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Evacuated Stepped Basin Solarstill with PCM and Intermittent Water Collector

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Abstract*— The main aim of the project is the design, fabrication and performance analysis of a solarstill for purification of water. Solar energy has great potential for lower running costs, greater reliability and longer working life than any other source of energy, which have been generally used in remote areas. A 20Leatre stepped basin was fabricated for this purpose and was redesigned by adding a heat reservoir of material stearic acid and intermittent water collector to collect more water. Performance analysis of the stepped basin solarstill with heat reservoir and without heat reservoir was done by conducting the experiment. In this experiment we reduce the material for designing of the solar still so that cost of equipment is reduced by 1000 rupees. The experiment mainly studies the variation of solar energy, effect of vacuum, effect of the heat reservoir and intermittent water collector. Compared with stepped basin type solar still it was found that its productivity is increased, when evacuated solarstill with PCM and intermittent water collector is used.

***Keywords*— Solar energy, Stearic acid, solarstill, PCM, Intermittent water collector**

I. INTRODUCTION

Energy is the basic input required to sustain economic growth and to provide basic amenities of life to the entire population of a country. Energy can be an effective weapon in the battle against object poverty in a country like India. Like other developing countries, India is also in the process of planning and development such needs a quantum of energy for its development plans. Due to increasing gap between demand and supply of energy there is an urgent need to utilize the different forms of non-conventional energy sources such as solar, wind, biomass etc. Among these energy sources one of the most important sources is solar energy. Adequate quality and reliability of drinking water supply is a fundamental need of all people. Without potable or fresh water there is no human life. Solar distillation is a well-known and established technology in many countries including India. Throughout the world in promoting projects concerning to supply of fresh water for drinking purposes.

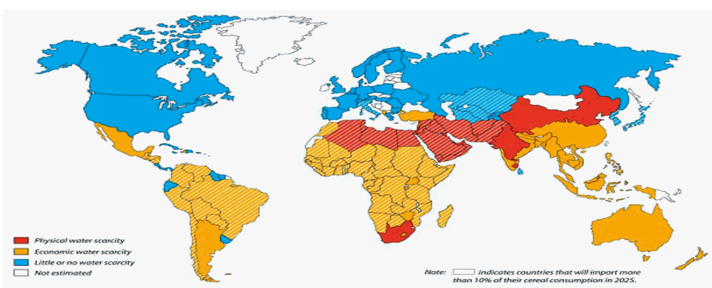

Fig 1: Projected water scarcity in 2015

Fresh water which is obtained from rivers, lakes, and ponds is becoming scarce because of industrialization and population explosion. Presently more than 2000 million people are not getting potable water which leads to many diseases. Many countries around the world, especially developing countries and countries in the Middle East region, suffer from a shortage of fresh water. The United Nations (UN) Environment Program stated that one-third of the world's population lives in countries with insufficient freshwater to support the population. Consequently, drinking water of acceptable quality has become a scarce commodity. The total global water reserves are 1.4 billion km3, of which around 97.5% is in the oceans and the remaining 2.5% is fresh water present in the atmosphere, Ice Mountains and ground water. Of the total, only 0.014% is directly available for human beings and other organisms. Thus, tremendous efforts are now required to make available new water resources in order to reduce the water deficit in countries which have shortages. According to World Health Organization (WHO) guidelines, the permissible limit of salinity in drinking water is 500 ppm and for special cases up to 1000 ppm. Most of the water available on the earth has a salinity up to 10 000 ppm and seawater normally has salinity in the range of 35 000–45 000 ppm in the form of total dissolved salts. Desalination is a process in which saline water is separated into two parts, one that has a low concentration of dissolved salts, which is called fresh water, and the other which has a much higher concentration of dissolved salts than the original feed water, which is usually referred to as brine concentrate. The desalination of seawater has become one of the most important commercial processes to provide fresh water for many communities and industrial sectors which play a crucial role in socio-economic development in a number of developing countries, especially in Africa and some countries in the Middle East region, which suffer from a scarcity of fresh water. There is extensive R&D activity, especially in the field of renewable energy technologies, to find new and feasible methods to produce drinking water. Currently, there are more than 7500 desalination plants in operation worldwide producing several billion gallons of water per day. Fifty-seven per cent are in the Middle East where large-scale conventional heat and power plants are among the region's most important commercial processes, they play a crucial role in providing fresh water for many communal and industrial sectors, especially in areas with a high density of population. However, since they are operated with fossil fuel, they are becoming very expensive to run and the environmental pollution they produce is increasingly recognized as very harmful to the globe. Moreover, such plants are not economically viable in remote areas, even near a coast where seawater is abundant. Many such areas often also experience a shortage of fossil fuels and an inadequate electricity supply. The development of compact, small-scale systems for water desalination is imperative for the population in such areas Thermal solar energy water desalination is known to be a viable method of producing fresh water from saline water in remote locations; conventional basin solar stills with a relatively large footprint are an example of such simple technology. And using a clean natural energy resource in water desalination processes will significantly reduce the pollution that causes global warming. This article aims to present a review of the published literature on the various desalination technologies and their advantages and disadvantages in addition to their economics.

