A Review: Experimental performance study on solar water heating system for increasing heat transfer

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ABSTRACT

The purpose of this study is to improve the technology available for solar water heater. It is mature technology still it has many opportunities for modifications. Further research work is required in the field of cost and performance of collector plates and glazing cover plates.

Keyword : - *Solar collector modification, Solar water heating system, Absorber plate technologies, Tube-in flat plate collector*

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1. INTRODUCTION

Solar energy is a sustainable source of energy and environment friendly. According to over 14 years of span report on annual basis from 2000 to 2014 of National Renewable Energy Laboratory USA (NREL), in most of the India, direct solar irradiation intensity is about 4 $kWh/m^2/day$ to 5 $kWh/m^2/day$. But solar water heating technologies are costlier than regular electrical water heating system. Technology improvement efforts for solar water heater should focus on maintaining the performance and reliability of current solar water heater systems and reducing total system installation costs. Recent analysis led to identification of technology improvement opportunities to overcome barriers related to cost, performance, operation and maintenance, and reliability. According to K.Hudon[1], there are many opportunities in field of glazing cover plates and absorber plates in collector designing.

2. SOLAR WATER HEATING SYSTEM

Solar water heaters use solar radiations from sun to heat water. Solar collectors absorb radiations and transfers it to water. Most residential solar water heating system consists of basically five components:

i. Solar thermal collector – flat-plate and evacuated tube collectors are the most typical.
ii. Storage system – they are used to meet the thermal energy demand when solar radiation is not available.
iii. Heat transfer system – piping and valves for liquids; pumps, fans, and heat exchangers (HXs), if necessary.
iv. Control system – They are used to manage the collection, storage, and distribution of thermal energy.
v. Auxiliary storage tank – to provide supplemental heat when solar energy is not sufficient to meet demand. This is typically a conventional electric resistance or natural gas storage tank water heater.

2.1 SOLAR COLLECTOR

Solar collector or solar thermal collectors consist of following basic elements:

i. Flat absorbing plate, normally metallic, upon which the short wave solar radiation falls and is absorbed.
ii. tubes, attached to absorber plate to circulate the liquid required to remove thermal energy from plate.
iii. Thermal insulator provided at the back and sides of the absorber plate to minimize heat losses.
iv. A transparent cover of glass to reduce the upward heat losses from the absorber plate.
v. Weather tight container to enclose all above components and; side and bottom heat losses from absorber plate.

Its major advantages are as following:

i. Absorbs direct, diffuse and reflected components of so
ii. lar radiation.
iii. Fixed in tilt and orientation and thus there is no need of tracking sun.
iv. Easy to make and are low in cost.
v. Comparatively low maintenance cost and long life.
vi. Operate at comparatively high efficiency.

2.2 TYPES OF SOLAR COLLECTORS

Solar collector can be classified by many ways. On the basis of flat plate arrangement, it can be classified as:

i. Lower bounded tube collector: Tubes are bounded below the plates as shown in figure 1.
ii. Upper bounded tube collector: Tubes are bounded above the plates as shown in figure 2.
iii. Tube-in flat plat collector: Tubes are in between the plates as shown in figure 3.

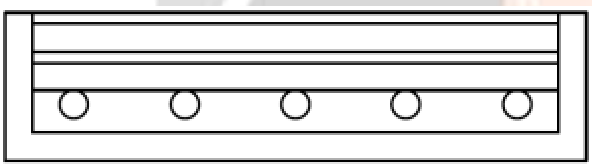

Fig-1: Lower bounded tube collector

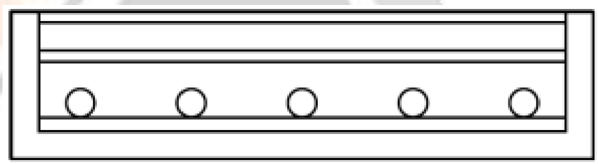

Fig-2: Upper bounded tube collector

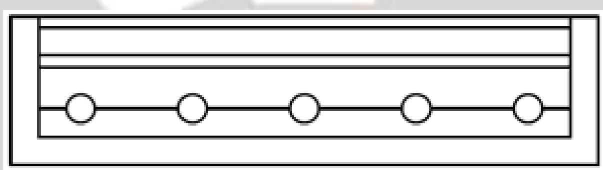

Fig-3: Tube-in flat plate collector

2.3 EXPERIMENTAL SETUP FOR INVESTIGATION

The experimental setup contains some of the basic testing equipment like flowmeter, manometer, pyrheliometer or pyranometer and some thermocouples.

