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Theoretical and experimental investigation of the effect of heat flux to lift water in a solar bubble pump

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HIGHLIGHTS

- A theoretical and experimental study was conducted on the bubble pump
- A new model and design for the bubble pump were developed
- Heat flux impacts the performance of the bubble pump
- Future scopes of work on the bubble pump show promise

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ABSTRACT

In remote areas, a scarcity of accessible water poses a significant predicament, and sun-powered propelling contraptions offer promising solutions. It is possible to collect solar energy with the goal of raising a fluid. Bubble pumps are used in the process of creating two-phase flows via the boiling of fluids in diffusion-absorption refrigeration cycles. In this investigation, a solar-powered bubble pump lifted the water. EES, which stands for engineering equation solver, was used in order to carry out the theoretical study of the bubble pump technology. Based on the results, it was determined that the void fraction displays a pattern that is comparable in applications using diffusion absorption refrigeration. In addition, the maximum water lift occurs at a certain heat flux value and any rise that is greater than this threshold causes the bubble pump to collapse entirely. Empirical tests were conducted utilizing bubble pumps with diameters of 8 mm and 10.21 mm to raise water across a distance of 4.53 m. The experiments examined a certain range of heat flow values at specified submergence ratios. According to the testing results, increasing the heat flux within the prescribed range significantly increased the 10.21 mm bubble pump's ability to lift water, yielding a maximum increase of 21%. According to the findings of the study, a universal set of optimal conditions and values for the bubble pump is not feasible to ascertain. This is because every system possesses distinct characteristics and operational elements that necessitate the utilization of optimized parameters for optimal performance.

1. Introduction

It is widely acknowledged that conventional energy sources possess a finite and nonrenewable supply and that a number of these sources also engender significant detrimental environmental impacts. As a result of this, scholars worldwide are presently engaged in active investigations into alternative renewable energy sources. Energy derived from renewable sources has numerous advantages, such as reduced environmental impact and long-term cost savings. Moreover, it can be applied in a wide range of environments due to its adaptability. Nevertheless, the unpredictability of the existence of wind and solar energy is one of the most significant obstacles that must be overcome [1– 4]. One commonly used method to move liquids from one place to another is through the use of bubble pumps, a specific class of pumps. Bubble pumps have a number of benefits that make them especially effective in situations when other kinds of pumps would not be appropriate. For example, when working with very viscous liquids or massive quantities of gas, bubble pumps are particularly beneficial. Additionally, in order to contribute to the enhancement of the text, particular examples of industries that make use of bubble pumps should be given. As an additional point of interest, he spoke more on the advantageous characteristics of bubble pumps that make them appropriate for the challenging circumstances that have arisen [5].

Airlift compressors are used in a wide variety of industries, particularly the petroleum and petrochemical industries, because of their versatility. In cooling systems that depend on spreading and absorption concepts, the use of bubble pumps is

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more effective than traditional mechanical pumps. This preference is due to the prominent advantages of bubble pumps. When it comes to preserving fluid movement and removing the absorbed cooling material from the mixture, these pumps bear the full responsibility to implement basic activities. On the other hand, the challenges in the study of these systems lie in the complexities of the prediction of the flow of the two phases within their channels. The study of these systems is a major challenge due to the complex nature of the phenomenon of flow in two phases. As a result, it becomes necessary to conduct a comprehensive analysis of the fundamental properties of airlifting systems and bubble pumps. Because of the strong relationship with which these pumps are associated with several main components, an in-depth study of these specified types of pumps must be conducted. By dealing with the complications of these systems and revealing their secrets, this research provides explorers an opportunity to provide valuable visions that may contribute to overcoming the challenges they face in the context of their studies [6–8].

The complexity of momentum and dynamics in the flow has been adopted in two phases as a basic attention point in the leading research conducted around bubble pumps and air bridge pumps. The foundations of these basic ideas laid the researchers Stenning and Martin [9], which contributed to the continued development of research in this field. Based on these ideas, a comprehensive study was conducted on air transport pumps, which are characterized by moderate lifting ranges and relatively small diameters. Based on the results resulting from this study, it is clear that the most effective way to transport water through pipes is to ensure a specific amount of air capable of flowing through the tube, while maintaining a specific diameter.

