Solar Distillation Unit Coupled with Water Lens Concentrator

Renjini C[1] Sebin Joseph[2]
[1,2]Nehru College of Engineering and Research Centre, Thrissur

Abstract— One of the main problem that the world faces today is shortage of portable water. An efficient distillation system integrated with concentrated solar collector is developed in this work. The objective of this project is to increase the yield of distillate output in cost effective manner by design an active single basin double slop solar still with water lens. Water acting as lens, which can be substitute for other solar concentrated systems in an economical way. The solar radiation is concentrated at a point by passing through the water lens. The water lens is developed by pouring water on the transparent thin sheet. The concentration of focus point depends on water lens curvature. And effectively utilize the energy from the water lens concentrated copper collector to increase the temperature of water in the still basin. The water vaporizes at pressurization temperature and these vapours are sucked using a suction pump and passed through the condenser. The condensate water outlet is the purified water from the system.

Key words: Water Lens, Solar distillation Unit, Copper Collector, Condenser, Suction Pump

I. Introduction

Water is an abundant natural resources on earth and an integral part of all human beings. Even though around three fourths of earth surface is covered with water, unfortunately, Ninety seven percent of the water on the earth's surface is saline in nature. The remaining small percentage is used to satisfy the needs of living beings. The separation of salts from sea water using fossil fuels require a huge amount of energy and can cause harm to the environment. Hence it can be avoided to a large extent by the use of environmental friendly techniques for desalinating the seawater. In conventional process fossil fuel is used as the thermal source, but due to rapid decrease in the fuel availability it is necessary to go with renewable energy for desalination process. There are many parts where plenty of underground water is available but it is of highly salinity. The saline water contains 35000 ppm impurities and the acceptable salt content in fresh water for human consumption is only 500 ppm, thus desalination of sea water is important.

The natural resources of water are depleting day by day due to global warming and due to many other natural phenomena. Hence fresh water shortage is the main problem that world faces today. Even though around three fourth of earth is covered with water only a few percentage is useful for drinking hence due to scarcity of water a large population is depending on desalination. Desalination is the process of converting brackish or saline water by evaporating using solar thermal energy and resulting water vapour is collected and condensed as final product. Instead of going for conventional desalination process solar thermal desalination is an eco friendly method that is adopted in this research work.

II. Objectives

The main problem that world faces is the shortage of drinking water and solar desalination system is an ecofriendly method to solve this problem. Different type of conventional desalination systems are existing which uses electricity and fossil fuels to run the system, but such system causes environmental effects. Hence Renewable sector plays a key role in desalination. Desalination with solar thermal energy is the concept used in this research work.

For high efficiency the solar still should maintain:

- A high feed (undistilled) water temperature.
- A large temperature difference between feed water and condensing surface.
- Low vapour leakage.
- High feed water temperature can be achieved if :
- A high proportion of incoming radiation is absorbed by the feed water as heat.
- Heat losses from the floor and walls are kept low.

A large temperature difference can be achieved if:

- The condensing surface absorbs little or none of the incoming radiation.
- Condensing water dissipates heat which must be removed rapidly from the surface.

The main drawback of desalination unit is the high cost and low yield, hence the introduction of novel technology of water lens can replace the problem economically.

III. Methodology

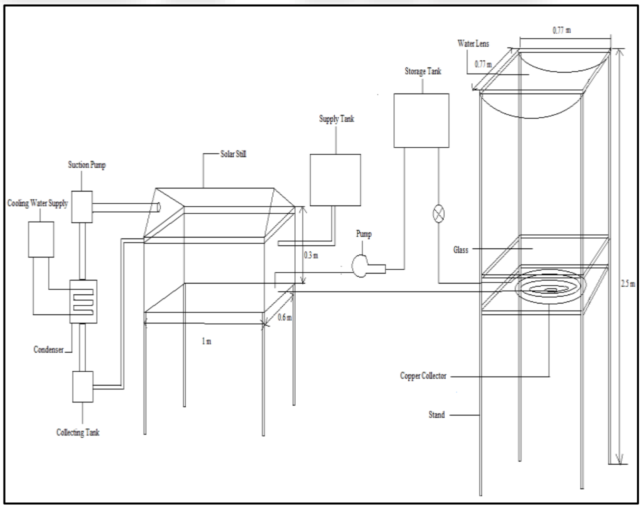

Fig. 1: Schematic diagram of solar distillation unit coupled with water lens concentrator

