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Design And Development Of Improvised Glass Evacuated Parabolic Trough Collector

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Abstract: Parabolic trough solar water heating is a well proven technology that directly substitutes renewable energy for conventional energy in water heating. The basic principle of solar water heating is intuitive and straightforward. A dark surface is positioned to absorb sunlight and convert it to heat. Water or another heat transfer fluid passes along that hot surface to pick up the heat either for direct use or for transfer through a heat exchanger to the end use. As concentrating systems, parabolic troughs use only direct radiation. Unlike flat plate collectors, hence the parabolic trough should use a tracking system which tracks the sun continuously and the setup has to be mounted on a north – south direction.

The absorber tube is covered with an insulated tube so that there won't be any heat loses to the atmosphere from the absorber. Passive flow of water takes place from the absorber to the thermal tank if it is placed at a proper height from the parabolic trough. In the present work an attempt to design and construct the parabolic trough collector which would harness the solar energy and convert water into steam which can be used for various purposes in domestic and industrial scale.

Keywords: Heat Transfer fluid, parabolic trough collectors (PTC), Heat pipe, Glass evacuated tube, L-channels.

I. INTRODUCTION

The parabolic trough collectors (PTC) consist of solar collectors (mirrors), heat receivers and support structures. The parabolic-shaped mirrors are constructed by forming a sheet of reflective material into a parabolic shape that concentrates incoming sunlight onto a central receiver tube at the focal line of the collector. The arrays of mirrors can be 100 meters (m) long or more, with the curved aperture of 5 m to 6 m. A single-axis tracking mechanism is used to orient both solar collectors and heat receivers toward the sun. PTC are usually aligned North-South and track the sun as it moves from East to West to maximise the collection of energy.

The receiver comprises the absorber tube (usually metal) inside an evacuated glass envelope. The absorber tube is generally a coated stainless steel tube, with a spectrally selective coating that absorbs the solar (short wave) irradiation well, but emits very little infrared (long wave) radiation. This helps to reduce heat loss. Evacuated glass tubes are used because they help to reduce heat losses.

A heat transfer fluid (HTF) is circulated through the absorber tubes to collect the solar energy and transfer it to the steam generator or to the heat storage system, if any. Most existing parabolic troughs use synthetic oils as the heat transfer fluid, which are stable up to 400°C.

New plants under demonstration use molten salt at 540°C either for heat transfer and/or as the thermal/storage medium. High temperature molten salt may considerably improve the thermal storage performance.

II. CONSTRUCTION FRAME

Fig.1 Construction of frame

The frame shown in Fig.1 has been constructed using mild steel square channel is having 2.5*2.5cm where the length of bottom frame is 122cm and the length of the main frame is 180.5cm and width of both the frame is 122cm. The total length of the frame including the support to the parabolic trough is 185cm and the height of the support is 54cm as shown in figure. There is an option provided between the main frame and bottom frame to fold and unfold using hinge support so that the whole supporting frame can be inclined from the horizontal to the required angle.

Fig.2 Construction of parabolic trough:

By using the formula $x^2 = 4ay$ parabola is constructed on a graph sheet which has been later transformed to five plywood sheets where the focal point of the parabola is 200mm.

All five plywood sheet arranged parallel to each other as shown in the Fig.3 with equal spacing length of 174.5 cm where all the five sheets are screwed to two aluminium L-channels. A galvanised aluminium sheet of thickness of 0.7 mm having length of 174.5 cm*106 cm has been fixed on the parabolic curve of the plywood sheets. The galvanised aluminium sheet as shown in Fig.5 are nailed to the plywood sheet for safety. Upon which the same size of acrylic mirror is placed on top of the galvanised aluminium sheet thickness of 1mm as shown in figure. Now there are n-number of parabolic curves for the length 174.5 cm forming a parabolic trough where two more aluminium L-channels has been screwed to the plywood sheet on the inner side of the parabolic curve.