When Delano [10] conducted his studies on the bubble pump, he relied on the model set by Steining and Martin and used it as a basis for his research. Delano intended to establish a research framework for the bubble pump with the aim of highlighting the operational challenges in the Einstein cooling cycle and its interpretation better. Thanks to this research framework, the researcher can explain the function of the course using the laws to save mass and momentum. Delano's accurate investigation showed slight changes in the flow of liquid mass as a result of the adjustments to the heat entrances and the channel diameter. Furthermore, in order to enhance the efficiency of the cooling and diffusion cooling system, a research team led by Chen et al. [11] developed a unique composition that includes a bubble birth and pump. It used this training in its research studies. The working fluid was deliberately composed using three fluids: ammonia, water, and hydrogen. Ammonia acts as a refrigerant, water as an absorbent, and hydrogen as a secondary gas. The bubble pump tube for the system has an outer diameter of approximately 2 cm and a height of approximately 94 cm. The results of this study indicated a significant improvement in the overall system efficiency. The study showed that the coefficient of performance increased by 50% for a full operating cycle of this system. Additionally, Pfaff et al. [12] designed a model of a bubble pump. They conducted an experimental and analytical study on a bubble pump operating in a water-lithium bromide working fluid absorption system. A theoretical mathematical model was developed to study the time required to generate a vapor bubble from a working fluid. The effect of input temperature, immersion ratio, and diameter were studied. The study showed that for a cooling capacity of 100 watts, the appropriate pipe diameter is 10 mm, and the required heat is 40 watts. The results also indicated that pumping increases with increasing immersion rate, and the pumping frequency increases with increasing heat input. Wurts et al. [13] studied the airlift pump experimentally by changing the diameter of the lift pipe and the depth point of air pumping to lift water. The work team installed a lifting tube with a length of 185 cm and changed the diameter in ranges of (7.6, 10.2, and 15.2) cm. After regulating the system airflow, which ranged from 71 to 324 liters per minute, we then calculated the corresponding water flow. The research findings indicate that the pumping capacity of an airlift pump is subject to the impact of both the diameter and depth of the air injection. Typically, the pumping capacity has a positive correlation with both the diameter and depth of the air input. The rates of water pumped via the airlift system varied between 66 and 225 liters per minute across the numerous variables that were examined. The implementation of this advanced design resulted in a notable 50% increase in the coefficient of performance of the whole cycle, indicating a substantial improvement in the overall energy efficiency of the system. In contrast, a novel two-phase flow-based flow modeling approach for bubble pumps was devised by White [14]. The drift flux model, two-phase friction factors, and mixture properties were all incorporated into the model. To incorporate pump design details, the model incorporated independent variables, including height, diameter, and immersion rate (calculated by dividing the static tank height by the total pump height). Experimental results indicated that the bubble pump operates more efficiently in the slug flow regime. Jakob et al. [15] conducted an extensive investigation, including the construction, use, experimental evaluation, and simulation of a water-ammonia dual absorption cooling machine (DACM) that uses solar energy as the energy source. The researchers used a bubble pump, which involves completely submerging the lift tube in a liquid that helps transfer heat. The results show that the lower country is witnessing a decrease in response to an increase in surface tension while an increase in response to the expected volumetric vapor flow rate. The researchers performed many accounts using a wide range of bladder sizes, ranging from 5 mm and 41 mm, with the aim of ensuring the passage of the ball without interruption under certain operating conditions. Furthermore, Zohar et al. [16– 19] conducted a comprehensive analysis of refrigeration courses with absorption and spread, with a special focus on improving the general efficiency of these courses. The purpose of this study is to investigate the optimization of absorption chiller systems, with a particular emphasis on bubble pumps for performance enhancements. The research focused on increasing the efficiency of the system by reducing the input heat to the lowest possible level and the possibility of increasing the ability of the absorbent solution to absorb the refrigerant to the maximum possible extent. This was done through methods, one of which was a unique coolant separation method that required removing the coolant from the dilution solution first and then introducing heat through circular holes. This improves bubble pump performance and increases system efficiency. Three systems were studied, each of which has a special generator structure.

Their performances are analyzed through a complete numerical evaluation, which paves the way for chiller designs that are optimized and have the potential to redefine cooling technology through its application. The research yielded fundamental results that highlight its importance and deserve attention. What distinguishes it from the other two models is that the second model showed the highest degree of efficiency in absorbing refrigerant under heat input conditions equivalent to those found in the other two configurations. The desorption process that was included in the first design was the least efficient since it did not include simultaneous heat exchange with the solution that had been diluted via the procedure. The third configuration showed a somewhat lower coefficient of performance efficiency in comparison to the second configuration despite the fact that a concentrated solution was used in the third configuration. Following this, it was decided, after carrying out an exhaustive investigation, that the original setup displayed the performance characteristics that were the least advantageous. The initial configuration layout, which is common in commercial systems, is extensively implemented. This is an important point to discuss.

