Design, Fabrication and Experimental Testing of Solar Parabolic Trough Collectors with Automated Tracking Mechanism

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ABSTRACT

This paper was concerned with an experimental study of parabolic trough collector’s with its sun tracking system designed and manufactured. To facilitate rapid diffusion and widespread use of solar energy, the systems should also be easy to install, operate and maintain. In order to improve the performance of solar concentrator, different geometries and different types of reflectors were evaluated with respect to their optical and energy conversion efficiency. To assure good performance and long technical lifetime of a concentrating system, the solar reflectance of the reflectors must be high and long term stable. Therefore, different types of reflector materials and absorbing materials were analyzed in this work; also the optical properties and degradation of the reflecting surfaces were assessed. During the research, focus has shifted from evaluation of the performance of concentrating solar collector to analysis of the optical properties of reflector and absorbing materials. The shift of focus was motivated by the need to assess long term system performance and possibilities of optimizing the optical efficiency or reducing costs by using new types of reflector materials and absorbing materials. For the design of the SPTC frame, a finite element model had been developed and used to check the capability of the structure to absorb torsion and bending forces, under dead and wind loads. The SPTC was fabricated in local workshops and the sun tracking system was assembled using electric and electronic components in the market, while the mechanical components making up the driving system were procured from the second hand market. The fabricated SPTC and its tracking system were tested outdoors in the campus under dry and wet weather. The experimental results obtained have shown that the obtained characteristic curve of the tested Aluminium collector is considerably lower than that of a mirror collector which can be attributed to the higher thermal losses for the lack of the evacuated glass envelope around the absorbing tube, the end losses of the collector and the inaccuracy in tracking the sun. However, the mirror collector efficiency is about 8% higher than that of Aluminium under dry weather condition, which is fairly acceptable, considering that it was the first attempt to manufacture such mirror collector locally. Thus, the overall aim of the
work presented in this research was to investigate the possibilities to increase the efficiency of the solar energy systems, and thereby reducing the cost of the electricity or heat that was produced. Attention was also given to the long term durability and robustness of the system. The basic hypothesis was that the use of durable, light weight, low cost reflectors for increasing the concentrator efficiency.

**Keywords**: Solar Parabolic Trough Collector, Cost Effective Design, Automated Sun Tracking Mechanism, Solar Collector Efficiency.

1. **INTRODUCTION**

The operation of any solar thermal energy collector can be described as an energy balance between the solar energy absorbed by the collector and the thermal energy removed or lost from the collector. If no alternative mechanism is provided for removal of thermal energy, the collector receiver heat loss must equal the absorbed solar energy. The temperature of the receiver increases until the convective and radiation heat loss from the receiver equals the absorbed solar energy. The temperature at which this occurs is termed the **collector stagnation temperature**. For control of the collector temperature at some point cooler than the stagnation temperature, active removal of heat must be employed. This heat will then available for use in a solar energy system. The rate at which heat is actively removed from the collector determines the collector operating temperature. For removal of a large fraction of the absorbed solar energy as useful heat, the amount of heat lost from the receiver must be kept small.

Receiver heat loss can be reduced by operating the collector near the ambient temperature (such as with low-temperature flat-plate collectors) or by constructing the collector such that heat loss at elevated temperature is reduced. The most common way of reducing receiver heat loss at elevated temperatures is to reduce the size of the hot surface (i.e., the receiver) since heat loss is directly proportional to area of the hot surface. Concentrating collectors reduce the area of the receiver by reflecting (or refracting) the light incident on a large area (the collector aperture) over an absorber of small area. With reduced heat loss, concentrating collectors can operate at elevated temperatures and still provide significant quantities of useful thermal energy.

A second reason for using concentration in the design of solar collectors is that, in general, reflective surfaces are usually less expensive than absorbing (receiver) surfaces. Therefore, large amounts of inexpensive reflecting surface area can be placed in a field, concentrating the incident solar energy on smaller absorbing surfaces. However, concentrating collectors must track the sun’s movement across the sky, adding significant cost to the construction of a concentrating collector system.

