"Solar Still: A Review"

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Abstract

Naturally there is only one source of pure water is Rain. Now a day's water became polluted and potable water for all the living human being cannot fulfil the requirement. However following the same principle of natural rain that is principle of evaporation and condensation in a presence of sun ultimately solar radiation we can purify water and that process is called solar distillation and the system is called Solar Still. Conventional solar still is less efficient and required to increase the productivity and efficiency of conventional solar still. Conventional Single basin Solar Still efficiency can be increased by the use of an additional Condenser and insulation by Polyurethane material. Condenser will help to increase evaporation and condensation rate by achieving essential temperature difference. PU foam material provides Insulation and reduces the heat loss for the essential working condition.

Keywords: Solar still, Condenser, Insulation

1. Introduction

1.1 Introduction to solar distillation

Solar water Distillation system also called "Solar Still". Solar Still can effectively purify seawater & even raw sewage. Solar Stills can effectively remove salts/minerals bacteria parasites, heavy metals & TDS.

Basic principal of working of solar still is "Solar energy heats water, evaporates it and condenses as clouds to return to earth as rainwater".

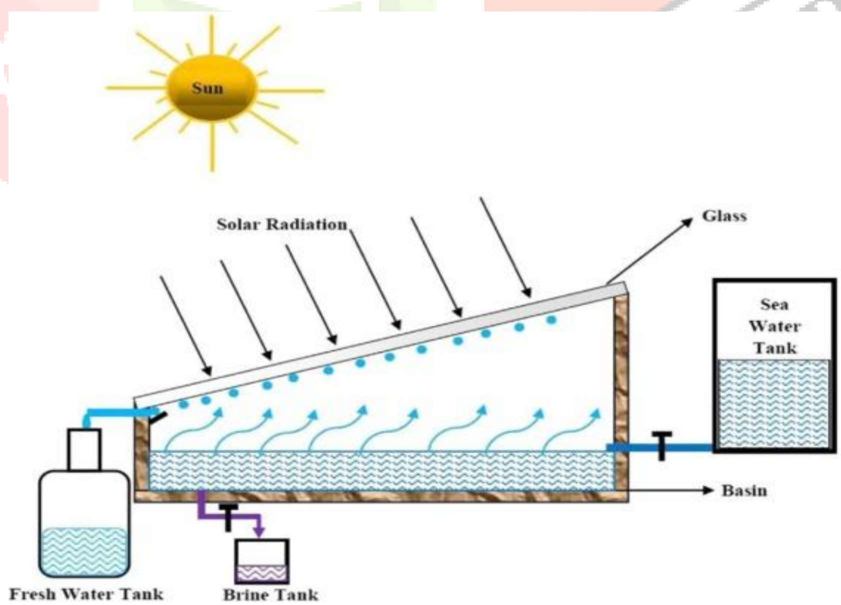

Figure 1. Single Slope Solar Still

1.2 Principle of desalination system

A basin of solar still has a thin layer of water, a transparent glass cover that covers the basin and channel for collecting the distillate water from solar still. The glass transmits the sun rays through it and saline water in the basin or solar still is heated by solar radiation which passes through the glass cover and absorbed by the bottom of the solar still.

In a solar still, the temperature difference between the water and glass cover is the driving force of the pure water yield. It influences the rate of evaporation from the surface of the water within the basin flowing towards condensing cover. Vapor flows upwards from the hot water and condense. This condensate water is collected through a channel.