Within a vertical lift tube of the bubble pump, Benhmidene et al. [20] carried out an exhaustive examination and developed a computer model of the heat transfer that occurred. A tube of different diameters surrounded the heating element, which was 1 meter long. The study conducted a wide range of numerical trials to explore a wide range of thermal flow values between 1 and 70 km/m^2. The corresponding liquid speed of these values has been calculated. To determine the optimum thermal flow, it was evaluated at collective flow rates ranging from 10 to 90 kg/m^2 per second for the tubes with diameters 4, 6, 8, 10 mm, and above. This study allowed us to determine the optimal thermal flow. The study was made with the aim of determining the relationship between the optimal thermal flow, the rate of mass flow and the diameter of the tube. Researchers also allow researchers a link between measuring the diameter of the tube and the minimum heat flow necessary to achieve the effectiveness of the pumping system. Additionally, Benhmidene et al. [21] analyzed the behavior of melting boiling water and ammonia under the influence of the regular heat flow using a single fluid model. The study aimed to analyze the behavior of the liquidation of the questioners with the aim of predicting the operational qualities required to build a bubble pump and a cooling unit successfully. Factors such as the display of the canal, the entered heat quantities, and immersion rates are considered in the sporty model. In the context of numerical analysis, a certain amount of thermal flow ranged from one to thirty kilowatts per square meter. These experiments included a variety of tubes between 4 and 10 millimeters and varying levels of ammonia amounts between 0.3 and 0.6. The effect of these factors has been examined to search for the best channel of one meter. In the aftermath of the initial rise in the heat flow, both the pumping rate and the liquid speed witnessed a decrease later, followed by an increase in the heat flow. It should be noted that the optimal rate of heat transfer is sensitive to changes in the diameter of the canal. Furthermore, Benhmidene et al. [21–23] conducted a series of research, one of this research included a simulation of the behavior of the cooling fluid flow in a stable condition. The researchers also created models of heat flow effects on the rates of flow rate on ammonia flow in two phases inside the bubble pump. These assessments and simulations were conducted, as well as experimental assessments of operating performance. In the context of the numerical study, a variety of thermal flow values were studied, especially from 2 to 20 kW/m^2, with 0.4 % ammonia and a tube diameter of 6 mm. A 1.6-meter-meter experimental device is designed, containing an internal tube with a 6 mm diameter, and a block of 0.6 mm of ammonia, used to test the NH_3/H_2O bubble pump performance. Twenty-five, thirty-five, and forty-five percent of the immersion rate were investigated, and the thermal input varied from twenty to two hundred watts of thrust. According to the findings of the research, the best range for heat output corresponds to between 30 and 130 watts when the immersion rate is between 35 and 45 percent and between 30 and 80 watts when the immersion rate is 25 percent. Using a drift flow model to represent two-phase flow behavior accurately, the research focused on liquid and vapor velocities, mass velocity, vacancy rate, and pumping rate. Simulation findings indicated early fluctuations in vapor, liquid, and mass velocities, with an increase in heat flux from five kW/m^2 to two kW/m^2, lengthening the duration of these fluctuations by twelve seconds.

The present study involved a comprehensive investigation of a bubble pump with the goal of elevating water to residential heights. The research encompassed both theoretical analysis and experimental investigations. Theoretical analysis was conducted using an engineering equation solver (EES) program. The heating section was segmented, and the void fraction was calculated based on water parameters, including the submergence ratio, pipe diameter, and heat flux. As well as studying the effect of heat flux on lift. In addition, as an experimental setup, a solar bubble pump was conceived, built, and successfully used to lift water. Solar energy was simulated using an induction heater with a maximum output capability of 3,000 watts. Experiments were carried out to determine the effect of heat flux on the maximum flow rate of a solar bubble pump with a fixed-length lift tube with diameters of 8 mm and 10.21 mm. It is worth noting that the first configuration layout, which is typically used in commercial systems, is quite common.

