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EXPERIMENTAL INVESTIGATION OF THERMAL PERFORMANCE OF CURTAIN-WALL-INTEGRATED SOLAR HEATER

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ABSTRACT

A wall-integrated solar heating system refers to an architectural design approach that combines hot water generation with the building's construction system. This combination allows this system to feature a hot water generation function and become part of the building façade. Environmental control devices and/or designs in buildings that are capable of harvesting solar thermal energy can effectively capture and store this solar energy and provide energy through the use of, for instance, a hot water system or a low-power thermoelectric material. Thermal energy storage (TES) is the key component for such solar energy use, and it is one of the most promising and sustainable methods for energy storage in buildings. The TES systems used in buildings can be easily divided into three types: sensible, latent, and thermo chemical energy storage (TCES).Because of its numerous advantages, such as its wide range of storage temperatures, high thermal capacity, non toxicity, low cost, and easy obtain ability, water is often used as the storage medium in a solar water heating (SWH) system for domestic solar utilization. However, more effective integration of solar collection in SWH systems within the building envelope is always desirable.

In this study, we have attempt to combine the curtain wall structures, building construction practices, heat transfer mechanisms, and a natural circulation loop designed to develop an innovative, wall-integrated solar heater using $CuO+H_20$ nanofluid on the concept of an “energy-harvesting” façade. This work accomplished by performing an experimental investigation using two different types working fluid, water and CuO+water nanofluid with 1%, 2%, 3% of volume fraction of nanopowder. For this combination of working fluid the efficiency of system is found, 42.48%, 48.26%, 55.58% and 66.63% respectively. The highest values of efficiency are found at 108 LPH.

INTRODUCTION

Within the exterior wall of light steel houses, an environmental control device can be placed that can “harvest” solar thermal energy. This device should effectively buffer the solar heat gain and even capture this heat energy and transfer it in such a way that it can be used. At night, this device should be able to use this preserved energy via a hot water system or low-wattage thermoelectric materials during the winter, this device would be able to absorb the limited heat from the sun during the day so that this preserved heat could be transferred indoors, and effective wall insulation should maintain the heat at night. Thus attempts are made to develop an innovative wall heat collection prototype based on the façade energy-harvesting concept.

The present study aims to provide insights into an innovative, wall-integrated solar water heater with nanofluid for which little or no information is available. The thermal performance of the proposed prototype is experimentally investigated for the physical configuration under consideration of particular emphasis in this study, the operational performance assessment of the solar heater under practical conditions.

LITERATURE SURVEY

Chi-ming Lai et al. [1] studied that combined curtain wall structures, building construction practices, heat transfer mechanisms, and natural circulation loop designs to develop an innovative, wall-integrated solar heater based on the concept of an energy-harvesting facade. The heat transfer performance of this prototype was investigated experimentally. The results indicate that the average Nusselt numbers and flow thermal resistances in the heated and cooled sections increase and decrease, respectively, with an increasing modified Rayleigh number under isothermal boundary conditions for the heat sink. During daily use conditions, the system-wide energy harvest ratio of the test cell is between 0.45 and 0.78 and is not significantly affected by the cooling (feed) water flow rates. He found that When the cooling (feed) water flow rate is decreased to 20 or10 mL/s, the system-wide energy harvest ratio and the extract able solar radiation heat of the cooling section are not significantly affected by the cooling water flow rate. However, as the cooling water flow rate is reduced, the average Nusselt number of the cooling section increases. In addition, the average Nusselt number of the heated section displayed a somewhat non-monotonic variation over the range of the cooling water flow rates.

Dharuman et al. [2] Thermal energy storage (TES) is the key component for such solar energy use, and it is one of the most promising and sustainable methods for energy storage in buildings. The TES systems used in buildings can be easily divided into three types: sensible, latent, and thermo chemical energy storage (TCES).Because of its numerous advantages, such as its wide range of storage temperatures, high thermal capacity, no toxicity, low cost, and easy obtain ability, water is often used as the storage medium in a solar water heating (SWH) system for domestic solar utilization.