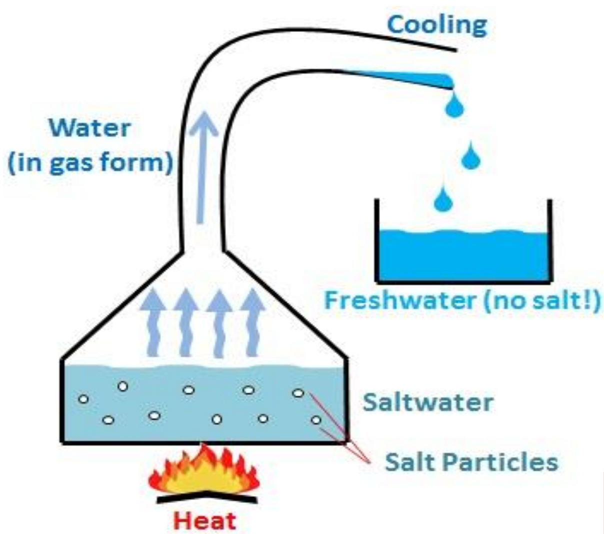

Figure 2. Principle of Desalination

The same principle is used in all manmade distillation systems using alternative sources of heating and cooling. Working of solar still is based on the simple scientific principle of evaporation and condensation.

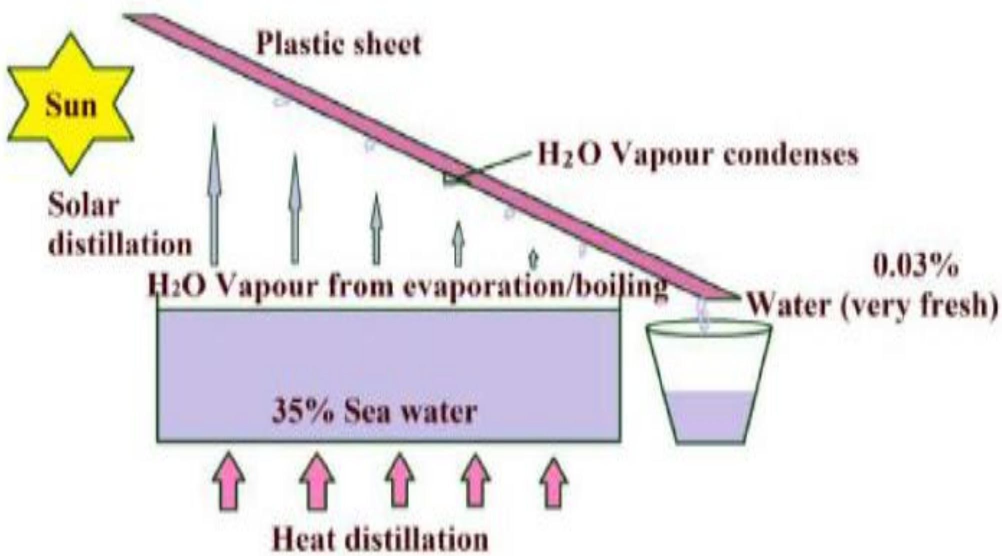

Figure 3. Sea Water Distillation

2. Objective

This research has focused on exploring new designs and ideas to increase the solar stills performance and increase their productivity. Aim of this research was to develop an advanced solar still with separate condenser. The difference between the temperature of basin water and glass cover is the driving force of the distillation process. It will affect the rate of evaporation from the surface of water in the basin to the condensing cover. Heat transferred from hot water to the transparent cover increase the temperature of the glass cover too, it will reducing the driving force and rate of distillation in a conventional solar still. The conventional solar still suffers from low efficiency. Objective of this research is to develop a solar still with additional condenser and experimental analysis of that still with the help of graphical representation.

3. Methodology

The main focus of research was to compare the experimental result of conventional solar still and advanced solar still with additional condenser and PU (polyurethane) material so after doing literature survey of various authentic research paper design of solar still had been decided. Solid work drawing of Expected solar still model was prepared. Two solar still basins made up of same dimension will be fabricated, one of them w used as will be reference still to compare the result of solar still with additional condenser and PU material. Experimental Result will be graphically presented based on that conclusion and discussion will be made.

3.1 Energetic working principles

In order to estimate the energy input for a distillation process, it is useful to split the process into two parts

1. Heating up the raw fluid

2. Transformation from the liquid to the gaseous phase

Distillation processes have a working temperature range between 30°C and 90°C, to which the fluid has to be heated in a first step.

