Solar Distillation of Water

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Abstract - ***Distillation is a process of separating the component substances from a liquid mixture by separate evaporation and condensation. A simple distillation process involves the heating of water using a flame and immediate condensation of the vapour in a condenser. The conventional distillation process, though simple and effective, uses conventional sources of energy such as fossil fuels. Seeing the rapid depletion of conventional sources of energy over the decades, in this project, we have decided to use a non – conventional energy source for the distillation of water. The project involves designing and fabricating a solar still which can produce sufficient amount of distilled water on a daily basis to cater to the needs of lead – acid battery retailers and thus, saving on conventional sources of energy and also reducing the cost price of distilled water for the retailers. The process involves the evaporation of water using solar energy from the sun. The evaporated water gets condensed on the inner surface of the glass, which is placed at an angle to the horizontal. Due to an inclination of the glass, the condensed vapour droplets slide down the inner surface of the glass and get collected in the delivery flask through a delivery pipe. The external reflector is used to increase the amount of solar radiation incident on the solar still, leading to an increase in the evaporation process. The rate of evaporation depends on the intensity of the solar radiations incident on the solar still.***

Key Words: *distillation, evaporation, condensation, solar energy, etc…*

1. INTRODUCTION

The project aims at producing distilled water using solar energy to cater to the daily requirement of Lead – Acid Battery retailers. Lead – Acid batteries are used in vehicles and distilled water is their most essential requirement. We selected our application on the basis of the feasibility of the project i.e. the amount of daily water needed for the application and also owing to the fact that distilled water is such an essential requirement in lead – acid batteries. The project involves designing and fabricating a solar still which can produce sufficient amount of distilled water on a daily basis to cater to the needs of lead – acid battery retailers. The process involves the evaporation of water using solar energy from the sun. The evaporated water gets condensed on the inner surface of the glass, which is placed at an angle to the horizontal. Due to an inclination of the glass, the condensed vapour droplets slide down the inner surface of the glass and get collected in the delivery flask through a delivery pipe. The rate of evaporation depends on the intensity of the solar radiations incident on the solar still. The aim of the project is to produce around 3 to 5 liters distilled water using solar energy to cater to the per day requirement of Lead-Acid Battery retailers and thus, saving on conventional sources of energy and also reducing the cost price of distilled water for the retailers.

2.METHODOLOGY

The design methodology of the project involves designing an asymmetrical solar still as per the output requirements. An asymmetrical design is chosen as it has higher output efficiency [1]. The solar still is designed for an estimated output of around 3 to 5 liters, which is the average requirement for our application. In addition to it, an external reflector has been fabricated to increase the output efficiency.

2.1 Design Calculations

a) Base Area
The calculation of the base area of the solar still is the most essential part as it is vital to know the area needed for desired amount of solar radiations to be incident in order to produce the required output. With a desired

output of 5 liters of water, the amount of solar energy required can be calculated as follows:

$$M_w = \frac{Q_{req}}{L_v}$$

Therefore,

$$5 = \frac{Q_{req}}{2260}$$

$$Q_{req} = 11300 \text{ KJ}$$

Now,

In order to calculate the amount of incident solar energy (Q_{inc}), it is needed to analyze the data of the average amount of solar energy incident in Mumbai every month.

The average solar energy received in Mumbai throughout the year is 6.23 $\text{KWhr/m}^2\text{/day}$. [4]

Therefore,

$$Q_{inc} = 6.23 \text{ KWhr/m}^2\text{/day}$$

$$= \frac{6.23 \times 1000}{24} \text{ W/m}^2$$

$$= 259.58 \text{ W/m}^2$$

Commercial glass transmits a minimum of 80% of light rays incident on it.

Therefore,

$$Q_{inc} = 259.58 \times 0.8 \text{ W/m}^2$$

$$= 207.66 \text{ W/m}^2$$

Assuming a period of 8 hours per day of incident solar energy,

$$Q_{inc} = 207.66 \times 8 \times 3600 \text{ J/m}^2$$

$$= 5980.72 \text{ KJ/m}^2$$

Thus,

For $Q_{inc} = Q_{req}$,

$$\text{Area of base required} = \frac{Q_{req}}{Q_{inc}}$$

$$= \frac{11300}{5980.72}$$

$$= 1.89 \text{ m}^2$$

Thus, considering area of base as 2 m^2,

$$Q_{inc} = 11961.44 \text{ KJ/m}^2$$

Fig 1 shows the basic design of the solar still.

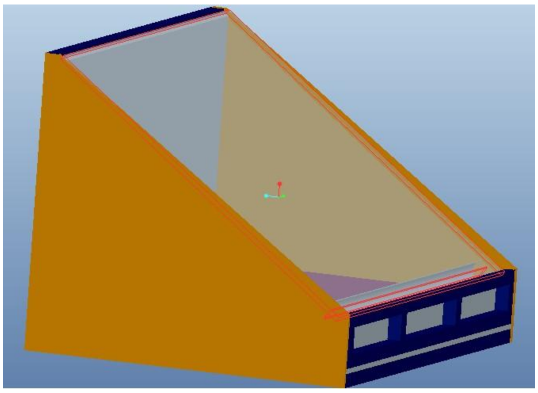

Fig -1: Basic design of solar still

b). External Reflector

The external reflector is used to increase the amount of solar radiation incident on the solar still, leading to an increase in the evaporation process. The additional amount of solar energy incident on the solar still, due to the external reflector can be calculated as follows.

Amount of incident solar energy, Q_{inc}

$$Q_{inc} = 207.66 \times 8 \times 3600 \text{ J/m}^2$$

$$= 5980.72 \text{ KJ/m}^2$$

The effective area of the external reflector is 4' x 3' which is equivalent to 1.15 m^2.

