DESIGN AND FABRICATION OF SOLAR WATER DESALINATION BY USING PARABOLIC METHOD

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Abstract - *This research aims towards the characteristics of water obtained on desalination of sea water using a parabolic trough under different parameters like ambient temperature, output TDS, wind temperature, time of day shape of parabolic trough. The most prominent parameters that affected the efficiency of system were the shape of parabolic trough i.e. the rim angle of the parabola. Secondary parameters include the materials used to manufacture the parabolic trough and the receiver pipe. Finally, at the end of the receiver pipe a capillary tube is attached to naturally condense the steam. The results that a maximum of 2.1 liters of water is obtained per hour for TDS range of 180-230 with ambient temperature ranging from 40-44 C.*

To conclude, this system's portable nature is a major driving factor for its implementation in households and with future developments the manufacturing costs can be brought down and the efficiency can be improved.

Key Words: Sea Water , TDS , Parabolic Trough , Steam , Solar Energy , Condensation.

1. INTRODUCTION

1.1 BACKGROUND

Although the government have made and implemented a lot of plans for solving the water crisis in the state of Gujarat, there are many places deprived of clean water. The waters of Narmada are constantly diverted to these drought-struck villages but it is nowhere close to solving the problem. There are number of districts severely affected by the lack of water for drinking and irrigation, biggest of which being Kutch, a whole district rapidly turning into desert due to the distance from Narmada river which is the biggest source of clean water in the state.

There have been several efforts to develop a desalination system but most of them are based of R.O. system which requires energy which is most commonly obtained by coal in India.

1.2 STATEMENT OF PROBLEM

Due to global warming, the state of Gujarat which is highly dependent on agriculture receives irregular as well deficit monsoon. This creates a state wide water shortage in the water reservoirs. In some places water is supplied once or twice a week only. Due to the low per capita income people can also not rely on Reverse Osmosis systems for filtration of water for individual and commercial use. Electricity shortage is also a major setback as 100 % of the country is still not electrified completely. Just like water electricity is supplied for a specific amount of time per week in some parts of the country.

1.2 JUSTIFICATION OF STUDY

As Gujarat is the state with a coastline of 1600 Kilometers which is highest in India, sea water is readily available to majority of the state. The geography is also such that the year-round weather of the state is comparatively warm to most of the states of India.

Most of the research done on solar desalination of water is done with using a flat plate collector of a circular collector as the main component. However, form the study it has been found that parabolic collector has highest efficiency over a higher temperature range as it has the capability to focus more sun rays at one line.

2. DESIGN AND CALCULATIONS

2.1 DESIGN OF PARABOLIC TROUGH SOLAR COLLECTOR

Equation of parabola $Y = 0.041667x^2$

Focal point at $\frac{1}{4a}$ above

Eccentricity = VF/VR

VF = Vertex to focus distance
VR = Vertex to directrix distance

Table -1: Different Curves

Eccentricity	CF	VF (Distance from Vertex to Foci)	CV (Distance between Pole to Vertex)	Angle
1.2	200	109.0909	90.9090	50.1944
1.3	200	113.0434	86.9565	52.4314
1.4	200	116.6666	83.3333	54.4623
1.5	200	120	80	56.3099
1.6	200	123.0769	76.9230	57.9946
1.7	200	125.9259	74.0740	59.5344
1.8	200	128.5714	71.4285	60.9453
1.9	200	131.0344	68.9655	62.2414
2	200	133.3333	66.6666	63.4349
2.1	200	135.4838	64.5161	64.5366
2.2	200	137.5	62.5	65.5560
2.3	200	139.3939	60.6060	66.5014
2.4	200	141.1764	58.8235	67.3801
2.5	200	142.8571	57.1428	68.1985
2.6	200	144.4444	55.5555	68.9624
2.7	200	145.9459	54.0540	69.6768
2.8	200	147.3684	52.6315	70.3461
2.9	200	148.7179	51.2820	70.9743
3	200	150	50	71.5650

Here different rim angles are tested to obtain the optimal shape of parabola and the focal distance where the maximum amount of the radiations are concentrated. Highest efficiency is obtained with eccentricity of 3 at rim angle of 71.56 ^{0}.