2. **Basic Theory and Terminology**

A *parabolic trough* is a type of solar thermal energy collector. It was constructed as a long parabolic mirror (usually coated silver or polished aluminum) with a Dewar tube running its length at the focal point. Sunlight is reflected by the mirror and concentrated on the Dewar tube. The trough is usually aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day. Alternatively the trough can be aligned on an east-west axis; this reduces the overall efficiency of the collector, due to cosine loss, but only requires the trough to be aligned with the change in seasons, avoiding the need for tracking motors. This tracking method works correctly at the spring and fall equinoxes with errors in the focusing of the light at other times during the year (the magnitude of this error varies throughout the day, taking a minimum value at solar noon). There is also an error introduced due to the daily motion of the sun across the sky, this error also reaches a minimum at solar noon. Due to these sources of error, seasonally adjusted parabolic troughs are generally designed with a lower solar concentration ratio.

Heat transfer fluid (usually oil) runs through the tube to absorb the concentrated sunlight. The heat transfer fluid is then used to heat steam in a standard turbine generator. The process is economical and, for heating the pipe, thermal efficiency ranges from 60-80%. The overall efficiency from collector to grid, i.e. (Electrical Output Power) / (Total Impinging Solar Power) is about 15%, similar to PV (Photovoltaic Cells) and less than Stirling dish
Concentrators. Current commercial plants utilizing parabolic troughs are hybrids; fossil fuels are used during night hours, but the amount of fossil fuel used is limited to a maximum 27% of electricity production, allowing the plant to qualify as a renewable energy source. Because they are hybrids and include cooling stations, condensers, accumulators and other things besides the actual solar collectors, the power generated per square meter of space ranges enormously.

2.1 Advantages of Concentrating Collectors

1) Reflecting surfaces require less material and are structurally simpler than flat plate collectors.
2) The absorber area of a concentrator system is smaller than that of flat plate system for same solar energy collection.
3) Heat lost to the surrounding per unit of solar energy collecting area is less than that of flat plate.
4) Working fluid can attain higher temperature in concentrating collector.

2.2 Losses in Collectors

1) Conductive losses: Heat transfer takes place through adjacent surfaces by conduction; this can be minimized by placing insulating materials in place of good conductors of heat.
2) Convective losses: Heat losses due to carry of heat by some medium like air from the surface can take place in these kinds of devices. This can be minimized by closing all the air gaps.
3) Radiative losses: Radiative losses from the absorber can be prevented by the use of spectrally selective absorber coatings. Such coatings have a high absorption of about 0.9 in the solar spectrum and a low emittance, usually of the order of 0.1, in the infrared spectrum, in which the absorber radiates to the environment. Selective absorber coating, therefore decrease heat losses and increase collector efficiency.

2.3 Basic Terminology

Solar Concentration Ratio:
The total amount of solar light energy concentration achieved by a given collector is termed as Solar Concentration Ratio. It is defined as ratio of averaged radiant solar flux integrated over the receiver area to the flux incident on the collector aperture. It directly relates the reflector quality. A higher concentration ratio allows the collector to reach a higher working temperature with minimal thermal loss, but requires higher manufacturing precision too. A very carefully constructed and adjusted collector may reach an effective concentration ratio as high as 100.

Tilt Angle:
Tilt angle is defined as the angle subtended by the focal line of trough collector with horizontal. Collectors based on heat pipes can have a strong tilt dependency and this must be considered when testing such collectors. Normally slopes below 20°-30° should be avoided but this cannot be taken as a general rule.

Rim angle (Ψrim):
The rim angle is defined as the angle subtended by the edges of the reflector at the focus.

Collector Acceptance angle:
Collector acceptance angle is defined as the sensitivity of the solar parabolic trough collector to tracking misalignment.
3. Geometric Design of SPTC Assembly

3.1 Design Objectives

1) To Design parabolic solar trough collectors for energy concentration.
2) To make cost effective solar trough collectors, so that it’s affordable to common people.
3) To develop an automated sun tracking mechanism (N-S horizontal).
4) To bring up a system that constantly works with intended mechanism.
5) A system, which eliminates the human work considerably.

3.2 Solar Parabolic Trough Collector Design

The Parabolic concentrating collector assembly was modelled by using UNIGRAPHICS NX3.