Corbin and Zhai [3] proposed a BIPV/T collector and demonstrated its potential for providing increased electrical efficiency of up to 5.3% over a naturally ventilated BIPV roof, reducing the negative effects of integration into the building facade. Vijayan et al. [4] studied the effect of the heater and cooler orientations on the single-phase natural circulation in a rectangular loop. Three oscillatory modes and instability were observed in the experiments.

Lai et al. [5] developed and experimentally tested an in-wall heat collection prototype that was simplified to a natural circulation loop with a rectangular configuration. The objective of the present study is to provide insights into an innovative, wall-integrated solar heater for which little or no information is available. The thermal performance of the proposed prototype was experimentally investigated for the physical configuration under consideration. Of particular emphasis in this study was the operational performance assessment of the solar heater under practical conditions. Joshi et al.[6] reviewed standards based on steady-state models for the outdoor testing of domestic thermosyphon-type solar hot water systems.

DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

The experimental test cell can be consisted of an exterior wall plate (1), a vertical flow duct with a square cross section (2), a circulation loop (3), and a cooling sleeve (4). The exterior wall (1) width can be 40 cm and the height could be 80 cm, which is a commonly used curtain wall height.

On one side of the wall, solar radiation will be used to heat the wall surface, simulating the solar radiation received by the exterior wall plate on the other side (inside the curtain wall), the vertical flow duct measured 30 mm wide by 20 mm high and can be welded specifically to form a heat exchanger. The circulation tubes (3) could also use as structural support for the curtain wall; therefore, the tube material used in this study can be copper. The joints between the circulation tube and square duct could be constructed with filet material, and the tubes can be shaped to maintain a constant cross-sectional area throughout the circulation loop. The outer radius of the tube can be 12.7 mm, the inner radius could be 11 mm, and the wall thickness can be 1.7 mm. To align the loop with the exterior wall, we have to fix the horizontal distance S to be approximately 200 mm to match the typical wall thickness. Therefore, the overall exterior size of the test cell was 40 cm wide, 20 cm deep, and 80 cm high, which matches the dimensions of typical metal curtain walls. In addition, valves were installed at the top and bottom of the loop to allow for the removal and addition of fluid.

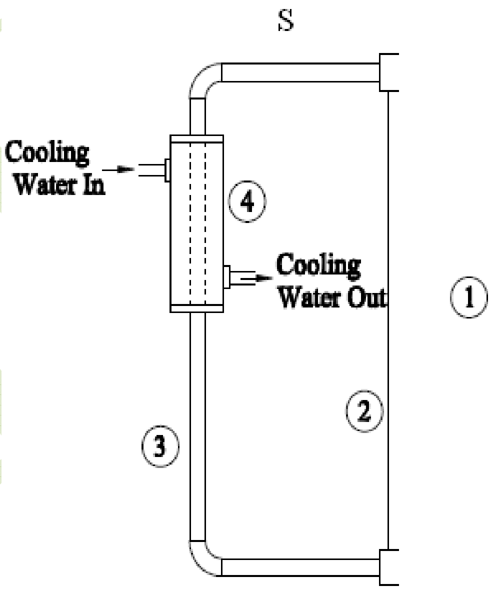

Fig.1.Proposed developed prototype in this study

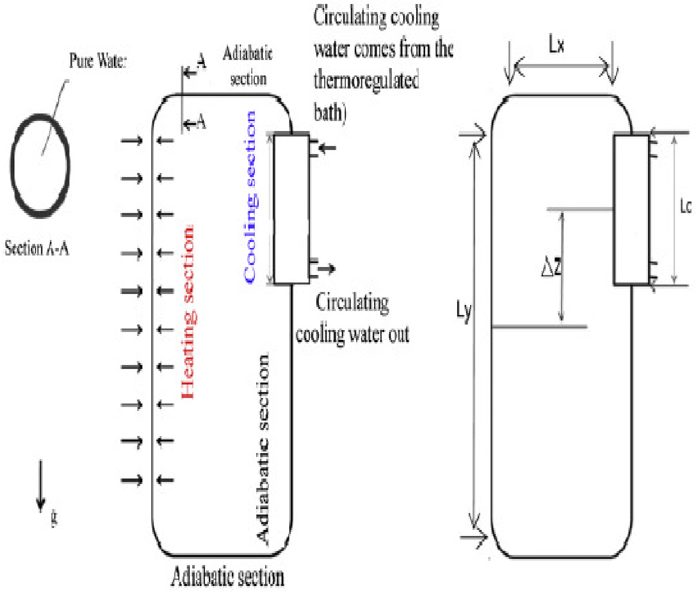

Fig.2: Experimental test cell and geometric parameters.

