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Thermal Analysis of Vacuum based Trough Collector At High Temperature: A Review

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***Abstract*— Solar energy is one of the environment friendly and clean form of energy. Many technologies have been developed to harness this energy among which parabolic trough collectors are extensively used. The receiver tubes used in these collectors are quite long which leads to large heat losses. An evacuated receiver tube can be the alternative to reduce these losses. This papers reviews at the techniques that can be implemented for evacuation and the performance of collector.**

Keywords*— *Parabolic trough collector, receiver tube, vacuum

I. INTRODUCTION

Now-a-days, the energy demand of the world increasing very rapidly. The population of world currently depends upon the non-renewable sources of energy exaggeratedly for their energy consumption. Most of these resources include coal, fossil fuels, oils etc. But the time is not that far when these resources will become extinct. Apart from this they have certain impacts on the environments such as acid rain, green house effects, ozone depletion etc. This insists us to rely on non-renewable sources of energy in future.

The non-conventional energy sources are hydro, wind, tidal, ocean thermal, geothermal and solar being the primary source. The solar energy received on the earth in one hour is equivalent to energy consumed in one year. Still the electricity production from solar energy contributes in fraction. The solar energy can be harnessed by either concentrating or non-concentrating collector. The trough type collectors which falls in the category of concentrating types are more popular and among that parabolic trough collectors are intensively used since higher temperature can be achieved.

The parabolic trough collectors generally has mirror polished surfaces which concentrates the solar beam radiation falling on them on the linear receiver tube placed at the focus. The continuous focusing is ensured by tracking of collector with sun's path. Thus the receiver tube is part of prime importance. It consist of a metal tube surrounded by a glass cover and metal bellows at the end to account for thermal stresses. The receiver tubes are quite long in solar generation plant. Thus large heat losses are associated with solar receivers. Thus in order to reduce the heat losses the work in going on in the R & D section to evacuate the space between the metal tube and glass cover of a receiver tube. There are also challenges faced during the work such as leakage of vacuum at the tube joints.

II. SYSTEM DESCRIPTION

The parabolic trough collector is a solar thermal collector which has a curved parabolic surface extended over a length having polished mirror metal surface. The sun rays enter into the parabolic shaped trough and focused at its focus point over an entire length as shown in fig. 1. The receiver tube is placed at the focal line in which fluid needed to be heated is placed. The receiver tube consists of a metal absorber tube which contains heat transfer fluid and is surrounded by a glass cover having metal bellows at its end to compensate for expansion due to high temperature. The water placed in absorber tube can be converted into steam which may have higher temperature of order 400 ˚C. The Rankine cycle can be then operated at other end to generate electricity.

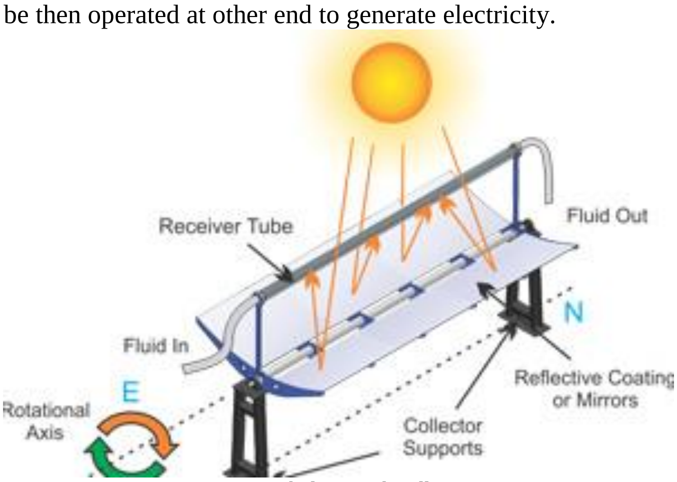

Fig. 1 Parabolic trough collector

III. LITERATURE REVIEW

V. K. Jebasingh and G. M. Joselin Herbert [1] have focused on the performance and the efficiency of solar trough collector. They also have mentioned about the working of a solar parabolic trough collectors along with its applications such as Industrial heating process, desalination, which will be helpful for people working on parabolic trough collector.

Hongbo Liang, Shijun You and Huan Zhang [2] have presented one dimensional mathematical model for a parabolic trough collector under certain assumptions. All the possible modes and places of heat transfer were considered. They also proposed a simple algorithm to make the governing equation linear and solve easily. They used the experimental data from Sandia National Laboratory to analyze the accuracy of presented model.

