Performance Evaluation of Solar Parabolic Trough Collector Using Two Fluids Water and Ethylene Glycol

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Abstract—The Section "Parabolic Trough Collectors" presents the solar thermal energy technology using parabolic trough collectors for the concentration of solar radiation. Performance of solar collectors depends upon various factors like collector & receiver material, solar intensity, nature of working fluid etc. Above all, nature & the properties of the working fluid which flows through the collectors, greatly affects its performance. Here, an attempt has been made to improve the performance of a parabolic solar collector by using ethylene glycol and water as working fluid. The present investigation mainly focuses on the ethylene glycol based concentrating parabolic solar collector. The performance of a parabolic solar collector is investigated experimentally by studying the effect of ethylene glycol and water as working fluids. Study is taken under the constant mass flow rate. Comparison of water and ethylene glycol is done as a working fluid the value for maximum instantaneous & thermal will evaluate the performance of solar parabolic trough collector. An investigation has been carried out with two fluids and on the basis of comparative results is made which one give the best heat transfer rates.

Keywords:*Parabolic Trough Collectors, Thermal Energy Technology, Ethylene Glycol,Heat Transfer Rates.*

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I. INTRODUCTION

A parabolic trough is a type of solar thermal collector. It is that straight in one dimension and curved as a parabola in the other two. It is lined with a polished metal mirror. The energy of sunlight which enters the mirror parallel to its plane of symmetry is focused along the focal line. On focal line the objects are positioned that are intended to be heated. For example, food may be placed at the focal line of a trough, which causes the food to be cooked when the trough is aimed so the Sun is in its plane of symmetry. For other purposes, there is often a tube, known as receiver tube, which runs the length of the trough at its focal line. The mirror is oriented so that sunlight which it reflects is concentrated on the tube, which contains a fluid which is heated to a high temperature by the energy of the sunlight. The hot fluid can be used for many purposes. Often, it is piped to a heat engine, which uses the heat energy to drive machinery or to generate electricity. This solar energy collector is the most common and best known type of parabolic trough. The paragraphs below therefore concentrate on this type.

The parabolic trough collectors are reflectors curved around an axis in linear parabolic shape, which collect parallel rays around a single focus line, where a long pipe receiver is placed for heating the heat exchange fluid. The heat collector element (HCE) consists of a copper tube with a selective coating of metal-ceramic enclosed by an evacuated antireflective glass tube. The vacuum envelope primarily serves to significantly reduce thermal losses at highoperating temperatures and to protect the surface of the absorber from oxidation. The vacuum in the HCE should be below theconduction band Knudsen gas to reduce convective losses in the annular space, which is typically maintained close to 0.0001 mm Hg. The metal-ceramic multilayer cover is placed over the steel tube to provide optimum optical properties with high absorptive of direct solar radiation and low thermal emissivity at the temperature of operation to reduce heatradiation. The glass cylinder has an outer antireflective coating to reduce Fresnel reflective losses from glass surface, maximizing the solar transmittance. It considers the effects of solar intensity and incident angle, collector dimensions, material properties, fluid properties, ambient conditions and operating conditions on the performance of the collector for use in a power plant.

II. OBJECTIVE AND SCOPE OF WORK

The proposed work has the following objectives and contributions in the field of parabolic trough solar collector system:

- To propose a methodology by which the design and selection of parabolic trough solar collector system can be made comprehensive and easy.
- Optimization of PTSC system with respect to the performance i.e. collector efficiency, quality, liability and most importantly the cost of different materials constituting the PTSC system

. • Complete analysis, evaluation, and comparison of the different PTSC system available in the global market, and also the optimum selection of the PTSC system.

• To design and fabricate the Prototype Parabolic Trough Solar Collector system in which generation of steam from water. And also used for its feasibility in other applications like cooking, as a solar water heater etc.

To calculate heat transfer rate of water also for different working fluid. But in this we made the comparison between the working fluid is done on PSTC i.e. water and ethylene glycol.

