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Analysis of Heat Transfer Fluids in Concentrated Solar Power (CSP)

A Review Paper

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***Abstract*— The conventional sources of energy are getting costlier and results in environmental impacts and so renewable energy production came into existence where the resources are available naturally and in abundant. One of such proven technologies is solar energy generation by solar photovoltaic (PV) and concentrated solar power (CSP). Both use different technologies for energy generation and this paper deals with CSP technology where an indirect method is used with the help of heat transfer fluids (HTF). The reason for usage of heat transfer fluids and its selection criteria are explained along with the fluids that are used in recent days and the problems faced by the fluids that were used in the previous years.**

Keywords*— *Concentrated Solar Power; Heat Transfer Fluids; Analysis; Review

I. INTRODUCTION

Considering environmental impacts into account the renewable means of power production has grown up and these sources are naturally available in abundance and free of cost. Among different types of renewable power generation, concentrated solar power has become one of the emerging technologies in the world. In this, there are two modes of power generation viz. direct and indirect. The plants working on CSP – Parabolic trough will look similar to a conventional thermal power plant with the construction including turbine and generator housing. The direct method uses only water as a heat transfer fluid for power generation whereas the indirect method uses heat transfer fluids whose heat is liberated to water in the steam generator for phase change from water to steam. In the indirect method, there will be a cycle for heat transfer fluid to circulate and the other will be a conventional Rankine cycle with the heat exchanger to convert water into steam which can run the steam turbine for power production.

II. SELECTION OF HEAT TRANSFER FLUIDS

The heat transfer fluids used in CSP technologies include air, water, molten salts, glycol based, glycerol based and synthetic oils which can transfer heat effectively. Of these air and water are not being used now-a-days as air upon heating will increase by volume and so the heat exchanger to be installed should be of larger size for efficient heat transfer which also increases the investment cost to a greater extent. Water on high temperatures will get oxidized quickly that can encourage the materials of the absorber tube to react and can cause corrosion in the inner parts of the tube. Molten salts have the tendency to get solidified when it reaches high temperature. The other fluids available are used for different operating temperatures. Glycol based fluids are used for applications below 175ºC and synthetic fluids for applications above 400ºC. The basic idea for the CSP-PT plant to use heat transfer fluids in their operation is shown in the figure below.

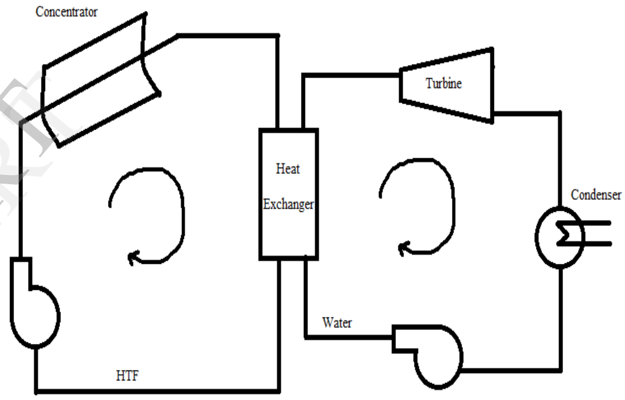

Figure: Basic Layout of CSP Plant

For the CSP plants to be operated at colder regions water cannot be used as it freezes at 0°C. So there should be some HTFs selected with anti-freezing properties and the fluid lifetime should be for over 20 years. Adding anti-freeze agents to water will have negative impacts on system performance by increasing the boiling point thereby resulting in higher power consumption as the viscosity increases. Also the heat transfer efficiency gets reduced because the thermal conductivity and specific heat decreases by introduction of anti-freeze agents.

When taking the effect of corrosion, the salts are corrosive and its effect cannot be protected by corrosion inhibitors. The glycols and alcohols without corrosion inhibitors are corrosive as glycol produces acid on oxidation which will result in lower pH value due to high temperature. This leads to acid formation which is corrosive in nature. So pH buffers should be used to maintain HTF in neutral and proper corrosion inhibitors should be used.

The corrosion can be controlled by design and operation such as selection of materials, temperature limit and exposure to oxygen. The selection of fluids as HTF is also important to select by considering the usage of corrosion inhibitors and purity level of fluid to be used. It is necessary to maintain metals in the passive state rather than active state which reduces the corrosion rate and increases the life time of materials.

When considering the health, safety and environmental aspects of heat transfer fluids it should not be toxic. From the literatures viewed and among the HTFs that are in old practice alcohols and glycols are classified as moderately toxic. Alcohols have flammability and due to fire safety concerns it is avoided. Among the glycols, propylene glycol is formally approved by Food and Drug Administration because of the advantages like freeze protection, non-corrosive, relatively efficient heat transfer, and no adverse health & safety effects and less cost.

The HTFs with higher concentration should not be used in CSP plant as the load increases and so it has to be diluted with distilled or de-ionized water and the minimum concentration achieved can be 20 to 25% to the maximum concentration of 60 to 65%. The HTFs should not be over diluted for example, when propylene glycol is over diluted leads to corrosion and bio-fouling (growth of algae or micro-organisms along the surface of material) which causes unpleasant odour.

III. CRITERIA FOR SELECTION OF HTF

From the above literature surveys, the criteria for selecting the heat transfer fluids are selected. The heat transfer fluids play an important role in indirect mode of power production where it delivers heat to the water when comes in contact inside the heat exchanger. The steam that is generated from the heat released by heat transfer fluids is then sent to the turbine for power production. The turbine will operate only when there is sufficient rated pressure of fluid is passed through it. So the desired pressure and temperature has to be obtained when the heat is released from the HTF in heat exchanger. There are certain criterias for a suitable HTF to be selected and those are as follows.

- High operating temperature
- Stability at high temperature
- Low material maintenance and transport costs
- Non-corrosive
- Safe to use
- Low vapour pressure
- Product life cycle
- Low freezing point
- Low viscosity

IV. HEAT TRANSFER FLUIDS USED

The heat transfer fluids mainly used in concentrated solar power are based on the selection criteria specified above and few HTFs are listed down with their properties that are collected from different literatures. Out of the heat transfer fluids used in present days, phenyl-naphthalene has been considered as the best on evaluating its performance.

HTF	T_{max} (K)	C_p (KJ/kg.K)	ρ (kg/m^3)	K (W/m.K)	μ (mPa.s)
Xceltherm	580	3	672.36	0.113	0.252
Biphenyl	500	2.03	869	0.118	0.32
Phenyl-naphthalene	600	2.6	849	0.077	0.11
Dowtherm A	678	2.73	672.5	0.0771	0.12
Therminol 66	648	-	1011	0.09	0.29
Nitrate Salts	873	1.495	1899	-	3.26
Hitec	720	2.319	1992	-	6.37

*Source: NREL, ORNL for Heat Transfer Fluids

V. CONCLUSION

The selection criteria for the heat transfer fluids that can be used in concentrated solar power plants are studied along with the drawbacks that were incurred with older heat transfer fluids used for power production. The present day heat transfer fluids in use are noted with its properties which can be used for comparing it with the criteria mentioned for selection.

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