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A Review on Solar Line Concentrator to Improve Its Performance by Varying Concentration Ratio

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Abstract: ***Presently, constant diameter receivers are used for line concentrating systems. This gives constant concentrating ratio. The concentrating ratio (CR) is selected depending upon the outlet temperature of the fluid/receiver. There are many industrial requirements which have a large difference in outlet and inlet temperature of the heating fluid. Using a constant C.R. for such a system reduces its efficiency. The intercept factor (energy intercepted) depends upon diameter of the receiver. Higher the diameter, higher is the energy intercepted by the receiver. While, the heat loss from the receiver, for a given receiver temperature increases with receiver diameter. To optimize the concentrator system, it is necessary to balance energy intercepted and the heat loss. This can be done by using lower concentrator ratio (higher receiver diameter) at the initial portion of the concentrator where the fluid temperature is low. Further portion of the concentrator where fluid temperature is higher, a high concentrator ratio can be used to reduce the loss of heat through reduction of area of the receiver tube (smaller diameter receiver). Thus, the concentrator system will have different diameter receivers offering variable concentration ratio system. This concept is confirmed with the help of G.O. Lof, Fester and Duffie Beck paper. The authors (Lof et al) have evaluated performance of two receivers having diameter of 0.060 m and 0.027m. In this attempt the authors of present paper have superimposed the two graphs presented by G.O.L of and Duffie Beck. The superimposition shows that the receiver tube with 0.060 m diameters gives higher efficiency up to 170°C receiver temperature and further the receiver tube of 0.027m diameter offers higher temperature performance. Therefore, it is promising to use reduced diameter receivers in steps offering varying CR to enhance the performance of line concentrator.***

Keywords: Line concentrator; variable concentration ratio; intercept factor

1. Introduction

The solar energy can be converted into thermal energy by using either a flat plate collector or a concentrator. Although the design of flat plate collector is simple, it has several drawbacks. The heat loss takes place through the entire cover area which is equal to the aperture area. This puts a limit on the maximum temperature attainable from the collector which is of the order of 65-70^{0}C.Since the flat plate collectors are not tracked; the out let temperature of fluid varies substantially. It will be maximum in the afternoon while the temperature falls substantially in the morning and evening hours. In the concentrating system either reflection or refraction principle is used to focus the solar radiation on the receiver. As the area of receiver in the concentrating system is less as compared with that in flat plate collector, the loss of heat from the receiver is reduced and hence higher air temperatures can be attained. The concentrator can be very well used where higher temperature is required. Line focus systems have cylindrical symmetry and are generally used when medium concentration ratio is sufficient to provide the desired operating temperatures. The concentration ratio(CR) with line focusing systems can be the order of 100 and the temperature obtainable is about 500^{o}c[1]the main advantage of line concentrator is, the absorbing area from which heat lost to surroundings per unit of energy collected is less than that of flat plate collector. Presently a constant diameter receiver is used for line concentrating system offering a constant concentration ratio (C.R.). For many industrial applications, require heating of fluid through large temperature difference. If the outlet and inlet temperature difference is high, then a concentrating system having 2-3 various receiver diameters, offering variable concentration ratio would give better results.

In this paper, variable concentration ratio concentrator is proposed with the analyses of earlier literature and experimental results presented by Lof et al [3].Hence in line concentrating the insolation flux at the receiver is higher and the working fluid can attain higher temperature [2].Lof et al [3] carried out the experiments, and have reported "Energy balance on a parabolic cylindrical solar collector" for two different receiver tubes of 0.060m and 0.027m diameter , aperture of reflector is 1.89m and evaluated that intercept factor and loss of heat for larger diameter receiver is more.. Balbir Singh et al [4] studied equilibrium between the increasing thermal losses with the increasing aperture area, and the increasing optical losses with the decreasing aperture area. Houtan Moaveni[5] has performed the experimental analyses, mathematical simulation and described temperature rise in the receiver is more sensitive to the collector intercept factor as well as the mirror reflectivity. Tasgaonkar G. S. [6] evaluated the relation between receiver diameter and intercept factor.

