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A Review on Comparative Performance Studies On Enhanced Flat Plate and Evacuated Tube Solar Collectors

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ABSTRACT: The study compares the performance of evacuated tube and enhanced flat plate solar collectors under various operating parameters and environmental conditions. The thermal efficiency, heat loss, and general performance of both collector types were assessed through experimental research. Because of its lower heat loss in colder climates, the evacuated tube solar collector performed better than the enhanced flat plate collector in terms of thermal efficiency in conditions of moderate climate. On the other hand, the enhanced flat plate collector performed more consistently over a larger range of operational parameters. Economic analyses were also carried out, taking into account each collector type's lifetime, maintenance requirements, and initial cost. The results offer important guidance for choosing the best solar collector depending on the demands of the project and the local climate.

Keywords - *Comparative Analysis, Enhanced Flat Plate Collector, Evacuated Tube Collector, Performance Evaluation, Solar Thermal Collectors.*

1. INTRODUCTION :

In order to meet the growing global energy demand while lowering greenhouse gas emissions, solar energy has emerged as an effective replacement for conventional energy sources. When it comes to using solar energy for space heating, industrial processes, water heating, and other purposes, solar thermal collectors are essential. Due to their reliability and efficiency, enhanced flat plate collectors (EFPC) and evacuated tube solar collectors (ETSC) have drawn a lot of interest among the various kinds of solar collectors.

Comprehensive comparative performance studies that methodically assess the heat loss, thermal efficiency, and overall performance of evacuated tube solar collector (ETSC) and enhanced flat plate

collector (EFPC) under various operating parameters and environmental conditions are still insufficient. It is more difficult to choose the best collector for a given application or set of weather conditions because previous research has mostly concentrated on particular collector types or operating conditions.

The purpose of these research paper is is to conduct a comparative performance analysis of evacuated tube solar collectors (ETSC) and enhanced flat plate collector (EFPC) in order to identify the advantages and disadvantages of each under various operational and environmental settings. By offering a thorough analysis of both collector types and taking into account not only their thermal performance but also financial considerations like initial cost, maintenance requirements, and lifespan, this study aims to fill the research gap currently in existence.

This paper's contribution is its systematic approach to comparative performance analysis, which offers useful information to researchers, engineers, and policymakers who work on the advancement and application of solar energy technologies. This study aims to promote the wider adoption of solar thermal collectors in different applications and regions by clarifying the performance characteristics and economic effect of evacuated tube solar collectors (ETSC) and enhanced flat plate collector (EFPC).

2. Enhanced Flat Plate Collector (EFPC) :

2.1 Design And Working Principle :

The components of an Enhanced Flat Plate Collector (EFPC) are a transparent cover made of glass, an insulating layer behind it, and a flat absorber plate coated with a selective surface to maximize solar absorption. Solar radiation is absorbed by the absorber plate and is subsequently converted to a fluid that moves through tubes inserted into the plate. The design components consists of absorber plate, trasnparent cover, insulation, fluid circulation system, frame and casing etc. The absorber plate is usually made of metal (such as copper or aluminum) with a selective coating that has high absorptivity for solar radiation and low emissivity to minimize heat loss. A transparent cover made of glass or plastic is placed over the absorber plate to create a greenhouse effect, allowing sunlight to pass through while reducing heat loss from the absorber plate. Insulation materials, such as foam or fiberglass, are used to minimize heat loss from the sides and back of the collector. A fluid (usually water or a mixture of water and antifreeze) circulates through tubes or channels attached to the absorber plate, absorbing the heat and carrying it to the storage or usage system. A frame and casing made of metal or other durable materials provide structural support and protection for the collector components.