• To fabricate a cost efficient receiver tube which is available in the global market and it fabricated with the use of different alternative materials.

• To calculate the performance of the PTSC system for steam the production in terms of useful heat gain, temperature of water in the storage tank, collector efficiency and its heat transfer rate.

• Experimental analysis, performance evaluation and comparison of glass cover tubes of a copper pipe diameter in terms of efficiency and selecting the best result for improved efficiency of the fabricated PTSC system.

In the present work, new parabolic trough collector system with manual tracking system which has been developed for steam generation. The proposed methodology is used to obtain optimum parameters and conditions such as operating conditions and parasitic losses. It considers the effects of solar intensity and collector dimensions, material properties, fluid properties, ambient conditions and operating conditions on the performance of the collector for use in steam generation. Fabrication and design of a solar parabolic trough is done using locally available materials. The great advantage of solar trough is that it is clean, cheaper and can be supplied thermal energy without any environmental pollution. It there by directly substitutes renewable energy for fossil-fuels, non-commercial fuel namely- firewood and also helps to cut utility electricity bills. At rural level and remote areas this system can use for hot water generation, crop drying, Laundries, in dairy, Food preparation and service facilities hence low temperature trough will be a better solar thermal device for the rural area.

III. LITRETURE REVIEW

3.1Mayur G Tayade -[2015]: This paper was concerned with an experimental study of parabolic trough collector designed and manufactured. A parabolic trough solar collector uses Aluminium sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards an absorber tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the absorber tube.

3.2Kapilet. al-[2014]:Experimentation on nano fluid Based Concentrating Parabolic Solar Collector Dimensions used for making the system are stainless steel sheet(2.4m x 1.2m), Receiver Tube (Cu tube- Inside dia. 27mm outside dia. 28mm, 4 feet long, Glass Cover Tube- Inside diameter 64 mm Outside dia. 66mm,3feet long), Support Structure Material-Cast Iron, Piping Insulation- Superlon Material, Submersible pump- Maximum height of 5 ft. 1100 l/hr output and 18 W power.

Gang Xiao Laboratoire J et. al-[2013]: This article offers an illustrated description of a method to produce a closed parabolic trough solar energy collector box based on the elasticity of the material. What is described here is basically a manual method to make high efficiency solar collectors against very low cost, which is particularly suited for teaching, research or demonstration purposes.

Matthias Güntheret. al [2008] : In this section we will get to know the currently most frequent form of large scale CSP plants: parabolic trough power plants. We will learn about their history and their current status. We will understand their structure and how their components work. Important design parameters will be explained. At the end, the efficiency of the generation of electricity with parabolic trough power plants will be specified.

IV. METHODOLOGY OF WORK

The assemblies of solar parabolic trough collector are of various types.

Fig 4.1: Experimental Setup

Such as we used thermometer to measure temperature at which the thermometer is fixed at different section to measure the temperature as in heat exchanger. And steam passes through various section involved in it. It take one after another stage at which one stage was that the temperature of water and heat exchanger become to be same then by actually calculating of two different temperature by using thermometer we can able to calculate specific heat, and due to mass flow rate discharge can be calculated. We can able to calculate the heat transfer rate efficiently. As there is a need of some component such as receiver tube, storage tank, reflector plate, heat exchanger and other assemblies for a solar parabolic trough collector. The receiver tube is a hollow glass tube and air present in it is removed out efficiently. It means that the vacuum is created inside manually by using devices. It also consist of a storage tank it is fitted with the water up to the given level, at after certain levels the water in storage tank moves towards into the piping system connected to it and connected to tap to remove excess water by using stopwatch flow rate of water is calculated. Then after heat transfer rate is calculated .this set up of an solar parabolic trough collector start from 10am daily. The set up must be set in open sunlight that maximum sunlight should be fall on reflector. As it is parabolic in construction of an reflector therefore more sunlight falls on focal length made by it. As the rays get strucked on the reflector as the reflector is full of fluid as fluid passes through it get heat up as per the time

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passes the temperature of fluid get rises up. As in afternoon the sunlight is quite dark therefore the efficiency of heat gaining by the reflector is high that's why the temperature of solar parabolic trough collector is so high at that period respectively.