2. Theoretical Consideration

The Figure.1 shows effect of increasing concentration ratio (CR) by decreasing the size of the receiver tube. The lower limit curve represents CR at which the thermal losses will equal the absorbed energy; higher ratio will then result in useful heat gain for a given system [7]. Concentration ratio (CR) is defined as the ratio of the collector aperture area to the surface area of the receiver [8].

$$CR = \frac{Aa}{Ar}$$

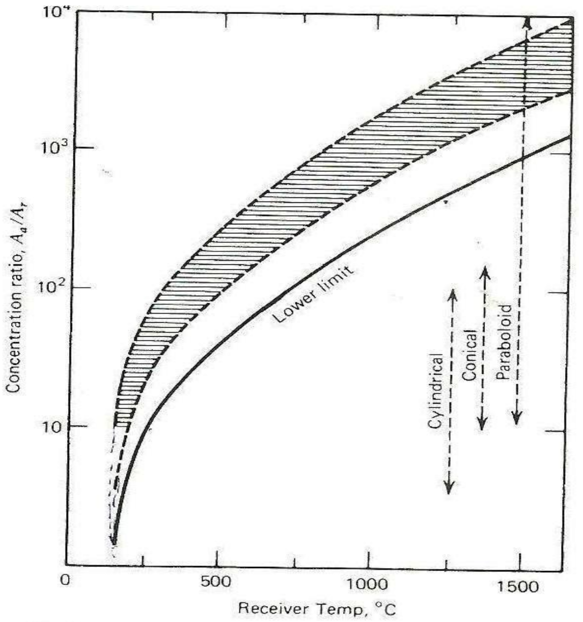

Figure 1: Relation between concentration ratio and temperature of receiver [7]

Lof et al [3] have evaluated the intercept factor and its dependence on receiver diameter. This graph is represented in Figure 2 shows that 0.027 m receiver intercepts 58% of the specularly reflected radiation. The interception would have been 70% if the focal pattern had been symmetrical normal distribution and 57 % if the shifted normal distribution had applied. Corresponding values for a 0.060m receiver are 89, 95, and 90%, respectively. Thus an assumption of symmetrical normal distribution may lead to considerable error in predicting collector performance if the actual distribution is shifted from the theoretical focus, particularly for small receivers. A very close approximation of actual intercept factor is obtained with the shifted normal distribution for the system studied in these experiments. Hence for the system in reference, larger diameter receiver intercepts more amounts of solar reflected rays as compared to smaller receiver diameter. However the losses from larger receiver diameter are predominant.

Figs. 3 and 4 show the distribution of incident energy for the full sized reflector with large and small receivers as a function of receiver surface temperature at comparable conditions of incident solar radiation, wind velocity, and ambient air temperature. The distribution of losses is evident from these illustrations, and the logical directions to proceed for improving performance are indicated. Optical losses predominate in the case of the small tube, while optical and thermal losses are of comparable importance with the larger tube at higher temperatures. The use of a transparent envelope would result in reduced convection and radiation loss but increased optical loss. Thermal loss could be reduced by use of selective coatings on the receiver; however, some additional "imperfect absorption loss" would be incurred if absorptivity of receiver for solar radiation were below 0.95.

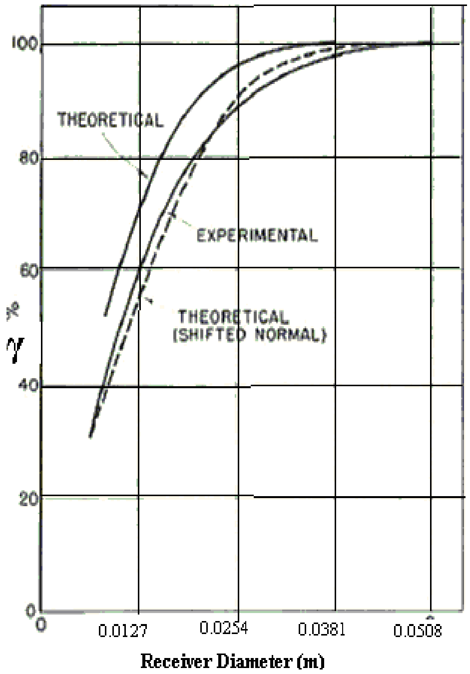

Figure 2: Relation between Intercept factor and receiver diameter [3]