Test cell, Circulation tubes, Cooling sleeve, Insulating over cooling sleeve, Temperature sensors and indicator, Pyranometer, Calibrated measuring flasks/Rota meter, Flow Control valve

The cooling section (4) can be opposite the heated section. This section includes a cylindrical cooling sleeve made of copper. In addition, the cooled section uses water from a thermally regulated bath to extract heat from the loop. The cooling sleeve measured 61 mm × 300 mm and had internal dimensions of 40 mm × 280 mm. Cotton can be wrapped around the cooled section and the exterior of the circulation tube as insulation to reduce heat losses from the system. Desired radiation intensity measurements can be taken using a pyranometer. We installed K-type thermocouples at various points around the loop to measure the water and wall temperatures. In addition, we have to install the resistance temperature detectors (RTDs) at the cooling water entrance and exit in the cooling sleeve.

TEST METHODOLOGY

In order to Thermal performance of curtain wall-integrated solar water heater with nanofluid, it has been decided to vary the mass flow rate from 36 LPH to 108 LPH in the step of 36 LPH. Heat exchanger is placed at backside of collector. Cold water is get supplied to heat exchanger, it absorb heat from hot fluid. Whole teat set up is mounted vertically.

TEST PARAMETERS AND CALCULATIONS

Experimentation was carried on the designed setup as shown in fig 1.

Table 1 Test parameters

Parameter	Description
Mass Flow Rate	36LPH, 72LPH, 108LPH
Time	11.00am to 4.00pm

All the necessary components were assembled and experimental set was developed. The necessary instruments were attached at correct configuration and the set up is ready for the experimentation.

FORMULAE USED

Heat Supplied by Solar Energy (Qs) = It X A
Heat Gain by hot Water (Qg) = m X Cp X
Efficiency = Qg/Qs

RESULTS AND DISCUSSION

Experiments were carried out by using two working fluids for heat pipes such as: pure water, CuO+water. The results are depicted in Figs. 4.2-4.5. By varying the mass flow rate, inlet water temperature and outlet water temperature for four different working fluid are measured.

Fig 4.1 shows the variations in solar intensity. From fig 4.1 it can be say that variations in solar intensity is very less for all days of testing.