The higher inlet temperature is required for improving the productivity of solar still. Hence it is desirable to prefer active solar stills than passive solar still. The schematic diagram of the proposed system of solar distillation unit coupled with water lens concentrator is shown in fig. For experimental set up consists of mainly two parts; (i) solar still and (ii) water lens coupled with copper collector. To get high temperature with a point focus concentration, an economical method was introduced in this work that is water acting as lens which can concentrate maximum amount of temperature at the focal point.

Water is the most commonly available transparent liquid on earth and can exist naturally in different forms and here water is a powerful weapon which acts as lens. For water lens a particular amount of water is poured over a thin transparent sheet, which is supported by a stand. The curvature of water lens is due to the elasticity of transparent sheet, and as whole forms the shape of Plano convex lens. Even though the water at the focal point gets heated up, the water that acts as lens maintains the initial temperature. That means water that act as lens allow the amount of solar radiation incident on it to converge at a focal point without absorbing thermal energy.

Furthermore, the solar desalination unit uses heat energy from sun to produce distillate output. In this experimentation single basin double slop solar still is used. The inner surface is coated with black paint to absorb maximum amount of heat. The copper collector acts like an auxiliary heater that allows the pre heated water to pass on to the solar still where heated water alone with the trapped radiation makes the rate of evaporation more easier. The solar radiation incident on desalination unit gets trapped inside the system due to the green house effect. The solar green house effect depicts that the glass cover has the property to capture the short radiation and won't allow long radiation to escape back. Due to this property the water starts heat up; it evaporates and gets condensed on glass cover. The solar radiation incident on earth surface can be concentrated through water that act as lens on to a focal point, were the copper collector unit is placed. The water lens which focuses solar radiation on copper collector unit that is to increases the rate of evaporation through which the yield of the system can be increased. The position of copper collector changes by manual tracking to focus point of water lens. Glass cover is placed over the collector which helps to trap maximum heat inside the collector. Some vapour is condensed inside the still and flows to the trough and is collected in a collecting tank through a pipe. A suction pump connected to the still to suck the excess vapour present in the still and it is directly condensed through an external condenser. The external condenser has a cooling water supply to transfer the heat from the vapour. The condensed water is tapped through a pipe and collected in a collecting tank.

IV. Instrumentation and Error Analysis

The intensity of solar radiation was measured using pyranometer. K type thermocouples are used to measure the temperature inside the still and at other locations which were connected to a digital temperature controller with a selector switch. Thermocouples are to be attached at the various locations. A plastic measuring jar was used to measure the desalinated water from the still. The accuracies and error for various measuring instruments are given in the Table 1. The minimum error that occurs in any instrument is equal to the ratio between its minimum gradation and the minimum value of the output measured.

Instruments	Range	Accuracy
Pyranometer	0 - 1200 W/ m²	±5 W/m²
K type thermocouple	0^0C - 700 ^{0}C	±1^0C
Digital temperature indicator	0^0C - 1200 ^{0}C	±2^0C
Measuring jar	0-1000 ml	±10 ml

Table 1: Range and accuracy limits for various measuring instruments

V. Experimentation

A. Case 1: Single basin double slope passive solar still alone:

Initially Single Basin Double Slope passive type solar still was taken for experimental study from 9 A.M to 4 P.M for three consecutive days. Solar radiation, temperature at various locations and distillate output are measured for every one hour. Two centimeter water depth was maintained continuously by adding the equivalent amount of distillate output to the still for every one hour.

B. Case 2: Single basin double slop solar still with suction pump and condenser:

The single basin double slop solar still is integrated with suction pump and condenser for increase the evaporation rate. The excess vapour is sucked by using suction pump and passes to the condenser. The condensated water is collected in a collecting tank.

C. Case 3: Single basin double slope solar still with copper collector:

Single basin double slope passive solar still was converted to an active solar still by connecting the copper collector. Water from the still is pumped to water tank and water flow is controlled by using a valve. Cold water from still rushes to the copper collector. Constant water depth of two centimeter was maintained and all other parameters are measured.