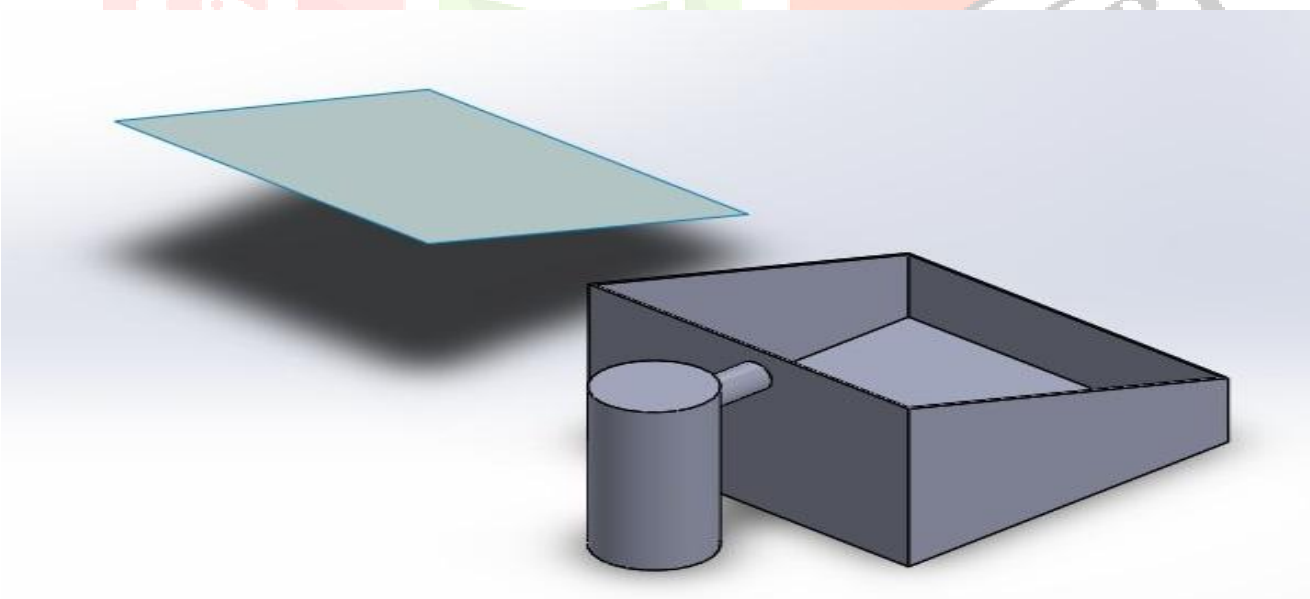

Figure 4. Solar Still with External Condenser

4. Classification of condensers:

Based on the external fluid, condensers can be classified as:

a) Air cooled condensers

b) Water cooled condensers

c) Evaporative condensers

a) Air-cooled condensers:

As the name implies, in air-cooled condensers air is the external fluid, i.e., the refrigerant rejects heat to air flowing over the condenser. Air-cooled condensers can be further classified into natural convection type or forced convection type.

Natural convection type:

In natural convection type, heat transfer from the condenser is by buoyancy induced natural convection and radiation. Since the flow rate of air is small and the radiation heat transfer is also not very high, the combined heat transfer coefficient in these condensers is small. As a result a relatively large condensing surface is required to reject a given amount of heat. Hence these condensers are used for small capacity refrigeration systems like household refrigerators and freezers. The natural convection type condensers are either plate surface type or finned tube type. In plate surface type condensers used in small refrigerators and freezers, the refrigerant carrying tubes are attached to the outer walls of the refrigerator

Forced convection type:

In forced convection type condensers, the circulation of air over the condenser surface is maintained by using a fan or a blower. These condensers normally use fins on air-side for good heat transfer. The fins can be either plate type or annular type. Figure 5 shows the schematic of a plate-fin type condenser. Forced convection type condensers are commonly used in window air conditioners, water coolers and packaged air conditioning plants. These are either chassis mounted or remote mounted. In chassis mounted type, the compressor, induction motor, condenser with condenser fan, accumulator, HP/LP cut- out switch and pressure gauges are mounted on a single chassis. It is called condensing unit of rated capacity. The components are matched to condense the required mass flow rate of refrigerant to meet the rated cooling capacity.