4.1 Parabolic Dish Collector

A parabolic dish collector is a concentrating solar collector which having mirror like reflector. It is made up of stainless steel sheet. Because of mirror like finish so that the solar radiation which are colliding are get reflected on the receiver tube which is located at the focal point in front of dish.

Dimensions:

Length = 1.2 x 0.91 y2 = 4ax

Where y = half of the parabolic sheet

x = height of parabola, a = focal length parabola

y = 34.5 cm, x = 22 cm a = 13.52 cm

4.2 Receiver Tube

The receiver tube is also called as the heat collecting tube which receives the reflected solar radiation from the parabolic dish collector or parabolic reflector.

V. CALCULATION

On 26-3-17 (WATER IN RECEIVER TUBE)

Inlet temp of water in receiver tube on 10 am = Ti = 26 0 C

Outlet temp of water in receiver tube on 3 pm = To = 159 0 C

Intensity of sun radiation = Ib = 464 W/m2

Specific heat of water = cp= 4.187 x 103 J/kg K

Discharge of water = q = 3.03 X 10-7 m3/s

Change in temperature = ΔT = (To - TI) = 159-26 = 133 0 C

Density of water = ρ = 1000 kg/m3

Inner Diameter of receiver tube = di = 25mm = 0.025m

Outer Diameter of receiver tube = do = 27mm = 0. 027m

Inner Diameter of glass tube = dci = 54mm=0.054m

Outer Diameter of glass tube = dco = 57mm = 0.057m

Area of receiver tube = A = Π/4 x (do2-di2)

= Π/4*(0.0272- 0.0252) = 8.16 x 10-5m2

V= velocity of water flowing in receiver tube.

Discharge q = A x V

and

Mass flow rate »

ṁ = ρ x A x V = ρ x q = 1000 x 3.03 x 10-7= 3.03 x 10-4 kg/s

Heat transfer »

Q = ṁ x cp x ΔT

= 3.03 x 10-4 x 4.187 x 103 x 133

= 168.73 W

Aperture area of collector »

Aa = (W-dco) x L

= (0.9 -0.056) X 1.2

= 1.01 m2

Efficiency of parabolic trough collector »

$\eta = \frac{Q}{Ib\ X\ Aa}$ x 100 = $\frac{168.74}{464\ X\ 1.01}$ x 100

= 36.00 %

On 28-03-2017 (Glycol in receiver tube)

Inlet temp of glycol in receiver tube on 10 am = Ti = 38 0 C

Outlet temp of glycol in receiver tube on 3 pm = To = 189 0C

Intensity of sun radiation = Ib = W/m2

Specific heat of glycol = cp = 2.2 x 103J/Kg K

Discharge of glycol = q = 5.14 x 10-7m3/s

Change in temperature = ΔT = To – Ti= (189-38) = 151 0 C

Density of glycol = ρ = 1097 kg/m3

Inner Diameter of receiver tube = di = 25mm = 0.025m

Outer Diameter of receiver tube = do= 27mm = 0.027m

Area of receiver tube = A = Π/4 x (do2 - di2)

= Π/4 x (0.0272-0.0252) = 8.15 x 10-5 m2

V= velocity of water flowing in receiver tube.

