Review Article

REVIEW OF SOLAR WATER HEATING SYSTEMS

Kishan Patel[1], Mrs. Pragna Patel[2], and Mr. Jatin Patel[3]

Address for Correspondence

[1]Master of Engineering Student, Mechanical Engineering, [2]Asst. Prof., L.D.R.P. Institute of Technology & Research, Gandhinagar-Gujarat.

[3]Lecture, School of Technology, Pandit Deendayal Petroleum University, Gandhinagar-Gujarat

ABSTRACT

In the present review paper, the existing solar water heating systems are studied with their applications. Now a day, plenty of hot water is used for domestic, commercial and industrial purposes. Various resources i.e. coal, diesel, gas etc, are used to heat water and sometimes for steam production. Solar energy is the main alternative to replace the conventional energy sources. The solar thermal water heating system is the technology to harness the plenty amount of free available solar thermal energy. The solar thermal system is designed to meet the energy demands. The size of the systems depends on availability of solar radiation, temperature requirement of customer, geographical condition and arrangement of the solar system, etc. Therefore, it is necessary to design the solar water heating system as per above parameters. The available literature is reviewed to understand the construction, arrangement, applications and sizing of the solar thermal system.

KEY WORDS: solar energy collector, storage tank, active & passive system, heat transfer fluid.

I. INTRODUCTION:

The solar energy is the most capable of the alternative energy sources. Due to increasing Demand for energy and rising cost of fossil type fuels (i.e., gas or oil) solar energy is considered an attractive source of renewable energy that can be used for water hearing in both homes and industry. Heating water consumes nearly 20% of total energy consumption for an average family. Solar water heating systems are the cheapest and most easily affordable clean energy available to homeowners that may provide most of hot water required by a family.

Solar heater is a device which is used for heating the water, for producing the steam for domestic and industrial purposes by utilizing the solar energy. Solar energy is the energy which is coming from sun in the form of solar radiations in infinite amount, when these solar radiations falls on absorbing surface, then they gets converted into the heat, this heat is used for heating the water. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases.

II. SOLAR WATER HEATING SYSTEM

SWH systems are generally very simple using only sunlight to heat water. A working fluid is brought into contact with a dark surface exposed to sunlight which causes the temperature of the fluid to rise. This fluid may be the water being heated directly, also called a direct system, or it may be a heat transfer fluid such as a glycol/water mixture that is passed through some form of heat exchanger called an indirect system. These systems can be classified into three main categories:

(A). Active Systems:

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. So, the Active systems are also called forced circulation systems and can be direct or indirect. The active system is further divided into two categories:

- Open-loop (Direct) Active System
- Closed-loop (Indirect) Active System

(1) Open-Loop Active Systems

Open-loop active systems use pumps to circulate water through the collectors. This design is efficient and lowers operating costs but is not appropriate if the water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in non-freezing climates.

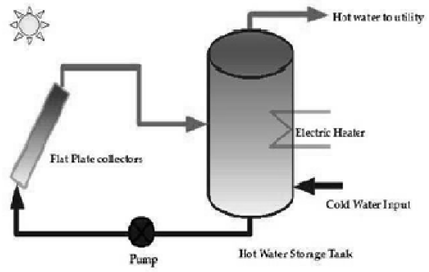

Fig1. Open Loop Active System[1]

(2) Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water stored in the tanks. Closed-loop glycol systems are popular in areas subject to extended freezing temperatures because they offer good freeze protection.

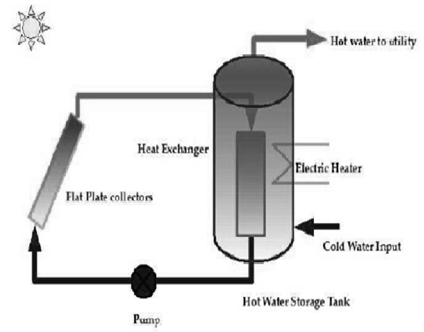

Fig 2.Close Loop Active System[1]

(B).Passive Systems

Passive systems simply circulate water or a heat transfer fluid by natural convection between a collector and an elevated storage tank (above the collector). The principle is simple, as the fluid heats up its density decreases. The fluid becomes lighter and rises to the top of the collector where it is drawn to the storage tank. The fluid which has cooled down at the foot of the storage tank then flows back to the collector. Passive systems can be less expensive than active systems, but they can also be less efficient. Thermosiphon system is the best example of passive systems.

