Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 84 (2015) 33554-33558

ISSN: 2229-712X

# Modified Parabolic Trough

Sonali Roy* and Atul Kumar Singh

Mechanical Engineering, Babu Banarasi Das University, Lucknow, India.

ARTICLE INFO

Article history:
Received: 12 May 2015;
Received in revised form: 19 June 2015;
Accepted: 1 July 2015

Keywords
Solar Energy
Highly reflecting surface,
Nickel Plated Stainless Steel plate,
Oven Effect,
Temperature Variation.

ABSTRACT

Solar parabolic trough collectors are the most useful technology that directly supports renewable energy for conventional energy for water heating. But it is observed that due to ambient temperature many convective losses occur which effects the temperature variation. This article shows the practical work for increasing temperature to cover it by thin transparent glass plate which creates the oven effect and decreases its convective losses which increases the temperature and finally it increase its efficiency.



## Introduction

Today the Renewable sources of energy is playing a vital role in the generation of electricity in them the solar energy is the most important form of energy which can be easily be obtained. Many devices are there which absorbs the radiations of the sun by which we get the high temperature then it converts to another form of energy. In them solar parabolic trough are one of the most mature technology for large scale exploitation of solar energy. Parabolic-trough collectors use highly reflecting surfaces curved in a linearly extended parabolic shape to focus sunlight on a dark surfaced absorber tube running the length of the trough. There is considerable potential for using these technologies at Federal facilities in the South western United States or other areas with high direct-beam solar radiation. A parabolic trough is a type of solar thermal collector that is straight in one dimension and curved as a parabola in the other two, 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, where 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. Further information on the use of parabolic troughs for cooking can be found in the article about solar cookers.

## Principal

Solar parabolic trough based on the principal of Reflecting Theory of light. In this principal light comes from an object attracts to the mirror and meet it into the focal point .In this mechanism the light comes from the sun and reflects from the reflecting surface and absorbs in the absorber tube or receiver which consist a fluid which absorbs heat energy of the sun and later on it is used for further cases.

## Modified Solar Parabolic Trough

In this article there is an experimental work on designing of closed parabolic trough which is fully covered by transparent thin glass and side by side there is a use of composite material by plating or covering it by reflecting material usually here it is used as aluminum foil because it is easily available in the market.

Firstly there is a use of aluminum foil in its reflective part then after testing it in the presence of sunlight we found that due to rough surface we losses some radiations of the sun later on it is replaced by nickel plated stainless steel sheet which replaced these losses. Both cases are tested in front of the sunlight in same weather conditions (which is done in the month of April) and we found some fluctuating results which are described later.

As we all know that there is very much difference in the result of proto type model compared to the plant set up. Mini parabolic trough does not gives as much temperature variations like plant set up it only gives maximum temperature range of 60-70 degree Celsius. But we can compare its efficiency for large plant set up.

## Benefits of Implementation

Normally the parabolic trough is not covered by anything it is opened in the atmosphere in front of the sunlight after covering it by side covers and thin transparent glass it shows beneficial effect over normal parabolic trough. Some of its benefits are as follows.

### *Produce Oven Effect*

Modified Parabolic Trough produces oven effect which can be increased the backup capacity of the whole plant because at the time of sun set the intensity of the sun radiations goes on decreasing so due to its oven effect it creates a range of temperature in that time also which increases the backup capacity of the plant.

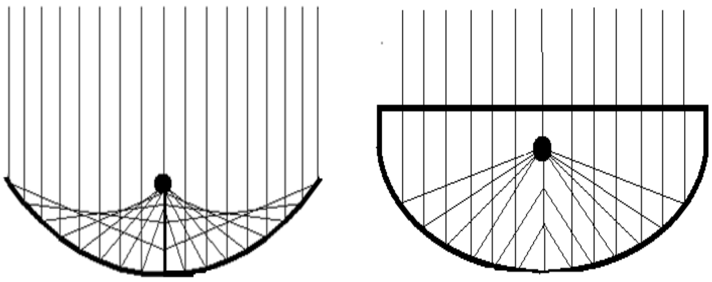

**Figure 1. Non- Oven and Oven Condition of a Parabolic Trough**

Tele: 09532686530
E-mail addresses: sona2misti@gmail.com

***Prevent Heat Loss during winter and windy Day***

During winter seasons and windy season there is very much fluctuations of weather which creates maximum loses in the results so if we cover it by glass plate we found it very much effective over these problems.