A. C. Ratzel, C. E. Hickox and D. K. Gartling [3] have done extensive work on techniques for reducing thermal conduction and natural convection heat losses in annular receiver geometries. They have carried out the experimentation with electric heater and suggested to maintain Rayleigh number below 1000 to suppress natural convection but doing this increases conduction in annular space whose effect can be minimized by evacuating the space. If keeping the annulus below atmospheric pressure is not possible then Rayleigh number can be maintained by appropriate sizing to a desired value.

M. J. Bai, Y. N. Niu and E. S. Xu, Y. Xu [4] described the heat loss model for newly designed vacuum transfer tube and also proposed the model of the time sample under the unit's operating conditions according to the actual weather conditions in typical years of a parabolic trough solar thermal power plant construction site. They also have done an intensive research on the cost and the economy of the parabolic trough solar thermal generation system which make a use of vacuum transfer tube. They also found out the actual heat loss with and without vacuum during day time, night hours and cloudy days. The heat losses were found to be minimum in case of vacuum tube. But the cost of vacuum transfer tube is more than conventional tube. However, considering the economic benefits, bringing by the vacuum tubes, the payback period for incremental cost was found to be very short.

Victor C. Pigozzo Filho, Alexandre B. de Sa, Julio C. Passos and Sergio Colle [5] described the methodology and the results of an experimental and numerical investigation of the thermal losses of a small scale parabolic trough collector. The analysis was done for a 3m wide and 4m long collector with evacuated tubes with selective coating. They have used the one dimensional heat transfer model and compared their measured value with this model. They also found that the system performance was very sensitive small change in an operating conditions and the degradation of vacuum from the annular space during the experimentation.

Antonio Marcos de Oliveira Siqueira, Paulo Eduardo Neves Gomes, Larissa Torrezani, Eliene Oliveira Lucas and Geraldo Magela da Cruz Pereira [6] described the mathematical modelling for calculating the flow parameters and heat transfer applied to the parabolic trough collector. They also compared the result obtained along with the values obtained by simulation technique which showed that the mathematical model developed for heat transfer analysis was reasonable.

M. Yaghoubi, F. Ahmadi and M. Bandehee [7] described the heat loss through absorber tube of Shiraz power plant for various conditions. They compared their experimental measurements with the values obtained by simulation. The temperature measurements were done by infrared thermograph camera and the images are then calibrated. The heat loss was compared for vacuum, lost vacuum and broken glass tubes. The plant showed highest performance during the vacuum tube instead of bare tubes and broken glass tubes.

Abhishek Rajan, Hemanth S., Nikhil V. S. and Sreekumar PC [8] showed the theoretical heat loss calculation for parabolic trough collector with vacuum within the annulus gap and compared these values with heat loss during the air as a medium. They losses during the vacuum were found to be less. They also designed a simple seal to maintain the vacuum within the annulus. They also mentioned the cost calculations for the making of seal which proved to be efficient.

J. Barriga, U. Ruiz-de-Gopegui, J. Goikoetxea., B. Coto and H. Cachafeiro [9] explained about the selective absorber coating of receiver tube. With newly designed coating, they tested it for 600 degree centigrade and at the low pressure. The main advantage of this new design was increased efficiency, reliability and reduced manufacturing costs.

H. Cachafeiro, L. Fdez. de Arevalo, R. Vinuesa, R. Lopez-Vizcaino and M. Luna [10] described the new concept of absorber tube. This absorber tube is based on the concept of dynamic vacuum, where the evacuation is produced in the solar field during the start up. They also performed an experiment by creating number of joints in the system and analyzed it for vacuum retention. These helped them in achieving lower manufacturing costs and also use the vacuum pump whenever is necessary to reduce the pressure level and hence thermal losses.

Jian Li, Zhifeng Wang, Jianbin Li and Dongqiang Lei [11] explained the necessary details regarding vacuum reliability analysis of parabolic trough collector. It also explained about various possible sources of gas in a receiver tube. They also told about the various term such as outgassing rates in a receiver and effect of high temperature on outgassing and getter performance.

IV. CONCLUSION

Now-a-days, the energy demand has increased significantly. Thus solar energy is the perfect solution for the enhanced power demand in future. The parabolic collectors have ability to reach high temperatures and can be effectively used for power generation. Thus the thermal analysis reveals that performance of these collectors is the major thing to be taken care of by optimizing the parameters such as working heat transfer fluid, heat transfer characteristics, appropriate sizing or evacuation of solar receiver tubes to minimize losses.

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