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TO STUDY THE ASSESSMENT OF THERMAL PERFORMANCES OF SOLAR HOT WATER SYSTEMS

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ABSTRACT

The array of solar collectors was built and the cylindrical tubes were joined in order to fabricate the solar water hot water systems. The storage tank was attached to this array. The cylindrical tubes' lower edges were fastened to the supporting base. The concentrators were fastened to the supporting foundation as well as beneath the cylindrical tubes. It is important to note that the connecting auxiliaries were used to fix the integral elements. After conducting a leak test, it was determined that the manufactured solar hot water systems did not leak heat or fluid. In the current study, a solar hot water system was constructed using cylindrical tubes with a nano-absorptive covering. The solar hot water system was similarly constructed using cylindrical tubes with anti-reflective and nano-absorptive coatings. The second heating device was made using cylindrical tubes based on nano copper oxide absorptive coating, whereas the first heating device was made using cylindrical tubes based on nano aluminium oxide absorptive coating. Nano copper oxide absorptive and silicon oxide anti-reflective coatings based cylindrical tubes were used to manufacture the third heating device. The thermal performances of each of these hot water systems were evaluated through testing.

KEY WORDS: *Thermal Performances, Solar Hot Water Systems, Nano Copper Oxide.*

INTRODUCTION

The current study examined the physics of solar thermal hot water systems in relation to heat transmission to the working fluid, absorption of incident solar radiation, and thermal performance of solar water heating collectors. In light of this, the current study project was especially concerned with evaluating the thermal performances of solar cylindrical tubular collectors using recently developed concentrators. The evaluation of the thermal performance of solar cylinder tube collectors with different nano-absorptive and antireflective coatings was another particular emphasis of the current research project. The solar cylindrical tubular collectors in these views were purchased with different tube coatings. Additionally, several materials for the concentrators were created for the solar cylindrical tube collectors. Following development, tests were conducted on the integrated hot water systems with solar cylinder tube collectors to assess temperature increases, thermal gains, and thermal performances.

The recently developed cylindrical concentrators were mounted beneath the cylindrical tabular collectors in the current study project. The first concentrator was constructed using LG stainless steel, and the second concentrator was constructed using MG stainless steel. Furthermore, the third concentrator was constructed using HG stainless steel. All of these concentrators were installed beneath the hot water systems' cylindrical tube collectors, and an experimental evaluation of the systems' thermal capabilities was conducted.

Thirty degrees Celsius of water was kept in the storage tank and allowed to flow through the collector. The water heated up as the collector came into contact with the sun. During the hours of sunshine, the circulation process was maintained and the hot water generated could travel to the storage tank. The main characteristics, including the water's entrance and outflow temperatures, were noted during the experiment. The influencing factors, which included wind speed, ambient temperature, and incident solar radiation, were also noted. It is important to note that the experiments were performed seven days in a row, increasing the working fluid's temperature by 10 degrees Celsius each time. The temperature rises of the outlet water were also noted, along with the factors that influenced them. It is also important to note that the thermal performances of solar collectors were estimated experimentally, and that major and influencing parameters were documented along with advances in thermal performances.

SOLAR COLLECTORS

The devices that transform the radiated energy into thermal energy are called solar collectors. They transform the radiated energy into heat by either absorbing it or concentrating it. They transmit heat to the fluid that passes past them. Concentrating collectors are solar collectors that track the sun. Power towers, parabolic dish collectors, and spherical dish collectors are a few types of concentrators. Non-concentrating collectors are solar collectors that do not follow the sun. Flat plate collectors and cylindrical tubular collectors are two types of non-concentrating collectors. The integral components of flat plate collectors include the glass cover, which can be toughened, plain, or nano-textured to transmit incident solar radiation, the absorber, which can be flat, corrugated, or grooved and attached with tubes to absorb transmitted solar radiation, and the insulation, which lowers heat loss from the collector's sides and back. According to the solar flat plate collector's operating concept, sunlight strikes the glass cover of the device. It passes through the cover made of glass. The absorber gets heated as a result of the transmitted radiation striking it. The fluid that travels through the absorber's tubes receives the thermal energy that is produced. Regarding the cylindrical tubular collectors, they consist of integral components like concentrators, which can be flat, V-shaped, or U-shaped to reflect radiation on the bottom sides of cylindrical tubes, and cylindrical tubes, which are shaped like tubes for the purpose of transmitting incident radiation, absorbing transmitted radiation, and transferring heat to the fluid. Regarding the cylindrical tubular collector's operation, solar radiation strikes the collectors outside glass cover. It passes through the exterior pane of glass. The black-coated inner glass cover is struck by the transmitted radiation on its exterior. The surface covered in black coating heats up as a result of absorbing the transmitted radiation. The fluid that goes through the collector receives the created heat energy. The hot fluid that is produced is then utilized for low temperature applications in the commercial, industrial, residential, and agricultural sectors.