***Increase temperature of flowing liquid***

The liquid which is placed in the absorber tube (in this project water is used) shows increased temperature compared to the normal parabolic trough this is the main and important benefit for this implementation which shows increased efficiency of the whole plant. This can be possible due to the oven effect created.

***Increase working time a day***

As we discussed above it creates oven effect which maintain some temperature range inside the parabolic trough after the sun set also so it increases working time of the day which also increases the backup capacity of the plant.

***It protect parabolic trough surface from dust***

A Modified Parabolic Trough is covered by thin transparent glass so it protects it from dust. Dust particles in the reflecting part is also responsible in the loses.

**Designing Of Modified Parabolic Trough**

For this article there is design of the closed parabolic trough proto-type model.

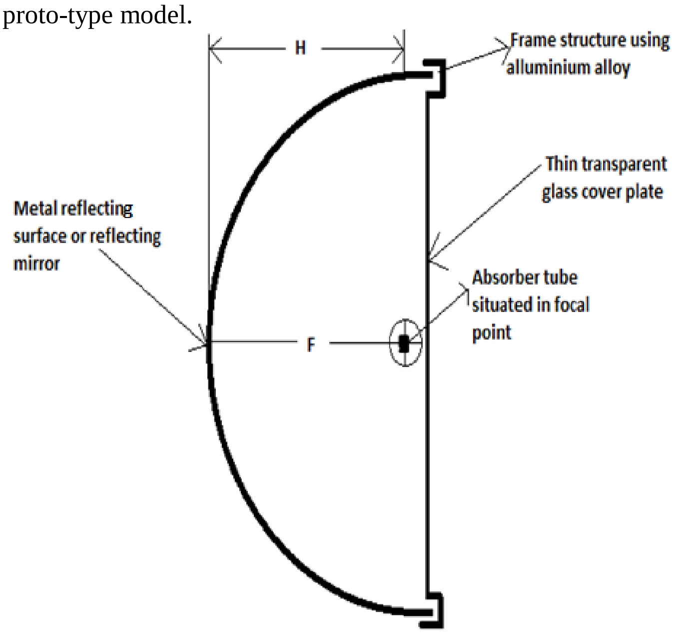


**Figure 2. Side View Of the Proto-type Model**

Here are some of the parameters which are used in the proto-type model they are

Effective Length of trough-360mm

Diameter-270mm

Height-30.8mm

Surface area- 360*446 mm square

Reflective material- Nickel plated stainless steel plate

Insulating shield- 5mm

Copper tube- length-24 inch

Diameter-12.7mm

Thickness-.64mm

Glass thickness -1.2mm

The total efficiency of the parabolic trough is,

$$\eta = \eta_0 - \eta_I \quad (1)$$

Where η is the total efficiency of the parabolic trough,

$\eta_0$ is the optical efficiency

$\eta_I$ is the thermal loss efficiency

η is also can be written as,

$$\eta = \frac{NQ_l}{I_{DN} A_{COLL}} \quad (2)$$

Where N is the number of collectors used in the whole plant set up

$Q_l$ Is the heat losses

$I_{DN}$ Is the incident radiation of the sun where experiment is analysed

$A_{COLL}$ Represents area of collector

$$Q_L = m \, . C_p . \Delta T \quad (3)$$

Where m is the mass flow rate of fluid (23ml)