2. Theoretical model

A schematic diagram of the bubble pump is shown in Figure 1. The vertical adiabatic conduit, known as the lift tube, enables the upward transportation of a two-phase flow consisting of air and water. The present technology guarantees the prevention of heat transfer with the surrounding environment, hence preserving adiabatic conditions throughout the vertical ascent of the two-phase mixture. In their research, White [14] conducted a comprehensive investigation of the principles of air-lift pump theory. Furthermore, they designed, fabricated, and evaluated an adiabatic air-lift pump by using compressed air in conjunction with water at ambient pressure. The correlation obtained from Delano's reference example [10] allows for the estimation of the maximum attainable pump height for a given generator height. The maximum pump height is contingent upon the average pressure gradient along the lift tube. Nevertheless, the first design model proposed by Shelton and Stewart [24] failed to include the potential fluctuations in density, velocity, and temperature that may occur during the boiling process inside the generator pipe. In order to account for these variations, a change was implemented to the correlation. The prevalence of the first configuration arrangement, which is routinely used in commercial systems, is deserving of attention.

In order to generate a swift slug flow, air-lift pumps introduce gas from the exterior. Conversely, bubble pumps utilize heat to induce vaporization and a rise in temperature, which ultimately leads to a reduced exit liquid mass flow. Discrepancies in the design model are accounted for by the modified correlation as in equations from 1 to 6 [14],[25].

$$\text{Term1} = \frac{f_{tp}\left(\rho_{l,o} j_{l,o} + \rho_{v,o} j_{v,o}\right)^2}{2 g d_i \rho_{l,o} \rho_{tp}} \quad (1)$$

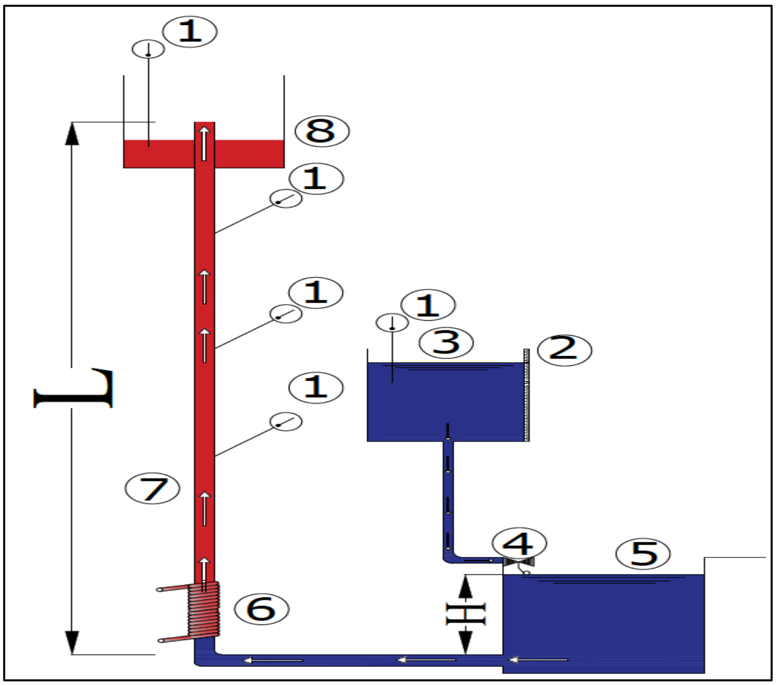
$$\text{Term2} = \frac{j^2_{liquid,out}\left(\frac{d_i}{d_{enterace}}\right)^4}{2 g L_{L.t}} \quad (2)$$

$$\text{Term3} = \frac{j_{l,o} \rho_H \left(\frac{d_i}{d_{en}}\right)^2 \left[\left(j_{l,o} + j_{v,o}\right) - j_{l,o}\left(\frac{d_i}{d_{en}}\right)^2\right]}{\rho_{l,o} g L_{L.t}} \quad (3)$$

$$\text{Term4} = 1 - \varepsilon \quad (4)$$

$$\text{Ratiosub} = \frac{H}{L_{L.t}} \quad (5)$$

$$\text{Ratiosub} = \text{Term1} + \text{Term2} + \text{Term3} + \text{Term4} \quad (6)$$



1. Thermocouple	**2. A Ruler with centimeter markings**	**3. Scale tank**	**4. Float**
5. Storage tank	**6. Induction heater**	**7. Tube**	**8. Temporary tank**

Figure 1: Schematic diagram of the bubble pump

3. Description of the experimental setup and procedure

3.1 Experimental setup

Float, storage tank, induction heater, lift tube, thermocouple, ruler, scale tank, temporary tank, and storage tank constituted the experimental configuration depicted in Figure 2. The bubble pump was supplied with water from the storage tank. In contrast, a float connected to the scale tank maintained a constant submersion ratio. The conduit was heated by means of an induction furnace, while water was transferred into the impermanent receptacle via the bubble pump. An additional glass scale vessel was employed to capture the water. The main components can be a briefly enumerated tank with a cross-sectional area of 15×15 cm², a generator (Induction heater with 3000 W), and a tube (with 8 and 10.21 mm). The water level was changed at atmospheric pressure to obtain submergence ratios of 0.195-0.26. The tube length of the bubble pump was 4.53 m.