II. LITERATURE SURVEY

R. VIDYA SAGAR RAJU, R. MEENAKSHI REDDY, E.SIVA REDDY- Performance Evaluation Of Solar Still – Steric Acid As A Phase change material, 2013. The simplest application of a thermal solar energy installation is in the distillation of water. The solar distiller purifies water by first evaporating and then condensing it. Distilled water contains no salts, minerals or organic impurities. It is not, however, aseptic, as is sterilized water, of which more later. Distilled water can be used for: drinking purposes, applications in hospitals replenishing batteries, and so on. Such an installation is suited to areas where water is ample but polluted, salty or brackish; naturally, there must also be abundant sun. Finally, glass or UV resistant transparent foil which is the most important material in the construction must be available and affordable. A reasonably functional solar distiller is able to produce adequate amount of water, so as to make it economically justifiable.

S.RAMASAMY AND B.SIVARAMAN — Heat Transfer Enhancement of Solar Still Using Phase Change Materials (PCMs), 2013. In the recent scenario, distillation process with solar still plays vital role for getting pottable water from brackish and sea water. In this paper, attempt has been made to enhance the productivity of the solar still with the help of LHTESS (Latent heat thermal energy storage sub-system). Latent heat storage in a phase change material PCMs is very attractive because of its high storage density with small temperature difference. For experimentation and comparison purpose, a Cascade Solar Still with and without LHTESS were designed and constructed for water purification with a view of enhancing productivity. Solar still of the present study mainly consists of stepped absorber plate integrated with phase-change energy storage sub-system or LHTESS and single slope glass plate. This setup will be placed at an angle of 25° to the horizontal. Paraffin wax is used as LHTESS due to its feasible general and economic properties [1]. The hourly productivity is slightly higher in case of solar still without LHTESS during sunny days. The disadvantages of phase change material are corrosion when in direct contact with metal piping or housings [5]. Index Terms—Distillation, Solar Still, LHTESS, Paraffin wax, salt hydrated phase change materials, PCMs.

SYED FIROZUDDIN AND DR. P. V. WALKE - Thermal Performance on Single Basin Solar Still with Evacuated Tubes Solar Collector, 2013. Various aspects of single basin solar still with evacuated tubes solar collector have been discussed in this paper with a focus on the use of evacuated tubes to increase the daily productivity of solar still with less heat losses. The pure water can be obtained by distillation in the simplest solar still. Various active methods have been adopted to increase the temperature of the basin so as to improve the productivity of solar still.

SARAVANAN AND MANIKANDAN- Experimental analysis of Single Slope Stepped Solar Still with and without Latent Heat Thermal Energy Storage System (LHTESS), 2012. An experimental study was conducted to analyse the thermal performance of single slope stepped solar still with and without latent heat thermal energy storage system (LHTESS). Solar desalination could be used as a green alternative for production of potable water from saline or brackish water. Two single slope stepped solar stills were constructed with and without latent heat thermal energy storage system. Paraffin wax was selected as phase change material (PCM) which act as a LHTESS. Thermal performance of the stills with and without LHTESS were compared in a typical sunny days. Based on the obtained results, the total productivity of still with LHTESS was slightly higher than the still without LHTESS on a typical sunny day. Also the effect of flow rate on the still productivity was further investigated during three sunny days. The results show that the maximum productivity was obtained in lowest possible flow rate.

