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Performance Evaluation of scheffler Concentrator

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Abstract

Scheffler concentrator, used widely for cooking purpose, is simple in design and efficient, hence performance analysis of the reflector is essential. In this regard, an experiment is conducted to evaluate its performance. A lateral section of paraboloid having fixed focus at a distance is taken as a reflector to minimize the effect of the shadow of the receiver. The water contained in a dome shaped receiver located at fixed focus, gets converted into steam and collected in the steam header until ample pressure is reached and further, it can be utilized for cooking purpose.

Keywords: *Scheffler concentrator, receiver, fixed focus, steam header, solar energy*

1. Introduction

Over the past few years solar energy has been strongly recommended as a feasible source of energy both economically and its availability in abundance. Almost all the fossil fuels (coal, wood, natural gas, oil, etc.) have originated from solar energy as they have been formed due to high pressures and temperatures over a long period of time. Also, the increasing rate of consumption of oil and gas would not be able to meet the future demand in energy. In this situation one of the alternative source of energy is solar energy, available free of cost. In recent years, solar energy is being utilized in power generation, water desalination, cooking purpose etc. (Sanga 2013). Solar energy is also pollution free and in present context it is one of the major advantages for the society.

Concentrators designed and developed by Delaney (2003) are suitable for medium temperature applications because of their ability of delivering temperature in the range of 300^0 C. One of the major properties of solar concentrator is its fixed focus, which is desirable for domestic and industrial application. Munir et al. (2010) concluded that it is possible to construct a concentrator having fixed focus for all the days of the year. In this regard, a Scheffler concentrator was constructed and tested by Solare Bruecke (2010). In the study, a thermal storage device is constructed for storing heat that could further be utilized in the evening. It has also been showed that the available energy in the cooking vessel fixed at the focal point of the reflector is approximately half of the energy falling over the reflector.

2. Experimental Description

The experimental set up consists of a dome shaped receiver, steam header, Scheffler reflector, pressure relieve valve and pressure gauge as illustrated in Fig. 1. The specification of the complete set up is mentioned in table 1. The Scheffler reflector is exclusively used for cooking application because of fixed focus and single axis tracking. The shape of the concentrator chosen is a lateral section of a paraboloid having reflectivity of 90% and

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above. Protection of the mirror coating has been taken into consideration at the time of fixing the mirrors. The purpose of this break is to have reflectivity equal to conventional secular's anodized finishes and resistant to ultraviolet light like glass. The axis of daily rotation of the reflector is fixed at an angle equal to the latitude angle of the site (Ranchi, India) with horizontal in north-south direction parallel to the earth axis and runs through the centre of gravity of the reflector. It helps the reflector to maintain its gravitational equilibrium, hence it requires less force to rotate it. The performance of the concentrator depends upon the efficiently utilization of tracking system coupled to a gearbox which runs with the help of digital timer and a DC motor.

Table 1: Experimental set up specification

Parameter	Specification
Inner base diameter of receiver	337 mm
Outer base diameter of receiver	355 mm
Height of the receiver	150 mm
Inlet Pipe diameter	0.5 inch
Outlet Pipe diameter	1 inch
Inner diameter of steam header	255 mm
Length of steam header	800 mm
Thickness of steam header	19 mm
Length of mirror	225 mm
Breadth of mirror	170 mm
Total mirror used	212
Total cutting mirror used	20

Table 2: Nomenclature and symbols

Quantity	Symbol	Unit
Enthalpy	h	kJ/kg
Volume	V	m^3
Density	ρ	kg m^{-3}
Beam Radiation	I_b	W m^{-2}
Concentration ratio	C	
Area	A	m^2
Efficiency	η	
Time	t	s

The steam generated in the receiver gets collected in the cylindrical steam header. The working pressure of the steam header is about 15 kg/cm^2. A Bourdon tube pressure gauge is used for measuring the pressure inside the steam header. The range of the pressure gauge used is 0 kg/cm^2 to 15 kg/cm^2. Pressure-relieve valve controls or limits the pressure, if it exceeds the desired pressure. The temperature gauge attached with steam header is having range varies from 0^0 C to 200^0 C. The interconnecting pipe between steam header and receiver is insulated with glass wool having minimum thickness of 50 mm.