![Solar Parabolic Trough Collector Assembly](image)

Figure 1: Solar Parabolic Trough Collector Assembly

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Value Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector aperture area</td>
<td>2.52x10^6 mm^2</td>
</tr>
<tr>
<td>Collector aperture</td>
<td>1200 mm</td>
</tr>
<tr>
<td>Aperture to Length ratio</td>
<td>0.57</td>
</tr>
<tr>
<td>Rim angle</td>
<td>180°</td>
</tr>
<tr>
<td>Receiver diameter</td>
<td>25 mm</td>
</tr>
<tr>
<td>Tracking mechanism type</td>
<td>Electronic</td>
</tr>
<tr>
<td>Mode of tracking</td>
<td>N-S horizontal</td>
</tr>
</tbody>
</table>

Table 1: SPTC system specifications

The collector is designed with simple parabolic equation and merged of solar radiation method in order to optimize the fabrication with local material. According to the size limitation of highly polished Aluminium and Mirror sheet, 2100 mm long, 1200 mm wide and rim angle of 180°, makes the focal line in place with the cord line. Simple parabolic equation can be applied to solve the above condition, where x is axial to parabolic curve, y is centre line of focal, R is radius of parabolic curve, and f is focal line, as shown in Figure 2.

Consideration the simple parabolic equation:

\[x^2 = 2fy\]  \hspace{1cm} (1)

\[f = \frac{R}{2}\]  \hspace{1cm} (2)
The sheet is 1200 mm wide, has a curve of R, and focal point ‘f’ is half of R.
Therefore, α is
\[ R \cos \alpha = \frac{R}{2} \]
\[ \cos \alpha = \frac{(R/2)}{1/R} \]
\[ \alpha = 60° \]
Thus, a curve length of 1200 mm and \( \alpha = 60° \), it can be used to find length R:
\[ L = \frac{b(18000)}{2 \pi} \]
Then finding the concentration ratio ‘C’, using a ratio between collecting area \( A_a \) and absorbing area \( A_r \)
\[ C = \frac{A_a}{A_r} \]
The solar collecting area \( A_a \) is calculated by the projected area of collector, and \( A_r \) will consider that of absorber
\[ \frac{a}{2} = R \sin \alpha \]
\[ a = 2R \sin \alpha \]
Where ‘a’ is only the width of collector, which is reconsidered to be the width of absorber.

**FOCAL LENGTH:**

Here
\[ X = 500 \text{ mm} \]
\[ Y = 225 \text{ mm} \]
From simple parabolic equation we have
\[ X^2 = 2R \times Y \]
Radius (R) = \( \frac{X^2}{2Y} \)
\[ R = \frac{500^2}{2 \times 225} = 555.6 \text{ cm} \]
Hence Focal length
\[ = \frac{R}{2} \]
\[ = 555.6 / 2 \]
\[ = 277.7 \text{ mm} \]

**a) Support Stand of SPTC**

The support stand was made of Mild Steel. It consists of ‘L’ and rectangle shaped cross sectioned bars welded together and two ball bearings fixed with the inner race with a rod. The outer race is rotary and mounted in the housing of absorber supporting plate. The specifications of the support frame are as given in Table 2.
Table 2: Specifications of Support Stand

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of the support stand due south</td>
<td>790 mm</td>
</tr>
<tr>
<td>Height of the support stand due north</td>
<td>1190 mm</td>
</tr>
<tr>
<td>Distance between the two stands</td>
<td>2100 mm</td>
</tr>
<tr>
<td>Width of the stand</td>
<td>45 mm</td>
</tr>
<tr>
<td>Thickness of the stand</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

![Figure 3: Model of Support Stand](image)

b) Supporting frame of SPTC

The frame modelled was of the form of ‘L’ cross section and made of Mild Steel. The specifications of the support frame are as given in Table 3.

