"Water Distillation System using Parabolic Dish Solar Collector"

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Abstract - *Coastal areas are facing problem concerning water like intrusion of sea water into fresh water aquifers and making it saline, which results in reduced availability of good quality drinking water. Coastal areas have limited availability of clean water resources and the abundance of impure water. Access to drinking water is one of the crucial problems faced by the people in these areas. With most of the water turning saline, the limited potable water available cannot meet the demand. Keeping in notice the free Solar Energy, a water distillation and desalination system has been introduced which aims at purification of water in minimum cost without any harmful effect for meeting the requirements of the locals.*

Key Words: *Water Distillation, Saline Water, Solar Dish Collector, Parabolic Dish Collector, Coastal area.*

1. INTRODUCTION

About 70% of the planet is covered in water, yet of all of that, only around 2% is fresh water, and of that 2%, about 1.6% is locked up in polar ice caps and glaciers. So of all of the earth's water, 98% is saltwater, 1.6% is polar ice caps and glaciers, and 0.4% is drinkable water from underground wells or rivers and streams. And despite the amazing amount of technological progress and advancement that the current world we live in has undergone, roughly 1 billion people, or 14.7% of the earth's population, still do not have access to clean, safe drinkable water. A few of the negative results of this water crisis are:

- Inadequate access to water for sanitation and waste disposal
- Groundwater over drafting (excessive use) leading to diminished agricultural yields
- Overuse and pollution of the available water resources harming biodiversity
- Regional conflicts over scarce water resources.

In addition to these problems, according to Water Partners International, waterborne diseases and the absence of sanitary domestic water is one of the leading causes of death worldwide. For children less than 5 years old, waterborne disease is the leading cause of death, and at any given moment, roughly half of all hospital beds are filled with patients suffering from water-related diseases. Clearly, having affordable potable water readily available to everyone is an important and pressing issue facing the world today.[1]

1.1 Problem Statement

Coastal areas are facing problem concerning water like intrusion of sea water into fresh water aquifers and making it saline, which results in reduced availability of good quality drinking water. As there is no shortage of Solar Energy, our aim is to use Solar Energy to achieve the objective at low cost. Our purpose is to design a water distillation system which converts saline water into potable water.

1.2 Objectives

- To improve the properties of the selective coating on the receiver efficient use of Solar Energy
- To increase the temperature at focal point
- To manufacture whole setup at low cost
- To obtain proper shape of parabolic dish
- To use the saline water and distill it to obtain the potable water

2. DESIGN SPECIFICATIONS OF PARABOLIC DISH SOLAR COLLECTOR

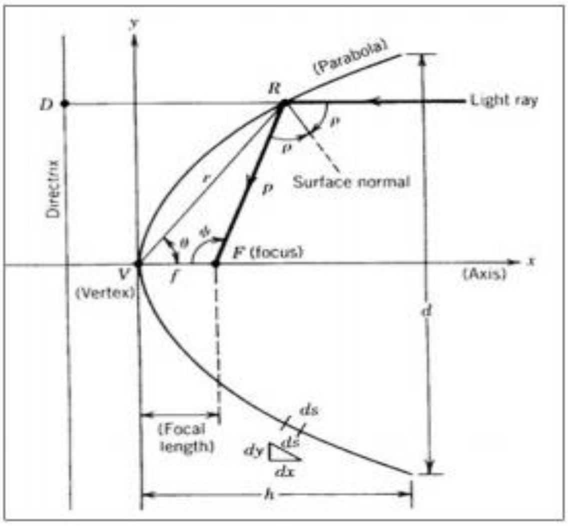

Fig-1 Design parameters of Dish collector

A parabola is the locus of a point that moves so that its distances from a fixed line and a fixed point are equal. Fig. 1 shows a parabola, where the fixed line is called the directrix and the fixed point F, and the focus. The length FR equals the length RD. The line perpendicular to the directrix and passing through the focus F is called the axis of the parabola.