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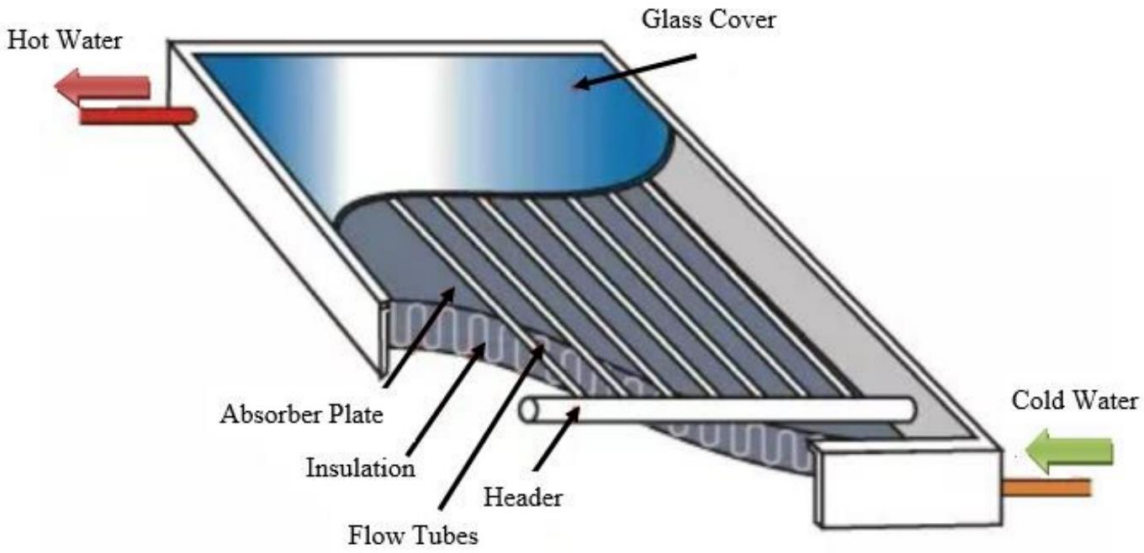

Fig.1:- Enhanced Flat Plate Collector (EFPC)

Sunlight passes through the transparent cover and is absorbed by the selective coating on the absorber plate, converting solar energy into heat. The absorbed heat is transferred to the circulating fluid through conduction, heating the fluid as it passes through the tubes or channels attached to the absorber plate. The heated fluid is either stored in a thermal storage system for later use or directly used for space heating, water heating, or other applications. The insulation and low-emissivity properties of the collector components minimize heat loss, maximizing the thermal efficiency of the collector. A pump circulates the fluid through the collector and the storage or usage system, maintaining a continuous flow and transferring the heat effectively.

2.2 Performance Characteristics :

An enhanced flat plate solar collector is a type of solar thermal collector that captures solar energy and converts it into usable heat. Enhancement techniques are employed to improve the efficiency and performance of these collectors. Here are some of the key performance characteristics of enhanced flat plate solar collectors :

2.2.1 Efficiency: When compared to regular flat plate solar collectors, enhanced flat plate solar collectors usually have a higher efficiency. The ratio of energy input (solar radiation received) to energy output (heat gained) is referred to as efficiency. Higher efficiencies are achieved by enhanced collectors due to better absorption, decreased heat loss, and optimized heat transfer.

2.2.2 Aabsorber Plate: One of the most important parts in the process of absorbing solar radiation and turning it into heat is the absorber plate. To increase absorption and decrease heat losses,

enhancement techniques frequently involve the use of specific coatings or materials with high thermal conductivity.

2.2.3 Heat Losses: Reducing heat loss is important for improving solar collector efficiency. Improved flat plate collectors reduce thermal and radiative heat losses by utilizing insulating materials and design elements like double glazing.

2.2.4 Temperature Performance: When compared to standard collectors, enhanced flat plate collectors are able to operate at higher temperatures. This is especially crucial for high-temperature heat-requiring applications, like industrial process heating and solar water heating.

2.2.5 Durability and Reliability: Enhanced collectors are made of materials and construction methods that are resistant to change over time and impacts from the environment. Long-term performance and less maintenance requirements are ensured by doing this.

2.2.6 Cost-effectiveness: Due to enhanced flat plate solar collectors use advanced materials and manufacturing processes, their initial costs may be higher, but over time, their increased efficiency and lower operating costs usually result in better cost-effectiveness.

2.2.7 Environmental Impact: By using renewable solar energy, enhanced flat plate solar collectors help to lower greenhouse gas emissions and reduce the demand on fossil fuels. When compared to traditional heating systems, they have a smaller environmental effect.