![Figure 4: Model of supporting frame](image)

Table 3: Specifications of Support frame

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the Support frame</td>
<td>2100 mm</td>
</tr>
<tr>
<td>Breadth of the Support frame</td>
<td>1090 mm</td>
</tr>
<tr>
<td>Thickness of the Support frame</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

c) Absorber Supporting Plate

There are 2 supporting plates welded to the two opposite sides along the length of the support frame. It houses the absorber pipe at both ends while the lower end of plate has two ball bearings mount which in turn connected to the supporting stand with one rotational degree of freedom.
The absorber was designed according to the limitation of the collector, with considering parameters and common practice, such as, piping, working fluid velocity, fabrication and heat loss. Thereby, the absorber is fabricated by the seamless chromium pipe, with the inner diameter of 23 mm, outer diameter 25 mm and 2100 mm in length.

Furthermore, the collector is fixed; therefore, the altitude angle will be affected to the image of all the times. It moves for 10° per day. Since the pipe is very long, so that two strips of carbon steel is attached to the tube for increasing the strength of absorber. Each Strip has the width of 25 mm.
Thus, overall width of absorber ‘w’ is 98 mm \((25x2 + 48)\).

![Figure 7: Cross section of the absorber pipe.]

Thus the concentration ratio is modified to:

\[
\frac{D'}{\text{develop}} = r_{e} \sin \theta
\]

(8)

\[
C = \frac{[(a-w) \times L]}{(w \times a \times L)}
\]

(9)

Where ‘L’ is the length of both collector and absorber pipe. The reflection coefficient of collector is approximated range of 0.8 to 0.85 by polished technique and the absorber pipe is coated with black colour.

e) Parabolic trough

**ALUMINIUM TROUGH:** To obtain the desired dimensions two highly polished Aluminium sheets are used. Each highly polished Aluminium sheets dimensions are as follows:

- Length : 1220 mm
- Breadth : 1250 mm
- Thickness : 3 mm
- Length of the reflector : 2100 mm
- Arc length of the reflector : 1200 mm

![Figure 8: Aluminium trough]

**MIRROR GLASS TROUGH:** To obtain the desired dimensions 110 rectangular mirror pieces are used. Each highly reflective rectangular mirror piece dimensions are as follows,

- Length : 400 mm
Breadth : 50 mm  
Thickness : 2 mm  
Length of the reflector : 2100 mm  
Arc length of the reflector : 1200 mm

\[ \frac{360}{(24 \times 60)} = 0.25^\circ \]

Therefore, in 30 minutes the sun moves by an angle = 0.25° x 30 = 7.5°

This implies an error of \( \cos (7.5^\circ) = 0.99 \approx 1 \% \).

Since this error is small, we have included only a basic manual tracking mechanism which must be set at the beginning of the 30 minutes span and need not be changed for 30 minutes. So in order to obtain maximum concentration the lens has to be rotated by an angle of 7.5° after every 30 minutes. Some concentrators can only be cost effective by tracking both the sun's daily path and the sun's annual inclination (which causes the sun to appear to move in declination by 47° over the year). Thus, concentrators may be non-tracking, single-axis tracking (which tracks east to west), or two-axis tracking (which tracks both east to west and north to south). Two-axis tracking provides the maximum solar energy collection but is not cost effective for most applications or collector designs. The Tracking Mechanism consists of a Stepper motor, Sprocket, Chain drive and 8051 Micro-Controller arrangement.

**STEPPER MOTOR**

A stepper motor is an electromechanical device which converts discrete electrical pulse into discrete mechanical movements. The shaft or spindle of a stepper motor rotate at equal angle of increment called **steps** when electrical command pulses are applied to it in the proper sequence. The sequence of the applied pulse is directly related to the direction of rotation of motor shaft and its speed directly related to the frequency of input pulses and total radiation at a stretch is directly related to the number of input pulse applied. Stepper motors with steps of 12, 24, 72, 144, 180 and 200 per revolution are available resulting in angle of the shaft increments of 30°, 15°, 5°, 25°, 2° and 1.8° per step. Special micro-stepping circuitry is sometimes provided to allow many more steps per revolution and these circuitry offer 10,000 steps per revolution or even more.
Consider a Parabolic trough as a large Sprocket or gear. Let a chain drive be meshed with both sprockets, one mounted on the Stepper Motor & another on parabolic trough.