The operation of the bubble pump, in short, was to operate the induction heater at a certain power while determining the water level in the storage tank so that the water would then boil inside the tube. Thus, the boiling water bubbles would rise, raising the water column above it to the upper tank, and so on. The Experimental uncertainty value is shown in Table 1.

Table 1: Experimental uncertainties

Independent parameter (e)	Uncertainty (w)
Temperature	± 0.87 °C
Diameter	±0.0007 m
Length	±0.0007 m

4. Results and discussion

4.1 Void fraction

Precisely determining the void fraction is of utmost importance in the research of two-phase flow. One effective method for identifying the flow regime is by using void fraction correlations. It is crucial to precisely determine the present flow regime due to the bubble pump's excellent performance in the slug flow regime. This research investigated void fraction correlations in different flow patterns in both horizontal and upwardly inclined pipes. Using the drift flux correlations suggested by Rouhani I (1970), the vertical flow is very good at predicting the vertical database, with an error index of less than 15% [26].

The Rouhani-Axelsson (Rouhani I) void fraction correlation is considered an appropriate selection for this study, mainly because it tends to converge towards 1 for higher void fractions. This correlation calculates the void fraction using the vapor mass fraction (quality), surface tension, density, and fluid mass flow. Notably, all characteristics, except for the mass flow, are inherent to the fluid, guaranteeing a greater degree of precision in calculating the void fraction. By only using mass flow as the input in the computation, the accuracy of the outputs is further enhanced [25]. Figure 2 displays the graphical depiction of the Rouhani-Axelsson void fraction correlation.

Benhmidene used a water-ammonia blend with an intake pressure of 18 bar, utilizing heat flux and mass flux values of 20 kW/m^2 and 20 kg/m^{2}s, respectively. Walt used a pipe with a diameter of 10 mm and a mass flow rate of 20 kg/m^{2}s in his experiments. The pipe contained an ammonia-water combination under a pressure of 8 bars. On the other hand, the current model used water as the working substance, with an 8-mm pipe diameter, atmospheric pressure, a heat flux of 1000 kW/m^2, and a mass flow of 10 kg/m^{2}s to accomplish almost total evaporation of water. The Rouhani-Axelsson correlation is shown on top of the Samaras and Margaris [27] two-phase flow regime maps in Figure 2. This shows the upward flow of gas and liquid in an air-lift pump.

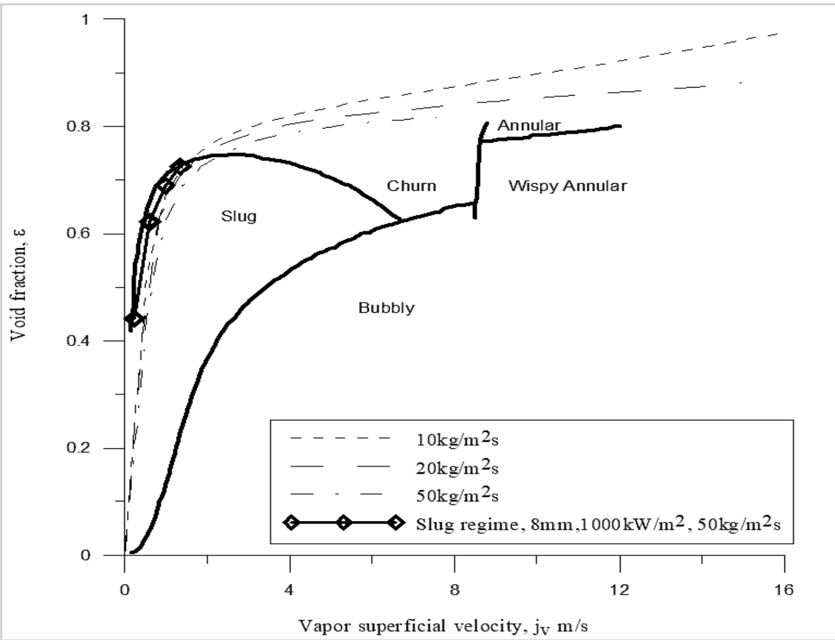


Figure 2: Rouhani-Axelsson void fraction correlation for mass fluxes ranging from 10–50 [kg/m^2 s] and a tube diameter of 8 mm [27]