P.VISHWANATH KUMAR, AJAY KUMAR KAVITI, OM PRAKASH, K.S REDDY- Optimization of design and operating parameters on the year round performance of a multi-stage evacuated solar desalination system using transient mathematical analysis, 2012. The available fresh water resources on the earth are limited. About 79% of water available on the earth is salty, only one percent is fresh and the rest 20% is brackish. Desalination of brackish or saline water is a good method to obtain fresh water. Conventional desalination systems are energy intensive. Solar desalination is a cost effective method to obtain potable water because of freely available clean and green energy source. In this paper, a transient mathematical model was developed for the multi-stage evacuated solar desalination system to achieve the optimum system configuration for the maximum year round performance and distillate yield. The effect of various design and operating parameters on the thermal characteristics and performance of the system were analysed. It was found that an optimum configuration of four stages with 100mm gap between them when supplied with a mass flow rate of 55kg/m2/day would result in best performance throughout the year. The maximum and minimum yields of 28.044 kg/m2/day and 13.335 kg/m2/day for fresh water at a distillate efficiency of 50.989% and 24.245% and overall thermal efficiency of 81.171% and 40.362% are found in the months of March and December respectively owing to the climatic conditions. The yield decreases to 18.614 kg/m2/day and 9.791 kg/m2/day for brine solution at a distillate efficiency of 33.844% and 17.802% and overall thermal efficiency of 53.876% and 29.635% for March and December respectively The maximum yield of 53.211 kg/m2/day is found in March at an operating pressure of 0.03 bar. The multi-stage evacuated solar desalination system is economically viable and can meet the needs of rural and urban communities to necessitate 10 to 30 kg per day of fresh water.

MITESH PATEL, P M MEENA AND SUNIL INKIA- Experimental investigation on single slope- Double basin active solar still coupled with evacuated glass tubes,2012. On the basis of different literature survey, a double basin active solar still is selected for further development and performance analysis which is subjected to be coupled with evacuated glass tube solar collector for high temperature water feeding in to the basin of solar still. The developed solar still basin area of 1m is proposed to be tested with convert into double basin by using glass tray inside the solar still. So heat loss of the upper portion was reduce it give more output of the pure water. Also the evacuated glass tubes are coupled with solar still to increase the temperature inside the solar still is more than 80 degrees. The experimental set up was analysed by single and double basin active solar still. It has been seen that output with double basin is more compare to single basin because of reduce the heat loss of the upper glass was much more compare to other.

V.VELMURUGAN, MGOPALAKRISHNAN, R. RAGHU, K. SRITHAR-Single basin solar still with fin for enhancing productivity, 2008. Distilled water productivity of the single basin solar still is very low. In this work, to argument evaporation of the still basin water. Fins were integrated at the basin of the still. Thus production rate accelerated. Also, for further increase in exposure area sponges were used. Experimental results were compared with ordinary basin type still and still with wicks. The governing energy balance equations were solved analytically and compared with experimental results. It was found that 29.6% productivity increased, when wick type solar still was used, 15.3% productivity increased when sponges were used and 45.5% increased when fins were used. A good agreement has been achieved with theoretical results.

ABOUL-ENEIN, A.A.EL-SEBAIIA AND E.EL-BIALY -Investigation of a single- basin solar still with deep basins, 1998.A single basin solar still (SBSS) is designed and constructed. A simple transient mathematical model is presented for the still. It is based on analytical solution of the energy - balance equations for different parts of the still. Analytical expressions for temperatures of different components have been obtained. The thermal performance of the still has been has been investigated both experimental and theoretically. Good agreement between experimental and theoretical results is observed. The influence of cover slope on the daily productivity of the still was investigated. Effect of heat capacity of basin water on the daylight and overnight productivities was also studied. It is inferred that, the productivity of the still decreases with an increase of heat capacity of basin water during daylight and the reverse is the case overnight. The optimum tilt angles of the still cover were found to be 10 to 50 degrees during the summer and winter seasons respectively, in Tanta (30 degrees 47' n) . The daily efficiency of the still is about 27%.

III.EXPERIMENTAL PROCEDURE

Solar stills are called stills because they distil, or purify water. A solar still operates on the same principle as rainwater: evaporation

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and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills mimic this natural process.