The parabola intersects its axis at a point V called the vertex, which is exactly midway between the focus and the directrix. [1]

2.1 Dimensions of the Parabolic Dish Solar Collector [1]

The heat demand load of the heater is such that it will heat about 40 litres of water in a day, from ambient temperature to 1000C. However, in order to reduce space requirement, the heater will be designed in such a way that it will heat about 10 litres of water only at a time. Thus at an average uniform rate of solar insolation, the heater will make 4 cycles of almost equal lengths in time to heat the quantity of water required. The absorber of the heater will be a cylinder of outside diameter Dabs, internal diameter dabs, height l, and thickness tx= 2mm. The internal volume of the cylinder is the same as the volume of water, Vw, to be heated.

Therefore: $\pi(d_{abs}{}^{2} /4)X\ l = Vw$

For simple solution of the equation and optimum design of the absorber the height l is made to be the same as the diameter d_{abs}:

$d_{abs}{}^{2} /4 = 0.01$

$d_{abs} = {}^{3}\sqrt{}\ 4\ X\ 0.01/ \pi\ = 0.234$ m

d_{abs}= 23.4 cm

l = d_{abs}= 23.4 cm

D_{abs}=d_{abs}+ 2t =0.234 + 2 (0.002)

d_{abs}=0.238m = 23.8cm

The effective surface area of the absorber is given as:

$A_{abs} = (\pi D_{abs}{}^{2} /4) + \pi D_{abs} l$

$=(\pi\ X\ 0.238^2 /4) + \pi\ X\ 238\ X\ 234$

$A_{abs} = 0.219 m^2$

The concentration ratio is given as:

C= (A_a /A_{abs})

To reduce the frequency of tracking the sun C is set at 10.

A_a= C X 0.219 = 2.19m^2

The aperture diameter D_a is given by:

$(\pi D_a{}^2/4) = 2.19$

$D_a = \sqrt{}\ (4\ X\ 2.19) /\pi = 1.67$m

$D_a = 167 cm$

The half-acceptance angle $\emptyset$ is given by: C= 1/ $sin^2\emptyset$

$\emptyset = sin{-}1\sqrt{}\ 1 /C$

$= sin{-}1\sqrt{}\ 1 /10$

$\emptyset = 18.43°$

The optimum rim angle φrim is:

$\varphi rim = 90° - \emptyset = 90° - 18.43°$

$= 71.57°$

The focal length, f, of the dish is obtained from:

$f / D_a = (1 + cos\varphi_{rim} /4sin\varphi_{rim})$

$f\ \ = [D_a(1+cos\varphi_{rim}) /4sin\varphi_{rim}]$

$= 1.67(1+\cos 71.57)\ 4sin 71.57$ f

= 0.579m

= 57.9cm

The height, h, of the dish is given by:

$h = D_a{}^{2} /16f$

= 1.672 16X0.583

=0.3010

h =30.10 cm

2.2 Selection of Materials for Solar Disc Collector

- Material for the Body of the Dish:

Mild Steel (M.S.) is selected because of its strength and lower cost, ease of fabrication and also reduces the amount of work to be done for turning the dish from east to west and vice versa(Melting Point-660°C).

- Material for the Reflecting Surface:

To reduce the overall weight of the solar water heater, a reflective shiny silver colored foil of high surface quality and good specular reflectance is selected. A silver colored foil of high reflectivity is used because of light weight, ease of covering the dish and low cost compared to aluminium foil or glass.

- Material for the Absorber:

Aluminium was selected over copper and steel because of its lower cost, light weight, ease of fabrication and energy effectiveness in use of material. Its light weight reduces the overall weight of the solar water heater and also reduces the amount of work to be done for turning the dish about its horizontal axis. (Thermal Conductivity: 237 W/m*K)

- Material for the Vertical Support of the Dish:

A cylindrical, hollow, iron rod having a circular cross-sectional area base made of cement is selected for the support of the dish. This is because of its strength, rigidity, resistance to deflection by commonly encountered winds, and its ability to withstand transverse and cross-sectional loads of the entire heating portion of the Parabolic Solar Disc Collector.

- Material for the Base of the Parabolic dish solar collector :

The rod is supported on a block made of cement and having square cross sectional area for proper base.