2.2 ASSEMBLY

The Assembly color coded according to the materials used, is shown in the 3D figure.

Figure -1: Assembly

The dimensions of the frame of the parabolic reflector, the stand on which the frame rests and the reflector itself is shown in different projections.

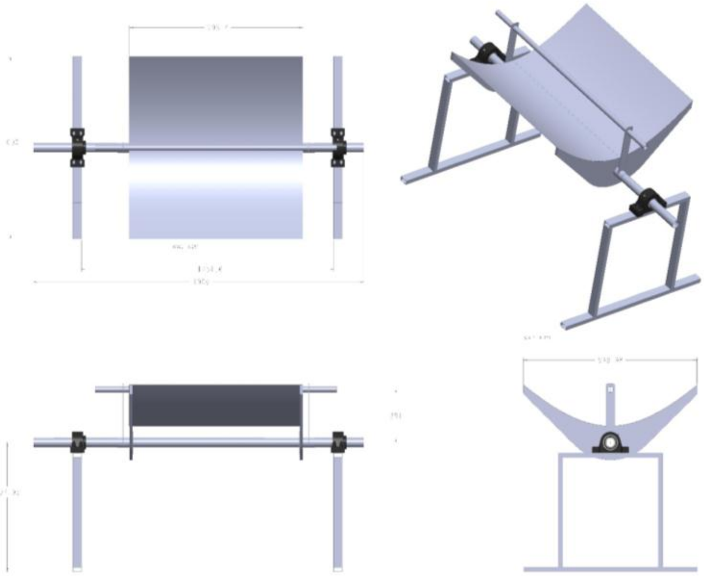


Figure -2: All views of model

2.3 ANALYSIS

Here, three parts are available.

1) Reflective trough –	Surface area	: 2.2368 m^2
	Thickness	: 0.001 m
	Material	: Stainless steel
	Length	: 1 m
2) Pipe -	Diameter	: 0.0635 m
	Thickness	: 0.001 m
	Material	: Polished Copper
	Length	: 1 m
3) Water Domain -	Area through which water is flowing.	

Material Properties

Water Liquid:

Density	: 998.2 kg/m^3
Cp (Specific Heat)	: 4182 j/kg-k
Thermal Conductivity	: 0.6 w/m-k
Viscosity	: 0.0010 kg/m-s

Stainless steel:

Density	: 2719 kg/m^3
Cp (Specific Heat)	: 871 j/kg-k
Thermal Conductivity	: 202.4 w/m-k

Copper:

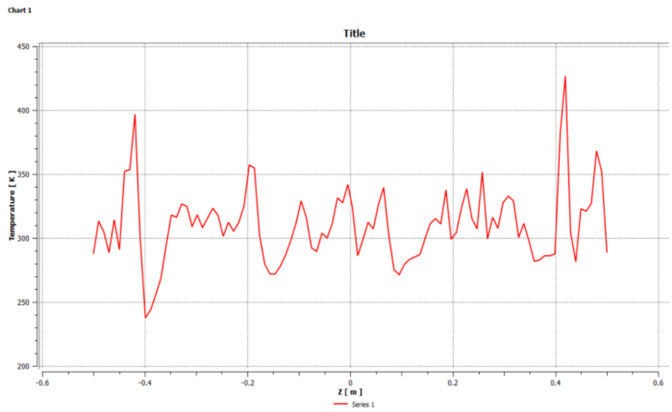
Density	: 8978 kg/m^3
Cp (Specific Heat)	: 381 j/kg-k
Thermal Conductivity	: 387.6 w/m-k