A. Description For Evacuated Stepped Basin Type Solar Still

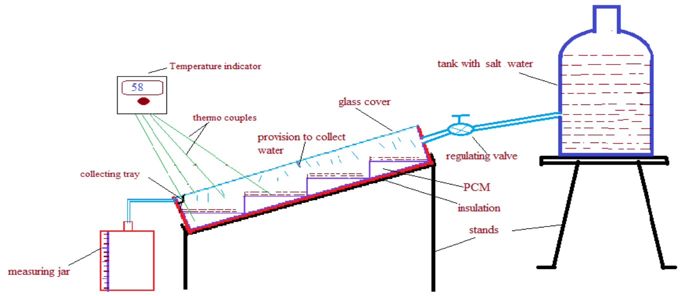

FIG 2: Schematic diagram of evacuated solar still with PCM and Intermittent water collector

Fig. 2 shows the schematic of the solar still with simple basin. The experimental setup consists of following things.
Storage tank
Phase change material
Insulated basin plate
Glass cover
Measuring jar
Temperature measuring devices
Vacuum pump
Intermittent water collector
The metallic storage tank of capacity 25 litres was used in order to avoid corrosion. Water from the storage tank enters the still through flexible hoses and a valve 'V' to maintain constant water level in the still. The valve controls the mass flow rate. Poly vinyl chloride (PVC) hoses were used for greater flexibility. The still basin was painted black. The area below the basin was filled with glass wool for insulation purpose. A small glass piece obstruction was fixed on the inside surface of the glass cover, to facilitate the deflection of the concentrate return in to the collection channel, which in turn affixed with the wooden box. The gliding water from the channel was transferred in to the measuring jar through the flexible piping.

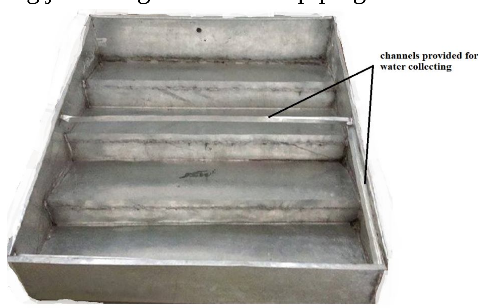

FIG 3: Stepped basin solarstill with intermittent water collector

This experimental set up was designed. The inner dimensions of the basin 100X100 cm2.The upper glass cover is tilted at 200 with respect to the horizontal. Installed and tested at G. Pullareddy engineering College, Kurnool, and Andhra Pradesh, India. The whole experimental setup was kept in the North-South direction. Copper-constantan thermocouples were used for temperature measurement. The Condenser surface of the still is made of 4 mm ordinary glass. The bottom of this still is insulated with 50mm. Filled the water up to 8 cm depth.

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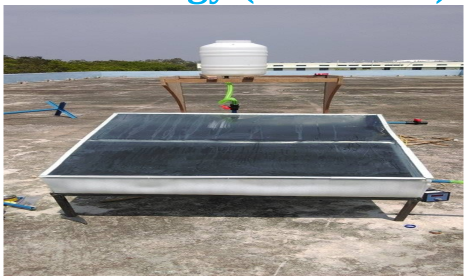

Fig 4: overall evacuated solarstill equipment

Thermocouples are fixed at the following locations:
Still basin plate
Water and
Outside of the glass cover
Temperatures were measured at more than one location and averaged for the case of base plate temperature and basin water temperatures. Thermocouples are integrated with temperature indicator and selector switch.

B. Description For Solar Still With PCM As Storage Medium

This is as similar to the basin type solar still, but we have placed stearic acid at the bottom in the basin and placed a tray to store water. The height of the tray is of 8cm and the water is poured in it to a height of 8cm. Here PCM is used to store heat in the day time and release the heat during night which gives continuous production of distilled water. This experimental set up was designed. The inner dimensions of the basin 100X100 cm2.The upper glass cover is tilted at 200 with respect to the horizontal. Installed and tested at G .Pulla Reddy College Of Engineering, kurnool, Andhra Pradesh, India. The whole experimental setup was kept in the North-South direction.

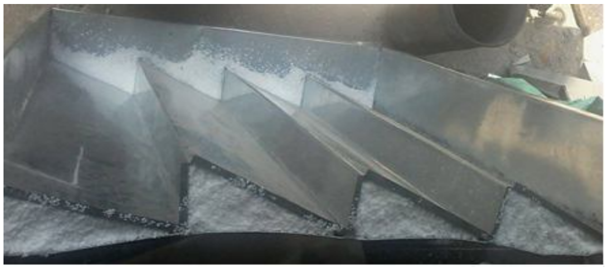

Fig 5: Stearic acid filled in equipment

IV. RESULTS AND DISCUSSIONS

In this experiment we collect the more water when compared to the earlier techniques regarding desalination of water. Besides to more efficiency we reduce the cost of the experiment also.
The readings of the experiment are listed below.

