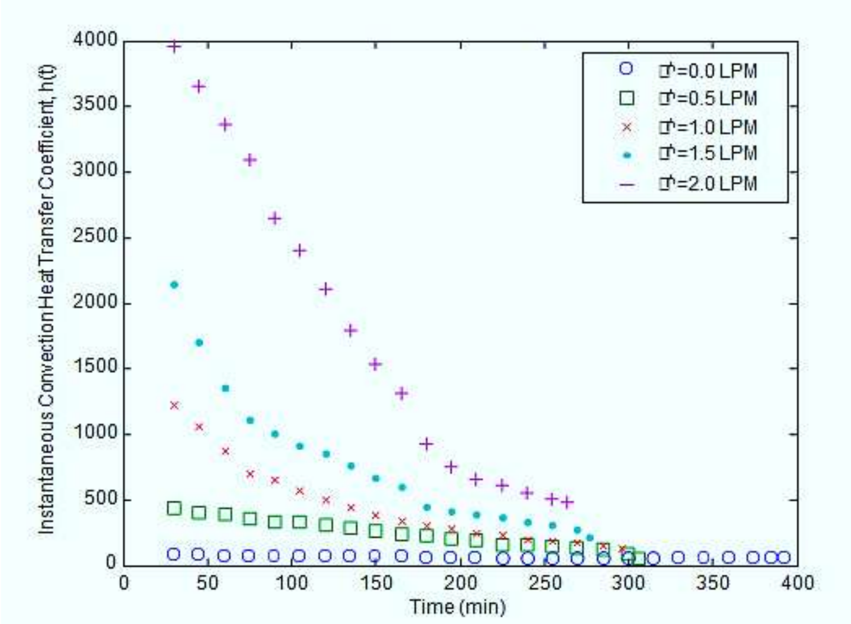

Fig. 7. Instantaneous convection heat transfer coefficient with time at different airflow rates

Figure 8 shows the variation of the dimensionless temperature ratio with instantaneous Nusselt number, Nu(t). it's clearly revealed that the maximum Nusselt number become at the beginning of the cooling process and at dimensionless temperature equal (1) and then decreases to final cooling process at (0). Also, escalations volume air flow rate caused the water instability privileged the water basin which escalations the instantaneous Nusselt number Nu(t).

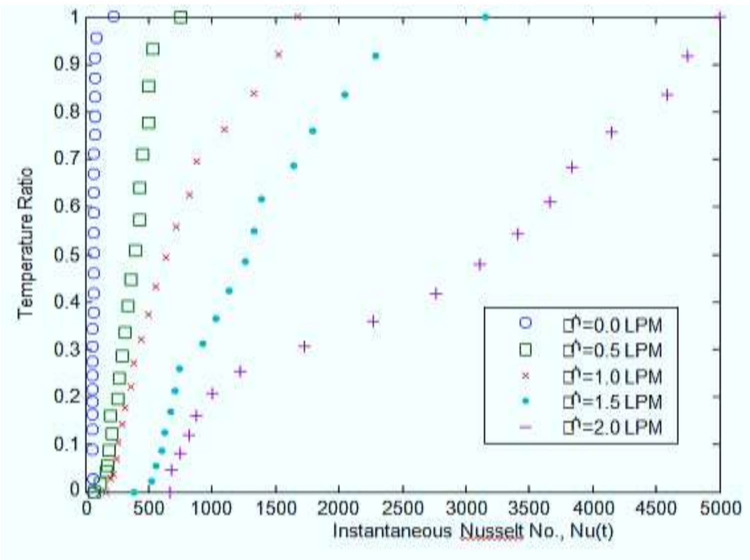

Fig. 8. Instantaneous Nusselt number with dimensionless temperature ratio

The guidance of middling Nu number with air bubbles flow rate which injected through sparger is publicized in Figure 9. It is Cleary publicized that, an important parameter Nu number in the cooling procedure is to maximize the convection heat transfer for a specified air volume flow rate. Also, the figure shows that the Nu number is directly comparative to air volume flow rate which indicates that with escalations the air volume flow rate the turbulence effects will be increased

[22]. The turbulence effect or mixing quantity due to increase of air volume flow rate inside water basin caused reduction in time to end the cooling process and this is shown in Figure 10.

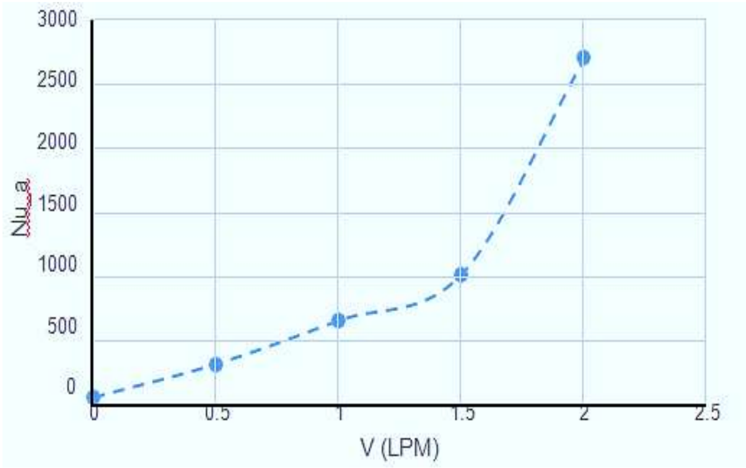

Fig. 9. Variation of average Nu with air volume flow rate

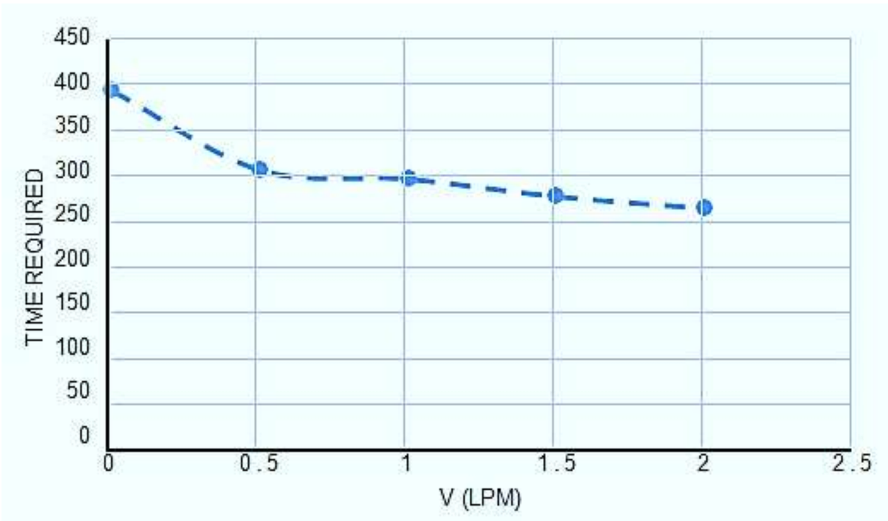

Fig. 10. Variation of time required to reach the required temperature with air flow rate

5. Conclusions

The main conclusion can encapsulate as there is a shortage of available data in the previous worker on the effect of the size of small bubbles, and air pressure on the performance of the water cooler. In the present work, average water temperature variation over a rise cylindrical and water basin surface temperature because the injection of air was laboratory investigated. To explain the significant notice that has uncollected in the previous works, the calculations illustrated that small air bubbles motility amount have a very significant guidance on time. The possibility of reaching the end of the cooling process can be achieved quicker as air flow rate amount is increased. It was clear how much electricity is saved using air bubble inoculation technique.

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