DESIGN AND FABRICATION OF SOLAR COLLECTORS

Material properties, thermal properties, and contiguous properties were the three main attributes of the solar collectors. Heat capacity, heat conductivity, and heat transfer rate fall under the division of thermal characteristics, but mass, density, strength, modulus of elasticity, and melting point are within the division of material characteristics. Contiguous qualities also include resistance to UV deterioration, moisture dispersion, and pollutant degradability. When designing and manufacturing solar collectors, careful consideration should be given to all of these features of the essential components of collectors as well as solar collectors.

The sizes of the solar collectors' main components, supporting components, and solar collectors themselves were listed. Integral pieces come in the following sizes: thickness, breadth, length, and spacing between vital sections. The dimensions of the supporting components include their thickness, breadth, length, and separation from one another. The dimensions of the solar collectors included their height, width, length, gross area, and aperture area all at the same time. When designing and fabricating solar collectors, careful consideration must be given to all of these sizes of the collectors' essential parts as well as solar collectors.

The solar collector must be constructed so that it can have an insulation layer at the bottom, an absorber in the center, and a glass cover at the top. Additionally, the solar collector must be built so that its supporting components may be positioned correctly on the solar fluid heating collector. In order for the collector to hold the integral and supporting parts at the proper locations of the collector, the materials, forms, and sizes of the integral parts as well as collectors must be optimized constructed collectors. To create collectors that are dependable, portable, and compact, all of these aspects pertaining to the sizes, forms, and materials of integral pieces must be carefully taken into account.

THERMAL EFFICIENCYOF SOLAR COLLECTORS

The ratio of the useable energy gain to the incident solar energy during a given period is known as the collecting efficiency. According to the study evaluations, wind speed, ambient temperature, and incident sun radiation all affect thermal efficiency. The research review also reveals that the fluid's mass flow rate, specific heat capacity, and temperature increase all affect the fluid's thermal efficiency. The study's findings show that the glass cover's aperture area, the collector's area of shadow covering, and the amount of dust on it all affect thermal efficiency. The study's findings also show that the values of the glass cover's transmittance, absorber's absorptance, and insulator's thermal resistance at different thicknesses all affect thermal efficiency. In this regard, it is preferable to test the solar collectors under ideal climatic conditions in addition to optimizing the fluid's mass flow rate. In addition, it is preferable to use supporting components with optimal sizes in designated locations in addition to integral parts with improved transmittance, absorptance, and thermal resistance. The solar collectors' optimal thermal efficiency will be realized by integrating integral pieces with desired properties. The improved thermal efficiency will be realized by adding integral components to solar collectors that have desired structural, optical, and thermal properties.

RESEARCH METHODOLOGY

DESIGN AND FABRICATION OF FLAT PLAT SOLAR WATER HEATING COLLECTOR

The BIS standards served as the foundation for the design of the flat plat solar water heating collector used in this research project. The idea of water flowing via risers and headers using the thermosyphon method served as the foundation for the construction of the solar collector. Figure 1 shows the water flow via the fluid carriers of the current study's solar collector.