5. Heat flux impact on bubble pump diameter and length

The heat input is an essential operating element in the context of bubble pumps. In order to mitigate energy usage, heat may be obtained via the use of sun collectors or concentrated solar collectors. Figure 3 illustrates the correlation between heat input and both the height of the bubble pump and the ideal diameter. The change in heat input results in corresponding adjustments to both the height and diameter of the pump. Under certain specified operational circumstances, there exists an ideal diameter for a tube that allows for the attainment of maximal pumping height while maintaining a constant mass flow. Significantly deviating from this range has a significant influence on the lifting height.

The duration of a bubble pump may not always grow with an increase in heat input. When the diameter and mass flow remain constant, it is seen that an increase in heat input might potentially decrease the pump bubble lift. The increase in vapor phase velocity and the resulting increase in frictional forces attribute to this phenomenon. To determine the optimal operating point for a particular application, a complete understanding of the various design and operating characteristics in a wide range of situations is essential. Certainly, obtaining this information is vital thing to ensure an effective and likely design that meets the specific needs. In the context of complex systems studies and research such as bubble pumps and cooling units, it allows analysis of flow and heat behavior, and to understand how different variables affect the system performance, the ability to improve the design and amend the effects. With a deep understanding of the relationships between the various variables, such as the diameter of the tubes, the amount of heat, and the concentration of fluids, engineers and researchers can improve the design of pumps and improve their performance continuously. This contributes to the development of effective and economic systems and better refrigeration and heat transfer requirements.

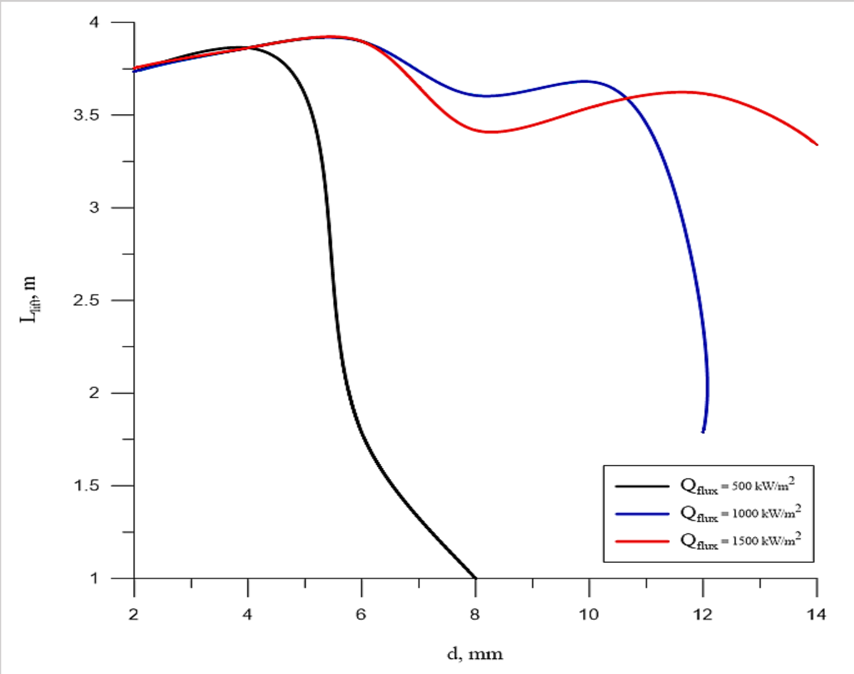


Figure 3: The effect of the diameter and heat flux to lift water at a rate of 50 kg/m^2 s mass flux

5.1 Effect of diameter and heat flux on mass flux

The bubble works to push the liquid into the pipe, whether in cooling systems or to raise water for home use, as is the current work. The bubble height depends on a very important design factor, which is the tube. Choosing the right pipe diameter is not just about size. It is a delicate balance between speed and efficiency. For example, increasing the amount of liquid crushing the bubble and increasing the diameter of the tube will cause the balance between the buoyant force and the attractive force, which leads to the pump collapsing. Several factors must be taken into consideration when choosing the pipe diameter, including the volume of the liquid raised, the required flow rate, and the properties of the liquid.