b) Water Cooled Condensers:

In water cooled condensers water is the external fluid. Depending upon the construction, water cooled condensers can be further classified into:

1. Double pipe or tube-in-tube type
2. Shell-and-coil type
3. Shell-and-tube type

Double Pipe or tube-in-tube type:

Double pipe condensers are normally used up to 10 TR capacity. Figure shows the schematic of a double pipe type condenser. As shown in the figure, in these condensers the cold water flows through the inner tube, while the refrigerant flows through the annulus in counter flow. Headers are used at both the ends to make the length of the condenser small and reduce pressure drop. The refrigerant in the annulus rejects a part of its heat to the surroundings by free convection and radiation. The heat transfer coefficient is usually low because of poor liquid refrigerant drainage if the tubes are long.

Shell-and-coil type:

These condensers are used in systems up to 50 TR capacity. The water flows through multiple coils, which may have fins to increase the heat transfer coefficient. The refrigerant flows through the shell. In smaller capacity condensers, refrigerant flows through coils while water flows through the shell. Figure shows a shell-and-coil type condenser. When water flows through the coils, cleaning is done by circulating suitable chemicals through the coils.

Shell-and-tube type:

This is the most common type of condenser used in systems from 2 TR up to thousands of TR capacity. In these condensers the refrigerant flows through the shell while water flows through the tubes in single to four passes. The condensed refrigerant collects at the bottom of the shell. The coldest water contacts the liquid refrigerant so that some sub cooling can also be obtained. The liquid refrigerant is drained from the bottom to the receiver. There might be a vent connecting the receiver to the condenser for smooth drainage of liquid refrigerant. The shell also acts as a receiver. Further the refrigerant also rejects heat to the surroundings from the shell. The most common type is horizontal shell type. A schematic diagram of horizontal shell-and-tube type condenser is shown in Fig 5.

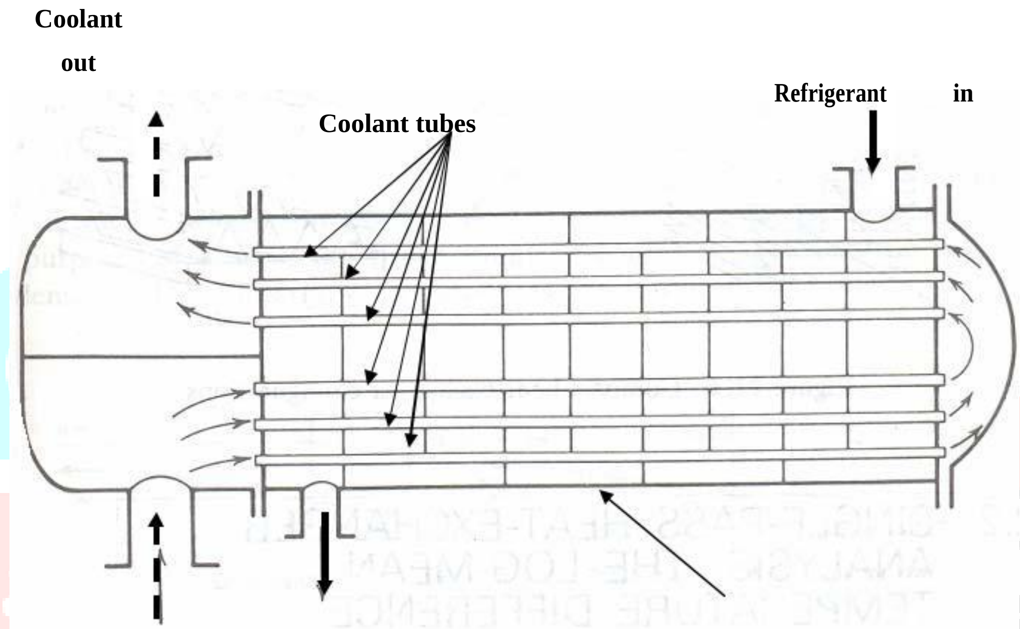

Figure 5. A two-pass, shell-and-tube type condenser

c) Evaporative condensers:

