Energy Efficiency of Solar Boiler System with Different Solar Collector

Jogendra Kumar[1], Ashish Sethiya[2]

[1]*Research Scholar (Energy Technology), Rajiv Gandhi Technical University Madhya Pradesh, India*

[2]*Department of Mechanical Engineering, MIT Mandsaur, Madhya Pradesh, India.*

Abstract: To research the final outcome of a system integrated with solar collector by using two different solar collectors in a traditional boiler whose efficiency is to be improved. This paper deals with two different boiler systems whose efficiency is improved by flat plate collector as well as concentric collector. Further it would be considered which of the system can be used for different requirements and cost efficiency of both the systems is to be considered. At the end it would be clear which system would be more beneficial and in what kind of requirement.

Keywords: Solar collector, Flat plate collector, concentric collector, solar boiler, Boiler efficiency, Energy efficiency.

1. INTRODUCTION

Today renewable energy is the most desirable energy source of the world. Worldwide technologies have been developed for improving energy efficiency in different systems, including residential as well as commercial buildings also. In different countries laws have been declared to have certain percentage of energy source to be developed from renewable energy source, for example America has declared to have 20% of total energy requirement from renewable energy source to be necessary. Solar collector is the basic collector which converts solar energy to electrical or heat energy [1]. It is the sun's light which is utilized either as form of heat or light directly or indirectly depending on the requirement and design. Solar flat plate can generate up to 100°C whereas solar concentric collectors are used when higher temperatures are required. Typically concentric solar plate can generate temperature ranging from 100°C to 350°C or more.

Boilers are used to make steam which is used in different works of industry. Here we would develop such traditional boilers by integrating them with solar components so that the efficiency of both boiler and solar collector together would result in higher efficiency for a complete system. Traditional boiler at most gives 81% efficiency. By the help of adding solar collectors to the system we can quite improve the entire efficiency of the system by different methods. In the first case we will use solar flat plate collector with the boiler. However the second case comprises of the solar concentric collector used with the boiler [2].

System description

The different solar integrated boilers are studied in which two different types of solar collectors are used and their boiler parameters are as below:

a. Solar boiler with flat plate collector

The water to be heated is not passed through the collector instead heat collected is transferred to different sections to perform different processes. Any fluid with high heat absorption ratio and boiling point is taken instead [3].

The design of a solar integrated boiler with flat plate collector is as shown. Its parameters are as below:

Parameters of Solar integrated boiler with flat plate collector.

Boiler Capacity	10 T/hr.
Water temperature (after distillation)	50°C
Steam pressure	20 bar
Fuel	Coal
Thermal efficiency of boiler	81%
Average temperature added due to pre-heater	70°C
Temperature rise due to economizer	24°C
Total temperature gain	94°C
Temperature of water feed to boiler	144°C
Heat required for temperature added	94 x 5000 = 470000 kcal/hr
Saving of fuel	470000/ 10000 = 47 kg/hr
Year round saving	8600 x 47 = 404200 kg

So as it can be clearly seen from this that an amount of approx 4lac. Kg of fuel is saved yearly by use of solar pre-heater and economizer. The required area & type of flat plate collector can be decided in the required output and efficiency available depending upon the location. This can be ensured by the below efficiency formula:-

$$\text{Efficiency} = \frac{Q_u}{I_T A_c}$$

There are also other feature advantages of this system that would help in improving efficiency of the entire system [4].The key features of this are discussed below

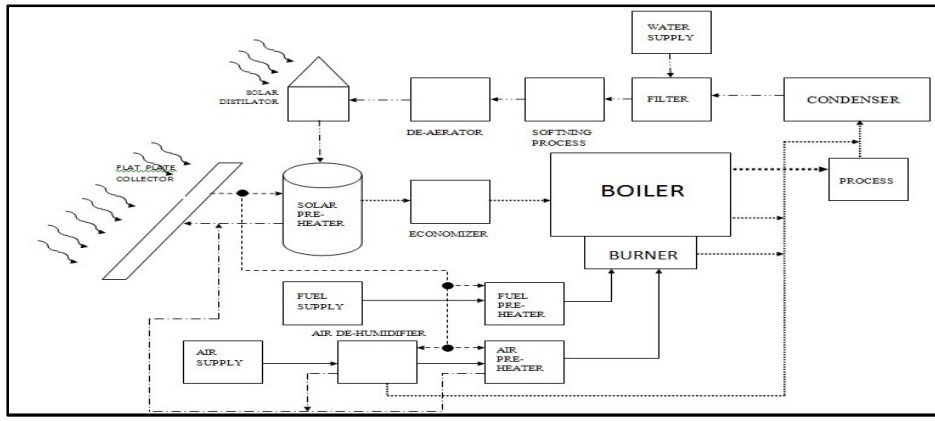

Figure 1: Block diagram of solar integrated boiler with flat plate solar plate

- **Solar distillation:** The water feed to the pre-heater is distilled so as to remove unwanted solid components present in water and pure water is obtained, it also decreases the hardness of water and amount of dissolved gases. The TDS of feed is an important factor for blow down as blow down % is obtained using formula shown below

$$\text{Blow down (\%)} = \frac{\text{Feed water TDS} \times \text{\% Make up water}}{\text{Maximum Permissible TDS in Boiler water}}$$

- **Fuel pre-heater:** This block is operated with the solar thermal energy obtained by the flat plate collector. This helps in reduction of moisture present in fuel as this moisture absorbs heat generated in the burner. It also helps in making the fuel warm before burning which ultimately result in improvement in efficiency as the amount of heat generated by a particular amount of fuel which is pre-heated is quite more than the same amount of fuel which is not pre-heated[2,3].