The concentration ratio of the reflector is the ratio of aperture area to the receiver area and is given by Sukhatme et al. (2013).

$$C = \frac{\text{Aperture area}}{\text{Absorber area}} \qquad \text{(eq. 1)}$$

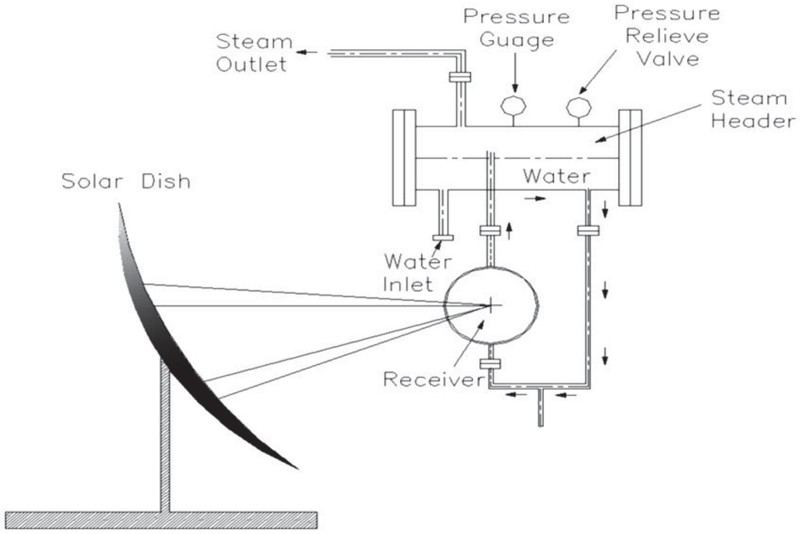

Fig. 1: Schematic of experimental set up

The effective area of the aperture is obtained by the total number of mirrors used. The enthalpy of the steam stored in the steam header is determined by steam table using linear interpolation. The experiment was carried out in February, 2015 and the average readings were taken at the time interval of 15 minutes as given in table 3. Beam and diffused radiation were measured with the help of precision pyranometer. The performance of the system is determined by the effective utilization of the reflected radiation. Therefore, efficiency of the system is defined as a ratio of energy stored in steam header to the energy reflected on the receiver.

$$\eta = \frac{h \times V \times \rho}{I_b \times C \times A \times t} \qquad \text{(eq. 2)}$$

Table 3: Experimentation reading

S.N.	Time (Hrs.)	Average Global Radiation (W/m^2)	Average Diffused Radiation (W/m^2)	Average Beam Radiation (W/m^2)	Average Pressure (kg/cm^2)	Average Temperature (^{0}C)
1	9.00	564	115	449	0.1	50
2	9.15	599	120	479	0.1	52
3	9.30	650	121	529	0.2	60
4	9.45	694	125	569	0.5	70
5	10.00	750	143	607	0.75	80
6	10.15	785	146	639	1	91

7	10.30	775	153	622	1.2	100
8	10.45	842	168	674	1.8	112
9	11.00	812	173	639	2	120
10	11.15	840	163	677	2.4	124
11	11.30	829	176	653	2.6	129
12	11.45	866	168	698	2.6	134
13	12.00	907	186	721	2.6	135
14	12.15	920	197	723	2.8	138
15	12.30	854	176	678	3.4	142
16	12.45	920	197	723	4	153
17	13.00	844	188	656	5	155
18	13.15	872	180	692	5.9	160
19	13.30	830	183	647	6.8	164
20	13.45	797	181	616	7.6	168
21	14.00	761	162	599	8	170

3. Results and Discussion

The variation of beam radiation and temperature with respect to time is depicted below in Fig. 2. Both of them increase with respect to time. It has been observed that there is an increase in temperature of the steam stored in header even if the beam radiation falls down.

