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Design and Analysis of a Unit for Water Desalination using Solar Concentrator

[1]***Kevin Trivedi***: *Student at Mechanical Engineering Department, Indus University, Rancharda via Thaltej, Ahmedabad, Gujarat, India.*
[2]***Bhavin Khatri***: *Asst. Professor at Mechanical Engineering Department, Indus University, Rancharda via Thaltej, Ahmedabad, Gujarat, India.*
[3]***Dhruv Gandhi***: *Student at Mechanical Engineering Department, Indus University, Rancharda via Thaltej, Ahmedabad, Gujarat, India.*
[4]***Pritesh Malavi***: *Student at Mechanical Engineering Department, Indus University, Rancharda via Thaltej, Ahmedabad, Gujarat, India.*
[5]***Faijan Vadhavaniya***: *Student at Mechanical Engineering Department, Indus University, Rancharda via Thaltej, Ahmedabad, Gujarat, India.*

Abstract - - *Clean water is the basic necessity for every human being and industries. There are many different types of water purification processes such as filtration, reverse osmosis, ultraviolet radiation, carbon absorption, but the processes that require least electricity are distillation and boiling. Water purification, such as distillation, is important in regions where water resources or tap water is not suitable for ingesting without boiling or chemical treatment. In designed project the water is treated by combining different methods such as solar concentration and Distillation. In this project, solar energy heats the water and converts into vapor leaving contaminants behind and by condensing, it converts vapor into potable water. This clean water is then collected in a water container. This way desalination of saline water is done by a unit using solar concentrator.*

Key Words: purification, filtration, reverse osmosis, ultraviolet radiation, distillation, solar concentrator

Declaration

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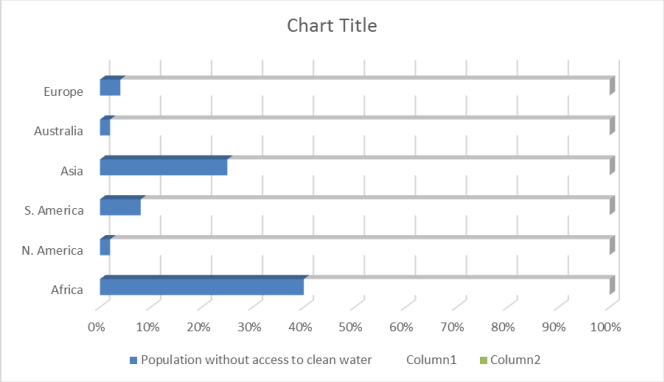
Consent for participation: There was no explicit or implicit coercion on any participant while conduction of research work.

Consent of publication: We feel happy to provide the publication with authority to publish this research paper.

1. INTRODUCTION

Access to clean water is an integral part of daily life. Its impact on cultivation, industry, overall health, and well-being is impossible to ignore. The majority of water on Earth is polluted with contaminants or chemical substances. Therefore it cannot be used for agriculture, industry, and daily human consumption. The unavailability of healthy drinking water in impoverished regions is increasing at an alarming rate parallel to increasing populations throughout the world. Rather than the use of costly non-renewable resources to meet this requirement, solar energy can be equipped to power a simple distiller. Solar distillation is a modest and reliable source for potable water that is often neglected and underutilized. In areas with extensive amounts of sunlight and access to seawater, a solar distiller can probably provide a family or small community with enough water for daily consumption. Most of our earth surface is covered by water; however, less than 1% of total available water is fresh water which is mostly available in lakes, rivers and underground. Again, about one-third of that freshwater can only be used for human needs due to combined factors. Roughly 1.1 billion people in this world don't have a sufficient amount of safe drinking water. If you think about this issue globally, around 26 countries do not have enough water to maintain cultivation and economic development. At least 80% of arid and semiarid countries have serious periodic droughts. One-third of Africans & most of Middle-East people live without enough water (Bouchekima, 2003). The population growth - coupled with industrialization and urbanization results in rising water demand. In India, the scarcity of desalinated water is critical in coastal areas, especially in remote coastal areas. Renewable energy-based desalination plants can solve this freshwater generation problem without causing any fossil energy exhaustion, hydrocarbon pollution, and environmental degradation. Despite the limitations of being a dilute source and intermittent, solar energy has the potential for meeting and supplementing different energy requirements. Different energy systems

based on solar powers can be used anywhere as they are budget-friendly, long-lasting, and can be fitted in any place.