$C_p$ is the specific heat capacity of the fluid

ΔT is the change in temperature of the fluid

$$\eta_I = \eta_R + \eta_C \quad (4)$$

Where $\eta_R$ is the efficiency of radiative losses

$\eta_C$ is the efficiency of convective losses

Similarly, in parabolic trough total heat losses is due convective and radiative losses i.e.

$$Q_L = Q_C + Q_R \quad (5)$$

Where $Q_C$ is the convective heat losses

$Q_R$ is the radiative heat losses

$$Q_C = H \, A_{COLL} \, (T_{absorber} - T_{ambient}) \quad (6)$$

Where H, is the convective heat transfer coefficient

$T_{absorber}$ is the temperature of the absorber tube

$T_{ambient}$ is the temperature of surrounding of the absorber tube

After placing glass cover plate the ambient temperature is much reduced so there is a less difference which automatically decreases the value of $Q_C$.This experiment is based on the solar radiation of the sun the value of the incident radiation is same but its deflection angle will be changed.

***Proto-Type Model***

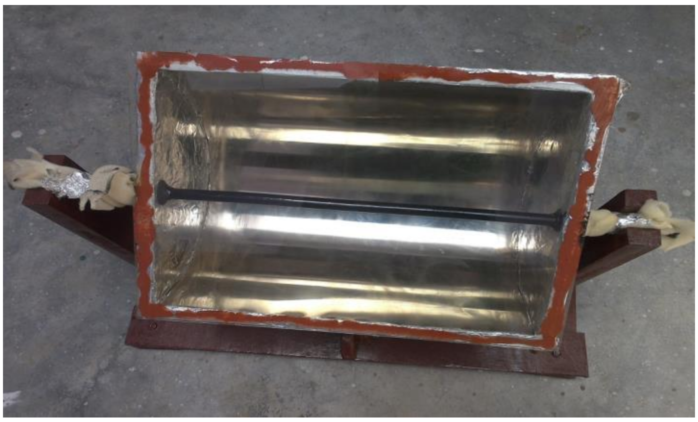

**Figure 3. Proto Type Model made for experiment**

**Results and Discussion**

It was found that during experimental procedure of proto-type parabolic trough there is the variation in the temperature in both of the cases that is temperature in without covered transparent glass plate and with covered transparent glass plate. The following experimental results are shown below on the table when there is a use of nickel plated stainless steel as a reflecting surface. All the temperatures are on degree centigrade ($^{o}$C):

**Table 1. Experimental results in the case of nickel plated stainless steel as a reflecting surface**

| Time | Temperature (Atmosphere) | Temperature ( Water With Glass) | Temperature (Water without Glass) |
|---|---|---|---|
| 7:00 | 28.88 | 22 | 22 |
| 7:30 | 28.88 | 30 | 29 |
| 8:00 | 31.67 | 37 | 33 |
| 8:30 | 32.78 | 42 | 36 |
| 9:00 | 33.89 | 45 | 40 |
| 9:30 | 34.44 | 50 | 42 |
| 10:00 | 36.11 | 52 | 45 |
| 10:30 | 36.67 | 55 | 48 |
| 11:00 | 37.78 | 58 | 50 |
| 11:30 | 37.78 | 60 | 52 |
| 12:00 | 38.89 | 64 | 54 |
| 12:30 | 40.56 | 65 | 54.5 |
| 13:00 | 41.67 | 65 | 55 |
| 13:30 | 40 | 69 | 56 |
| 14:00 | 39.44 | 64 | 53.4 |
| 14:30 | 39.44 | 65 | 52 |
| 15:00 | 38.88 | 63 | 49 |
| 15:30 | 39.44 | 63 | 47.8 |
| 16:00 | 38.33 | 61 | 47.5 |
| 16:30 | 36.67 | 58 | 43 |
| 17:00 | 36.67 | 50 | 39 |
| 17:30 | 35 | 45 | 38.1 |
| 18:00 | 33.88 | 42 | 35 |
| 18:30 | 31.78 | 40 | 33 |
| 19:00 | 29 | 40 | 31.6 |

The chart shows the temperature variation of the parabolic trough which is also represented in graph.

