Experimental Investigation of Parabolic Trough Collector Solar Air Heater

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Abstract—The sun which is source of all energy the solar energy which is available from sun can be used for many application water hearing, drying and power generation like Solar air heaters are the systems those collects solar energy and transfers the heat to passing air, which is either stored or used for space heating. Solar collector plays a vital and important role in solar air heater. Experimental investigation of parabolic trough collector with different material aims to compare two types of solar air heater (1200×500×120) mm in which both arrangement having straight tubes 1.2 m length with parabolic trough collector and thermal performance will be carried out to compare which arrangement is more efficient. The absorber plate of stainless steel sheet with 2 mm thickness and attached with solar air heater and study the thermal performance of such air heater using K type thermocouple.

Key words: Experimental Investigation, Solar Collector, Thermal Performance

I. INTRODUCTION

Solar energy, directly or indirectly is the major source of renew- able energy available to humankind The increase in energy production costs for fossil fuels has led to a search for an economically viable alternative energy source. One alternative energy source of particular interest is solar energy. Both the solar energy supply and the energy needs are time dependent but in a different mode than each other. Therefore, energy storage must be considered in the light of a solar process system.

Historically, methods used for collecting and transferring solar heat were passive methods, that is, without active means such as pumps, fans and heat exchangers. Passive solar heating methods utilize natural means such as radiation, natural convection, thermo syphon flow and thermal properties of materials for collection and transfer of heat. Active solar heating methods, on the other hand, use pumps and fans to enhance the rate of fluid flow and heat transfer. Passive systems are defined as systems in which the thermal energy flow is by natural means: by conduction,

Radiation and natural convection Passive features increase the use of solar energy to meet heating and lighting loads and the use of ambient air for cooling.

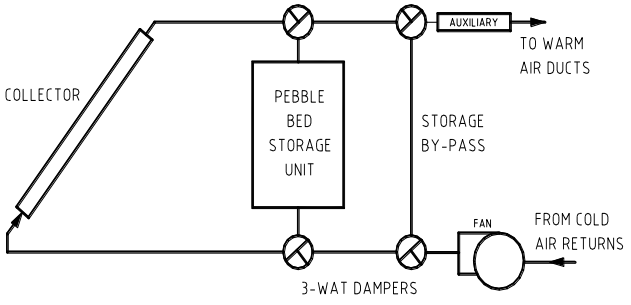

Fig. 1: Schematic of Basic Hot Air System

Sun energy which transform its radiation into heat and than transfer that heat into air or water. As name suggest solar air heating is conversion of solar radiation to thermal heat. Thermal heat is absorbed and carried out by air which is delivered to a living or working space Fig. Absorption of solar radiation by a solid body results in the body heating up. This solid body called 'collector'.

There are many reports which describe the thermal performance of the solar air heater on its different type of shape, surface roughness, using obstacle or various types of work on duct related many paper review by us. According to reports the experimental comparison of solar air heater for flat and parabolic trough type collector and prove which arrangement is better.

II. DESIGN OF EXPERIMENTAL SET UP

By study the literature review it was find that there are many work is done on solar air heater. So In the present work for one set will be fabricated out which one having straight tubes of parabolic trough collector and thermal performance will be carried out to compare with different material of collector is use and which material is more efficient. Design of parabolic trough collector solar air heater discuss below.

NOMENCLATURE

- A Aperture Area
- Aa Collector Aperture
- Ar Surface area of receiver
- C_g Geometrical concentration
- e/D Relative roughness height
- f Focal Length
- h Height
- m Air mass flow rate (kg/s)
- Nu Nusselt number
- P/e Relative roughness pitch
- Re Reynolds number
- Tin Temperature inlet (℃)
- Tout Outlet fluid temperature (℃)
- ΔT Temperature difference (℃)

Subscripts

- a air
- av average
- In Inlet
- out outlet

Abbreviation

- CPC Compound parabolic concentrator
- ETC Evacuated tube collector
- FPC Flat plate collector
- PTC Parabolic trough collector

Greek Symbol

- η collector efficiency
- ψ Rim angle

III. DESIGN OF EXPERIMENTAL SET UP

A. Collector Design [9]

In any solar air or water heater system the design of solar collector system plays a vital and important role.