- Percentage of loss due to moisture in fuel is given by:

$$\text{Loss due to moisture present in Fuel} = \frac{M \times \{584 + C_p(T_f - T_a)\}}{\text{GCV of fuel}}$$

- Air De-Humidifier & Air pre-Heater: The Air or Oxygen feed to the burner for combustion is de-humidified and pre-heated with the help of solar energy. This helps in complete combustion as well as reduction in loss of heat due to moisture present in the air. This loss is calculated as follows:

$$\text{Loss due to moisture present in Air} = \frac{\text{AAS} \times \text{humidity factor} \times C_p \times (T_f - T_a)}{\text{GCV of fuel}}$$

These excess solar elements which are integrated with the boiler do not hold a key position in the production of steam they just add to the efficiency of the entire system. So there is no harm to use such an arrangement for a round the clock process, the only thing to be considered is that in the absence of solar energy the efficiency will drop down to the original boiler efficiency and not the new system efficiency.

B. Solar boiler with concentric collector:

The water to be heated is passed through the collector instead of only heat transferred to boiler. For this purpose the water is passed through the absorber section of the concentric collector and can be heated up to 300°C or even more [5]. If a steam of such a temperature is required then no excess fuel is burned. Thus completely saving the entire fuel consumption. The design of a solar integrated boiler with concentric collector is as shown. Its parameters are as below:

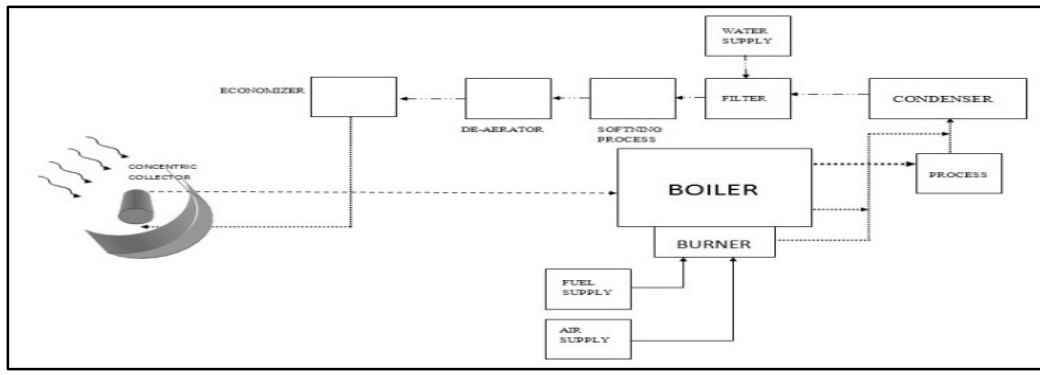

Figure 2: Block diagram of solar integrated boiler with concentric collector.

Table III: Parameters of Solar integrated boiler with concentric collector.

Boiler Capacity	10 T/hr.
Water temperature (after de-aerator)	73°C
Steam pressure	20 bar
Fuel	Coal
Thermal efficiency of boiler	81%
Average temperature added due to concentric solar heater	227°C
Temperature rise due to economizer	24°C
Total temperature gain	251°C
Heat required for temperature added	251 x 5000 = 1255000 kcal/hr
Saving of fuel	1255000 / 10000 = 125.5 kg/hr
Year round saving	8600 x 125.5 = 1079300 kg

So as it can be clearly seen from this table that an amount of approx 10lac. Kg of fuel is saved yearly by use of solar concentric collector and economizer [6].

However the efficiency cannot be further improved by any components like they were in solar boiler using flat plate collector. However we can add distillatory, air de-humidifier, air pre heater & fuel pre-heater but that would use energy in other form resulting in to dropping of energy efficiency of the system.

2. CONCLUSION

The use of solar integrated boiler definitely increases overall efficiency of the system as well it adds up environmental benefits by decreasing use of traditional fuel. Though the gain in concentric type collector used in the boiler system is more than the twice the gain of that in a flat plate type collector used in boiler, the other benefits of flat plate collector system have an upper hand. Flat plate has a drawback of lower temperature gain while concentric collector due to its high temperature gain can also be used alone without other fuel. Both the systems have their pros and cons which are needed to be considered as per requirement. Thus we can look forward to a high breed system including both collectors with their own benefits and cancelling out the drawbacks.

REFERENCES

[1] "Solar Energy Fundamentals and Applications" 1st Revised Edition by H P Garg and J Prakash Published by Tata McGraw Hill.
[2] Sotris A.kalogirou, "Solar thermal collectors and its application" progress in Energy and combustion science, 30(2004) 231-295.
[3] John A. Duffie,"Solar energy thermal processes" Awilly intersciences publication, pp. 15, 1974.
[4] Ing. Marinko Rudic Vranic "Development of a solar collector for thermal applications" 2011.
[5] "Checklist and tips for energy efficiency in thermal utilities" by Bureau of Energy Efficiency.
[6] "Energy performance assessment of boilers" by Bureau of Energy Efficiency.