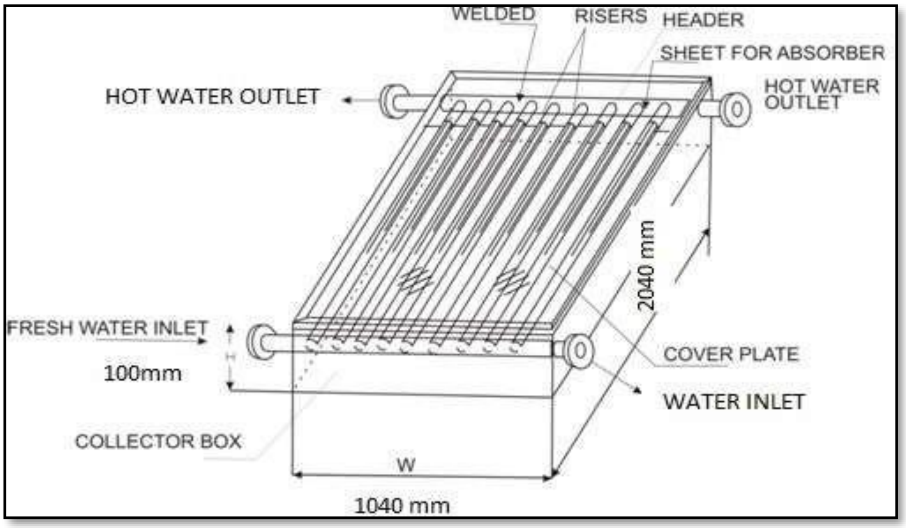

Figure -1 Design of solar collector

In order to maximize the production of efficient water heating in the solar collector, this design was carefully chosen. The improved thermal performance of the solar water heating collector would be expected given that the design was created with efficient water heating in mind.

The MNRE requirements served as the foundation for the construction of the flat plate solar collector used in this research project.

THEORETICAL COMPUTATION OF THERMAL PARAMETERS OF SOLAR WATER HEATING COLLECTORS

Thermal parameters including thermal performance and thermal losses were calculated theoretically. The calculated and empirically discovered results on thermal performances and thermal losses were contrasted. As far as is known, the sun-earth distance only varies by 1.7% due to the direction of the earth's orbit around the sun. The radiant energy flux received per second by a surface of unit area held normal to the direction of the sun's rays at the mean earth-sun distance, outside the atmosphere, is essentially constant throughout the year because solar radiation outside the earth's atmosphere is almost always of nearly fixed intensities. The value of this, also known as the solar constant Isc, is determined to be 1367 W/m2. The earth orbits the sun in an elliptic route, with the sun at one of the foci, rather than a circular one, which causes variance in the amount of extraterrestrial radiation. In terms of solar constant (Isc), the intensity of extraterrestrial radiation Iext measured on a plane normal to the radiation on the nth day of the year is expressed.

RESULTS AND DISCUSSION

Three newly designed concentrators were manufactured for the cylindrical tubular solar hot water systems used in the current study project. A MG-SS concentrator was used in the second cylindrical tubular solar hot water system, whereas an LG-SS concentrator was used in the first. The HG-SS concentrator was used in the construction of the third cylindrical tubular solar hot water system at the same time. According to Indian requirements, the thermal characteristics of these three solar hot water systems were determined through experimentation. The maximum temperature increase of the water in the cylindrical tubular solar hot water system with the LG-SS concentrator was 26.7°C during a period of seven days. The heating device's greatest thermal performance was 45.3%, despite its maximum thermal energy storage capacity of 2.89 KWh. The maximum temperature increase of the water in the cylindrical tubular solar hot water system with the MG-SS concentrator was 30.6°C during a period of seven days. The heating device's greatest thermal performance was 45.9%, despite its maximum thermal energy storage capacity of 3.37 KWh. The maximum temperature increase of the water in the cylindrical tubular solar hot water system with the HG-SS concentrator was 19.2°C during a period of seven days. The heating device's greatest thermal performance was 46.4%, despite its maximum thermal energy storage capacity of 3.53 KWh. When the thermal parameters of solar hot water systems with different concentrators were compared, it was discovered that the solar hot water system with the HG-SS concentrator had the highest temperature enhancement of the water, the thermal energy stored in the device, and the thermal performance of the heating device. Based on the research findings, it is possible to draw the conclusion that, depending on the end users' temperature needs, the solar hot water system with HG-SS concentrator would be favoured in the application sectors.