Thus,

$$Q_{inc} = 5980.72 \times 1.15$$

$$= 6877.82 \text{ KJ}$$

Now,

Let us assume that, at any given time and angle of inclination of the external reflector, at least 50% of the total incident solar radiations will be reflected directly onto the inclined glass of the solar still.

Thus,

The minimum amount of additional solar energy incident on the solar still due to the external reflector is

$$Q_{inc} = 0.5 \times 6877.82 \text{ KJ}$$

$$= 3438.91 \text{ KJ}$$

Therefore, the minimum total incident solar energy on the solar still is

Q_{inc} = Total solar energy incident on base + Total solar energy incident on reflector

$$= 11961.44 + 3438.91$$

$$= 15400.35 \text{ KJ}$$

Thus, amount of distilled water that can be obtained by using an external reflector attachment can be calculated by

$$M_w = \frac{Q_{req}}{L_v}$$

$$= \frac{15400.35}{2260}$$

= 6.8 kg
= 6.8 litres of water

Thus, using an external reflector, theoretically, about 35% increase can be obtained in the daily output of the solar still.

3. FABRICATION

The body of the solar still consists of a triangular structure mounted over a cuboidal base. Commercial plywood is used to fabricate the entire setup.

As per calculations, the dimensions of the base are taken as 1640 mm x 1220 mm for a 2 m^2 base area, considering the standard sizes of plywood available. The entire set up is a wooden frame of thickness 50 mm to ensure sturdiness.
The triangular section is designed using trigonometric calculations. The total height of the frame is considered 1000 mm.

As base of the frame is taken as 1220 mm and angle of inclination of glass as 30° [5], the height of the triangular frame is calculated as 705 mm.

The triangular side walls of the frame are accordingly given dimensions of 1220 mm x 705 mm x 1420 mm.
The total height of the frame is taken as 1000 mm and the height of the triangular section is calculated as 705 mm. Therefore, the height of the base frame is calculated as 295 mm. Considering 50 mm thickness of the frame on either side, the effective height of the base frame becomes 195 mm. Fig 2 shows the fabricated setup of the solar still.

Fig -2: Fabricated solar still

A blackened tray is placed at the base of the solar still which acts as a black body to absorb the incident heat. The condensed water from the glass is collected in a pipe placed at an inclination which enables the collected water to flow downwards to the final collection tank.

4. EXTERNAL REFLECTOR MECHANISM

An external reflector is a mirror attached externally to the solar still, which reflects a portion of the incoming solar radiations onto the inclined glass. The external reflector is thus able to reflect some amount of solar radiations that are incident outside the solar still, onto the glass, thereby increasing the total incident solar energy[2].

It is understood that the position of the sun constantly changes with time. Thus, to ensure maximum efficiency of the system, the reflector is hinged to the edge of the still and cantilevers are connected to the sides to enable free movement of the mirror. Thus, the position of the mirror can be changed as per the position of the sun. This incorporation will certainly allow a greater amount of solar radiations incident on the solar still, thus increasing the overall efficiency. Fig 3 shows the solar still with the external reflector mechanism.

Fig -3: Solar still with external reflector

5.RESULTS AND DISCUSSIONS

Testing was done on solar still in the month of March. The volume of water filled initially was varied and output for each volume was measured. The volumes of water filled were 10 liters, 15 liters and 20 liters.
The observations and readings recorded are as follows:
Testing time: 8 hours

Max temperature achieved: 65°C

Volume of water obtained with and without the use of reflector is shown in table 1.

Table -1: Volume of water obtained with and without reflector

Vol of water poured (Liters)	10	15	20
Volume of water obtained without reflector (Liters)	3.3	3.5	3.2
Volume of water obtained with reflector (Liters)	3.7	4	3.5

From the recorded data, it is observed that the maximum output of distilled water in a single day is obtained with an input of 15 liters of water.
Thus volumetric efficiency of the system is,

η_v , without reflector = 23.33 %

$\eta_{v,}$ with reflector = 26.67 %

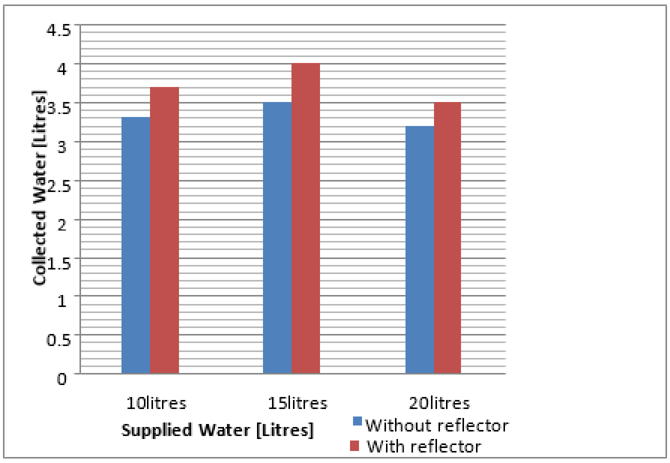

Fig -4: Supplied water versus collected water with and without reflector

5. CONCLUSION

It was observed that the volumetric efficiency of the system is 23.33% for an input of 15 liters of water per day.
The incorporation of an external reflector mechanism resulted in a 14.2% increase in the volumetric efficiency of the system.
The distilled water was successfully tested for pH value and EDTA test was also conducted. The pH value of water obtained was 6.

The total cost involved in the fabrication of the solar still is Rs. 12000, with a recovery period of around 10-12 months for the lead-acid battery retailers.

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