Fig.3 Basic frame

Fig.4 Basic frame with aluminium sheet

Fig.5 Acrylic mirror

The parabolic trough constructed can withstand any kind of climatic condition and is very rigid and has the life expectancy of three years. If plywood sheets are replaced by mild steel bars, the parabolic trough would lost longer up to seven years.

The rotating mechanism where the trough has to be pivoted at a distance of 200mm from the vertex of the parabolic trough which is called the focus and it must also have an option for an evacuated tube of external diameter 5.7 cm to align at focus.

A standard bearing shown in Fig.6 with internal diameter 6 cm and external diameter 11cm has welded between the two iron plates of 15*15 cm where one plate is welded with the outer face of the bearing and other plate is welded with inner face of the bearing, so that both the plates can turn opposite to each other giving an option for the parabolic trough to track the sun from morning to evening.

Fig.6 Standard bearings

The outer ring of the bearings is welded to the frame of parabolic trough. The evacuated tubes are placed in the inner rings. The rotating plates are pivoted at 200mm from the vertex whereas the mild steel flat rod is used to support them at four ends of the plywood to ensure uniform load distribution, and then load is transferred to the four aluminium L-channels.

III. HEAT PIPE

The heat pipe of high thermal conductivity made of soft copper as shown in Fig.7 with external diameter 3/8 inch and 6.5 ft length available as the commercial evacuated tube open at only one end and is welded together with a copper U bend of 40 mm with silver welding to withstand high temperature, forming copper mesh for proper heat coupling.

Fig.7 Copper mesh wound upon heat pipe

The open end of the evacuated tube facing the bottom when the setup is inclined, evacuated tube should be held between the two bearings one at each end of the parabolic trough to avoid sliding of the evacuated tube. Stoppers hold the evacuated tube rigidly at the focus of the parabolic trough. The other end of U bend reaches the top end of inner glass tube of the evacuated tube and at the open end rock wool insulation is placed to minimize the heat loss. The work was carried out in shade as the concentrated sun light might burn the skin and might damage the evacuated tube at the time of fixing.

IV. ALL GLASS EVACUATED TUBE

The all glass evacuated solar collector tube shown in Fig.8 comprise of the inner glass tube with solar selective absorbing coating on its outer surface and coaxial cover glass tube. The one end of the inner glass tube is closed at base and seated in a steel strut. The other end of the inner glass tube shall be thermally sealed with the other end of the cover glass tube. The space between the inner tube and outer cover tube shall be vacuumised before thermal sealing of the other end of cover tube.

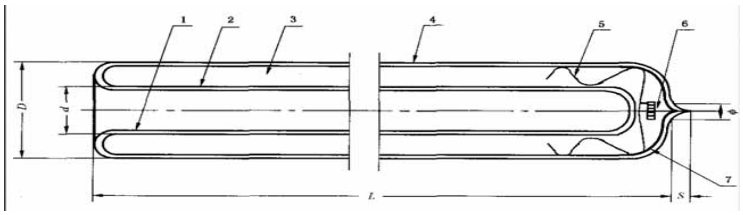

Fig.8 Structure of all glass evacuated tube

1— Inner glass tube;
2— Solar selective absorbing coating;
3— Vacuum jacket;
4— Cover glass tube;
5— Strut member;
6— Getter;
7— Getter mirror surface.
D — Outer Diameter of cover glass tub
d — Outer Diameter of inner glass tub
L — Length of tube
S — Length of sealing section

Technical specification of glass evacuated tube:
Dimensions:
Inner diameter of inner tube 44.4mm
Outer diameter of inner tube 47mm
Outer diameter of outer tube 58.0mm
Total length is 1800mm

Solar Selective Absorbing Coating:
The Solar selective absorbing coating contains three layers namely absorption layer (Aluminium nitride), bonding agent with absorption layer (Aluminium nitride –stainless steel) and anti-reflection layer (copper).

Designation:
All glass evacuated solar collector tube having AlN/AlN-SS/Cu multilayer selective coating with 58 mm outer diameter of cover glass tube and 47 mm outer diameter of inner glass tube, 1800 mm length and three target coating shall be designated as:
ET - AlN/AlN-SS/Cu - 58/47 - 1800 - 3T

V. RESULTS AND DISCUSSIONS

Water in the tank is kept at a height of 70 cm from the ground level and under full sun of ambient temperature 33.35 ^{0}C. The following values where the steam appears at outlet within five minutes after setting the trough and the steam was steady and continuous at the outlet.