As per the report of the World Resources Institute, India ranks 13 among the 17 most water-stressed countries. More specifically, States like Haryana, Chandigarh, Madhya Pradesh, and other states are facing water problems. At one hand, there are more cars or motor vehicles are dominating the transport medium, on the other hand these tricycles are being dominated by the fuel. The sellers of natural resources are also not able to complete this increasing demand. And As a result, the limited resources are being wiped by the manufacturers and sellers to satisfy this need which is leading us to a risky future with having the scarcity of non-renewable resources. So, it is clear that current trends in energy consumption, primarily oil, cannot be sustained much longer. Again, in view of the possibility of global warming, these resources are playing a negative role. Therefore, under these situations, it is pretty inevitable to make a new exploration of natural resources of energy and power. But why we have to do research when the resources are in front of our bear eye. It is powerful, less expensive, and above all, it is an everlasting source of energy. With greatly improved energy efficiency, a shift to this energy-based economy capable of bearing the anticipated growth in the world is possible. This effective source is “Solar Energy”.

2. Experimental setup and Design

Solar concentrator of Aluminium sheet, with solar tracker.

Solar concentrator of aluminium foil, without solar tracker.

2.1 Design of concentrator

- $D_a^2 = 16 (d) f$

  $f = \frac{(0.6)2}{16 * 0.0762} = 0.3$ m.

- where , D_a = Aperture Diameter
- d = Depth of Disk
- f = Focal point distance.
- $A_a = \frac{\pi}{4} (D_a)^2 = \frac{\pi}{4} (0.6)^2 = 0.2826$ m².
- where , A_a = Area of Aperture
- $A_c = A = \pi r^2$ (because the surface of the collector is circle in shape.)
- = 3.14*(0.032)²

- = 0.00322 m^2.
- The Concentric ratio: - Concentric ratio is between the area of Aperture and the area of the collector.
- $C = \frac{Aa}{Ac} = \frac{0.2826}{0.00322} = 87.76$
- $M_w = \frac{\eta \, id \, \pi \, Da2}{m * Cp * (Tw - Ta)} = \frac{0.4 * 750 * \pi * (0.6)2}{1.5 * 4.186 (100 - 25)} = 0.72$ kg / hr.
- where , M_w = Rate of heating water
- m= mass flow rate, Cp= sp. heat capacity
- i_d = Direct Radiation = 750 W/m^2

2.2 Design of condenser

- Latent Heat, Q = M x Lam
- Q = U x A x LMTD.
- Q = M x Lam = U x A x LMTD
- A = (M x Lam) / (U x LMTD)

M - Mass Flow Rate of vapor, Lam - Latent Heat of Vapor.

Q - Heat Energy, U - Overall Heat Transfer Coefficient, A - Available/Required Heat Transfer Area, LMTD - Log Mean Temperature Difference.

- A = n π d L

Where, n = No. of Tube passes.

d = Diameter of the Tube.

L = Length of the Tube.

Therefore,

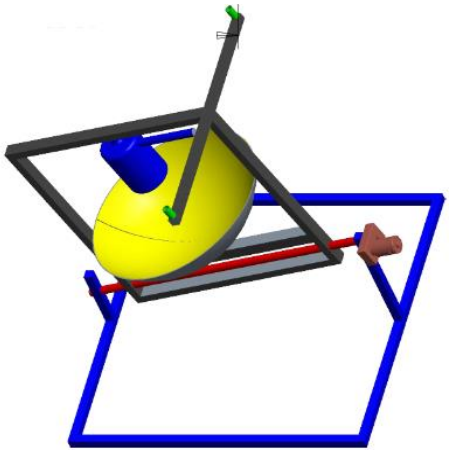
A = (M x Lam) / (U x LMTD) = n π d L

Mass flow rate through nozzle (M) may vary from 0.015 to 2.7 kg/s

0.9*2260/1440=8*3.14*0.05*L

L = 1.12 m

2.3 3-D Design



2.4 Working of System

The working is based on phenomena of evaporation on absorption of heat from sunlight and subsequent condensation of vapour on contact with the cooler walls.