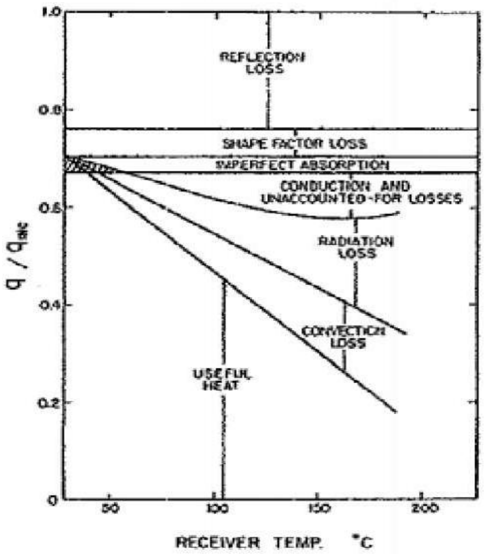

Figure 3: Distribution of incident energy for 1.89 m aperture reflector, 0.060 m receiver diameter [3]

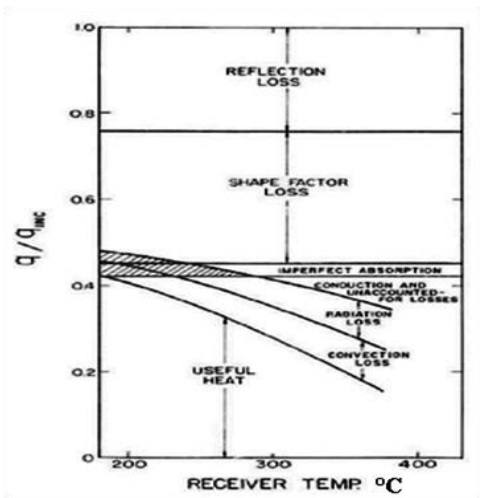

Figure 4: Distribution of incident energy for 1.89 m aperture reflector, 0.027 m receiver diameter [3]

Above literature describes that with use of uniform tube receiver, total heat loss from the receiver due to convection and radiation obtained is more and efficiency obtained by uniform receiver tube is less. Figure 3 and 4 presented by Lof et al [3] show the distribution of incident beam solar energy into useful heat gain and various losses for two receiver tube sizes, the first for 0.060m diameter receiver tube and the second for 0.027m diameter receiver tube. The relative magnitudes of the losses are evident. The graphical results show the efficiency of the collector is affected by variations in receiver size.

The intercept factor is a function of receiver size, which leads to increase of energy intercepted by the receiver. However, heat loosing area depends on the receiver diameter. The effect of large receiver diameter is predominant on the thermal performance for low temperature. However, for higher temperature as the heat loss is more, the efficiency decreases. On the other hand, for small receiver diameter (higher CR) although the energy intercepted is less, the loss of heat at higher temperature is comparatively low because of less surface area of the receiver. Hence it is necessary to optimize the CR for varying fluid temperature and receiver temperature to obtain better performance.

While evaluating performance of PTC all the references are available for temperature of receiver. However receiver temperature (Tr) and water temperature (Tw) they go hand in hand. This relation is proved and evident from graph (Figure 5). Authors have a set up of a line concentrator system, it consists of reflector aperture 0.6 m, length 6 m, having different diameter (without transparent cover) bare receiver tubes of black coating. Figure 5 shows experimental performance of this set up using 0.029m receiver. The difference in receiver temperature (Tr) and water temperature (Tw) is evident for given length. Initially temperature difference is less and goes on increasing with the length of receiver. Maximum temperature difference (Tr- Tw) at the end was 140C.

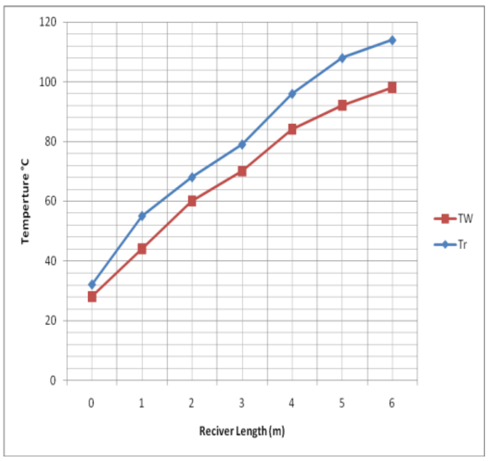

Figure 5: Difference in receiver temperature and water temperature

3. Comparison of Graphs (Figure 3 and 4)

Figure 6 shows superimposed resultant drawn by referring experimental observation values from (Figure 3 and 4) presented L of et al [3], this shows lower performance by using 0.060 receiver, up to temperature 170^0C, further higher temperature by using receiver of diameter 0.027m.Authors used this superimposed graph (Fig.6) to develop a new concept of variable concentration ratio concentrator system for improving performance of concentrator system. Presently constant concentration ratio (CR) systems are used which are having less performance. However, this work proves that whenever substantial outlet and inlet temperature differences in fluid are expected, a variable concentration ratio system as discussed in this paper may offer higher performance of concentrator system

