Development of Solar Thermal Desalination Plant Using Vacuum Tubes

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Abstract
Availability of drinking water is essential for all mankind. Adequate amount of water resources are available on our planet but very few of them can be used for drinking purpose. So, water purification is essential in current scenario. Direct sunlight can be used for desalination of sea water. It is useful for supplying desalinated water to small communities nearby costal remote areas. This project aims at developing solar desalination plant using vacuum tube for water purification and hence providing low cost drinkable water, especially in remote areas and regions with brackish water and sea water. It also includes the improvement of plant capacity and result comparison with solar still plant.

Keywords: *Desalinated water, purification, vacuum tube, solar, coastal areas.*

INTRODUCTION

In last few years the demand for fresh water has increased tremendously all over the world. The future demand will be very high and fresh water resources are getting depleted at a faster rate. We need to depend on the saline water resource for meeting the fresh water demand. A variety of desalination technologies has been developed over the year like electro dialysis, RO (reverse osmosis), freezing desalination etc. However, conventional desalination systems consume a lot of fuel, electricity or filters in operation. These systems are good for the well-progressed and developed areas, but not suitable for coastal remote area.

Solar energy is plentiful and can be used for converting saline water into distilled water. Solar desalination is a process where solar energy is used to produce fresh water from saline or brackish water for drinking and domestic use. Basic solar desalination process includes evaporation of water using solar radiation leaving behind the salts, minerals and other impurities. Vapour is collected in container in which vapour condenses and fresh water is obtained. Earlier solar operated water desalination system has been developed but it encountered with many problems. In order to reduce energy consumption for solar powered desalination has been used but the yield of water for existing system was very small. Further, it demanded heavy maintenance. Later in order to increase the yield multi stage vacuum desalination scheme with solar heat was used but it required a complicated vacuum control on large scale .Empty weight of the system was 5 tons and operating weight was 12 tons. Hence, cost of system was huge. In 2004, U shaped tubes were used but later on it could not be implemented as it possessed difficulty in cleaning of tubes.

Our objective is to provide low cost drinkable water with minimum cost and maintenance in remote areas where there is a scarcity of purified water. As our system is solar operated and do not include any moving parts, it ensures long life span of the system with maintenance almost negligible.

Solar thermal setup/ Modified solar still setup:

The modified solar still setup is made by the convention solar still which is smaller in size attached to evacuated glass tubes and fixed on a mild steel frame.

Principle of solar thermal: Solar thermal is a modified solar still setup with evacuated glass tubes. The water is to be filled from the rightmost end portion. There is an inlet pipe on the top left corner of the setup from which the water is filled in and it goes to the pipes and the water gets heated in the pipes as the exposed area of pipes are higher. The heated water by natural convection and thermo syphoning effect comes above and gets collected on the upper part which behaves as a small solar still thereby increasing the surface area and decreasing the volume of the setup and then it behaves same as the solar still. The water gets evaporated, travels through the periphery and combines and condensation takes place and collected from the PVC pipe below.

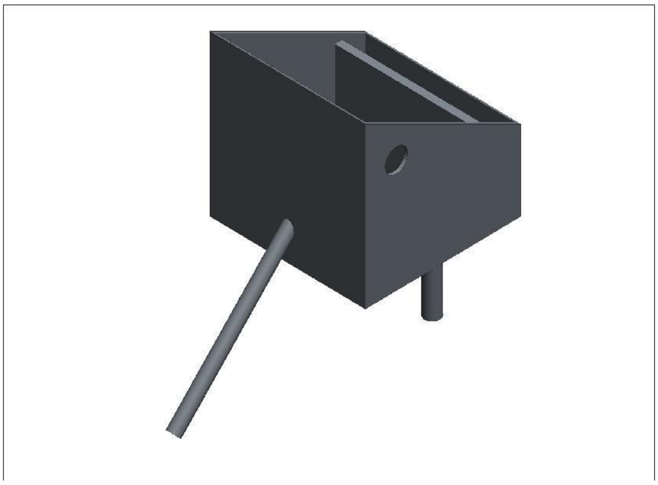

Figure : CAD model of Solar thermal

Construction: There are 15 evacuated glass tubes. Glass tubes inside which there is some air gap and between that tube there is a polymer pipe. The tubes are fixed to the frame both the sides and sealed with rubber. An inlet pipe is present in the top left corner and the outlet pipe is present in the middle of the solar still from where the condensed purified water is collected.