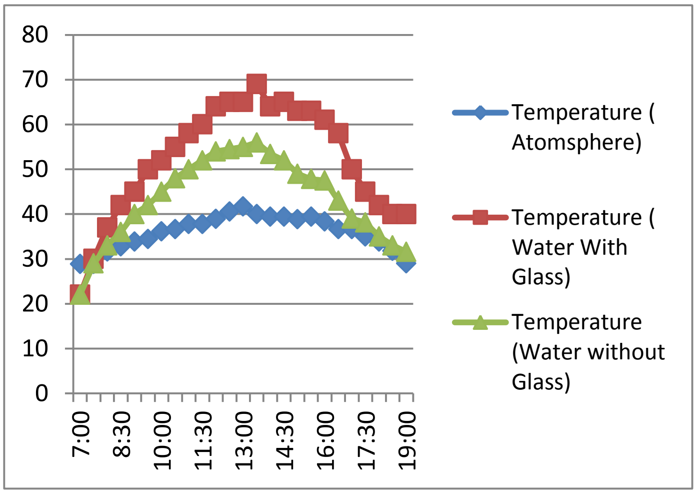


**Figure 4. Graph represents variation in temperature of atmosphere, water in with glass condition and water in without glass condition in case of nickel plated stainless steel plate.**

**Table 2. Variation of Sun incident Radiation and Heat loss at the time of the experiment**

| Time | Incident Radiation (KJ hr/m²) | Heat Loss (KJ) |
|---|---|---|
| 7:00 | 36 | 1.44 |
| 8:00 | 40 | 2.214 |
| 9:00 | 45 | 2.89 |
| 10:00 | 50 | 3.466 |
| 11:00 | 52 | 4.043 |
| 12:00 | 53 | 4.139 |
| 13:00 | 49 | 4.043 |
| 14:00 | 46 | 3.95 |
| 15:00 | 43 | 3.75 |
| 16:00 | 39 | 2.695 |
| 17:00 | 36 | 1.925 |
| 18:00 | 32 | 1.733 |

The value of heat loss is found from equation (3) by putting the value of $C_p$ is 1.008 for water as fluid.

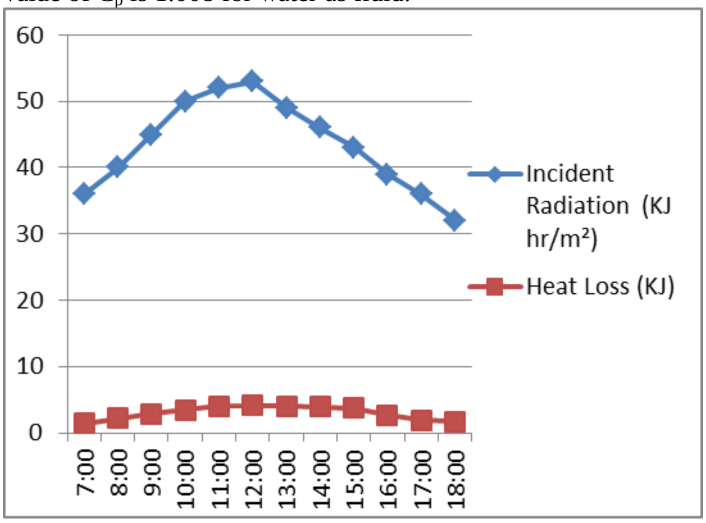


**Figure 5. Graph represents variation in incident radiation of sun and heat loss during the experiment.**

As on putting all the values in equation (2) we get the value of efficiency of the parabolic trough in both cases as shown on the table.