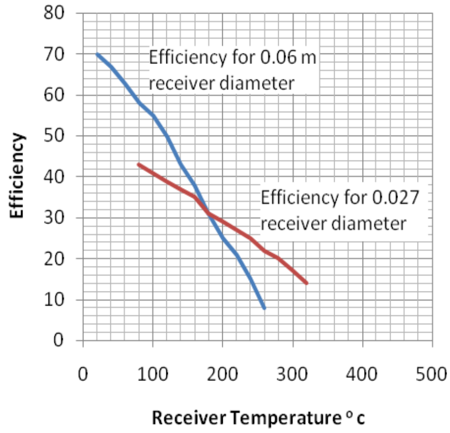

Figure 6: Superimposed graph form figure 3 and 4. [3]

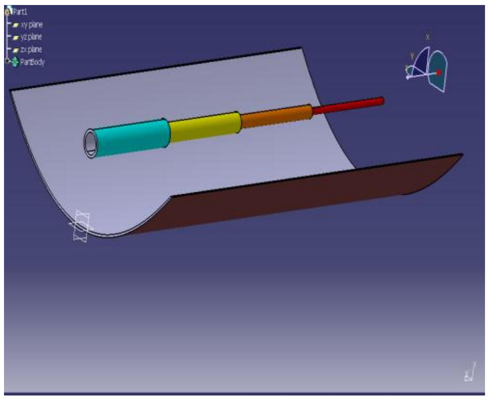

Figure 7: Proposed stepped tube receiver for obtaining variable C.R.

4. Conclusion

The resultant Figure 6 shows, the efficiency of these two receivers of diameter 0.06 m and 0.027 m intersect point at ‘A’. This proves that higher the diameter, higher is the energy intercepted by the receiver. While, the heat loss from the receiver, for a given receiver temperature increases with receiver diameter. Hence to enhance the performance optimization of the concentrator system is necessary by balancing energy intercepted and the heat loss. This can be done using lower concentrator ratio higher receiver diameter at the initial portion of the concentrator where the fluid temperature is low. Further portion of the concentrator where fluid temperature is higher, a high concentrator ratio can be used to reduce the loss of heat through reduction of area of the receiver tube (shown in Figure 7). Thus, the concentrator system will have different diameter receivers offering variable concentration ratio receiver is useful for enhancing performance of solar line concentrator The efficiency of 0.06

m diameter receiver is higher up to receiver temperature of 1700C. However for higher temperature of 0,027m offers higher efficiency. Hence, it can be concluded that use a stepped receiver with diameter of 0.06m up to 1700C and thereafter 0.027m can offer higher efficiency. Hence one can propose a multistepped receiver depending upon the temperature range and the fluid for the system in reference.

Nomenclature

A_a	Aperture area (m^2)	q_u	Rate of useful heat gain (w)
A_r	Area of receiver (m^2)	T_r	Surface Temperature of receiver (^0C)
γ	Intercept factor	T_W	Temperature of water (^0C)

References

[1] J. Krieth and F. Kreder." Principles of solar energy" McGrawHill Book Co.1978
[2] Magal B.S. "Solar power engineering" Tata McGrawHill Book Co.1990
[3] G.O.G.LOF "Energy balance on a parabolic cylindrical solar collector" ASME PP.24-32, Jan1962
[4] Balbir Singh Mahinder Singh, Fauziah Sulaiman, "Designing A Solar Thermal Cylindrical Parabolic trough Concentrator By Simulation "International Rio3 Congress, World Climate and Energy Event, pp. 1-5,December2003.
[5] Houtan Moaveni, "Numerical Analysis and Experimental Study in Design and Operation of Three Solar Parabolic Thermal Power Plants" ,powering, pp.12-14, April 2007,
[6] Prof.G. S. Tasgaonkar, "Studies of Solar Parabolic trough Collector for Air Heating", 1995.P.Hd.Thesis
[7] John A. Duffie, William A. Beckman, "Solar Engineering of Thermal Processes", John Wiley and Sons INC, pp. 324-373, 2006.
[8] Sukhatme S., "Solar Energy, Principles of thermal collection and storage," Tata McGraw Hill-Publication, pp.71-257, 2010.

Author Profile

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