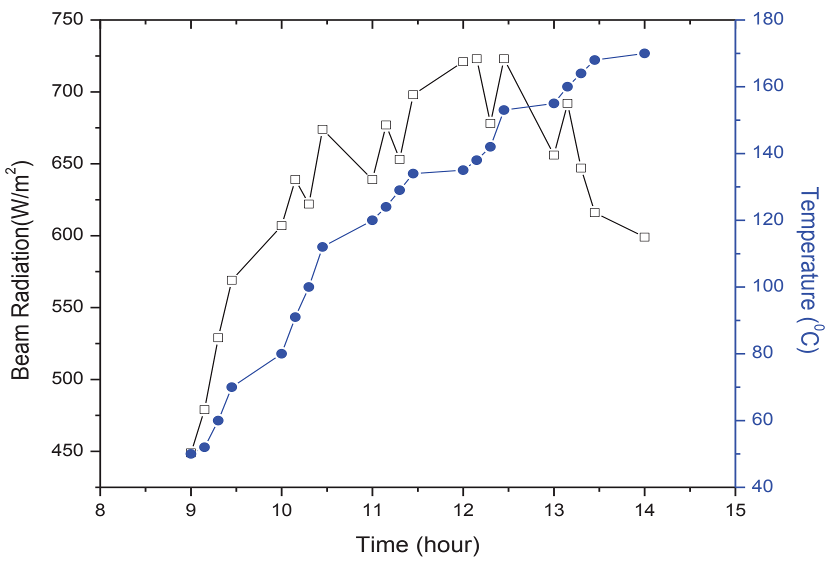

Fig. 2: Variation of beam radiation and steam temperature

The pressure and temperature of the steam collected in steam header is used to evaluate the physical state of the steam. It was also observed that the temperature of the steam is slightly more than the saturation temperature in the steam header after 12 p.m. as shown in Fig. 3, which is vital as the saturated steam has high heat transfer coefficient than the superheated steam.

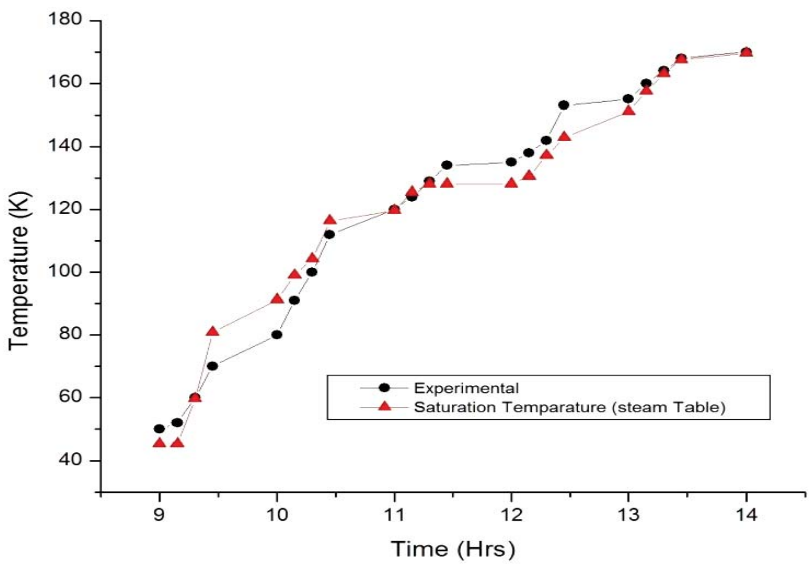

Fig. 3: Comparison of steam temperature at steam header with saturation temperature

The performance of the system is also evaluated. Maximum efficiency of the system was calculated to be 35 %.

4. Conclusion

The study suggests that the system can produce enough steam after 12 p.m. which can further be utilized for cooking purpose. It is also required to have a proper well insulated storage system to minimize the heat loss. As far as cooking place is concerned, it should be decided on the basis of the length of the pipe needed to maintain its temperature without any significant change or loss. The efficiency of the system can also be increased by minimizing heat loss.

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