3 COMPONENTS OF PARABOLIC DISH SOLAR COLLECTOR

3.1 Natural Condenser

We are familiar with the cooling of water in earthern pots in summer. In an earthen pots water gets evaporated quickly through the pores. Cooling is caused by evaporation. Since, this energy is taken from water itself, it leads to lowering of temperature in the remaining amount of water. Condenser coil is inserted in earthen pot/tank. Steam is condensed to liquid with the help of cool water present in pot/tank. This will improve the efficiency of condensation process and overall cost will be decreased.

Fig- 2 Earthen pot and condenser coil

3.2 Parabolic Solar Dish Collector

The device which is used to transform solar energy to heat is referred to a solar collector. Solar thermal collectors have been widely used to concentrate solar radiation and convert it into medium-high temperature thermal processes. Solar dish collectors are generally collectors that concentrate solar energy in a small area known as focal point.
A solar collector is as shown in figure below:

Fig-3 Parabolic Dish Collector

3.3 Vessel

A vessel is one of the most important components of the system. This vessel is mounted at the focal point of the parabolic dish. When sun rays incidents on this parabolic dish, they are concentrated at focal point. As they are concentrated, the temperature of saline water which is kept inside the vessel increases. A vessel is painted black on its outer surface so that it can absorb maximum heat as possible. A hole is provided on the cover of the vessel so that the steam so formed can be easily removed.

Fig-4 Vessel

4. CASE STUDY

Temperature reading for Pune city has been noted down to understand the solar radiation intensity for a year.

Table -1: Temperature from time 09 to 16 hours in degree centigrade

Month	Hourly Temp In Pune Time IST							
	09	10	11	12	13	14	15	16
January	17.5	21.7	24.3	26.2	27.5	28.4	28.8	28.8
February	19.7	23.8	26.2	28.1	29.3	20.2	30.5	30.5
March	24.4	28.0	30.5	32.2	33.4	34.2	34.4	34.4
April	28.0	30.8	33.1	34.8	35.9	36.4	36.1	36.1
May	28.3	30.3	32.2	33.7	34.8	35.3	34.8	34.8
June	26.2	27.2	28.2	29.0	29.5	29.7	28.9	28.9
July	24.8	25.4	26.0	26.5	26.6	26.8	26.1	26.1
August	24.2	24.9	25.5	26.0	26.2	26.2	25.5	25.5
September	24.4	25.7	26.8	27.6	28.1	28.2	27.4	27.4
October	24.3	26.6	28.2	29.4	30.1	30.5	30.0	30.0
November	21.9	24.7	26.7	28.0	28.9	29.3	29.4	29.4
December	18.0	21.7	24.2	25.8	26.8	27.4	27.6	27.6

4.1 Experimental Readings and Observations

The testing of the parabolic dish solar steam generator was done during various time of a day. The whole set was placed in an open space in the sun Resistance thermometer placed at the focal point was used to obtain its maximum obtainable temperature. The results obtained are tabulated in following tables.

Table -2: Variation of Temperature at Focal Point with Time on the First Day (12:10 to 12:50)

Time	Water Temp. in the vessel(°C)
12:10	29.3
12:15	53.4
12:20	70.7
12:35	84.2
12:40	92.5
12:45	98.6
12:50	102.7

Ambient Temperature of air: 40.2 °C
Temp at Focal point: 146 °C

Table -3: Variation of Temperature at Focus Point with Time on the Second Day (14:55 to 15:40)

Time	Water Temp. in the Vessel(°C)
14:55 pm	30.6
15:00 pm	51.4
15:05 pm	67.1
15:10 pm	79.3
15:15 pm	85.3
15:20 pm	89.2
15:25 pm	94.0
15:30 pm	96.3
15:35 pm	96.8
15:40 pm	97.3

Ambient Temperature of Air: 39.8 °C
Focal Point Temperature: 134 °C

Table -4: Variation of Temperature at Focal Point with Time on the Third Day (13:00 to 13:40)

Time	Water Temp. in the Vessel(°C)
13:00	31.2
13:05	53.1
13:10	69.9
13:15	80.5
13:20	88.4
13:25	94.2
13:30	96.7
13:35	98.5
13:40	99.4

Ambient Temperature of air: 39.5 °C
Temp at Focal point: 142.3°C

Based on the results obtained during the test of the parabolic dish solar steam generator, temperature of 146°C was recorded against the ambient temperature. The temperature at the focal point varied with time but however, a peak value was always reached. Variation of temperature with time was due to movement and position of the sun, the angle of inclination of the parabolic dish and the atmospheric condition. We only need water to reach only its boiling point to generate steam for condensation. Based on the data, 1 liter of water can be boiled within 2 hours.