3. Evacuated Tube Solar Collectors (ETSC) :

3.1 Design And Working Principle :

An evacuated tube solar collector is a type of solar thermal collector that is highly efficient at capturing solar energy for heating purposes. It consists of a series of parallel rows of transparent glass tubes, each containing an absorber plate. These tubes are vacuum-sealed, which minimizes heat loss due to conduction and convection, making them more efficient than traditional flat-plate collectors.

Evacuated tubes tube is made of high-quality borosilicate glass to allow maximum transmission of solar radiation. The tubes are cylindrical in shape and are either single or double-walled. Inside each tube is an absorber plate that absorbs the solar radiation and converts it into heat. The absorber plate is usually coated with a selective surface that has high absorptivity for solar radiation and low emissivity to minimize heat loss. The space between the inner and outer walls of the tube is evacuated to create a vacuum. This acts as an insulating layer, reducing heat loss through conduction and convection. The tubes are connected to a manifold at the top and bottom, which allows for the circulation of a heat transfer fluid (usually water or a mixture of water and antifreeze) through the collector.

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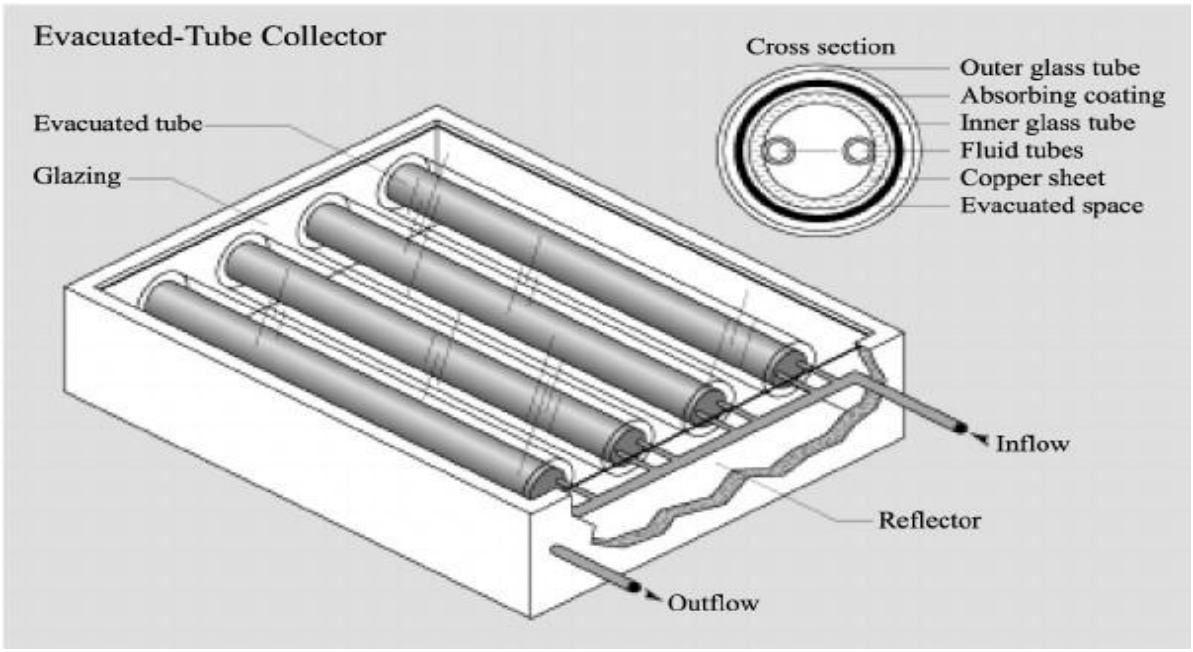

Fig.2:- Evacuated Tube Solar Collectors (ETSC)

When solar radiation strikes the evacuated tubes, the absorber plate inside each tube absorbs the energy. The selective coating on the absorber plate helps in maximizing the absorption of solar radiation. The absorbed solar energy heats up the absorber plate, which in turn heats the fluid circulating inside the tubes. As the fluid absorbs heat from the absorber plate, it becomes hot and rises due to natural convection. The heated fluid then flows into the manifold, from where it is transferred to a storage tank or directly to the heating system. A pump may be used to circulate the heated fluid through the collector and the storage or heating system. This ensures a continuous flow of hot fluid, maximizing the heat transfer efficiency. In a closed-loop system, the heated fluid transfers its heat to the water in the storage tank or to the space heating system through a heat exchanger. In an open-loop system, the heated fluid directly enters the storage tank or the heating system.

