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"Technical Analysis of Desalination System Working With Bubbler Humidifier"

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ABSTRACT

The scarcity of fresh water is an issue of high concern as most of the world population suffers from clean water shortage. One potential solution to tackle this issue is to develop efficient, reliable, and cost effective water desalination system to make the clean water accessible for most of the world population. Humidification-dehumidification (HDH) is a carrier gas based thermal technique that is ideal for a small scale water desalination system. An innovative design approach is to use the bubbler humidifier to enhance the performance of the HDH water desalination system. The aim of this work is to develop an analytical model for bubbler humidifier that can predict the heat and mass transfer. The effect of various design and working parameters on the performance of the proposal system is evaluated. For performance evaluation a computer simulation program has been prepared to solve the energy and mass balance equation of the proposed system.

Keywords: - water desalination; HDH systems; direct contact heat and mass transfer; bubbler humidifier

INTRODUCTION

Water Availability :-

Water is available in abundance on the earth however; there is a shortage of potable water in many countries in the world. Uses of water include industrial, household, agricultural, recreational and environmental activities. About 97% of the water present on the Earth is saline water [1] and only 3% is fresh water; slightly over 2/3rd of this is locked in ice caps and glaciers. The remaining 1/3rd part is iceless fresh water found mainly as under groundwater, and only small amount present above ground or within the air. Available fresh water accounts for less than 0.5% of the Earth's total water supply. By removing salt from the saline water, desalination has emerged as an important source of drinking water.

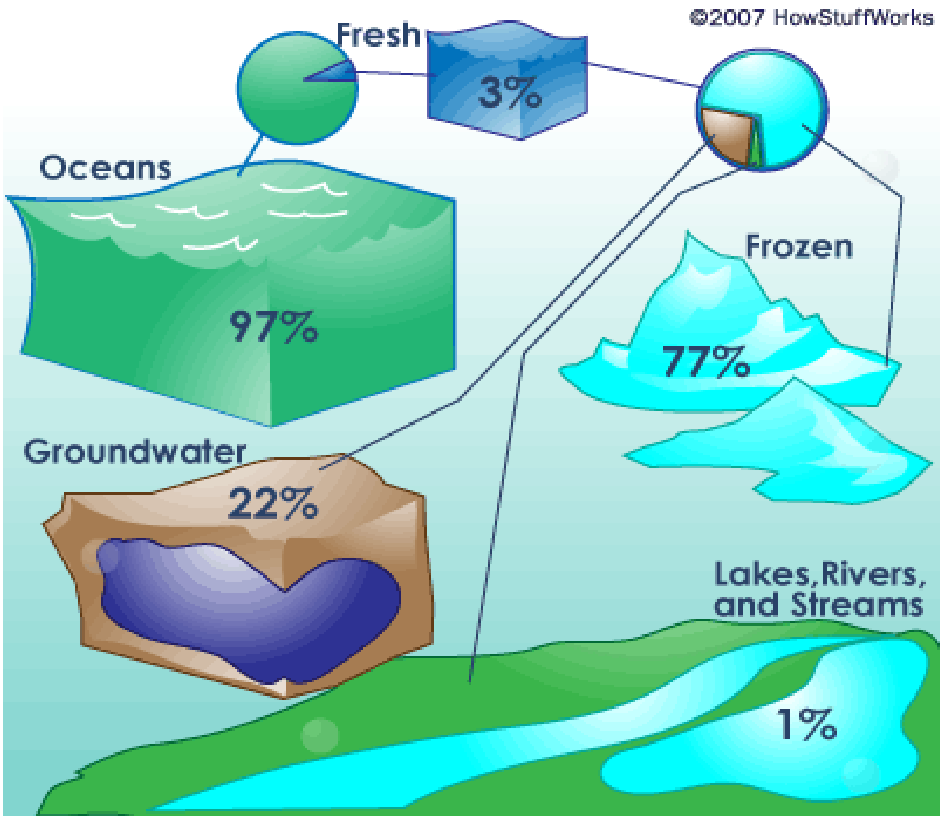

Fig: water availability [1].

Surface Water :-

Open water is water in a very stream, lake or fresh ground. Open water is of course replenished by precipitation and naturally lost through discharge to the oceans, evaporation and groundwater recharge. though the natural input to any open water system is precipitation at intervals its basin, the overall amount of water in this system at no matter broken time is likewise hooked on several alternative elements. These elements embrace storage capability in lakes, wetlands and artificial reservoirs, the permeableness of the bottom at a lower place these storage bodies, the runoff characteristics of the soil within the basin, the temporal order of the precipitation and native evaporation rates. All of those genes additionally have an effect on the proportions of water loss.