Discharge »

q = A x v

Mass flow rate »

ṁ = ρ x A x V = ρ x q = 1097 x 5.14 x 10-7 = 6.3 x 10-4 Kg/sec

Heat transfer »

Q = ṁ x cpxΔT

= 6.3 x 10 -4x 2.2 x 103x151

=209.43 W

Efficiency of parabolic trough collector »

$\eta = \frac{Q}{Ib\ X\ A}$ x 100 = $\frac{209.43}{464\ x\ 1.01}$ x 100= 44.69 %

VI. RESULTS

Graph 6.1 : Comparison of water temperatures in rough receiver tube

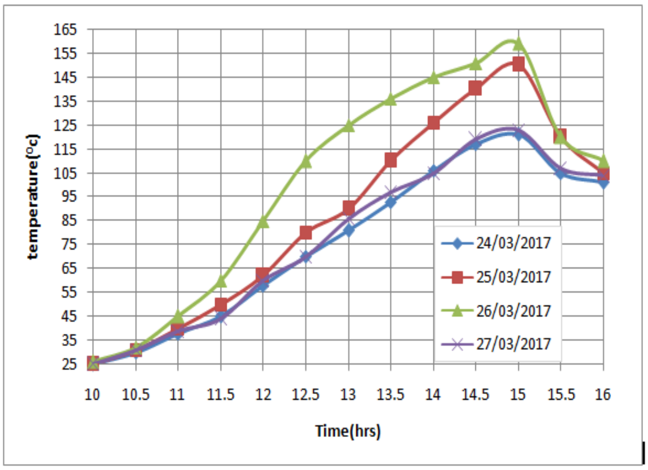

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Table 6.1: Comparison of water temperatures on different dain receiver tube

Time	24/03/2017	25/03/2017	26/03/2017	27/03/2017
10	25	25	26	25
10.5	30	31	32	31
11	38	40	45	39
11.5	45	50	60	44
12	58	62	85	60
12.5	70	80	110	70
13	81	90	125	86
13.5	93	110	136	97
14	106	126	145	105
14.5	117	140	151	119
15	121	150	159	123
15.5	105	120	120	107
16	101	105	110	104

Graph6.2 :Comparison of glycol temperatures through receiver tube.

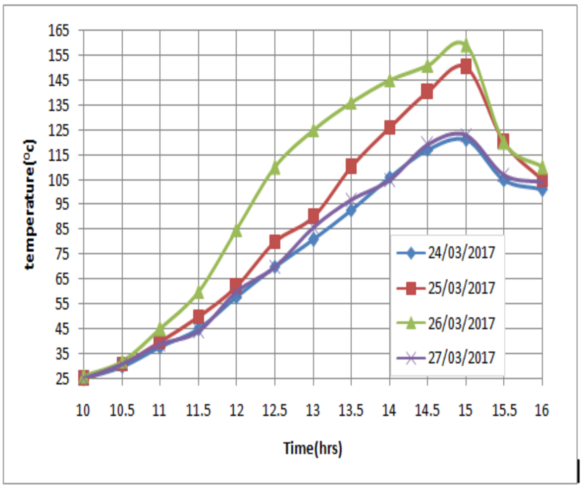

Table 8.1: Comparison of water temperatures on different days in receiver tube

Time	24/03/2017	25/03/2017	26/03/2017	27/03/2017
10	25	25	26	25
10.5	30	31	32	31
11	38	40	45	39
11.5	45	50	60	44
12	58	62	85	60
12.5	70	80	110	70
13	81	90	125	86
13.5	93	110	136	97
14	106	126	145	105
14.5	117	140	151	119
15	121	150	159	123
15.5	105	120	120	107
16	101	105	110	104

Graph8.2 :Comparison of glycol temperatures through receiver tube.

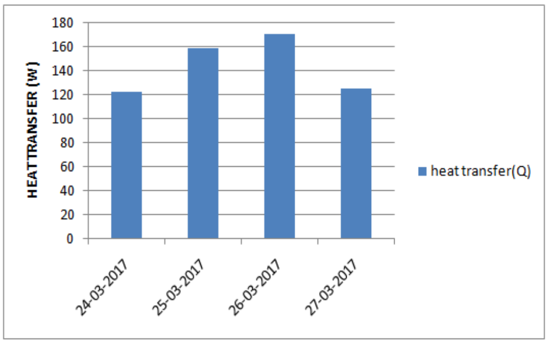

Table 8.2: Comparison of ethylene glycol temperatures on different days in receiver tube