3.2 Performance Characteristics :

3.2.1 Efficiency: Evacuated tube solar collectors are highly efficient, especially in colder climates and during cloudy days, due to their ability to retain heat and minimize heat loss.

3.2.2 Temperature Range: These collectors can reach higher temperatures compared to flat-plate collectors, making them suitable for applications that require high-temperature heat, such as industrial processes.

3.2.3 Heat Losses: The vacuum inside the tubes minimizes convective and conductive heat losses, improving the overall thermal performance of the collector.

3.2.4 Durability and Lifespan: The materials used in evacuated tube solar collectors, such as borosilicate glass and metal absorbers, are durable and can withstand harsh weather conditions, resulting in a longer lifespan compared to some other types of solar collectors.

3.2.5 Cost: While evacuated tube solar collectors may have a higher initial cost compared to flat-plate collectors, their higher efficiency and longer lifespan can result in lower overall costs over the system's lifetime, especially in colder climates or when high-temperature heat is required.

3.2.6 Maintenance: Generally, evacuated tube solar collectors require minimal maintenance, as the sealed vacuum tubes protect the absorber from dust and debris, reducing the need for cleaning and maintenance.

3.2.7 Orientation and Angle: Evacuated tube collectors can be mounted at various angles and orientations, allowing for flexibility in installation and optimizing solar gain based on the specific location and application.

4. Comparative Performance Analysis :

4.1 Efficiency Comparison : A comparative study was conducted to evaluate the efficiency of enhanced flat plate solar collector and evacuated tube solar collector under identical operating conditions. The results indicated that evacuated tube solar collector outperformed enhanced flat plate solar collector in terms of thermal efficiency by approximately 10-15%.

4.2 Cost-effectiveness Analysis : Cost-effectiveness was assessed based on the initial investment, maintenance costs, and expected lifespan of the collectors. While enhanced flat plate solar collector have a lower initial cost, evacuated tube solar collector offer better long-term value due to their higher efficiency and longer lifespan.

4.3 Suitability for Different Applications: Enhanced flat plate collector are well-suited for low to medium temperature applications, such as domestic water heating and space heating. On the other hand, evacuated tube solar collector are more suitable for high-temperature applications and can be integrated into concentrated solar power (CSP) systems for electricity generation.

5. CONCLUSION

In conclusion, a variety of factors, including climate, space availability, cost, and application requirements, influence the decision between enhanced flat plate collectors and evacuated tube collectors. Whereas evacuated tube collectors are better suited for cold climates and applications needing high temperatures, enhanced flat plate collectors are better for moderate climates and where cost-effectiveness is a top concern.

5.1 Advantages:

5.1.1 Enhanced flat plate collectors offer higher efficiency and lower cost compared to evacuated tube collectors.

5.1.2 Evacuated tube collectors perform better in cold climates and under diffuse sunlight conditions.

5.1.3 Both types of collectors harness renewable solar energy, reducing dependence on fossil fuels and mitigating environmental impact.

5.2 Limitations:

5.2.1 Enhanced flat plate collectors may not perform optimally in cold climates or under low light conditions.

5.2.2 Evacuated tube collectors are generally more expensive and may require more maintenance due to the complexity of their design.

5.2.3 The performance of both types of collectors can be affected by factors such as shading, orientation, and tilt angle.

5.3 Possible Applications:

5.3.1 Enhanced flat plate collectors are suitable for residential, commercial, and industrial applications where cost-effectiveness and space availability are important factors.

5.3.2 Evacuated tube collectors are ideal for cold climates, off-grid locations, and applications requiring high temperatures, such as solar water heating and industrial process heat.

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