**Table 3. Efficiency of the trough in both cases**

| Time | η (with glass) | η (without glass) |
|---|---|---|
| 7:00 | 41.15% | 30.26% |
| 8:00 | 56.94% | 44.57% |
| 9:00 | 66.07% | 50.61% |
| 10:00 | 71.31% | 55.45% |
| 11:00 | 79.98% | 60.93% |
| 12:00 | 80.34% | 61.67% |
| 13:00 | 79.98% | 68.72% |
| 14:00 | 88.34% | 67.61% |
| 15:00 | 89.72% | 62.18% |
| 16:00 | 71.10% | 64.76% |
| 17:00 | 55% | 46.75% |
| 18:00 | 55.71% | 40.21% |

The chart shows the variation in efficiency of the parabolic trough in with glass condition and without glass condition which is represented in graph as shown.

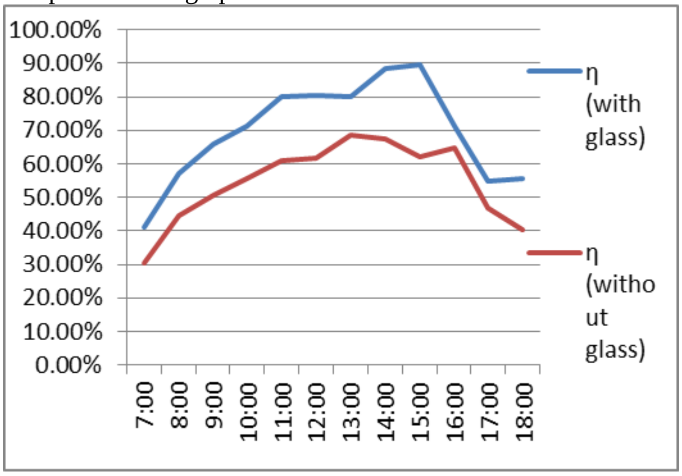


**Figure 6. Graph represent the variation in efficiency of the parabolic trough.**

**Table 4. Variation in Heat loss at the time of the experiment In both cases**

| Time | heat loss (KJ) with glass | heat loss(KJ) Without glass |
|---|---|---|
| 7:00 | 1.44 | 1.059 |
| 8:00 | 2.214 | 1.733 |
| 9:00 | 2.89 | 2.214 |
| 10:00 | 3.466 | 2.695 |
| 11:00 | 4.043 | 3.08 |
| 12:00 | 4.139 | 3.177 |
| 13:00 | 4.043 | 3.273 |
| 14:00 | 3.95 | 3.023 |
| 15:00 | 3.75 | 2.599 |
| 16:00 | 2.695 | 2.455 |
| 17:00 | 1.925 | 1.636 |
| 18:00 | 1.733 | 1.251 |

As on the data of the above table the graph can be made as shown.

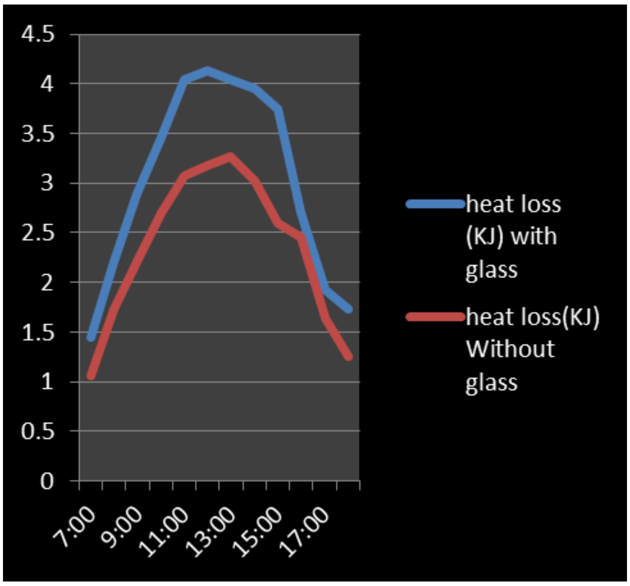


**Figure 7. The graph represents the variation in heat loss in both the condition**

**Acknowledgment**

My head bows with reverence before the Almighty God, and my Father Mr. Paresh Chandra Roy who has given me strength, wisdom and will to complete the work and to publish this article.