An investigation into the influence that diameter has on flow characteristics was carried out with the use of two copper tubes that had inner diameters of 8 mm and 10.21 mm, respectively. These tubes were joined to one another in order to produce a total length of 4.53 meters. Through the use of the submergence ratio, various degrees of heat conduction were produced as simulations. During the measurements, circumstances of bulk flow and increased water temperature were observed, respectively. There are graphical depictions of how the mass flow rate is affected by changing the diameter of the lift tube within a certain range of heat flux. These representations can be found in Figures 4 and 5, respectively. The water level was adjusted to a certain level, the induction heater was activated, and after the system reached a stable condition, measurements were recorded.

The results shown in Figures 4 and 5 indicate a positive correlation between the lift tube diameter and the mass flow rate, suggesting that a rise in the former leads to an increase in the latter. The reason for this phenomenon is that an increased diameter leads to a decrease in friction, resulting in a reduction of the counteractive force that opposes the buoyancy force of the vapor. The determination of the ideal tube diameter is contingent upon several elements, including but not limited to heat flux, mass flow rate, system pressure, fluid characteristics, friction coefficient, surface tension coefficient, and other pertinent considerations. The optimization of liquid elevation within a certain flow rate and defined heat flux range necessitates the determination of an ideal diameter based on a particular set of parameters. Nevertheless, the augmentation of the diameter will result in a decrease in the maximum achievable liquid height. Given the specified immersion rate and heat flux, a cylindrical object with a diameter of 10.21 mm can raise water to a vertical distance between 4 and 5 meters while maintaining a flow rate of 11.5 to 14.5 liters per hour.