A. Stepped Basin Solar Still

The readings of stepped basin solarstill are given below.

S.NO	TIME in hrs	Atmospheric Temp. in ^{0} C	Basin Temp. In ^{0} C	Glass Temp. In ^{0} C	Water Temp. in ^{0} C	Quantity of water Collected in lts
1	9AM-10AM	28	28	28	25	_
2	10AM-11AM	29	29	29	27	_

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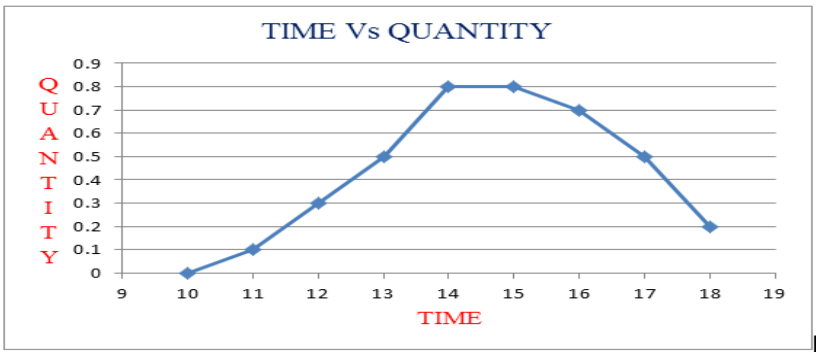
3	11AM-12PM	34	32	31	30	0.1
4	12PM-1PM	36	33	32	35	0.3
5	1PM-2PM	36	35	34	40	0.5
6	2PM-3PM	33	35	33	45	0.4
7	3PM-4PM	30	34	32	48	0.4
8	4PM-5PM	30	33	30	43	0.3
9	5PM-6PM	27	28	28	34	0.2

Table 1: readings of stepped basin solarstill alone

In the above technique stepped basin solarstill, the amount of water is collected in a one day is 2.2 Liters



Graph 1: stepped basin solarstill alone

B. Stepped Basin Solarstill With PCM

The readings of the stepped basin solarstill with PCM are given below.

S.NO	TIME in hrs	Atmospheric Temp. in ^{O}C	Basin Temp. In ^{O}C	Glass Temp. In ^{O}C	PCM Temp In ^{O}C	Water Temp. in ^{O}C	Quantity of water Collected in lts
1	9AM-10AM	28	28	28	25	25	_
2	10AM-11AM	29	30	29	29	29	0.1
3	11AM-12PM	34	36	31	38	39	0.3
4	12PM-1PM	36	40	32	49	50	0.5
5	1PM-2PM	36	50	34	62	63	0.8
6	2PM-3PM	33	45	33	63	63	0.8
7	3PM-4PM	30	42	32	57	57	0.7
8	4PM-5PM	30	41	30	44	45	0.5
9	5PM-6PM	27	35	27	40	40	0.4

Table 2: readings of stepped basin solarstill with PCM

In the above technique stepped basin solarstill, the amount of water is collected in a one day is 4.1 Liters

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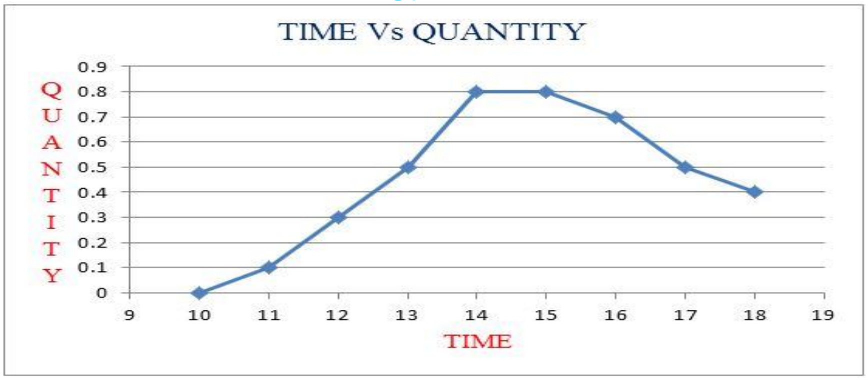

Graph 2: stepped basin solarstill with pcm

C. Evacuated stepped basin solarstill with PCM

The readings of the evacuated stepped basin solarstill with PCM are given below.