Actual image of solar desalination System

DIMENSIONS OF VACUUM TUBE:

Number of vacuum tube = 2

Length = 2 feet

Inner Diameter = 47 mm

Outer Diameter = 58 mm

Inner tube thickness = 1.8 mm

Outer tube thickness = 1.6 mm

Working:

Solar water desalination system is adjusted according to direction of sun rays. Water is poured into the tank and this saline water gradually fills the vacuum tube. Solar radiation is incident on the vacuum tube and heat is transferred to water inside the vacuum tube. Following the Thermosyphon Principle, natural flow of hot water takes place due density difference. This hot water rises up along the vacuum tube and fills the tank, thereby increasing the temperature of water inside the tank. As the temperature of water inside the tank increases, water vapour rises upwards and strikes the transparent glass fixed above the tank and gets condensed. Due to the inclination of the transparent glass, this condensed water gets collected through the pipe. Hence, pure desalinated water is obtained.

Productivity Comparison:

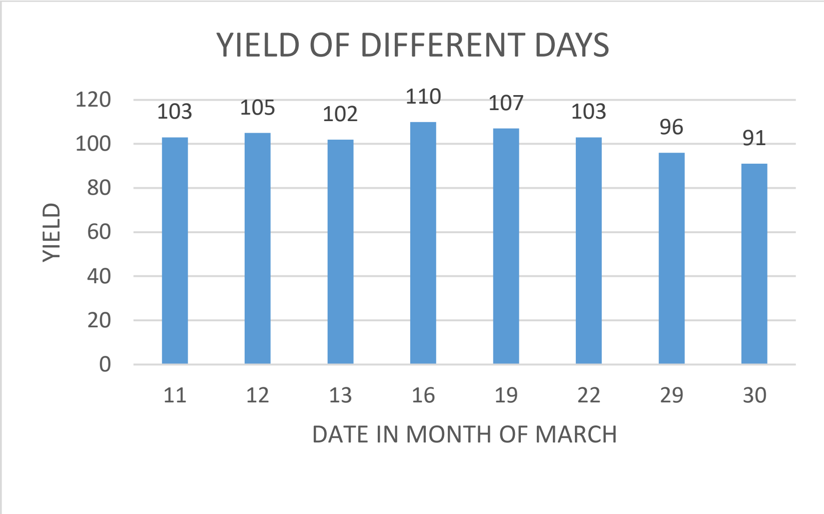

Fig. 1: **Yield on Various days in the month of March**

Date in the month of march	11	12	13	16	19	22	29	30
Yield(ml)	103	105	102	110	107	103	96	91

From the above graph we can conclude that average yield in the month of March is 102.125 ml.

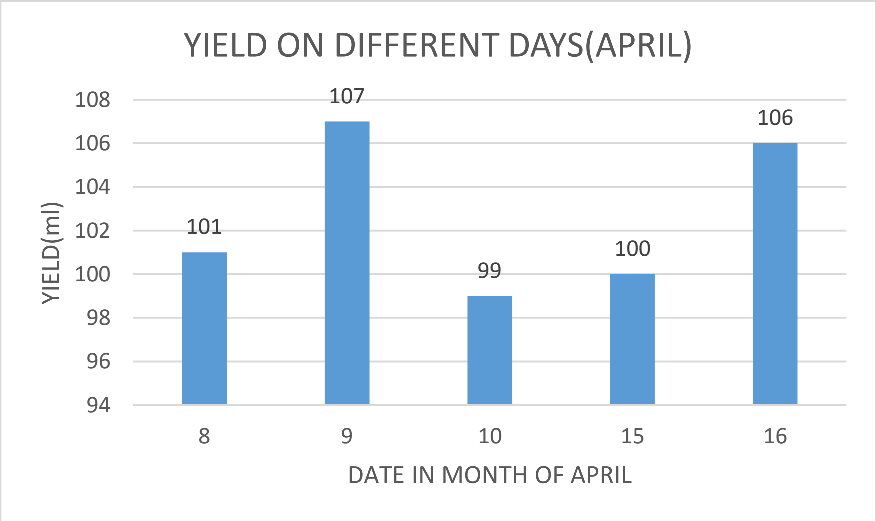

Fig.2: **Yield on Various days in the month of April**

Date in the month of April	8	9	10	15	16
Yield(ml)	101	107	99	100	106

From the above graph we can conclude that average yield in the month of April is 102.6 ml.