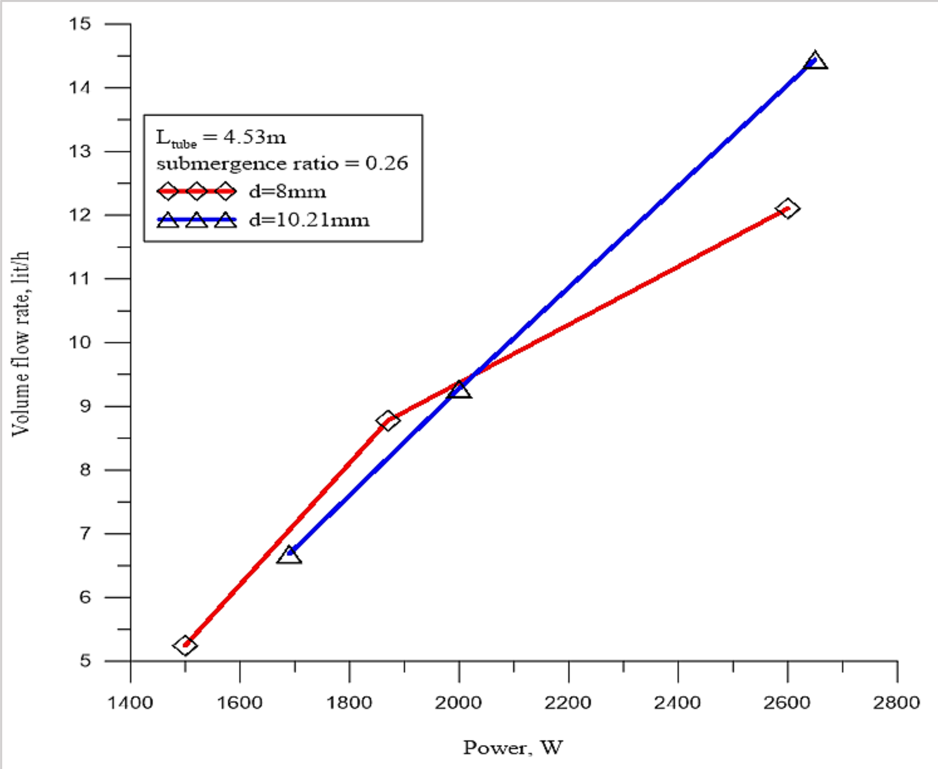


Figure 4: The impact of tube diameter and input power on the mass flow rate

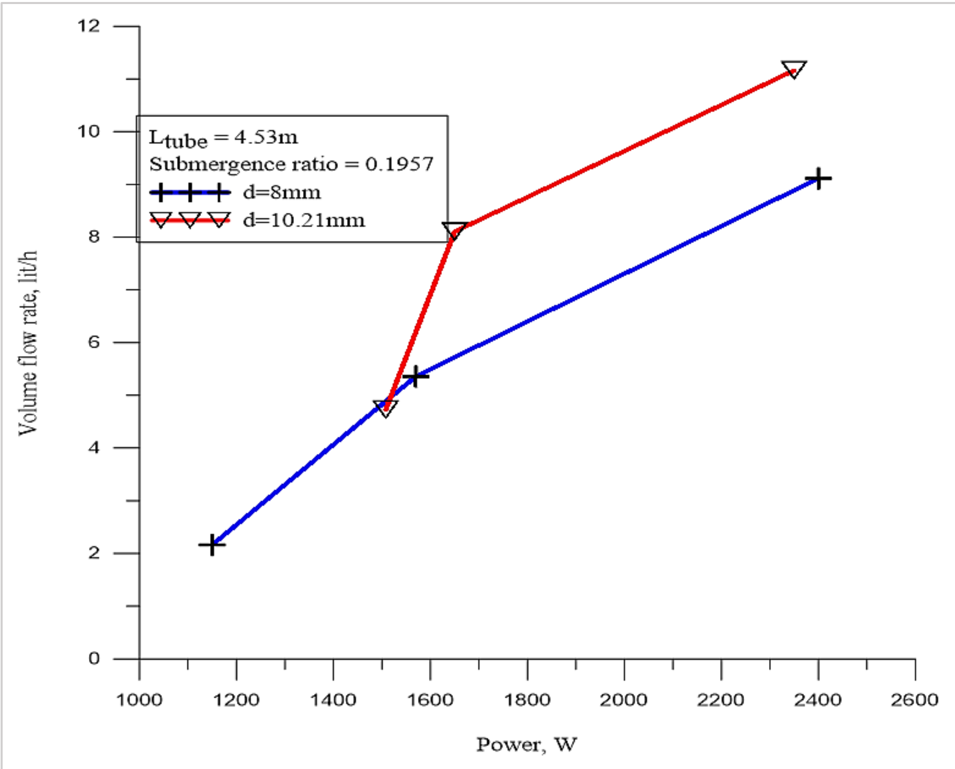


Figure 5: The impact of tube diameter and input power on mass flow rate

6. Conclusion

A comprehensive examination was conducted on the bubble pump, using water as the operational medium, including both theoretical and experimental approaches. A theoretical model was constructed using the engineering equation solver. A series of experiments were performed using a pipe of 4.53 meters in length, including internal sizes of 8 and 10.21 millimeters. The operational variables consisted of heat flux levels that were limited to a maximum of 3000 watts. The operating environment included consideration of air pressure, while the decision not to use the slug flow pattern was influenced by limitations in the available equipment. The following section presents the main results of the study:

1) The increase in heat flux does not lead to an increase in the maximum lift. Instead, for a given diameter and constant mass flow, there exists a specific maximum lift corresponding to each heat flux level.
2) When the heat flux is increased, there is a commensurate increase in the flow rate of raised water while keeping the tube length, diameter, and submergence ratio unchanged.
3) The outcomes of the research indicate that it is not possible to use a single set of ideal conditions and values for bubble pumps globally. This is because each system has distinct features and operating factors that need customized optimization.

A pipe with a diameter of 8 mm was used to lift the water to a height of 3– 4 meters. The water was flowing at a rate of around 12 liters per hour, but the heat flux remained below 3000 watts. In addition, the water is elevated to an equal level by means of a pipe measuring 10.21 mm in diameter while maintaining a flow rate of around 14.5 liters per hour and a heat flux that does not surpass 3000 watts.

7. Recommendation for future work

Future studies should study multi-stage bubble pumps and visualize the flow pattern.

	Abbreviations	
EES	Engineering Equation Solver	
DACM	Diffusion-Absorption Cooling Machine	
Symbol	**Nomenclature**	**Units**
d	diameter	m
f	friction factor	-
g	gravitational acceleration	m/s^2
j	superficial velocity	m/s
H	height of the water level	-
L	height	m
	Greek symbols	
ε	void fraction	-
ρ	density	kg/m^3
	Subscripts	
en	entrance	
H	homogeneous	
i	inner	
l	liquid	
L.t	Lift tube	
o	out	
sub	submergence ratio	
tp	Two-phase	
v	vapor	

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

Author contributions

Conceptualization, I. Omar and A. Saleh; methodology, A. Saleh.; software, I. Omar; validation, A. Alhusseny; formal analysis, I. Omar; investigation, I. Omar; resources, I. Omar; data curation, I. Omar; writing—original draft preparation, I. Omar; writing—review and editing, I. Omar, A. Saleh and A. Alhusseny; visualization, I. Omar; supervision, A. Saleh; project administration, A. Saleh. All authors have read and agreed to the published version of the manuscript.

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