S.NO	TIME in hrs	Atmospheric Temp. in ^{0} C	Basin Temp. In ^{0} C	Glass Temp. In ^{0} C	PCM Temp In ^{0} C	Water Temp. in ^{0} C	Quantity of water Collected in lts
1	9AM-10AM	28	28	28	25	25	0.1
2	10AM-11AM	29	30	29	29	29	0.3
3	11AM-12PM	34	36	31	38	39	0.4
4	12PM-1PM	36	40	32	49	50	0.7
5	1PM-2PM	36	50	34	62	63	0.9
6	2PM-3PM	33	45	33	63	63	0.9
7	3PM-4PM	30	42	32	57	57	0.8
8	4PM-5PM	30	41	30	44	45	0.7
9	5PM-6PM	27	35	27	40	40	0.5

Table 3: evacuated stepped basin solarstill alone with pcm

In the above technique stepped basin solarstill, the amount of water is collected in a one day is 5.1 Liters.

Graph 3: evacuated stepped basin solarstill alone with pcm

D. Evacuated stepped basin solarstill with PCM and intermittent water collector

The readings of the evacuated stepped basin solarstill with PCM and intermittent water collector is given below.

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S.NO	TIME in hrs	Atmospheric Temp. in ^{O}C	Basin Temp. In ^{O}C	Glass Temp. In ^{O}C	PCM Temp In ^{O}C	Water Temp. in ^{O}C	Quantity of water Collected in lts
1	9AM-10AM	28	28	28	25	25	0.1
2	10AM-11AM	29	30	29	29	29	0.4
3	11AM-12PM	34	36	31	38	39	0.5
4	12PM-1PM	36	40	32	49	50	0.8
5	1PM-2PM	36	50	34	62	63	1.0
6	2PM-3PM	33	45	33	63	63	1.1
7	3PM-4PM	30	42	32	57	57	0.9
8	4PM-5PM	30	41	30	44	45	0.7
9	5PM-6PM	27	35	27	40	40	0.6

Table 4: evacuated stepped basin solarstill alone with pcm and intermittent water collector

In the above technique stepped basin solarstill, the amount of water is collected in a one day is 6.1 Liters.

Graph 4: evacuated stepped basin solarstill alone with pcm and intermittent water collector

The readings of the evacuated stepped basin solarstill with PCM and intermittent water collector for different vacuum values.

S.NO	Vacuum pressure In bars	Quantity of water Collected in liters whole day
1	1	5.1
2	0.9	5.3
3	0.8	5.7
4	0.7	6.0
5	0.6	6.2
6	0.5	6.4

Table 5: evacuated stepped basin solarstill alone with pcm

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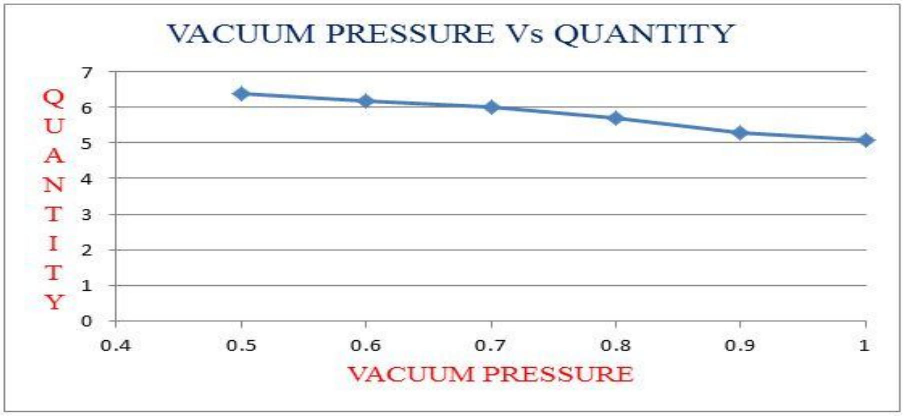

Graph 4: Vacuum Pressure Vs Quantity

Copper-constantan thermocouples were used for temperature measurement. The Condenser surface of the still is made of 5 mm ordinary glass. The bottom of this still is insulated with 50mm. Filled water up to 2 cm depth. These thermocouples are fixed at the following locations: sill basin plate, water and inside of the glass cover. Temperatures were measured at more than one location and averaged for the case of base plate temperature and basin water temperatures. Thermocouples are integrated with temperature indicator and selector switch.