For computing this analysis, we choose SIMPLEC method for accurate results

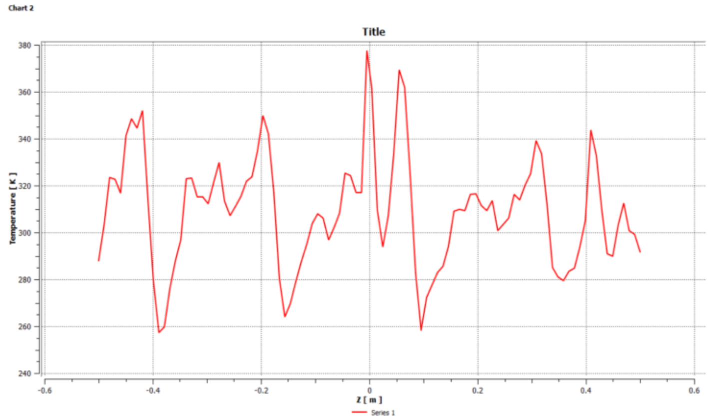
Results

Temperature difference at surface of the water domain.

It is shown in below figure and its minimum and maximum temperature 237.458 and 426.459 respectively.



Also referring the other details for the temperature variation of the water domain region, below graph shows the variation at the center of the pipe with 0.0005 m/s flow rate and 288 K inlet temp.



Here, above graph have different variation because of the water properties, flow rate, heat flux changes at surface and center region of the water domain. So, in above graph the temperature values lies between 257.253K and 377.534K.

At outlet section the steam will generate due to increase in temperature above the boiling point of water and may have some water droplets because of variation of the radiation properties and sun's location and time defense.

Consider above figure of Analysis for reference which is done in Ansys Fluent 2015.

3. EXPERIMENTATION

3.1 TEMPERATURE MEASUREMENT

We collected a data of ambient temperature , collector(trough) temperature and receiver(tube) temperature.

All the readings were taken on 12/04/2019 with wind speed ranging from 4 km/h to 7 km/h between the time of experimentation that is from 9:00 AM to 6:00 PM. These speeds are ideal higher wind speed creating convection losses from the collector and receiver.

Table – 2: Time vs temperature measurement

Time	**Ambient Temperature (in °C)**	**Collector(trough) Temperature (in °C)**	**Receiver(tube) Temperature (in °C)**
9:00 AM	33	40	98.7
10:00 AM	36	45	106

11:00 AM	38	54.7	132.1
12:00 PM	40	66.2	182.3
1:00 PM	42	68	185
2:00 PM	43	70	187
3:00 PM	44	78	196.8
4:00 PM	44	83	204
5:00 PM	43	71	192
6:00 PM	42	65	173