In evaporative condensers, both air and water are used to extract heat from the condensing refrigerant. Figure shows the schematic of an evaporative condenser. There is a thin water film around the condenser tubes from which evaporative cooling takes place. The heat transfer coefficient for evaporative cooling is very large. Hence, the refrigeration system can be operated at low condensing temperatures (about 11 to 13 K above the wet bulb temperature of air). The water spray counter current to the airflow acts as cooling tower. The role of air is primarily to increase the rate of evaporation of water. The required air flow rates are in the range of 350 to 500 m^3/h per TR of refrigeration capacity.

Evaporative condensers are used in medium to large capacity systems. These are normally cheaper compared to water cooled condensers, which require a separate cooling tower. Evaporative condensers are used in places where water is scarce. Since water is used in a closed loop, only a small part of the water evaporates. Make-up water is supplied to take care of the evaporative loss. The water consumption is typically very low, about 5 percent of an equivalent water cooled condenser with a cooling tower. However, since condenser has to be kept outside, this type of condenser requires a longer length of refrigerant tubing, which calls for larger refrigerant inventory and higher pressure drops. Since the condenser is kept outside, to prevent the water from freezing, when outside temperatures are very low, a heater is placed in the water tank. When outside temperatures are very low it is possible to switch-off the water pump and run only the blowers, so that the condenser acts as an air cooled condenser.

Another simple form of condenser used normally in older type cold storages is called as atmospheric condenser. The principle of the atmospheric condenser is similar to evaporative condenser, with a difference that the air flow over the condenser takes place by natural means as no fans or blowers are used. A spray system sprays water over condenser tubes. Heat transfer outside the tubes takes by both sensible cooling and evaporation, as a result the external heat transfer coefficient is relatively large. The condenser pipes are normally large, and they can be either horizontal or vertical. Though these condensers are effective and economical they are being replaced with other types of condensers due to the problems such as algae formation on condenser tubes, uncertainty due to external air circulation etc.

5. Air cooled vs water cooled condensers:

The Salient features of air cooled and water cooled condensers are shown below in Table 1. The advantages and disadvantages of each type are discussed below.

Parameter	Air cooled	Water cooled
Temperature difference, $T_C - T_{coolant}$	6 to 22^o C	6 to 12^o C
Volume flow rate of coolant per TR	12 to 20 m^3/min	0.007 to 0.02 m^3/min
Heat transfer area per TR	10 to 15 m^2	0.5 to 1.0 m^2
Face Velocity	2.5 to 6 m/s	2 to 3 m/s
Fan or pump power per TR	75 to 100 W	negligible

Table 1: Comparison between air cooled and water cooled condensers

Advantages and disadvantages:

Air-cooled condensers are simple in construction since no pipes are required for air. Further, the disposal of warm air is not a problem and it is available in plenty. The fouling of condenser is small and maintenance cost is low. However, since the specific heat of air is one fourth of that of water and density is one thousandth of that of water, volume flow rates required are very large. The thermal conductivity is small; hence heat transfer coefficient is also very small. Also, air is available at dry-bulb temperature while water is available at a lower temperature, which is 2 to 3 ^{o}C above the wet-bulb temperature. The temperature rise of air is much larger than that of water, therefore the condenser temperature becomes large and COP reduces. Its use is normally restricted to 10 TR although blower power goes up beyond 5 TR. In systems up to 3 TR with open compressors it is mounted on the same chassis as the compressor and the compressor motor drives the condenser fan also. In middle-east countries where is shortage of fresh water these are used up to 100 TR or more.