V. CONCLUSION

In this experiment we extract the more pure water compare to the evacuated solarstil with phase change material.
The cost of the experiment is very low per liter production of water.

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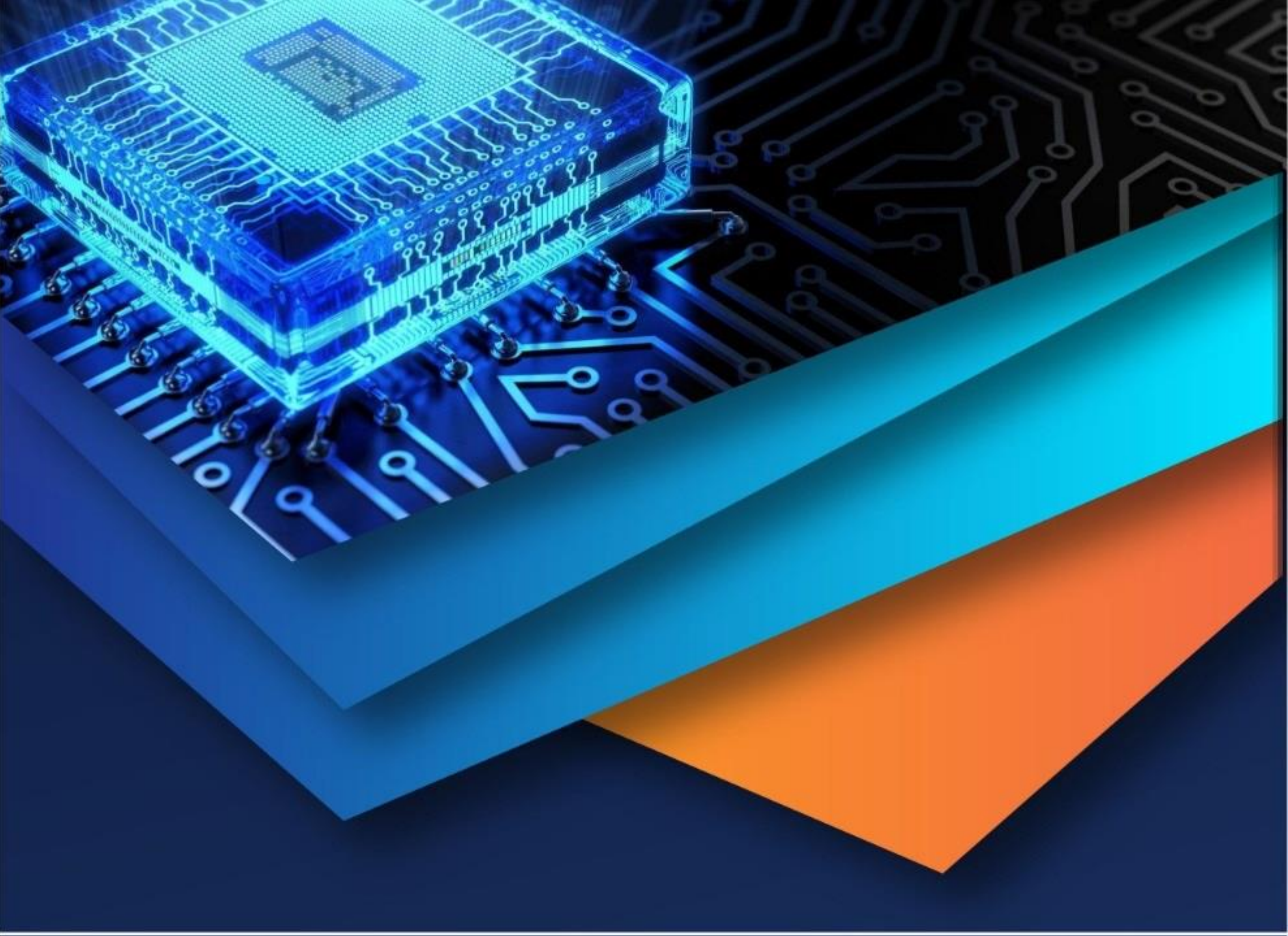

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