Under River Flow :-

Throughout the course of a stream, the whole volume of water transported downstream can usually be a mixture of the visible free water flow along with a considerable contribution flowing through rocks and sediments that underlie the stream and its plain known as the hypothetic zone. for several rivers in large valleys, this unseen part of flow could greatly exceed the visible flow. The hypothetic zone usually forms a dynamic interface between surface groundwater and surface water from aquifers, exchanging flow between rivers and aquifers that will be absolutely charged or depleted. this can be particularly important in karsts areas where potholes and underground rivers are common.

Ground Water :-

Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is the water that is flowing within aquifers below the water table. Sometimes it's helpful to form a distinction between groundwater that's closely related to surface water and deep groundwater in a geological formation generally referred to as "fossil water".

Frozen Water :-

Several schemes are planned to create use of icebergs as a water supply, but to this point this has solely been in serious trouble analysis functions. ice mass runoff is taken into account to be surface water. The Himalaya Mountains, which are usually known as “The Roof of the World”, contain a number of the foremost extensive and rough high altitude spaces on Earth as well as the greatest area of glaciers and land outside of the poles. 10 of Asia’s largest rivers ensue there and over a billion people’s livelihoods depends on them. To complicate matters, temperatures there are unit rising earlier than the worldwide average.

Desalination process :-

Many types of water desalination processes have been developed. The process of desalination can be classified into the following two categories which are: thermal processes and membrane processes. The thermal process is a phase change process and membrane processes are single phase process. In the thermal process a thermal energy source, such as fossil fuels, solar energy or nuclear energy may be used in water evaporation, which is condensed to obtain fresh water. The thermal desalination processes described here include, solar distiller, Multi-Stage Flash (MSF) distillation, Multi-Effect (ME) distillation, Vapour Compression (VC) distillation and Freezing distillation. In the single phase processes membranes are used in mainly two important desalination processes, Reverse Osmosis (RO) distillation and Electro Dialysis (ED) distillation.

Types of Desalination processes

I. Multi-Stage Flash Distillation.

II. Vapor Compression Distillation.

III. Reverse Osmosis.

IV. Solar Evaporation.

V. Electro dialysis.

VI. Freezing Desalination.

VII. Multiple Effect Distillation.

LITERATURE REVIEW

1. Mahmoud Shatat* and Saffa B. Riffat [4].

Water is one of the earth's most ample substances, overlaying about three-quarters of the earth surface. Yet, there is a critical deficiency of pure water in many countries, majorly in Africa and the Middle East region. The reason for this manifest antithesis is, of course, that _97.5% of the earth's water is salt water in the seas and only 2.5% is potable water in ground water, ponds and rivers and this fulfill most human and animal necessity. Confronting the water insufficiency problem must comprise best and more economic methods of desalinating oceans water. This paper shows a brief review of water desalination systems, whether functioned by conventional energy or renewable energy, to make saline water into potable water. These method comprise the thermal phase change and membrane processes, including to some surrogate methods. Thermal methods add the multistage flash, multiple effects of boiling and vapor compression, cogeneration and solar distillation, whilst the layer methods add reverse osmosis, electro dialysis and layer distillation. It also coats the combination into desalination systems of potential renewable energy resources, adding solar energy, wind and geothermal energy. Such methods are growingly preferable in the Middle East and Africa, areas abiding from insufficiency of potable water but solar energy is abundant and their functional and maintenance prices are minimum. The profits and nonprofits, adding the economic and environmental, of these desalination methods are showed.