5. COST ESTIMATION

The total cost of the Parabolic Solar Disc Collector is INR 2900. Cost of each component is given in the following table.

Table-5: Cost Estimation of Parabolic Solar Disc Collector

SR NO	COMPONENT	COST IN RS.
1	Parabolic Dish	1200
2	Vessel	100
3	Reflective Material	100
4	Condenser	500
5	Stand	100
6	Nuts, Bolts, Washer, Pipe	150
7	Paint and Adhesives	120
8	Fabrication of Dish	450
10	OTHERS	200
	TOTAL	2900/-

6 Project Set-up

Fig-5: Actual Project Model

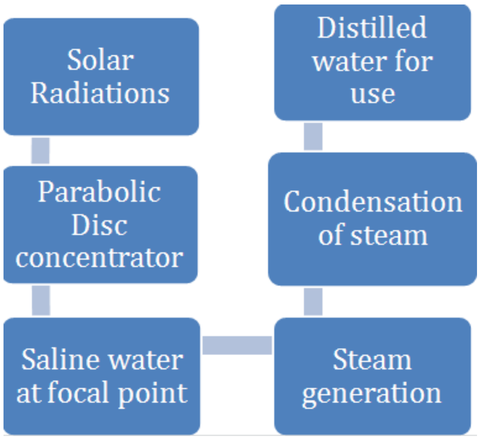

Fig -6: Working cycle of parabolic solar disc collector

7. FUTURE SCOPE

Coastal areas are facing problems related to availability of potable water. Therefore solar distillation can be considered as a possible solution of the water problem requiring no fuel. In the past two decade there has been a significant increase in the use of domestic solar water heaters around the world. Cost estimates indicate that solar collectors are every economical to build and operate and they may solve the water problems in coastal regions, where natural potable water is not available. It is obviously important that the efficiency of the solar distillation process be high and the initial cost of construction be as low as possible. When these aims are attained, fresh water can be produced by solar distillation for consumption. This can also be used to distill water at each household installed on the rooftops. This can also be used for drying purpose and heating water.

7. CONCLUSIONS

A parabolic solar disc collector has been designed, built and tested. The experimental results showed that the favorable conditions for distillation are:

• The best hour of distillation is between 12:00 – 12:30. The temperature obtained is 146 $°\boldsymbol{C}$ at focal point and the water temperature is 102.7 $°\boldsymbol{C}$

• The system will be more effective if the solar tracking is used.

REFERENCES

[1] Ibrahim Ladan Mohammed / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 1, Jan-Feb 2012, pp. 822-830

[2] Performance Analysis Methodology for Parabolic Dish Solar Collectors for Process Heating Using Thermic Fluid, Vanita Thakkar, Ankush Doshi, Akshay kumar Rana, OSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)

[3] Joshua Folaranmi / Design, Construction and Testing of a Parabolic Solar Steam Generator, Leonardo Electronic Journal of Practices and Technologies ISSN 1583-1078, Issue 14, January-June 2009

[4] Theoretical Analysis of Solar Distillation Using Active Solar Still Omar Badran, Mechanical Engineering Dept Int. J. of Thermal and Environmental Engineering, Vol. 3 No. 2 (2011) 113-112

[5] Grid Integration of Concentrating Solar Power Plant and Cost Analysis Prof. Mihir K.Patel , Hemish R.Choksi, IJIRS Vol. 4, Issue 12, December 2015

[6] Sun and water:An overview of solar water treatment devices, rolla, trudy c.. Journal of Environmental Health 06/98 v60:n10. p30(3)