Pyrheliometer are used to measure direct solar radiation and pyranometer is used to measure direct as well as diffused solar intensity. Solar intensity depends on many angles like declination angle of sun, hour angles, tilts of plane from horizontal etc. It also depends on the intrusion of the clouds as in cloudy weather solar intensity can't incident on the earth surface. Generally, the value of the reflectivity is not known precisely for most of the situation, so it is required to use pyrheliometer or pyranometer.

Flowmeter is used to measure flow rate. It is required to know the pumping power and the velocity of fluid flow.

Manometer is used to measure total pressure loss during flowing in bents and do to heat transfer.

Thermocouples are used to measure the temperature at any local points. By using thermocouples, we are calculating inlet and outlet fluid temperature to the collector.

The setup shown in figure 4 is a closed loop consisting of the flat plate collector under test, a liquid pump, a heat exchanger and a storage tank with an electric immersion heater. A bypass is provided around the pump so that the mass flow rate can be adjusted to the prescribed value. The purpose of heat exchanger is to remove heat. Thus the combination of the heat exchanger and the storage tank provide a means for adjusting and controlling the inlet fluid temperature to the collector to a desired value. The standard specifies that the collector shall be tested under clear sky conditions in order to determine its efficiency characteristics. On any given day, data is recorded under steady state conditions for fixed mass flow rate and initial fluid temperature. For each set of fixed values, it is recommended that an equal number of tests be conducted symmetrically before and after solar noon.