**STEP 1:** To calculate the length of open chain drive

\[ L = \pi (\delta_1 + \delta_2) + 2x + \left[ \frac{\delta_1 - \delta_2}{x} \right]^2 \]  

Where

- \( \delta_1 \) = Radius of Larger Sprocket = 500 mm
- \( \delta_2 \) = Radius of Smaller Sprocket = 47.5 mm
- \( x \) = Centre distance = 750 mm.

\[ L = \pi (500+47.5) + (2\times750) + \left[ \frac{500-47.5}{750} \right]^2 \]

\[ = 3600 \text{ mm} \]
\[ = 3.6 \text{ m}. \]

Actual length of chain = 3.6-\( \frac{1}{2} \pi D_1 = 2209.2 \text{ mm} \approx 2.2 \text{ m}. \]

**STEP 2:** To calculate the speed ratio
Let \( n_1 \) = Speed of Larger Sprocket
\( n_2 \) = Speed of Smaller Sprocket.

\[
\left(\frac{n_1}{n_2}\right) = \left(\frac{d_2 - t}{d_1 + t}\right) \left(1 - \left(\frac{S}{100}\right)\right)
\]

(11)

Where
- \( t \) = Thickness of Sprocket = 0.5 cm = 5 mm.
- \( S \) = Slip of chain = 0\% (assumed).

Speed ratio = \( \left(\frac{n_1}{n_2}\right) = \left(\frac{95+5}{100+5}\right) \) = 0.099 \( \equiv 0.1\)

If the small sprocket rotates 1.8°, then 1.8° \times (\pi/180) = 0.0314 radians.

Then the larger sprocket rotates by \( = 0.0314\times0.099 = 0.03124\) radians = 0.179°.

The stepper motor rotates 1.8° per step.

The trough rotates by 3.6° per 15 min.

Number of steps required for Stepper motor = 3.6°/0.179° = 20.1 \( \equiv 20\) steps/ 15 min.

20 steps are performed in 15 min.

For each step it takes = (15\times60)/20 = 45 sec.

8051 MICRO CONTROLLER ARRANGEMENT

A key feature of the P89V51RD2 is its X2 mode option. The design engineer can keep the same performance by reducing the clock frequency by half, thus dramatically reducing the EMI. The Flash program memory supports both parallel programming and in serial to be reprogrammed in the end product under software control.

![Figure 12: Block Diagram of the Microcontroller Arrangement](image)

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4. Experimental setup and testing

When SPTC, Mounting Stand, Copper pipe and Automated Sun Tracking Mechanism are integrated, the required assembly shall be configured. One Rotational degree of freedom was allowed about the focal line of the SPTC for sun tracking from 09:00 AM to 04:00 PM every day. SPTC shall be repositioned perpendicular to the sun, the next day and automatically rotated using sun tracking mechanism.
The experimental setups used for testing the manufactured SPTC’s are shown schematically in Figure 15 and Figure 16. In this experiment, water was filled from one end of the copper absorber pipe with other end closed. The temperature of water was measured by using mercury thermometer and tabulated for every hour from 09:00 am to 04:00 pm. The SPTC was rotated using a stepper motor and sprocket and chain mechanism to keep the sun perpendicular to the absorber pipe. The volume of water was measured by using a beaker. The battery supplies required power to the stepper motor to function.

Figure 15: Final Setup of Aluminium foil type SPTC Assembly

Figure 16: Final Setup of Mirror type SPTC Assembly
5 Observations and Results

Testing was made on four different days with dry and wet weather. To determine the solar energy concentration, both Aluminium and Mirror troughs were tested. The various results were tabulated and analyzed with graphs.