(1)Thermosiphon Systems

In the thermosyphon system, water comes from the over head tank to bottom of solar collector by natural circulation and water circulates from the collector to storage tank as long as the absorber keeps absorbing heat from the sun and water gets heated in the collector. The cold water at the bottom of storage tank run into the collector and replaces the hot water, which is then forced inside the insulated hot water storage tank. The process of the circulation stops when, There is no solar radiation on the collector. Thermosiphon system is simple and requires less maintenance due to absence of controls and instrumentation. Efficiency of a collector depends on the difference between collector temperature and ambient temperature and inversely proportional to the intensity of solar radiation.

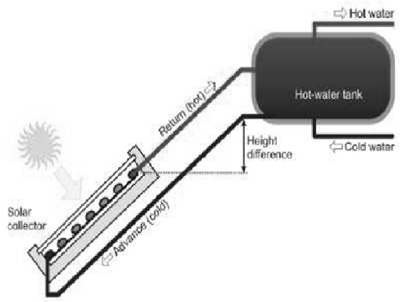

Fig.3Thermosiphon Systems[1]

(c) Batch systems

Batch System (also known as integral collector storage systems) are simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch systems have combined collection and storage functions. Depending on the system, there is no requirement for pumps or moving parts, so they are inexpensive and have few components in other words, less maintenance and fewer failures.

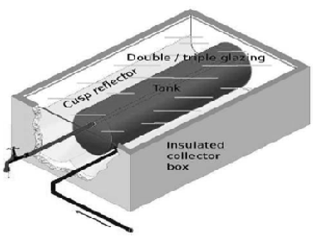

Fig 4.Batch System [1]

III.COMPONENTS OF SOLAR WATER HEATING SYSTEM

SWH generally consists of a solar radiation collector panel, a storage tank, a pump, a heat exchanger, piping units, and auxiliary heating unit. Some of important components are described in the next sections.

(A) Solar Collectors

The choice of collector is determined by the heating requirements and the environmental conditions in which it is employed. There are mainly three types of solar collectors like flat plate solar collector, evacuated tube solar collector, concentrated solar collector.

(1). Flat Plate Collectors

Flat-plate collectors are used extensively for domestic water heating applications. It is simple in design and has no moving parts so requires little maintenance. It is an insulated, weatherproofed box containing a dark absorber plate under one or more transparent covers. They collect both direct and diffuse radiation. Their simplicity in construction reduces initial cost and maintenance of the system. A more detailed picture of these systems is of interest and is presented in the following section.

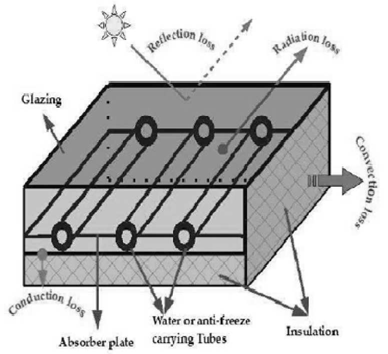

Fig.5 Flat Plate Collector [1]

(2) Evacuated-Tube Collectors

Evacuated-Tube Collectors are made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the tubes to form a vacuum, which eliminates conductive and convective heat loss. They are most suited to extremely cold ambient temperatures or in situations of consistently low-light. They are also used in industrial applications, where high water temperatures or steam need to be generated where they become more cost effective.

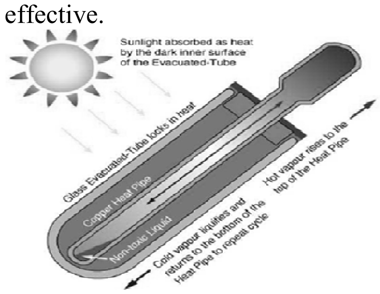

Fig.6 Evacuated Tube Collector [1]

(3).Concentrating Collectors

Concentrating collectors use mirrored surfaces to concentrate the sun's energy on an absorber called a receiver. A heat-transfer fluid flows through the receiver and absorbs heat. These collectors reach much higher temperatures than flat-plate collectors and evacuated-tube collectors, but they can do so only when direct sunlight is available. However, concentrators can only focus direct solar radiation, with the result being that their performance is poor on hazy or cloudy days.