Efficiency comparison

For finding out the efficiency of the setup we need to require the input and output of the setup. For the same, we are considering the average yield for the output and peak radiation as the input. So what we get is the minimum efficiency of the setup.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$= \frac{\text{Energy required to increase watr temperature and evapourate it}}{\text{Solar irradiation per meter square area}}$$

$$= \frac{\text{mL+mc}\Delta\text{T}}{\text{Solar intensity}}$$

$$= \frac{mL + mc\Delta T}{Solar\ intensity}$$

(Here, mass is taken as the amount of water purified in a day per meter square of surface area)

For, Solar still:

$m = \frac{1.38}{24*3600}$ kg/s = 1.597 X 10^{-5} kg/s

Latent heat of water = 2247 kJ/kg

C = Specific heat of water = 4.184 kJ/kg-℃

ΔT = Temperature difference = 58-33 = 25℃

Incident Solar irradiation (Peak) = 977.4 W/m^2

$$\text{Efficiency} = \frac{1.597*10^{-5}(2247*1000+4184(25))}{977.4} \times 100 = 3.84\ \%$$

For, Modified System:

$m = \frac{0.105}{0.044275\times24\times3600}$ kg/s

= 2.74 X 10^{-5} Kg/s

Latent heat of water = 2247 kJ/kg

C = Specific heat of water = 4.184 kJ/kg-C

ΔT = Temperature difference = 67-33 = 34°C

$$\text{Efficiency} = \frac{2.74*10^{-5}(2247*1000+4184(34))}{977.4} \times 100 = 6.57\ \%$$

Efficiency Comparison

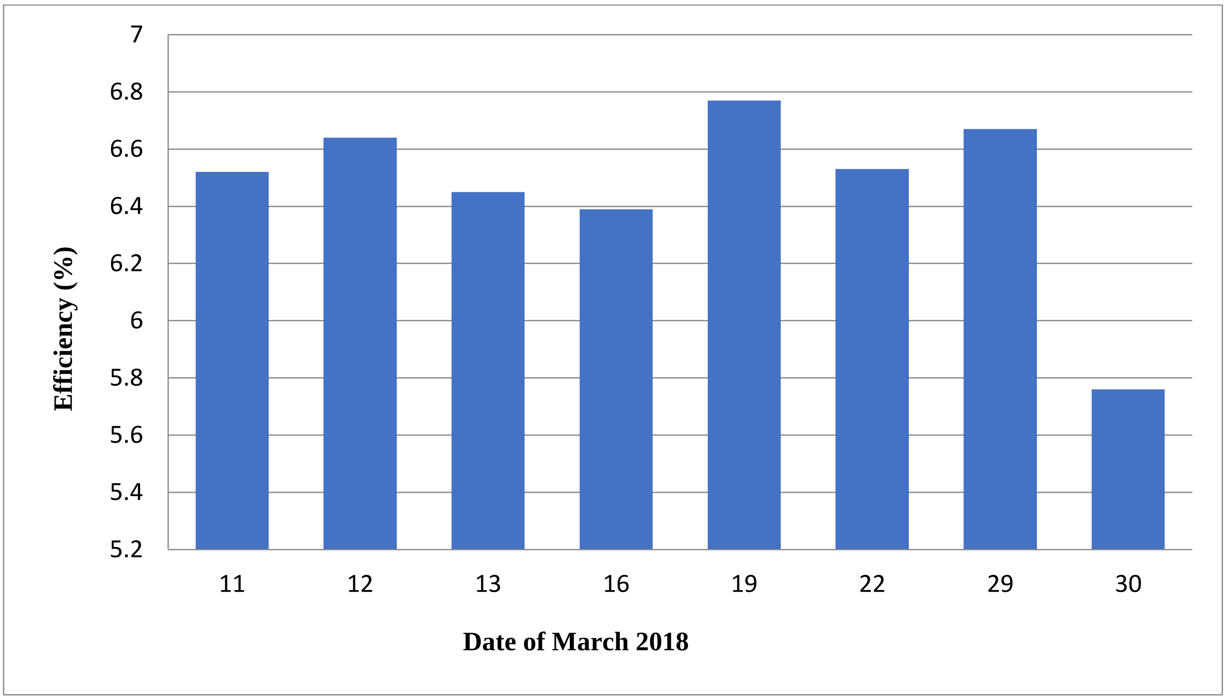

Fig.3: Efficiency in the month of March

Date in month of March	11	12	13	16	19	22	29	30
Efficiency (%)	6.52	6.64	6.45	6.39	6.77	6.53	6.67	5.76

From the above graph we can conclude that average efficiency in the month of March is 6.466 %.

CONCLUSIONS

From the experiment we have observed that the modified setup has the efficiency of about 6.5-7.0% which is more than that of conventional single basin solar still which have efficiency of 3-4 %.

The variation in the output of the system is due to the variation in the surrounding conditions and the solar radiation (seasonal variation).

The cause of loss of yield can also be the scaling on the interiors of the vacuum tube which has to be cleaned on regular intervals (once every 15-20 days depending on the TDS of the input water).

FUTURE SCOPE

Reflectors can be used to enhance the yield of the system and number of tubes can be varied as per the requirement of the plant

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