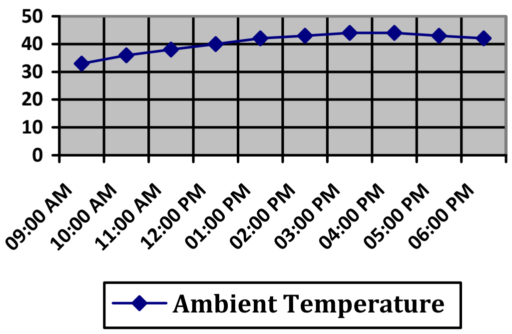


Chart -1: Time vs. Ambient Temperature

Highest ambient temperature is seen between 3:00 PM and 4:00 PM i.e 44 ^{0}C

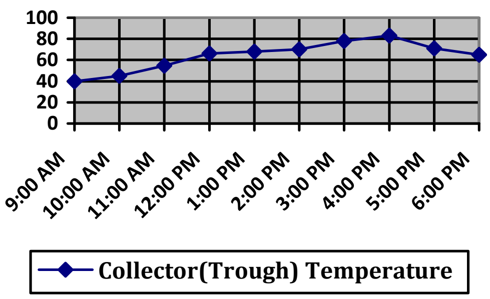


Chart -2: Time vs. Collector Temperature

Highest collector temperature obtained is 83 ^{0}C, attained at 4:00 PM

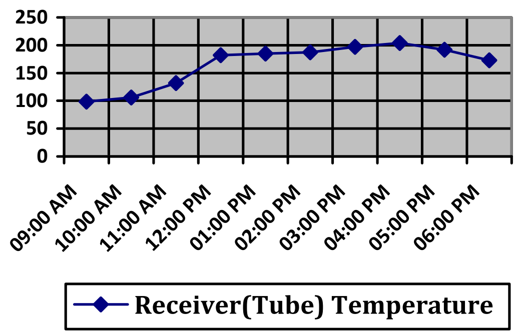


Chart -3: Time vs. Receiver Temperature

The temperature values obtained at the receiver are of most importance as that temperature will conclude into the amount of steam produced, which is at 204 ^{0}C at 4:00 PM.

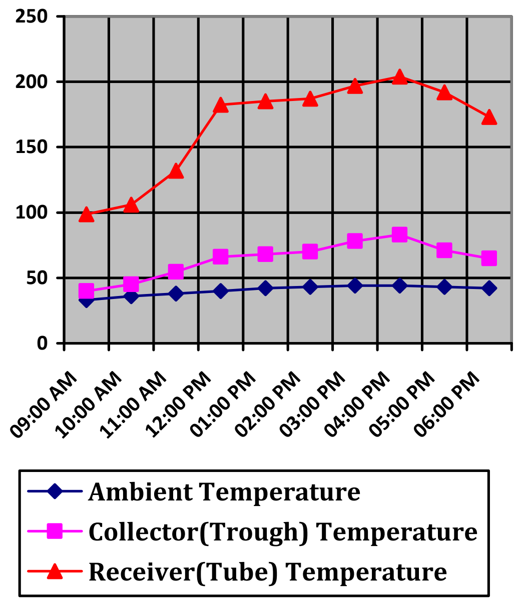


Chart -4: Relation Between Ambient, Collector and Receiver Temperature

3.2 MEASUREMENT OF DISSOLVED SALT IN OUTLET WATER

For this test sea water equivalent saline water is taken with TDS of 9800.

It can be seen from the results that as we change the flow rate the outlet water TDS changes. This is done so that different quality of water is obtained as per the requirement. For example, for household work like washing clothes, bathing etc. 1200 TDS water is suitable.

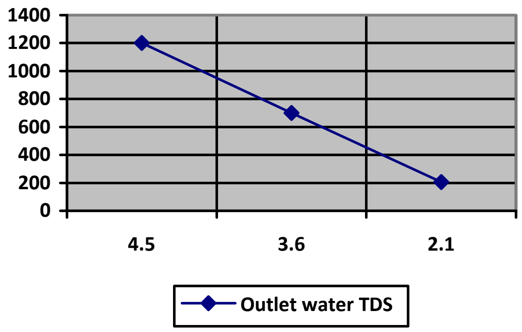
For washing utensils 700 TDS water is required because the hard water cannot remove all the bacteria so it needs to be softened.

For drinking purposes, the lowest TDS of water is required i.e. 204 TDS

Majority of R.O. plants have an outlet TDS of 130-200 TDS.

Table -3: Flowrate vs. Outlet water TDS

Flow rate(Liter/hr)	Outlet Water TDS
4.5	1200 TDS
3.6	700 TDS
2.1	206 TDS



4. CONCLUSIONS

Other than the one-time investment we can obtain the mentioned amount of water for free as the water is taken from sea and the energy used is also renewable. The materials used are such that there is a balance between cost, weight, strength and reflexivity so that the whole setup can be affordable, lightweight, low losses and less fragile as compared to using glass as collector. More than one collector troughs can be attached to form an array for more production. The steam generated from this can also be used to run a turbine for power generation.

As the technologies mature more and more advanced techniques will be found and use of materials with higher reflectivity and absorptivity will be possible, however the need of clean water will always be there and hence this model is destined to move forward for modifications and implementation in various parts of the world.

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