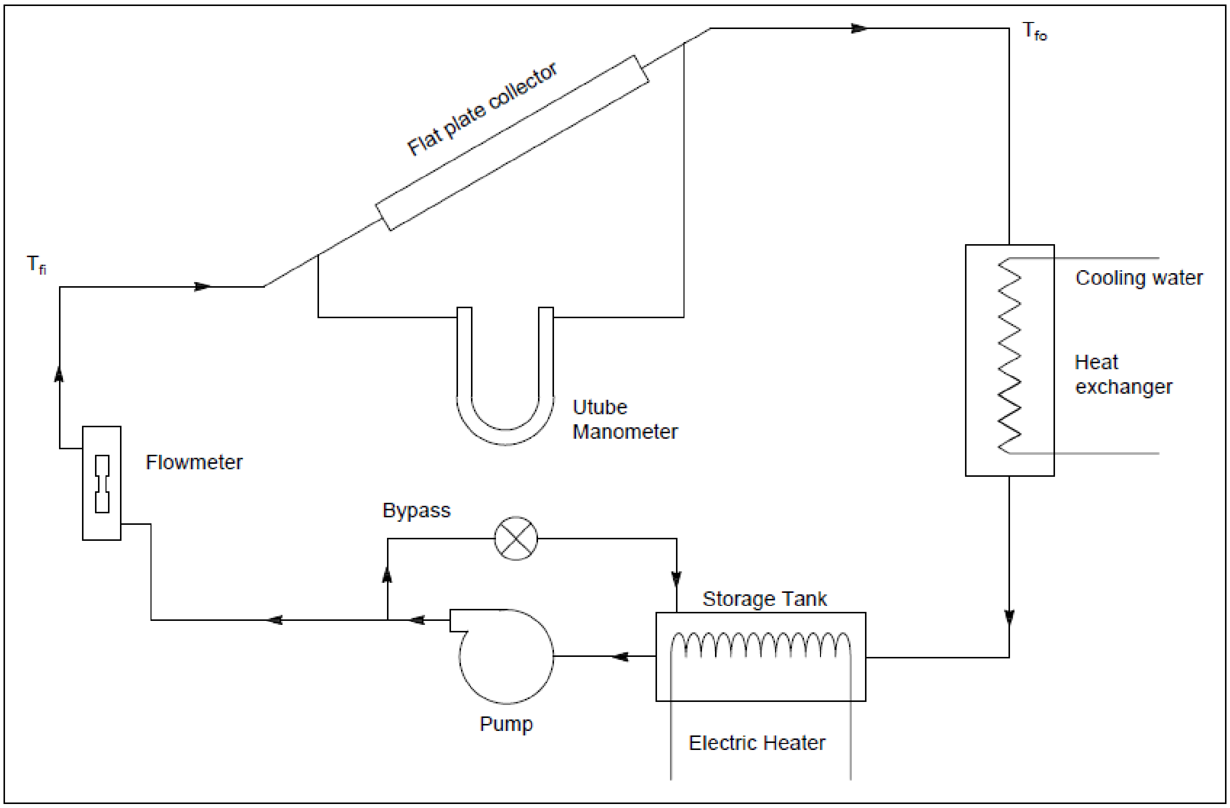

Fig-4: Experimental setup for solar water heater

The principal measurements made in each data set are the fluid flow rate (m), fluid inlet (T_{fi}) and outlet (T_{fo}) temperature of the collector, the solar radiation incident on the collector plane (I), the ambient temperature (T_a), the pressure drop across the collector (ΔP) and wind speed (T_∞). The efficiency is calculated from the equation:

$$Efficiency, \eta = \frac{q}{AI} = \frac{mCp(Tfo - Tfi)}{AI}$$

Where, A is total collector area.

3. SUMMARY OF THE PREVIOUS PAPER

T. H. Holland[2] and Nosa Andrew Ogie[3] explained designing and construction of a solar water heating system. They both explained method to design solar water heating system. According to T.H. Holland[2], efficiency of two covered flat plate collector is 4 percent higher than one covered flat plate collector for residential applications. Similar conclusion can be seen in the results of Nosa Andrew Ogie[3]'s procedure. Nosa Andrew Ogie[3], published paper on design and construction of solar water heater based on thermosiphon principle. They conducted experiment on plate over tube type solar water heating system type collector. They concluded that the insolation increases from low value at 7:00AM got to a peak value between noon and 3:00PM and then fall back to low value. They also explained absorber coating material and its effects.

P. Shivkumar[4], conducted experiments on solar heating system for performance enhancement. He also conducted experiments on flat plate collector solar water heater. They used experimental setup with riser tubes with three different arranges as follow: 9 numbers riser tubes flat plate collector, 12 numbers riser tubes flat plate collector and Zig-Zag arrangement of riser tubes. The collector efficiency at 9.00 hour is 36.4% for 9 riser tubes, 39.2% for 12 riser tubes and 42.00% for zigzag arrangement system. The maximum efficiency is observed at the time 13.00 hour in all the three cases as 53.38%, 59.09%, and 62.90%, respectively. The collector efficiency decreases after 13.00 hour till 17.00 hour in the same manner. The graph reveals that the maximum efficiency is at 13.00 hour in all the three cases. Maximum efficiency is recorded for zigzag arrangement.

M.Z.H. Khan[5], also conducted experiments in solar heating system for efficiency towards sustainable development. They conducted experiments on all the major three seasons. They used zigzag type solar water heating system for experiments. They concluded factors affecting the temperature of hot water. They are as follow: effect of exposure to sunlight, effect of DC heater and effect of carbon powder. Shading in the collector affects the heating of water and the maximum temperature is found during 10:00AM to 1:00PM due to hot, shiny and acute warmness of weather for higher intensity of solar energy. 6V rechargeable battery is used as backup system to heat the system water. Due to use of carbon powder as coating layer in solar heater increase in outlet temperature can be recorded directly proportional to percentage carbon in coating layer.

H.I. Abu-Mulaweh[6], explained designing and development of solar water heating system experimental apparatus. Standardized testing procedure is required for comparing the efficiency of different type of collectors and designing and selection of right equipment. Indian Standard IS: 12933 (1992): part 5 by Bureau of Indian Standard (BIS) can be understand. This is similar to experimental standard given by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Operation and maintenance is explained in Indian Standards IS: 12976 (1990): Solar water heating systems- Code of practice [MED 4: Non-Conventional Energy Sources].

4. REVIEW WORK ON SOLAR WATER HEATING SYSTEM

According to Nosa Andrew Ogie[3], the thermal insolation is highest during noon and due to that efficiency can be maximum during noon hours. It also means that difference between inlet fluid temperature and the surface temperature of collector is higher than the heat transfer will be higher. According to T. H. Holland[2], two mirrored transparent cover is best for designing. If proper insulator materials are applied, then heat loss can be minimized.