B. Trough Design

From geometrical relations of the parabolic section, equations (1), the cross section for the parabolic trough was traced as shown by Figure. The sheet was curved to form a parabolic trough module of 1m length and 0.5m aperture width with the simple parabolic equation in Cartesian coordinates is,

$$x^2 = 4fy \qquad (1)$$

From equation (1), the height of the parabola in terms of the focal length and aperture diameter is:

$$(\frac{a}{2})^2 = 4fh \qquad (2)$$

$$h = \left(\frac{a^2}{16f}\right) \qquad (3)$$

The rime angle ψ rim is given by:

$$tan\frac{\psi rim}{2} = \frac{a}{4f} \qquad (4)$$

Geometrical concentration ratio Cg is defined as "the area of the collector aperture Aa, divided by the surface area of the receiver Ar.

$$c_{g=\frac{A_a}{A_r}} \qquad (5)$$

From the selected values of the concentration ratio and the ratio between the concentrator length to its aperture width, the values of the aperture area, the receiver surface area, the aperture width, the receiver outside diameter, and the length of the concentrator were calculated from equation (1) and (3). For this model the focal point is selected at the aperture line i.e, the collector height h is equal to the focal length f with rim angle 90^0.

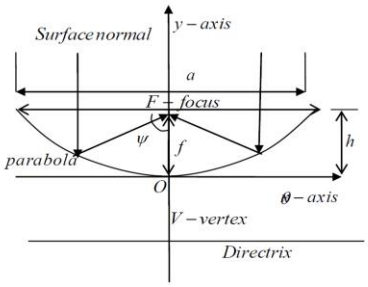

Fig. 2: The schematic of the collector

$$\eta = \frac{m_{ac_{a(T_0-T_{i)}}}}{I_b A} \qquad (6)$$

A *"*Parabolic trough Solar Air Heater*"* will be constructed to determine the thermal performance of the system.

C. Geometrical Data Of The Parabolic Trough Model.

ITEM	SAMPLE	VALUE
Length	L	1.20m
Aperture	a	0.5 m
Rim angle	ψ	90°
Focal length	*f*	0.12 m
Receiver diameter	d	0.0127 m
Concentration height	*h*	0.12 m

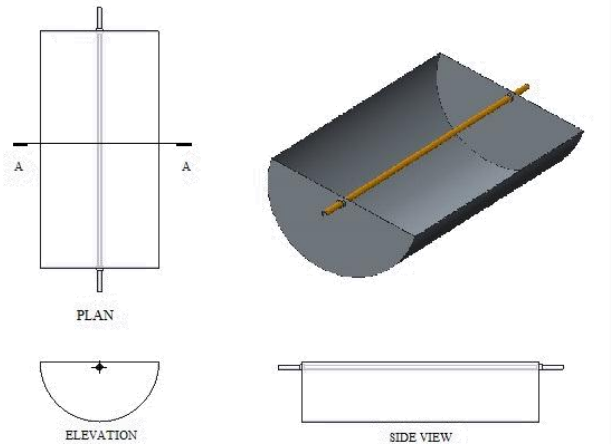

Fig. 3: Line Diagram of Parabolic Trough Collector Solar Air Heater

IV. DEVELOPMENT OF EXPERIMENTAL SETUP

By study thr literature review it was find that there are many work is done on solar air heater.So in the present work one set will be fabricated which one having straight tube with parabolic trough collector with different material like stainless steel and alluminium sheet as collector and thermal performance will carried out to compare which material is more efficient.

A. Specification of parabolic trough collector solar air heater.

- ½ inch copper pipe 1.2 m length.
- 2 mm thick ss sheet and alluminium sheet
- K type thermocouple
- Anemometer for air mass flow rate

B. Description of Experiment Set-Up:

- In the arrangement of experimental set up parabolic trough collector (1.20×0.5×0.12)m in which arrangement having single straight tubes of 1.20 m length with parabolic trough collector.
- The absorber plate of stainless steel sheet with 2 mm thickness and aluminum sheet use in proposed experimental set up the absorber plate will be parabolic in shape in parabolic trough collector solar air heater.
- The Fan of 10.16 mm diameter placed at the bottom of both heater pipes at inlet.
- The temperatures of air at inlet and outlet as well as surface temperatures of both pipes through which air using are estimated using K type thermocouples and readings will be obtained using digital temperature indicator.
- Air mass flow rate measure with a use of anemometer.

V. EXPERIMENTAL WORK

A. Experimental Set-Up of Parabolic Trough Collector Solar Air Heater.

Solar air heater consists of absorber plate, transparent cover, insulation material, and frame and air passage. A photograph of experimental set-up, construction detail and main properties of different solar air heaters are shown in fig.