1. Pump is used to reduce the pressure inside the chamber and it will take to reduce the boiling temperature of water.
2. Valve of storage tank is opened to let the water flow to copper tank.
3. Sunlight falling on concentrator is concentrated at focal point that is on the surface of copper tank.
4. This way, copper tank heats up and water is evaporated.
5. These vapors are directed to condenser with the help of hose and pump.
6. Condenser condenses the vapor
7. Desalinated water is collected and is ready for use.

3. Performance evaluation

Performance is evaluated on basis of experimental observations (analysis) of parts:

Clausius Clapyron Equation:

Log P2 / P1 = ΔH vaporization [1 / T1 - 1/T2] / 2.303 (R)

Where: R = universal gas law constant = 8.31 J/mol-K = 8.31 X 10-3 KJ / mol-K P1 and P2 = vapour pressure at T1 and T2

T1 and T2 = Kelvin Temperature at the initial state and final state at 373K the pressure is 1 atm.

Specific heat of water = 4.2 kJ/kg

Latent heat of vaporization = Latent heat of condensation = 2260 kJ/kg

3.1 Analysis

In this project analysis of different parts of the unit is done.

1. **Concentrator:**

1.1 Dimension:- 0.6 meter diameter parabolic dish type solar concentrator.

Concentrators are available in different shape and size. Here we will be discussing about parabolic dish concentrators.

These are preferred as they require least area.Best according to single point concentrator.

Can easily be manufactured.

1.2 Materials used:- There are many different materials used for manufacturing these.Concentrator can be made of metals, and glass also water (refractive type).Generally steel is used to manufacture them as steel is flexible. Aluminium is good reflector of light and bad conductor of heat. This makes it most preferable material. An Aluminium sheet is not as flexible as one of steel but steel under sunlight will get heated. Aluminium foil is also used in making solar concentrators. Aluminium sheet needs to be buffed before use for higher reflexivity on the other hand foil is most shiny product of Aluminium. Other metal sheet gets heated under sun so it is better to use Aluminium.

Firstly we have made a concentrator of Aluminium foil and then of Aluminium sheet (buffed).

We in this project have compared both the concentrators, one using Aluminium foil and other using Aluminium sheet.

Performance of concentrator dish: Below given is the table of observation of performance of both the concentrators.

(Solar concentrator was not attached)

1. Temperature of copper tank over two different solar concentrators (1. made of aluminium sheet and 2. Made of aluminium foil)

Time	Tank temperature (Aluminium sheet)	Tank temperature (Aluminium foil)
10 am	80 ℃	84℃
11 am	86℃	90℃
12 pm	94℃	98℃
1 pm	100℃	104℃
2 pm	100℃	102℃
3 pm	98℃	100℃

It is easy to handle foil than sheet.

Using any sheet of metal will end up forming dents on the surface and will have uneven surface at micrometers scale.

Using a press might prove to be expensive.

So Aluminium foil must be preferred over any other material.

1.3 Methods of manufacturing:-

Fabricators make solar concentrator by bending of sheets and riveting on the plates.

Some companies use only Aluminium foil to make concentrators.

They make a circular frame of metal, and place them over Aluminium foil. Then air is blown using pump to give shape to foil, air is blown till the desired depth is achieved. Then glue is applied on the surface of foil and foil is cemented with circular frame.

Our approach:-

1) A plate of Aluminium is taken and was given shape of solar concentrator. Then foil was glued on the surface.

2) To use Aluminium sheet, it was scissored into 3 pieces. These pieces were rivetted on the plate of Aluminium after removing foil from it.

This way both the time concentrator dish was made.

2. **Solar tracker**

Analysis part here includes observations

In this project, 2 types of solar trackers were attached one after another

1) Mechanism without any circuit.

2) Mechanism with light sensing circuit.

2.1 Mechanism without circuit:-

Components required are 12V 10 rpm geared motor, 2 solar panels.There are two motors one for panning the mount side to side and one for tilting it up and down each motor is connected to two solar panels with the wiring in opposite configurations. If one of the solar panel expose to sun light to generate enough electricity to power up to tiny geared motor rotating. One of this tracker covering them in a shadow in a proper align with a sun , as soon as the sun move certain distance out of alignment the shadow move with it solar panel get exposed and tracker will adjust. In the project, instead of wooden plate, concentrator was placed. Solar panels didn't have enough light incident on them to generate power to move 3 kgs. So, this proves that this mechanism can prove its worth in light weight operations like sun tracking solar panels.