- Max temperature 297^{0}C.
- Around 840 ml of water consumed per hour.

When the setup is inclined at 45^0 angle the outlet steam temperature is 191^{0}C and the steam was steady and continuous at the outlet later when the setup is inclined for 40^0 angle the outlet steam temperature is 234^{0}C was obtained.

For 35^{0}C angle the outlet steam temperature of 257^{0}C was obtained.
For 30^{0}C angle the outlet steam temperature of 289^{0}C was obtained.
For 25^{0}C angle the outlet steam temperature of 297^{0}C was obtained.

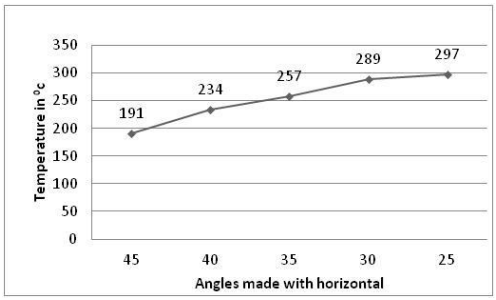

Fig.9 Setup is kept at 70 cm from ground level

VI. For saturated steam

When the water tank is kept under the height of 120 cm from the ground level and under full sun of ambient temperature 33.35^{0}C we recorded the following values where the steam appears at outlet within five minutes after setting the trough and the steam was steady and continuous at the outlet with droplets of water which shows that there is more moisture in the steam and such steam is known as saturated steam.

Max temperature 184^{0}C
Around five litres of water consumed per hour

When the setup is inclined at 45^0 angle the outlet steam temperature is 130^{0}C and the steam was steady and continuous at the outlet with droplets of water later when the setup is inclined for 400 angle the outlet steam temperature is 152^{0}C was obtained.

For 35^0C angle the outlet steam temperature of 160^0C was obtained.
For 30^0C angle the outlet steam temperature of 171^0C was obtained.
For 25^0C angle the outlet steam temperature of 184^0C was obtained.

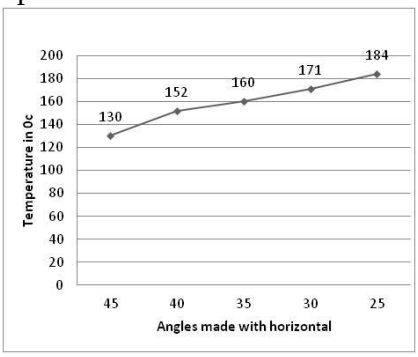

Fig.10 Setup is kept at 120 cm from ground level

VII. CONCLUSIONS

Dramatic technology break through to make parabolic-trough solar water heating economically attractive in areas with less sun or for facilities the have low cost conventional energy available are unlikely, incremental improvements in mirror and absorber coasting , however, are quite likely, and will make parabolic through increasingly efficient for the situations where the already are attractive. Any major cost reductions would come from economies of scale associated with substantially, or an increase in conventional energy prices. Climate change gas emission reduction the outlook is quite good the technology is more limited geographically to areas of high solar resources and to larger facilities than are other solar water heating technologies, but the economics are better. The following conclusions can be drawn from the work made.

- The parabolic trough collector is successfully developed
- The glass evacuated tube helps in reducing the heat loss
- The maximum temperature is found to be 297ºC, which can be used in most of the industrial applications which involve process heating.
- For 25º tilt angle, the maximum temperature obtained was 184º.

It was found to be a most effective solar water heating technologies.

VIII. FEATURE SCOPE

When the whole setup is flat and the inlet and outlet connection is given to the a thermal storage tank which is at proper height from the boiler as shown in figure convective flow of water takes place from the boiler to the storage tank as cold water is denser it moves to the bottom and hot water is less denser than the cold water it moves up to the storage tank.

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