2. Mr. AliAl-Karaghouli, Lawrence L.Kazmerski [5].

The basic thermal distillation methods add different multistage flash distillation (MSF), multi-effect desalination systems increase water attribute, eminently decrease water insufficiency difficulties, and increase attribute of liveliness and economic conditions. Two important methods are now a days applied in water desalination processes: thermal (phase-change) methods and layer methods distillation (MED), or vapor compression (VC). The VC methods constitute two types: mechanical (MVC) and thermal (TVC). The familiar membrane desalination methods add reverse osmosis (RO) or electro dialysis (ED or EDR). Energy price, functional and maintenance price, and money asset are the major suppliers to the water production price of any of these methods. Now the energy price is accountable for about approximately 50% of the converted water price. And for thermal distillation methods (MSF, MED, and TVC), two energy forms are essential for the function: (1) low-temperature heat, which shows the important part of the energy input and is contributed usually to the system by a number of many external resources (e.g., fossil fuels, waste heat energy, nuclear energy, solar energy) and (2) electrical energy, which is employed to move the system pumps and other electrical parts. For the MVC thermal distillation methods, electricity is required. For membrane methods (RO and ED), only electrical energy is needed as an energy source. Renewable energy methods such as the solar thermal, solar photovoltaic, wind energy, and geothermal methods are now a days employed as energy givers for desalination processes. These renewable resources are currently a proven technologies and become economically promising for remote areas, where the connection to the public electrical supply is either not or price effective or feasible, and where the water deficiency is extreme. As the methods continue to increase, and as potable water becomes minimum and fossil fuels energy costs increases, renewable energy desalination becomes more achievable economically. The technical function, energy depletion, environmental considerations, and capacity of renewable energy employed in moving the important desalination methods are reshowed and evaluated in this article. The current and projected prices of water converted from conventional and renewable-energy-driven methods are studied and compared.

3. Mr.Sandeep Parekh, Mr. M.M. Farid, J.R. Selman, Said Al-Hallaja [6].

Most important desalination methods consume a huge quantity of energy produced from oil and natural gases as heat energy and electrical energy. Solar desalination methods, although studied for over the two decades of period, has only currently appeared as a promising renewable energy source-powered technology methods for converting potable water. Solar desalination is based on the humidification– dehumidification cycle represents the best technologies of solar desalination due to the overall high-energy efficiency. This article gives a brief technical view of solar desalination methods with a multi-effect cycle giving a better understanding of the methods. Discussion on technologies to increase methods performance and efficiency makes the way towards the possibility commercialization of the units in the future.

4. Mr.Abu ElNasr M, Mr.Kamal M, Saad H and Mr. Elhelaly M [7].

The aim of this article is to represents an experimental investigation of a water desalination method using the solar energy that uses the humidification and dehumidification principle of the technologies. A sample test rig was designed and constructed, fabricated and assembled in order to research the effect of the water flow rate and the humidifier inlet water temperature against the desalinated water productivity. The system is consists of a spray type with no covering bed humidifier, a copper coiled dehumidifier, a flat plate solar water heater, an air blower type, a water pump for water circulation, a water flow meter, a water tank storage, three thermocouples and the four gate water valves. This method is based on an open water closed an air cycle.

5. Mr. Yasser Elhenawy, M. Abd Elkader, Mr.Gamal H. Moustafa [8].

A theoretical research of a humidification and dehumidification solar desalination unit has been carried out to improve a understanding the outcomes of the weather situations on the units productivity. A humidification and dehumidification (HD) solar desalination system has been constructed to give potable water for population in rural arid regions. It compromises of solar water collector and air collector; to give the hot water and the air to the desalination chamber section. The desalination chamber is also divided into the humidification and dehumidification towers sections.

The circulation of the air between the two towers is totally maintained by the forced convection process. A mathematical modelling has been formulated, in which the thermodynamic relationships were employed to research the flow, heat and mass transfer inside the humidifier and dehumidifier sections. Now the current method is performed in a order to increase the unit performance of the system. Heat and mass balance methods has been done and a set of governing equations methods has been solved using the finite difference technique methods. The unit productivity of the system has been calculated along with the working day during the summer days and winter days and has compared and studied with the available experimental outcomes. The average productivity of the system method in winter days has been ranged between 2.5 to 4 (kg/m2)/day, while the average summer days productivity of the system has been found between 8 to 12 (kg/m2)/day.

6. Adewale Giwa, Hassan Fath, ShadiW. Hasan [9].

Humidification and dehumidification (HDH) desalination technology systems with the use of the covered photovoltaic (PV) thermal energy and could be essential for the production of the converted small-capacity potable water and increment of the PV electric power generation efficiency. This paper investigates and studied the technical feasibility of the system and the environmental friendliness of an air-cooled PV system added with the encircling ocean water inflow into a HDH desalination system process. The technical analysis of the PV-HDH desalination methods was carried out through the various modeling of the physical and the thermodynamic properties which are involved in the recovery of the PV thermal energy and the finding of the effects of this recovery on the water converted under the environmental situations of the Abu Dhabi, UAE.