The air-cooled condensers cost two to three times more than water-cooled condensers. The water-cooled condenser requires cooling tower since water is scarce in municipality areas and has to be recycled. Water from lakes and rivers cannot be thrown back in warm state since it affects the marine life adversely. Increased first cost and maintenance cost of cooling tower offsets the cost advantage of water-cooled condenser. Fouling of heat exchange surface is a big problem in use of water.

6. References

Research Papers Literature

[1] Narayan Pandey, Dr A K Rai "Performance Study of Solar Still with Separate Condenser" | International Journal of Mechanical Engineering and Technology (IJMET) | Volume 7 | Issue 4 | July–Aug 2016 | pp.125–130 | Article ID: IJMET_07_04_012

[2] Samirkhan Malek "Experimental Analysis of Solar Still With External Condenser" | International Journal on Recent and Innovation Trends in Computing and Communication | Volume 2 | Issue 5 | ISSN 2321 - 8169 and 983 – 986

[3] R. Arun Kumar, G. Esakkimuthu, K. Kalidasa Murugavel "Performance Enhancement of a Single Basin Single Slope Solar Still Using Agitation Effect And External Condenser"

[4] Ahmed Rahmani and Abdelouahab Boutriaa "Numerical and Experimental Study of a Passive Solar Still Integrated with an External Condenser" | International journal of Hydrogen Energy (IJHE) | Volume 3 | Issue 9

[5] Ayman G.M. Ibrahim, Salman E. Elshamarka "Performance Study of A Modified Basin Type Solar Still" | Elsevier | Solar Energy 118 (2015) 397 – 407

[6] S.W. Sharshir, Nuo Yang , Guilong Peng and A.E. Kabeel "Factors Affecting Solar Stills Productivity and Improvement Technique: A Detailed Review" | Elsevier | Applied Thermal Engineering 100 (2016) 267 – 284.

[7] Hamdy Hassana, Saleh Abo-Elfadlb "Effect of the Condenser Type and the Medium of the Saline Water on the Performance of The Solar Still in Hot Climate Conditions" | Elsevier | Desalination 417 (2017) | 60 – 68.

[8] Radha Krishna Lal , Surya Ved Prakash Yadav, J. P. Dwivedi, Harshit Dwivedi "Comparative Performance Evaluation of an Active/Passive Solar Distillation System" | Elsevier | Materials Today | International Conference of Materials Processing and Characterization (ICMPC 2016) | Proceedings 4 | (2017) 2822–2831 |

[9] T.Arunkumar, K.vinodprashad, Amimul Ahsan, R.Jayaprakash and Sanjay Kumar "Experimental study on various design of solar still" published in ISRN Renewable Energy in 2012

[10] M.Koliraj Gnanadason, G Hariharan and P.Shenthil Kumar "Enhanced Performance of Design of a Single Basin Solar still made up of Copper" published in Indian journal of applied research Volume: 3 | Issue: 8 | Aug 2013 | ISSN - 2249-555X.

[11] Bhanu Pratab Singh "Performance Evaluation of a Integrated Single Slope Solar Still With Solar Water Heater" published in MIT International Journal of Mechanical Engineering in January 2011.

[12] Khaled m. s. eldalil "New concept for improving solar still performance by using vibratory harmonic effect experimental prediction", part-1 published in thirteenth international water technology conference, iwtc 13 2009.

[13] Alpesh Mehta ,Arjun Vyas and Dharmesh Lathiya "Design of Solar Distillation System" in International Journal of Advanced Science and Technology Vol. 29, April 2011.

[14] Alpesh Mehta ,Arjun Vyas and Dharmesh Lathiya "Design of Solar Distillation System" in International Journal of Advanced Science and Technology Vol. 29, April 2011.

Book

[15] Sadik Kakac and Hongtan Liu "Design of Heat Exchangers-selection rating and thermal design" | second edition | CRC press | Boca Ratan London New York | Washington D.C pp

[16] Sukhatme, S.P "Solar Energy: Principles of Thermal Collections and Storage", McGraw Hill Publishing Co.