Mechanism with light sensors and circuit:-

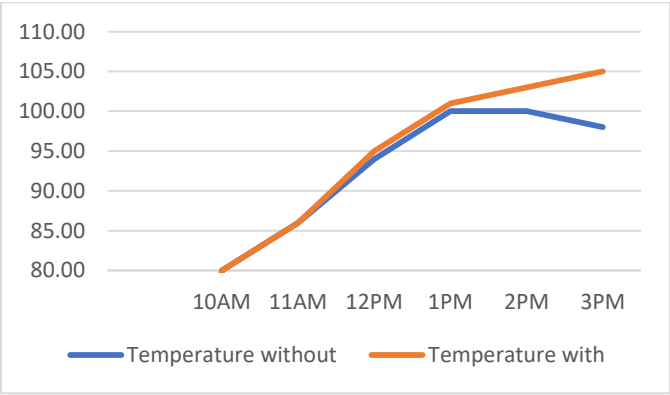
- As light incidents perpendicular to sensors, they are stable.
- But if light incidents at an angle, they pass current to motor and motor rotates to the direction of light until light falls perpendicular on the sensors.

5. Result and discussions

5.1 Observations of temperature of copper tank with and without solar tracker:-

Time	Temperature withoutSolar tracker	Temperature with solar tracker
10 am	80 °C	80 °C
11 am	86°C	86°C
12 pm	94°C	95°C
1 pm	100°C	101°C
2 pm	100°C	103°C
3 pm	98°C	105°C

2. Temperature of copper tank over a solar concentrator without solar tracker and one with solar tracker



Graphical representation of Table 2.

Time	Volume of water Without solar tracker (Liters)	Volume of water With solar tracker (Liters)
10:00 – 11:00 AM	1	1
11:00 AM – 12:00 PM	1.4	1.4
12:00 – 1:00 PM	1.9	2
1:00 – 2:00 PM	2.1	2.1
2:00 – 3:00 PM	1.8	2.15
3:00 – 4:00 PM	1.6	2.2
4:00 – 5:00 PM	1.5	2.1

As sun moves away, temperature starts decreasing in uni t without tracker. This happens due to high heat transfer rate and low concentration of light.

5.2 Without and with solar tracker, observations of amount of desalinated water:-

TDS readings of water measured before experiment were 5235 and that of desalinated water collected as outcome were 95.

With the help of solar tracker, more 2 liters of water can be desalinated per day.

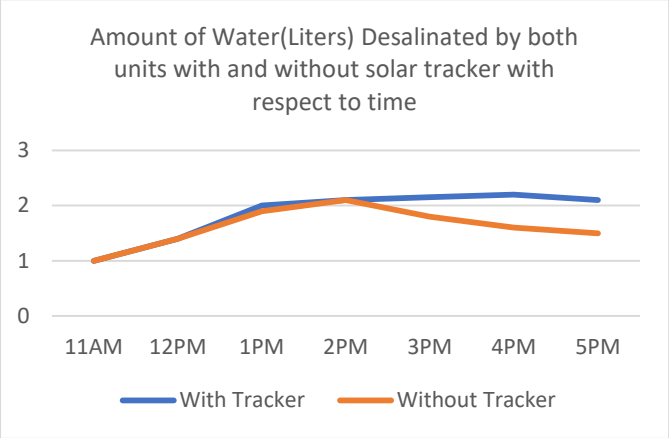
These are the observations of a unit with a solar concentrator of 0.6 meter diameter.

A concentrator of 1 meter diameter can concentrate light enough to heat up tank up to 120°C.

A dish may be of size 9 meter diameter that may concentrate 9 times higher.

Such units may be useful to a group of 5 – 6 families or more. For more usage, parabolic trough type concentrators may be useful.

3. Amount of water desalinated by a unit of solar concentrator without solar tracker and one with solar tracker



6. CONCLUSIONS

Clean water remains one of the most challenging international issues of today, and solar distillation offers important and effective solutions in meeting potable water needs.

Solar distillation is a important innovation that may help overcome clean water scarcity.

Solar distillation using solar concentrator does not only desalinate but also purifies water and makes it potable. Experiments needs to be done for improvisation of these units to decrease the use of non conventional approaches and increase the use of conventional energy sources for desalination of water.

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