**References**

[1] Lifang Li, Andres Kecskemethy, Steven Dubowsky, A. F. M. Arif, Optimized Bands: A New Design Concept for Concentrating Solar Parabolic Mirrors, 2008.

[2] Aed Ibrahim Owaid, Mohd Tariq, Hassan Issa, Husam Sabeeh & Mohammad Ali The Heat Losses Experimentally In The Evacuted Tubes Solar
Collector System In Baghdad-Iraq Climate, Vol. 2, Issue 4, Apr 2014, 13-24© Impact Journals 2014.

[3] M. Yaghoubi, F. Ahmadi, and M. Bandehee Analysis of Heat Losses of Absorber Tubes of Parabolic through Collector of Shiraz (Iran) Solar Power Plant, Journal of Clean Energy Technologies, Vol. 1, No. 1, January 2013.

[4] Robert Österholm , Jens Pålsson, Proceedings of the 10th International Modelica Conference March 10-12, 2014, Lund, Sweden.

[5] Bello, A.M.A., Makinde, V., and Sulu, H.T, Performance Tests and Thermal Efficiency Evaluation of a Constructed Solar Box Cooker at a Guinea Savannah Station (Ilorin, Nigeria) Journal of American Science, 2010.

[6] Parabolic-Trough Solar Water Heating Renewable technology for reducing water-heating costs.

[7] F. Burkholder and C. Kutscher, Heat-Loss Testing of Solel's UVAC3 Parabolic Trough Receiver, Technical Report NREL/TP-550-42394 January 2008.

[8] Alok Kumar, Improvements in efficiency of solar parabolic trough, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 7, Issue 6 (Jul. - Aug. 2013), PP 63-75 www.iosrjournals.org.

[9] Amirtham VALAN ARASU and Samuel Thambu SORNAKUMAR, PERFORMANCE CHARACTERISTICS OF THE SOLAR PARABOLIC TROUGH COLLECTOR WITH HOT WATER GENERATION SYSTEM, Original scientific paper
UDC: 536.331.:662.997 BIBLID: 0354-9836, 10 (2006), 2, 167-174.

[10] M. Abu-Khader, M. Abu Hilal, S. Abdallah, and O. Badran, Evaluating Thermal Performance of Solar Cookers under Jordanian Climate, Jordan Journal of Mechanical and Industrial Engineering Volume 5 , Number 1, February 2011 ISSN 1995-6665 Pages 107 – 112.
[11] ASHOK KUNDAPUR, SUDHIR C.V., PROPOSAL FOR NEW WORLD STANDARD FOR TESTING SOLAR COOKERS, Journal of Engineering Science and Technology Vol. 4, No. 3 (2009) 272 – 281 © School of Engineering, Taylor's University College
[12] Margo Fernandez-Burgos, Sarah Tracy-Wanck, Jordan Schmidt, Hannah Hastings, Emily Gorham Solar Cooker Earth Analog and Comparison of Design efficacy Spring 2008-Global Climate Change EES 359
[13] Charles Kutscher, Frank Burkholder, and Kathleen Stynes, Generation of a Parabolic Trough Collector Efficiency Curve from Separate Measurements of Outdoor Optical Efficiency and Indoor Receiver Heat Loss, National Renewable Energy Laboratory Presented at SolarPACES 2010 Perpignan, France September 21-24, 2010.
[14] Siddharth Arora, Shobhit Chitkara, R. Udayakumar and Muhammad Ali, Journal of Petroleum and Gas Engineering Vol. 2(4), pp. 74-82, April 2011 Available online at http://www.academicjournals.org/JPGE ISSN 2141-2677 ©2011 Academic Journals.
[15] http://www.nrel.gov/csp/troughnet/solar_field.html
[16] World Energy Outlook. International Energy Agency (2009)
[17]http://en.wikipedia.org/wiki/Parabolic_trough#/media/File: Quadric_Parabolic_Cylinder.jpg

**Author**

**Sonali Roy**
**Mtech Scholar**
**(Babu Banarasi Das University)**