According to P. Shivshankar[4], rearrangement of tube and plates is possible can be useful in enhancement of fluid outlet temperature and efficiency of solar water heating system. And according to M.Z.H. Khan[5], carbon powder usage over the tubes can further useful in increasing the tube surfaces temperature.

H.I. Abu-Mulaweh[6] gave a proper methodology to successfully conduct the experiment for solar water heating system.

Solar water heater is a mature technology, but the fact remains that solar water heaters are not cost effective against the current price of natural gas, as was previously identified as the target market for solar water heater technologies. Research and development (R&D) can lead to significant advances in materials, design, and manufacturability, which can contribute to lowering the cost of solar water heaters, improving their performance, and easing installation, both in new construction and in retrofit markets.

On the basis of all the above mentioned, there are many modifications are possible in case of solar water heating technologies. I am contributing in the serpent type solar water heating system. Plates of copper will be joined to tubes as tube-in flat plate type collector. It will increase the outlet temperature of the fluid and efficiency of the system. It may result in pressure drop but serpent type solar water heater is good for the residential utilizations. Insulated container will be made by mineral wool, rock wool or glass wool with aluminium foil cover. Heat gain rate per unit length can be increased by perfectly utilization of absorber plate. A proper setup can be implemented for the experiments as prescribed by BIS and ASHRAE. Using carbon powder is independent parameter so it may be applied.

5. CONCLUSIONS

The main objective of the research work is to increase the outlet temperature and efficiency of the water of solar water heater. To cover all the available area of the solar water heater. It is suggested to use extended surfaces (fins) to the tubes also known as tube-in flat plate type collector. Research work will produce experimental datasheets for the tube-in flat plate collector type solar water.

6. REFERENCES

[1]. K. Hudon, T. Merrigan, J. Burch and J. Maguire, "Low-Cost Solar Water Heating Research and Development Roadmap", National Renewable Energy Laboratory, Prepared under Task No. SHX1.1001

[2]. Nosa Andrew Ogie, Ikponmwosa Oghogho, and Julius Jesumirewhe, "Design and Construction of a Solar Water Heater Based on the Thermosyphon Principle", Ashdin publications, Fundamentals of Renewable Energy and Applications, Vol. 3 (2013), Article ID 23559

[3]. T. H. Holland and J. T. Borzoni, "Design, fabrication, testing and delivery of a solar energy collector system for residential heating and cooling", HONEYWELL INC., Energy Resources, Contract No. NAS8-31327.

[4]. P. Sivakumar, W. Christraj, M. Sridharan, and N. Jayamalathi, "Performance improvement study of solar water heating system," ARPN Journal of Engineering and Applied Sciences, vol. 7, no. 1, pp. 45–49, 2012.

[5]. M. Z. H. Khan, M. R. Al-Mamun, S. Sikdar,1 P. K. Halder, and M. R. Hasan, "Design, Fabrication, and Efficiency Study of a Novel Solar Thermal Water Heating System: Towards Sustainable Development", Hindawi Publishing Corporation, International Journal of Photoenergy, Volume 2016, Article ID 9698328

[6]. H. I. Abu-Mulaweh, "Design and development of solar water heating system experimental apparatus," Global Journal of Engineering Education, vol. 14, no. 1, pp. 99–105, 2012.

[7]. S. Seddegh, X. Wang, A. D. Henderson, and Z. Xing, "Solar domestic hot water systems using latent heat energy storage medium: a review," Renewable and Sustainable Energy Reviews, vol. 49, pp. 517–533, 2015.

[8]. L. Yuwu, C. Linlin, Y. Dandan et al., "The effect of measurement uncertainty and environment on domestic solar water heating systems' energy efficiency grades," Energy Procedia, vol. 70, pp. 371–378, 2015.

[9]. J. K. Kaldellis, K. El-Samani, and P. Koronakis, "Feasibility analysis of domestic solar water heating systems in Greece," Renewable Energy, vol. 30, no. 5, pp. 659–682, 2005.

[10] A. Houri, "Solar water heating in Lebanon: current status and future prospects," Renewable Energy, vol. 31, no. 5, pp. 663–675, 2006.

[11] R. Abdollah and T. Hessam, Experimental investigation on the performance of thermosyphon solar water heater in the South Caspian Sea, Thermal Science, 15 (2011), 447–456.