The outcomes represents that the heat recovered from the PV process consequences in the conversion of a daily average of 2.28 L of potable water of PV process. And on the other hand, the environmental conditions changes the estimation of this PV-HDH process and desalination system technology was also carried out from the first time in order to the determining its capacity for the small-scale potable water and the energy production. The PV-HDH system technology resulted in 83.6% decrease in the environmental changes when compared with the PV-Reverse Osmosis (PV-RO) system technology. Hence in result , the combined PV-HDH desalination technology system is efficient and promising and expected to play a important existence in the field of water desalination system.

7. Mr.G. Prakash Narayan, Mr.Mostafa H. Sharqawy, Mr.John H. Lienhard V, Mr.Syed M. Zubair [10].

Humidification and dehumidification desalination system (HDH) is a best technology methods for the small-scale potable water production applications processes. There are many examples of this technology system which have been investigated and studied by the researchers all around the world. And now however, from the previous literature review [1], we have found that no study and researches carried out a detailed thermodynamic analysis in order to increase the feasible and efficient of the system performance. In this article, we have analyzed the thermodynamic performance of the various HDH cycles by theoretical cycle analysis process. In conclusion, we declare the novel high-performance variations on those cycles. These various high-performance cycles include multi-extraction ,and the multi-pressure and the thermal vapor compression cycles. It is concluded that the systems based on these novel cycles will have profited the output ratio in excess of the 5 and will perform the existing HDH systems.

8. Mr .A. Khalil, Mr .S.A. El-Agouz , Mr .Y.A.F. El-Samadony, Mr. Ahmed Abdo [11].

An experimental study and research of a solar water desalination system using an air bubble column humidifier is investigated thoroughly . The main characteristics of the produced bubbles are changed by employing a different plate with the different hole sizes. The effect of the water temperature, and air flow rates, water height, and the hole diameters on the desalination system performance is studied effectively. Now the conclusions represented that the daily productivity results, efficiency and profit in output ratio are 21 kg, 63%, and 0.53; at the inlet water temperature is 62 °C. The change in the different temperature difference along the column is less than 2.5 °C for all measurements of the components. The better performance is produced from the sieve with 1 mm hole diameter and at which the outlet air from the bubble columns sections is always saturated. The air bubble column achieves the higher and better performance than that for the conventional humidifier.

9. Mr.E. W. Tow, Mr.J. H. Lienhard V [12].

Humidification and dehumidification is a better technology method for the decentralized, small-scale desalination system, but the high energy consumptions and large dehumidifier sizes are disadvantages. The direct contact dehumidification process in the bubble columns has earlier been display to the decrease in dehumidifier volume by an order of the amount. Now in a bubble column dehumidifier system, warm and moist air is bubbled through a column of the fresh water cooled by heat exchanger with the ocean water feed. And the concentration gradient from the warm bubble center to the cool bubble surface moves radial mass diffusions, and the water vapor condenses on the surface of the bubble. In this article, a parallel-flow effectiveness is defined to the complement heat flux when the function of a single-stage bubble column dehumidifier system. A bubble column dehumidifier is evaluated employing smaller cooling coils than those the studied in the previous work. Experimental conclusions are represented in the terms of the heat flux and the effectiveness in order to the better understanding of the reasons influencing the bubble column dehumidifier function. And it is discover that the heat flux can be increased dramatically by decreasing the coil area, but that this improvement is accompanied by a loss of effectiveness. Increasing air temperature leads to the increased heat flux but decreased in effectiveness. Because the pressure drop improves gradually with increasing the column liquid height, most importantly lower column liquid heights are tested than those the used in previous works. The main liquid height is discover to be below 4 cm and flow rate is tested. Additional heat transfer in the air gap is explored efficiently, but found to be minimum for the well-designed columns with the low temperature. These findings will inform the design of the bubble column dehumidifiers for the high heat recovery and the low capital cost.

10. Mr.Huicheng Liu, Mr.Mostafa H. Sharqawy [13].

The function of the bubble column humidifier and dehumidifier is researched experimentally under the sub atmospheric pressures for the humidifier and elevated pressures for the dehumidifier process. Now the bubble columns are evaluated of 10 cm diameter and 25 cm height. They are integrated with the internal cooling and the heating coils and the air is passed through the perforated plates at its bottom section. The pressure is evaluated in the humidifier ranges from 7 (0.48 bar) to 15(1.03 bar), whilst the pressure tested in the dehumidifier ranges from 15(1.03 bar) to 30 (2.07 bar). In conclusion with the water level in the bubble columns and the velocity were changed in the range of 5–7 cm and 2–20 cm/s.