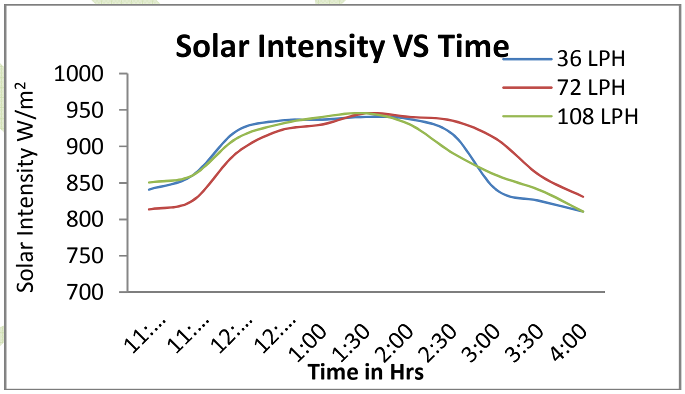

Fig 4.1: Variation in Solar intensity w.r.to Time

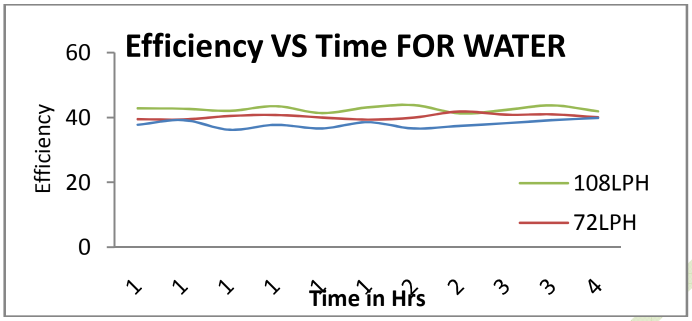

Fig 4.2: Variation in Efficiency w.r.to Time for Water

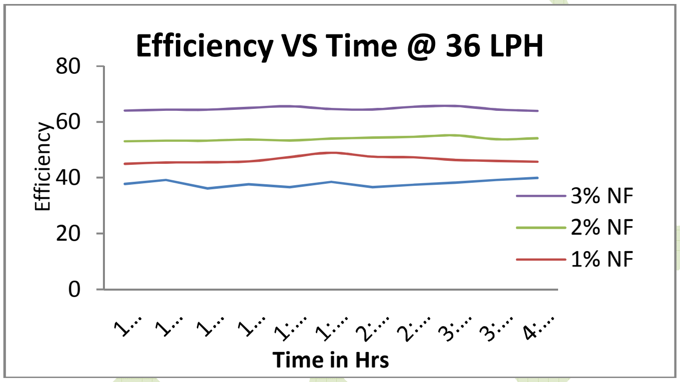

Fig 4.3: Variation in Efficiency w.r.to Time at 36LPH

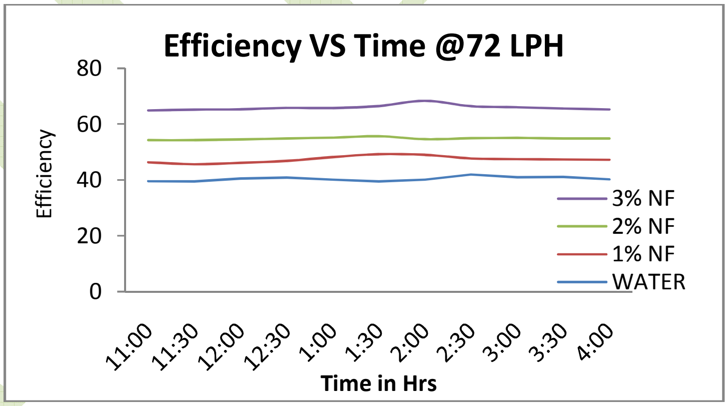

Fig 4.4: Variation in Efficiency w.r.to Time at 72LPH

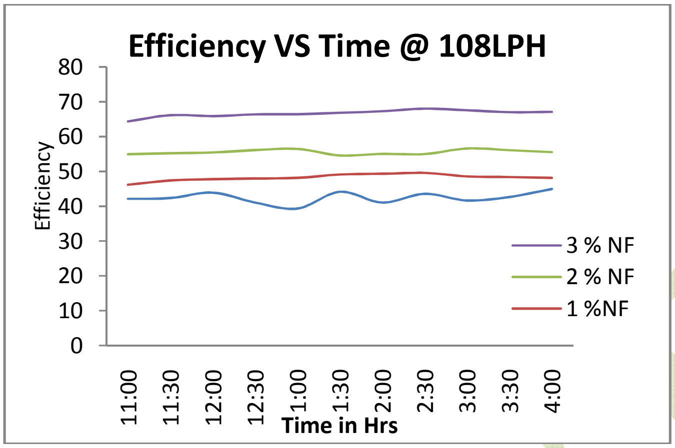

Fig 4.5: Variation in Efficiency w.r.to Time at 108LPH

From Fig 4.2 to Fig 4.5 it is conclude that because of using nanofluid, efficiency of curtain wall-integrated solar water heater is improved.

Fig 4.6 and Fig 4.9 shows the variations in output temperature.