TEMPERATURE OF WATER IN ABSORBING PIPE USING ALUMINIUM TROUGH COLLECTOR

<table>
<thead>
<tr>
<th>DATE</th>
<th>17/05/2009.</th>
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</thead>
<tbody>
<tr>
<td>WEATHER CONDITION</td>
<td>DRY WEATHER.</td>
</tr>
<tr>
<td>MINIMUM TEMP DURING OBSERVATION</td>
<td>31°C around 9AM.</td>
</tr>
<tr>
<td>MAXIMUM TEMP DURING OBSERVATION</td>
<td>111°C around 1PM.</td>
</tr>
<tr>
<td>TOTAL QUANTITY OF WATER TAKEN</td>
<td>760cm³.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE OF WATER IN ABSORBER PIPE (IN °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00AM</td>
<td>31</td>
</tr>
<tr>
<td>10:00AM</td>
<td>73</td>
</tr>
<tr>
<td>11:00AM</td>
<td>90</td>
</tr>
<tr>
<td>12:00PM</td>
<td>106</td>
</tr>
<tr>
<td>1:00PM</td>
<td>111</td>
</tr>
<tr>
<td>2:00PM</td>
<td>96</td>
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<td>3:00PM</td>
<td>87</td>
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<tr>
<td>4:00PM</td>
<td>62</td>
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<table>
<thead>
<tr>
<th>DATE</th>
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</thead>
<tbody>
<tr>
<td>WEATHER CONDITION</td>
<td>WET WEATHER.</td>
</tr>
<tr>
<td>MINIMUM TEMPERATURE</td>
<td>26°C around 9AM.</td>
</tr>
<tr>
<td>MAXIMUM TEMPERATURE</td>
<td>60°C around 1PM.</td>
</tr>
<tr>
<td>TOTAL QUANTITY OF WATER TAKEN</td>
<td>760cm³.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE OF WATER IN ABSORBER PIPE (IN °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00AM</td>
<td>26</td>
</tr>
<tr>
<td>10:00AM</td>
<td>32</td>
</tr>
<tr>
<td>11:00AM</td>
<td>37</td>
</tr>
<tr>
<td>12:00PM</td>
<td>45</td>
</tr>
<tr>
<td>1:00PM</td>
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<td>2:00PM</td>
<td>53</td>
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<tr>
<td>3:00PM</td>
<td>42</td>
</tr>
<tr>
<td>4:00PM</td>
<td>35</td>
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</tbody>
</table>

TEMPERATURE OF WATER IN ABSORBING PIPE USING MIRROR TROUGH COLLECTOR

<table>
<thead>
<tr>
<th>DATE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>WEATHER CONDITION</td>
<td>DRY WEATHER</td>
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<tr>
<td>MINIMUM TEMPERATURE</td>
<td>35°C around 9AM.</td>
</tr>
</tbody>
</table>

Table 6: Aluminium trough dry weather condition

Table 7: Aluminium trough wet weather condition
MAXIMUM TEMPERATURE : 123°C around 1PM.
TOTAL QUANTITY OF WATER TAKEN : 760 cm³.

Table 8: Mirror trough dry weather condition

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE OF WATER IN ABSORBER PIPE (IN ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00AM</td>
<td>35</td>
</tr>
<tr>
<td>10:00AM</td>
<td>78</td>
</tr>
<tr>
<td>11:00AM</td>
<td>94</td>
</tr>
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<td>12:00PM</td>
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<td>3:00PM</td>
<td>102</td>
</tr>
<tr>
<td>4:00PM</td>
<td>88</td>
</tr>
</tbody>
</table>

DATE : 16/05/2009.
WEATHER CONDITION : WET WEATHER.
MINIMUM TEMP DURING OBSERVATION : 29°C around 9AM.
MAXIMUM TEMP DURING OBSERVATION : 72°C around 1PM.
TOTAL QUANTITY OF WATER TAKEN : 760 cm³.

Table 9: Mirror trough wet weather condition

<table>
<thead>
<tr>
<th>TIME</th>
<th>TEMPERATURE OF WATER IN ABSORBER PIPE (IN ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00AM</td>
<td>29</td>
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<tr>
<td>10:00AM</td>
<td>40</td>
</tr>
<tr>
<td>11:00AM</td>
<td>49</td>
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<tr>
<td>12:00PM</td>
<td>61</td>
</tr>
<tr>
<td>1:00PM</td>
<td>72</td>
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<tr>
<td>2:00PM</td>
<td>63</td>
</tr>
<tr>
<td>3:00PM</td>
<td>57</td>
</tr>
<tr>
<td>4:00PM</td>
<td>42</td>
</tr>
</tbody>
</table>
COLLECTOR EFFICIENCY CALCULATION:

We have, Collector efficiency,
\[
\eta = \frac{Q_u}{R_1 + R_2 + R_3}
\]  