D. Case 4: Single basin double slope solar still with water lens concentrated copper collector:

The solar irradiance is concentrated over the copper collector. With the addition of water lens more heat can be concentrated and the productivity of the system can be improved. Since the focus of the water lens will change according to sun's position manual tracking of the system is required.

E. Case 5: Integration of solar still with water lens concentrated copper collector, condenser and suction pump:

In this setup the suction pump is attached to the active solar still. The working is same as in the previous case. When the suction pump is ON condition it sucks the excess amound of vapour from the solar still due to direct contact. It is then passes to external condenser which is coupled with suction pump. The vapour when passed through the surface of the cooling coil by heat transfer hot vapour condenses and the condensate is collected in a collecting tank through the pipe. The vapour which is condensed on the inner glass cover is collected in a distillate trough.

VI. Results And Discussion

This chapter explains the results that was from the experimentation that was explained in chapter 7. Different stages of experimentation was carried out to obtain the goal of the research work.

A. Case 1: Single basin double slope passive solar still alone:

The efficiency of passive still was determined using the formula:

$$\text{Efficiency } (\eta) = \frac{\Sigma m_{ew} \times L}{\Sigma I(ts) \times A_s \times 3600} \quad (1)$$

Σm_{ew} – Summation of hourly output from still in litre.
L – Latent heat of water = 2257000 J/Kg
ΣI(ts) – Intensity of solar radiation over inclined surface of solar still
As – Area of basin area of still = 0.6 m²

B. Case 2: Single basin double slop solar still with suction pump and condenser:

$$\text{Efficiency } (\eta) = \frac{\Sigma m_{ew} \times L}{\Sigma I(ts) \times As \times 3600 + \text{Suction pump input energy}} \quad (2)$$

Suction pump input energy = 500×12×60
= 36000 J

C. Case 3: Single basin double slope solar still copper collector:

$$\text{Efficiency } (\eta) = \frac{\Sigma m_{ew} \times L}{\Sigma I(tc) \times Ac \times 3600 + \Sigma I(ts) \times As \times 3600 + \text{Water Pump input energy}} \quad (3)$$

ΣI(tc) – The intensity of solar radiation over the inclined surface of the collector
Ac - Area of collector
Water pump input energy = 50 W × 5 × 60
= 15000 J

D. Case 4: Single basin double slope solar still with water lens concentrated copper collector:

Efficiency is calculated same as the above case 3.

E. Case 5: Integration of solar still with water lens concentrated copper collector, condenser and suction pump:

$$\text{Efficiency } (\eta) = \frac{\Sigma m_{ew} \times L}{\Sigma I(tc) \times Ac \times 3600 + \Sigma I(ts) \times As \times 3600 + \text{Suction Pump input energy} + \text{Water Pump input energy}}$$

From the above experiments, the maximum yield can be obtained from solar water lens concentrated copper collector, condenser and suction pump. The Table 2 shows the overall efficiency of distillation system for different experimental set up

Experimental Setup	Cumulative Hourly Yield	Average Intensity	Output energy (KJ)	Input energy (KJ)	Overall Efficiency
Case 1	1.5	870	3385.5	15044.4	22.50
Case 2	1.7	786	3836.9	13622.4	28.16
Case 3	2	828	4514.0	28647.9	15.75
Case 4	2.3	837	5191.1	28954.6	17.24
Case 5	2.5	703	5642.5	30303.9	18.61

Table 2: Overall efficiency of distillation unit

VII. Conclusion

This research work mainly focus on an economical method to increase the productivity of desalination unit. To eradicate the problems faced in active solar distillation, external condensation technique was incorporated in single basin double slope active solar still along with water lens concentrated copper collector. As a result a new technology of solar water lens was developed which can be a substitute for solar concentrating collectors. Experiments were carried out for five different cases under clear sky conditions. Based on the experimental study the following conclusions are obtained.

When the amount of thermal energy fed to basin is increased, vapour does not have time to condense on the glass surface.

Forced or external condensation removes the excess vapour that stuck the glass cover in active distillation thereby increasing the yield of the still.

Water lens increase the water temperature inside the copper collector, which increase the evaporation rate.

Productivity of solar still with water lens concentrated copper collector, external condenser and suction pump is higher than passive solar still and other active solar still.

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