The function was examined by calculating the total heat transfer rate and the effectiveness. The experimental magnitudes of the mass transfer coefficient are represented as a performance of the velocity and pressure. The conclusions shows that operating the bubble column humidifier at atmospheric pressure increases the overall heat transfer by about 35% and the effectiveness by about 7.1%.Moreover operating the dehumidifier at the elevated pressures, conclusions in higher heat transfer rate by about 27% but the lower effectiveness by about 3.2%. It was represented that the liquid height in the column has no major effect on the function however; the velocity improves both the heat transfer and effectiveness for the humidifier and dehumidifier system. Hence moreover a changed effectiveness number of the transfer units (e-NTU) model for the counter flow cooling tower was found to agree well with the experimental conclusion of the effectiveness and the NTU. The e-NTU model is an effective approach to evaluate the performance of the bubble column humidifier and dehumidifier system.

11. Ms.Emily W. Tow,Mr. John H. Lienhard V [14].

Bubble column dehumidifiers are a small and compact, inexpensive alternative method to the conventional fin-tube dehumidifiers for the humidification and dehumidification (HDH) desalination system, a technology methods that has a better promising applications in the small-scale desalination system and the industrial water remediation process. In this article, the algebraic equations for the mean heat and mass transfer moving forces are produced for the improved modeling of the bubble column dehumidifiers system. Because the mixing in the column makes sure a uniform liquid temperature, the bubble column can be presented as the two single stream heat exchangers in contact with the column liquid: the ocean water side, for which a long mean temperature difference , and which has a varying heat capacity and mass exchange rates. Under typical or critical situations, a log mean mass fraction difference is shown to move the latent heat transfer rate process, and an equation for the mean temperature difference of the moist gas stream is represented. These equations will facilitate modeling of the bubble column heat and mass exchangers.

12.Mr. Mario Schmack, Mr.Goen Ho & Martin Anda [15].

Various simple vapor cooling systems and pre-condensing concepts were employed for the purpose of mitigating bubble column vapor temperatures, a critical and important aspect for the development of the bubble column driven greenhouse desalination system process. And now the particular emphasis was on low-energy demand of the devices, simplicity of manufacture, very low investment cost and technical and operational for local people in rural or remote areas. Under the laboratory conditions, the copper tube type I and II concepts achieved water recovery rates of between 65 and 75%.

The water-tank cooled tube achieved 83% condensate recovery, at the price of the huge cooling water requirements needed , but whereas the air cooled and passive sleeve-cooled bubble condenser columns achieved condensate recovery rates of at least 50% under preferable conditions. A “self-cooling” effect was discovered for the passive sleeve columns that could perhaps be tailored to the produce small quantities of the pure water in the hot and remote regions. The effectiveness NTU method was used to allow for a meaningful and efficient comparison or study between the devices. And while the main majority of the evaluated concepts represented a “single-stage” approach to the humidification and dehumidification cycle, it is given weight that a well-designed latent heat recovery system would be very crucial for the economic necessity of a bubble greenhouse method.

Methodology

Principle of HDH Desalination system –

In the HDH process, evaporation takes place by the mixing of hot water with dry air in the humidification chamber, and then passed to the dehumidification chamber, where a condenser is used to obtain fresh water.