(12)

Where,
- \(Q_u\) = net useful heat gained by fluid…W/m²
- \(C_p\) = Sp. Heat of fluid…kJ/kg K
- \(m\) = mass of fluid…kg
- \(T_o\) = fluid outlet temperature…°C
For Aluminium trough:

Conditions: Dry weather
Minimum temperature = 31°C
Maximum temperature = 111°C

Mass of water,
\[ m = \text{density} (\rho) \times \text{Volume (V)} \]
\[ = 1000 \times 760 \]
\[ = 0.76 \text{ kg} \]

Net useful heat gained by fluid,
\[ Q_u = mC_p(T_{fo} - T_{fi}) \]
\[ = 0.76 \times 4.217 \times (111-31) \]
\[ = 256.4 \text{ W/m}^2 \]

Collector efficiency,
\[ \eta = \frac{256.4}{0.83 \times 350 \times 1.123} \]
\[ = 78.59\% \]

For Mirror trough:

Conditions: Dry weather
Minimum temperature = 35°C
Maximum temperature = 123°C

Net useful heat gained by fluid,
\[ Q_u = mC_p(T_{fo} - T_{fi}) \]
\[ = 0.76 \times 4.217 \times (123-35) \]
\[ = 282.03 \text{ W/m}^2 \]

Collector efficiency,
\[ \eta = \frac{282.03}{0.83 \times 350 \times 1.123} \]
\[ = 86.45\% \]

With the available solar radiation data, efficiency for both troughs was found. Efficiency of Aluminium trough collectors on dry weather is 78.59% whereas Efficiency of Mirror trough collectors on dry weather is 86.45%.

6 Conclusions

This research has its own special features. The collector cannot be easily tilted and orientated, as per the position of the sun with tracking mechanism and external power will be needed. The maintenance cost is minimum and hence economical. Running cost is nil. The labour cost is minimized on account of its simple design. Although the research has its own limitations, that is, intermittent supply of solar energy and converted energy cannot be stored; it is satisfactory considering the market survey report. The use of solar troughs is limited only to clear sunny days. The Solar trough tilting angle is limited to a maximum of 120°. The steam can produce scaling inside the metal absorber pipe and hence, non-corrosive coating should be applied in it. The Tracking Mechanism is of single Axis (North-
South horizontal). Additional maintenance is required to clean the dirt absorbed on the glass surface. Periodic maintenance is necessary to avoid any complications.

As other forms of energy are fast depleting and polluting the atmosphere, non-conventional energy resources like solar energy are best suited to use. The solar concentrating collector is among the best way to use solar energy efficiently due to its advantages to convert abundantly available solar energy into effective and convenient form of heat energy which can be used for various purposes. Herein, this converted heat energy has been used for several applications like water heating, candle making, solar cooking and for popping corns. Solar concentrating collector allows us to use solar heat energy for various purposes without using any external power source and avoids using separate devices for each individual purpose. Finally, it was concluded that concentration of Solar Energy on Mirror Parabolic Trough Collector has been intensified when compared to Aluminium Parabolic Trough Collector.

7 Scopes for Future Work

Solar cells can be used in places of absorbing pipe and electricity can be generated and thereby stored in battery. Thus electricity can be used for several purposes. Teflon coating can be given to the absorber pipes used instead of black paint in order to maintain cleanliness. This will be more useful for mass production of food products. Design involving automatic tracking of the sun using LED’s can be incorporated in support frame of the collector. A single highly Reflective Mirror sheet can be employed in place of Mirror pieces for better reflection of the incident sunlight and thus achieving higher temperatures. Dewar tubes which are constructed like Dewar flasks, but not silvered and open at ends, having the space between the walls exhausted so as to prevent heat conduction, and sometimes having the glass silvered to prevent absorption of Radiant heat can be used. The Two Axis Tracking Mechanism can be used instead of a single Axis Tracking Mechanism to obtain maximum intensity of solar radiation. A larger area can be covered using relatively inexpensive mirrors rather than using expensive solar cells. Concentrated light can be redirected to a suitable location via optical fibre cable. For example, illuminating buildings, like Hybrid Solar Lighting.

References


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