Fig. 4: Experimental setup of parabolic trough collector solar air heater

The system consists of following parts:

1) Reflector

Reflector is one of the vital part of the parabolic trough collector as it decides the fraction of solar irradiance to be collected by the absorber tube. A parabolic reflector reflects and concentrates all the sun rays on the absorber tube.

2) Copper Tube

The absorber tube is placed at the focal length 0.12m of the parabolic trough collector. The diameter of absorber tube 0.0127m respectively along with a length of 1.20 m. The solar radiations reflected by the parabolic trough collector are collected by the absorber tube. Air is used as working fluid in the absorber tube. In setup collector job is to reflect solar radiation to absorber tube then vents, ducts (air tubes) ,and fan carry the heated air from the collector to another part of the house or space heating.

3) Thermocouple

K type thermocouple was added to existing setup in the inlet and outlet of the air. The thermocouple at the inlet was placed in absorber tube and at outlet was placed at outlet of absorber tube as shown in figure.

4) Digital Temperature Indicator

To read out and record the temperatures during the experiment, the HH1384 data logger 4-input thermometer model from sensewell shown in figure 4.13, was used. This instrument is a digital, 4-input thermometer and data logger that accepts any K,J,E,T,R,S,N,L,U,B and C Type thermocouple temperature sensors. Powered by 6 "AA" batteries or DC 9V AC adaptor.

The dimension of solar air heater in which parabolic trough collector 1.20×0.5×0.12 m for parabolic trough collector solar air heater. Parabolic trough collector solar air heater was single pass solar air heater. The skeleton of solar air heater was manufactured by absorber plate was manufactured by stainless steel sheet of 2mm and alluminium sheet of 2mm. Insulation was provided to reduce heat loss. Two holes were made at both sides of skeleton for inlet and outlet in the dimension of 30mm in diameters. The tilt angle of solar air heater was taken 30^0 by adjustable part. Solar air heater was placed in direction of north-south without any shadow. Air is circulated by radial fan which was powered by electrical motor and flow between the absorber plate in solar air heater, it flows below the absorber plate and came out above the absorber plate from another side. Air flow rate was adjusted by fan regulator for different speed.

VI. Result and Discussion

This chapter present the results obtained from experimental work of parabolic trough collector solar air heater with different material collector plates. In this chapter observation table and result table of parabolic trough collector solar air heater with both material which use as absorber plate.

VII. Experimental Results

Parabolic trough collector with different collector material was formed in Gujarat and used to heat the air by manual tracking. Experiments is performed to check the thermal performance of parabolic trough collector. The concentrator has an aperture of a length of 1.20 m, while the absorber tube (0.0127 diameter) is used.

Such a parabolic trough collector is used to check the thermal performance of various reflecting sheets. When the radiation falls on parabolic trough collector reflector then whole of the radiations will be collected on a line of absorber where the absorber is placed which black painted. Now the blower placed at one end of pipe blows the air with mass flow rate 0.01066 kg/s rapidly, this is because of the same reason of changing intensity and temperature variations.

Experimental data for parabolic trough collector with stainless steel material corresponding to mass flow rate 0.01066 kg/s on 26/09/2015 for length 1.20 m and tilt angle ß=30˚

A. Experimental Data for Parabolic Trough Collector with Stainless Steel

t(hr)	Tin (c)˚	Tout (c)	η (%)	ΔT
11:00	26	30	11.4	4
12:00	30	35	12.5	5
1:00	32	38	15.6	6
2:00	34	40	15.9	6
3:00	33	38	12.4	5

Experimental data for parabolic trough collector with alluminium sheet material corresponding to mass flow rate 0.01066 kg/s on 26/09/2015 for length 1.20 m and tilt angle ß=30˚

B. Experimental Data for Parabolic Trough Collector with Aluminum Sheet

t(hr)	Tin (c)˚	Tout (c)	η (%)	ΔT
11:00	26	31	12.1	5
12:00	30	37	17.7	7
1:00	32	40	17.6	7
2:00	34	44	25.4	10
3:00	33	42	22.6	9

C. Variation of Inlet and Outlet Temperature of Parabolic Trough Collector with Time for Stainless Steel

The parabolic trough collector was exposed to solar radiation for half an hour before the start of reading and experimental data was recorded after regular intervals of hour during the day time (11:00 hours to 03:00 hours) trial data taken.