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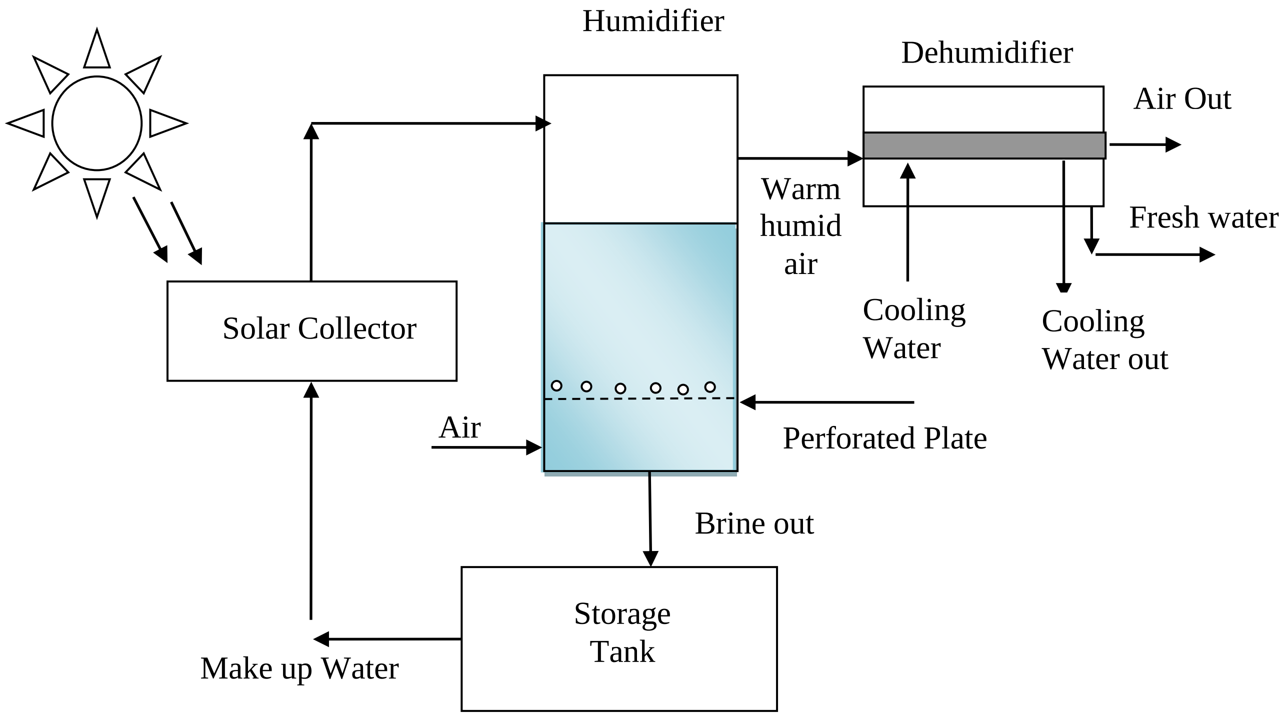

Fig:HDH Desalination system

Bubbler Humidifier

The present work introduces an innovative humidification technique called direct contact humidification by using bubbler humidifier. In this configuration of humidifier, the air is passed through the sparger to form bubbles in the hot water column then the air bubble propagates through hot water column and heat transfer and mass transfer takes place simultaneously. The air comes out hot and humid at the outlet at humidifier as shown in fig. 4.2. The formation of bubbles increases the surface contact and thus performance of humidification process enhances significantly.

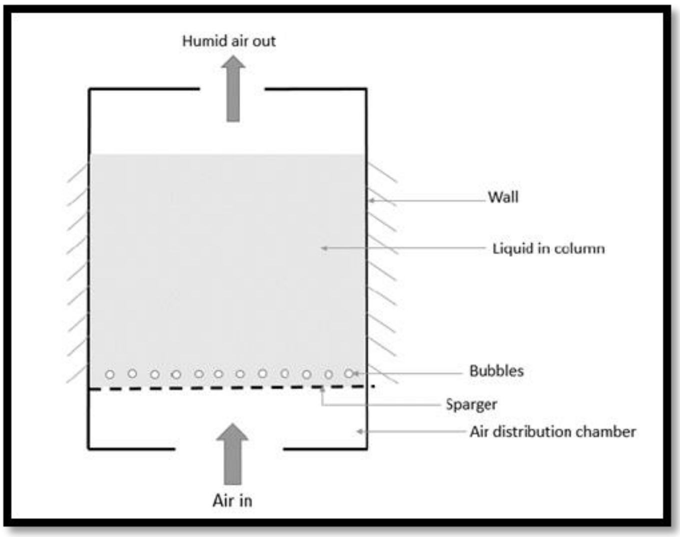

Fig.: Bubbler Humidifier.

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Conclusion

- It is observed from table -1 that by increasing air inlet temperature at humidifier by 2ºC increases the productivity by approximately 4.5-5.5%.

- It is observed from table -2 that by increasing water inlet temperature at humidifier by 5ºC increases the productivity by approximately 7.5-8%.

- It is observed from table -3 that by increasing mass flow rate of air at humidifier by 0.002 kg/s increases the productivity by approximately 5-5.5%.

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