Time	Day			
	28/03/2017	29/03/2017	30/03/2017	31/03/2017
10	38	35	35	37
10.5	49	46	48	48
11	80	76	75	77
11.5	110	99	103	106
12	134	128	132	131
12.5	152	148	150	152
13	164	159	161	163
13.5	179	173	172	176
14	189	179	176	183
14.5	186	175	170	181
15	181	164	163	178
15.5	176	157	155	170
16	162	153	149	159

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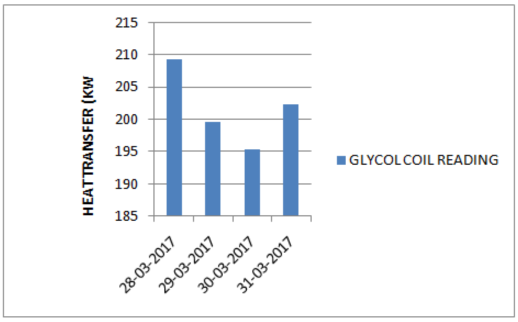
Table 8.3 :Heat transfer rate of water in reciver

Date	Heat transfer (W)	Efficiency (%)
24-03-2017	121.79	25.98
25-03-2017	158.58	33.82
26-03-2017	170	36
27-03-2017	124.32	26.52

Table 8.4: Heat transfer rate for ethylene glycol in Receiver tube:

Date	Heat transfer (W)	Efficiency%
28-03-2017	209.28	44.76
29-03-2017	199.58	42.58
30-03-2017	195.42	41.69
31-03-2017	202.35	43.17

Graph 8.3 :Heat Transfer Rate Of Water In Receiver Tube



VII.CONCLUSION AND FUTURE SCOPE

From the experimentation and thermal calculations of solar parabolic trough collector we obtain the efficiency of both working fluids viz. water and ethylene glycol and we got the efficiency of water is 36% and for ethylene glycol 44.69% respectively which are fairly acceptable. Using evacuated glass envelop around the absorbing tube and using stainless steel sheet will improve the collectors performance, considering that this is the first attempt to manufacture such collector locally. The purpose of this experimental work is to check the performance of parabolic concentrating solar collector by using water,and ethylene glycol as the working fluids. Following are the conclusions drawn.

By using ethylene glycol as a working fluid, collector' for water the collector efficiency is 36% and the heat transfer rate as 168.73 W it is increase when the working fluid is used as a ethylene glycol .

When working fluid is ethylene glycol then the efficiency of the collector is 44.69 % and the heat transfer rate as 209.43 W.

The collector efficiency has been found to be improved from 36 % to 44.69 % flowing the both the fluid separately from the receiver tube. And at a time of fluid flowing keep mass flow rate is constant. This efficiencies is found at peak temperature of both the fluid , which can be read at a time of experiment.

We can fabricate a receiver tube which cost efficient than available in global market, and the performance of that tube is good compared to others.

Also instead ofaluminium sheet as a parabolic collector here we used stainless steel sheet which also efficient and we got a best result and efficiencies for water and ethylene glycol experimentally.There is a lot of scope in the field of solar energy harvesting using different fluid on concentrating parabolic solar collector system. In the present experimental work we took fixed dimensions & same material of receiver tube, glass cover tube, and parabolic collector & take onlytwo working fluid. In addition, thermophysical properties (density, specific heat, viscosity & thermal conductivity) are taken at standard temperature. In the future various investigations will be carried out to check out the performance of parabolic collectors are given as follows:-

1. By varying the dimensions (length, diameter) of the receiver tube and glass cover tube.
2. By varying the dimensions (length, height) of parabolic collector.
3. By changing the material of receiver tube & glass cover tube such as quartz or Pyrex glass.
4. By changing the material of reflector such as stainless steel sheet, aluminum sheet.
5. Calculate thermophysical properties (density, specific heat,
6. viscosity & thermal conductivity of working fluid at varying temperature.

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