Table:1- Estimated thermal efficiency of solar hot water system(Cylindrical tube with HG-SS concentrator)

Day	**Solar radiation(W/m^2)**	**Rise in Temperature(°C)**	**Thermal efficiency(%)**
1	568.2	18.7	43
2	544.5	17.4	43
3	600.4	19.4	42
4	607.7	18.3	35
5	550.2	14.7	32

6	610.3	15.5	34
7	550.7	13.7	33

The cylindrical tubular solar hot water systems with three nano absorptive and antireflective coatings were also constructed as part of the current research project. The second heating device was made using cylindrical tubes based on nano copper oxide absorptive coating, whereas the first heating device was made using cylindrical tubes based on nano aluminum oxide absorptive coating. Nano copper oxide absorptive and silicon oxide anti-reflective coatings based cylindrical tubes were used to manufacture the third heating device. According to Indian requirements, the thermal characteristics of these three solar hot water systems were determined through experimentation.

Table:2- Estimated thermal losses of solar hot water system(Cylindrical tube with HG-SS concentrator)

Day	**Incident energy(J/s)**	**δ T (°C)**	**X**
1	1133.0	11.5	0.04
2	1088.3	16.3	0.06
3	1201.3	22.7	0.08
4	1215.0	27.3	0.08
5	1100.4	30.3	0.07
6	1220.4	33.2	0.07
7	1101.3	40.3	0.05

The maximum temperature increases of the water in the cylindrical tubular solar hot water systems with nano aluminum oxide absorptive coating-based tubes was 30.0^{o}C over a period of seven days. The heating device's greatest thermal performance was 41.8%, despite its maximum thermal energy storage capacity of 4.72 KWh.

The maximum temperature increases of the water in the cylindrical tubular solar hot water systems with nano copper oxide absorptive coating-based tubes was 29.2^{o}C for a period of seven days. The heating device's greatest thermal performance was 47.7%, despite its maximum thermal energy storage capacity of 4.22 KWh.

Over the course of seven days, the maximum temperature enhancement of the water in the cylindrical tubular solar hot water systems with nano copper oxide and silicon oxide antireflective absorptive coating-based tubes was 24.1^oC. The heating device's greatest thermal performance was 50.1%, despite its maximum thermal energy storage capacity of 4.92 KWh.

The highest temperature enhancement of water, thermal storage in the device, and thermal performance of the heating device were found in solar hot water systems with nano copper oxide absorptive and nano silicon oxide antireflective coating based cylindrical tubes. These findings were made while comparing the thermal parameters of solar hot water systems with variations in nano absorptive and antireflective coatings based cylindrical tubes. Based on the results of the experiments, it is possible to draw the conclusion that, depending on the end users' desired temperature, solar hot water systems with cylindrical tubes based on nanosilicon oxide antireflective and nanocopper oxide absorptive coatings would be preferable in the application sectors.

CONCLUSION

The current component materials would be utilized in solar water hot water systems since the integration of nanocomposite coated cylindrical tubes and concentrator could improve the thermal performance. Solar hot water systems would use cylindrical tubes with anti-reflective and nano-absorptive coatings integrated with solar collectors, which could lead to improved thermal performances. The newly developed and nanocomposite coated components would be utilized in future solar hot water systems since they raise the temperature of the water, the thermal gain of cylindrical tubes, and the thermal performances of hot water systems.

Using calibrated measurement devices, the sizes of the fundamental and supplemental components of solar hot water systems were measured in experimental experiments. Furthermore, the same calibrated measurement tools were used to quantify the sizes of the storage tanks and collectors. According to the parameters given in Indian standards, the values found in relation to the sizes of the components, collectors, and storage tanks were deemed to be appropriate. It is important to note that the current solar collector sizes were chosen with acceptability in mind for the design, tolerance for the fabrication process, and tolerance for the scaling up process.

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