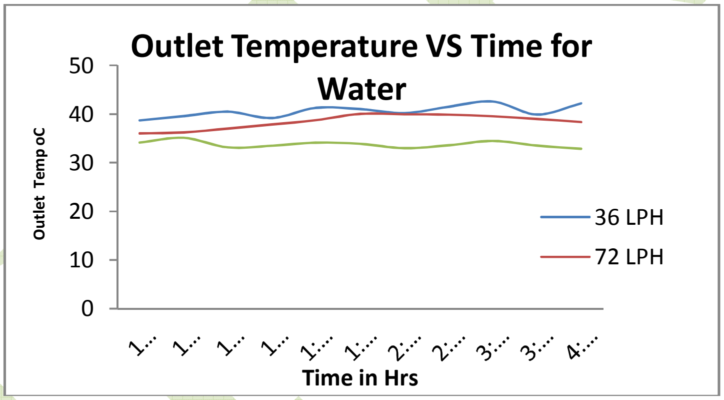

Fig 4.6: Hourly variation at Output Temperature for Water

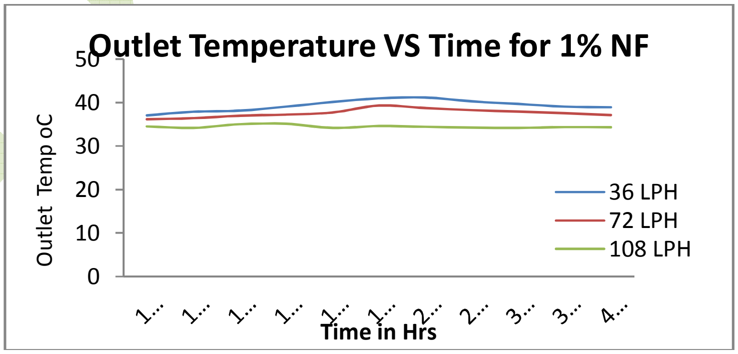

Fig 4.7: Hourly variation at Output Temperature for 1% nanofluid

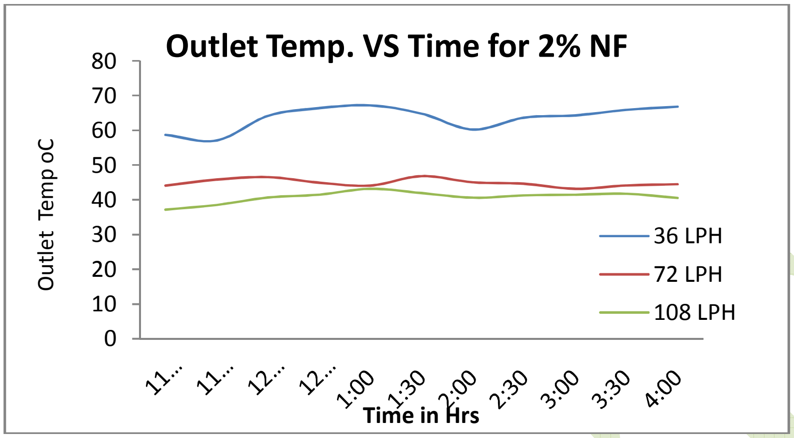

Fig 4.8: Hourly variation at Output Temperature for 2% nanofluid

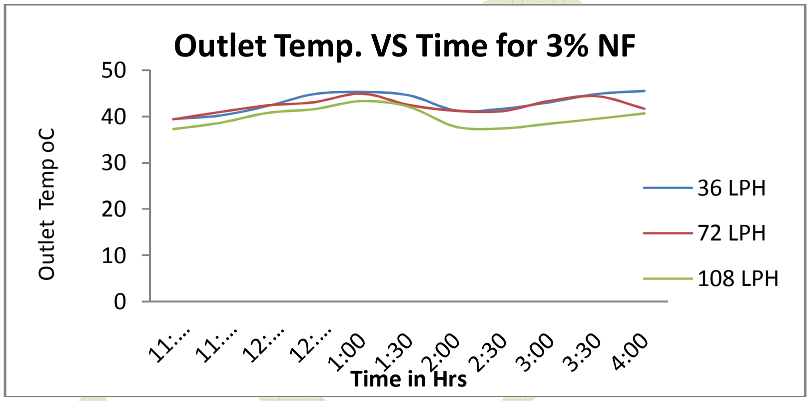

Fig 4.9: Hourly variation at Output Temperature for 3% nanofluid

From Fig 4.6 to Fig 4.9 it is conclude that because of using nanofluid, output temperature of hot water is improved.

CONCLUSION

An experimental study has been carried out to investigate the thermal performance of curtain wall-integrated solar water heater by using different working fluids such as: pure water, CuO+water nanofluid. Following conclusions are made from the experimental study and is detailed below:

- The efficiency thermal performance of solar collector is higher by using 3% nanofluid followed by pure water.
- The outlet temperature is found to increase low mass flow rate for both fluid as pure water and nanofluid.
- For same working fluid efficiency slightly increases as mass flow rate increases.

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