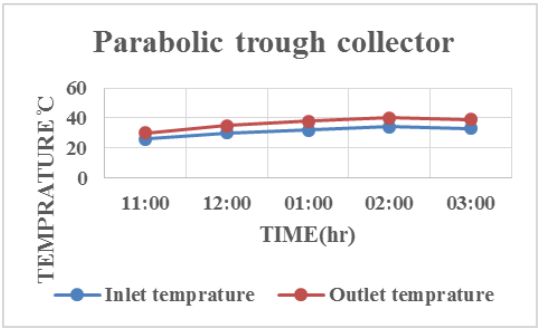

Fig. 5: Variation of inlet and outlet temperature of parabolic trough collector with time

From the graph it is analyzed that the outlet temperature of air is minimum at 11:00 hours which increases gradually with time and reaches its maximum 40˚ c at 2:00 hours. After that temperature starts to decreases gradually.

D. Variation of inlet and outlet temperature of parabolic trough collector with time for alluminium sheet

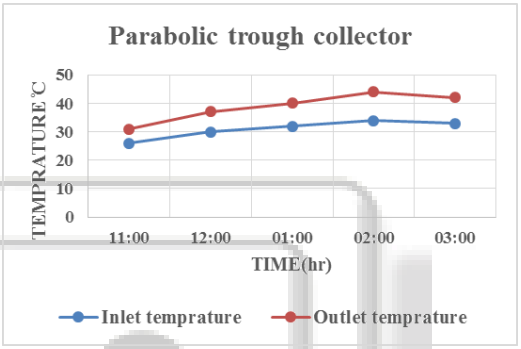

Fig. 6: Variation of inlet and outlet temperature of parabolic trough collector with time

From the graph it is analyzed that the outlet temperature of air is minimum at 11:00 hours which increases gradually with time and reaches its maximum 44˚ c at 2:00 hours. After that temperature starts to decreases gradually. In parabolic tracking device so solar radiation focus on absorber tube comparatively flat plate.

E. Variation of efficiency of parabolic trough collector with time for stainless steel and alluminium sheet.

Initially efficiency decrease and then increases gradually. Efficiency decreases from 2:00 hours to 4:00 hours in stainless steel collector.

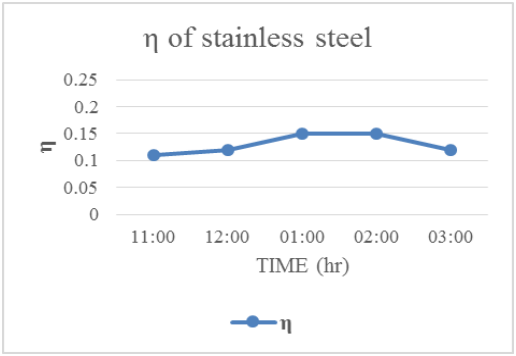

Fig. 7: Variation in efficiency of parabolic trough collector with time for stainless steel

Initially efficiency decrease and then increases gradually. Efficiency decreases from 2:00 hours to 4:00 hours in parabolic trough collector for alluminium sheet.

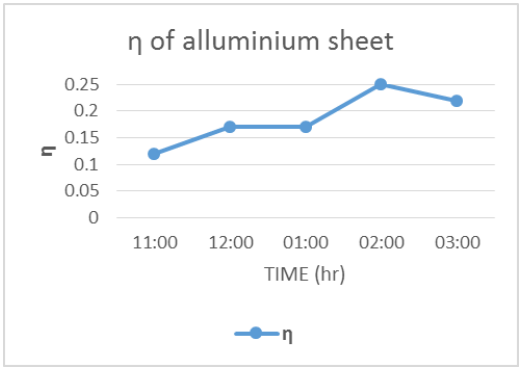

Fig. 8: Variation in efficiency of parabolic trough collector with time for alluminium sheet

VIII. Conclusion

Solar energy, directly or indirectly is the major source of renew- able energy available to humankind Solar energy can reduce the national demand for conventional fuels, reduce the damage to the environment, as it is a non-pollting free energy, and reduce the need to build new power station which require huge investment.

We use steel as reflector and found maximum temprature at the outlet of air 40˚c.

After that we use alluminium sheet as collector plate and found maximum temprature at outlet of air 44 c which one is 20% more than stainless steel as collector plate.

Stainless steel as collector use is costly as compare to alluminium sheet and efficiency is also less than alluminium sheet so it concluded that alluminium sheet as collector is economical than stainless steel as collector in parabolic trough collector solar air heater.

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