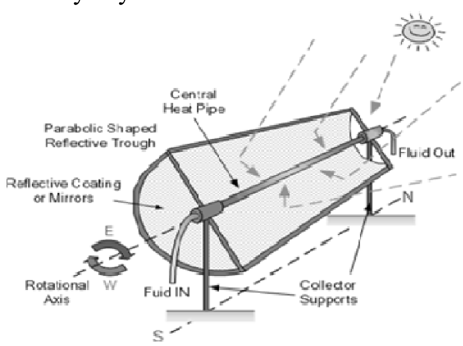

Fig 7.Concentrating Collector [1]

(B).Storage Tank

Most commercially available solar water heaters require a well-insulated storage tank. Thermal storage tank is made of high pressure resisted stainless steel covered with the insulated fiber and aluminium foil. Some solar water heaters use pumps to recirculate warm water from storage tanks through collectors and exposed piping. This is generally to protect the pipes from freezing when outside temperatures drop to freezing or below

(C).Heat Transfer Fluid

A heat transfer fluid is used to collect the heat from collector and transfer to the storage tank either directly or with the help of heat exchanger. In order to have an efficient SHW configuration, the fluid should have high specific heat capacity, high thermal conductivity, low viscosity, and low thermal expansion coefficient, anti-corrosive property and above all low cost. Among the common heat transfer fluids such as water, glycol, silicon oils and hydrocarbon oils, the water turns out to be the best among the fluids. Water is the cheapest, most readily available and thermally efficient fluid but does freeze and can cause corrosion.

IV. REVIEW

Soteris A. Kalogirou [2] presents a survey of the various types of solar thermal collectors and applications. All the solar systems which utilize the solar energy and its application depends upon the solar collector such as flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors which are used in these system. The solar collectors are used for domestic, commercial and industrial purposes. These include solar water heating, which comprise thermosyphon, integrated collector storage, direct and indirect systems and air systems, space heating and cooling, which comprise, space heating and service hot water, air and water systems and heat pumps, refrigeration, industrial process heat, which comprise air and water systems and steam generation systems, desalination, thermal power systems, which comprise the parabolic trough, power tower and dish systems, solar furnaces, and chemistry applications.

Table 1.Comparision of the Collectors [2]

Motion	Collector type	Absorber type	Concentration ratio	temperature range (°C)
Stationary	(FPC)	Flat	1	30–80
	(ETC)	Flat	1	50–200
	(CPC)	Tubular	1–5	60–240
Single-axis tracking	(LFR)	Tubular	15-45	60–250
	(PTC)	Tubular	15–45	60–300
	(CTC)	Tubular	10–50	60–300
Two-axes tracking	(PDR)	Point	100–1000	100–500
	(HFC)	Point	100–1500	150–2000

Samara Sadrin et al [3] present the alternative method of solar water heating system. This automated system would allow the user to get hot water from the solar water heater as long as the solar water heater can supply hot water above a set temperature. If the solar water heater is unable to supply water above the set temperature, then only will the electric water heater come into action. It is efficient because our controller ensures that the solar water heater is used to supply hot water 80% of the time, and the rest 20% will be supplied by the electric water heater. It is cheap because, our system runs on solar energy which is abundant and free. It uses very small amount of electricity and therefore, reduces the expenses for the user.

P. Rhushi Prasad et al [4] present experiment analysis of flat plate collector and comparison of performance with tracking collector. A flat plate water heater, which is commercially available with a capacity of 100 liters/day is instrumented and developed into a test-rig to conduct the experimental work. Experiments were conducted for a week during which the atmospheric conditions were almost uniform and data was collected both for fixed and tracked conditions of the flat plate collector. The results show that there is an average increase of 4^0C in the outlet temperature. The efficiency of both the conditions was calculated and the comparison shows that there is an increase of about 21% in the percentage of efficiency.

Wattana Ratismith et al [5] describes the design of the PTC in which increase the outlet temperature by reducing heat loss. In this design the maximum efficiency of the collector is 32% and has an ability to achieve high output temperature, the maximum temperature at header of evacuated tube is 235 degrees Celsius, and is therefore suitable for high temperature application such as industrial uses.

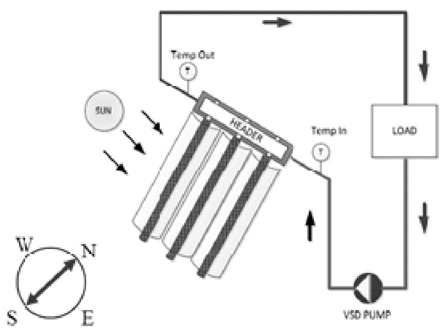

Fig.8 Diagram of Test Arrangement [5]

Krisztina Uzuneanu et al [6] describe optimum tilt angle for solar collectors with low concentration ratio. The performance of any solar energy system depends very much on the availability of solar radiation and the orientation of solar collectors. Solar collectors need to be inclined at the optimum angle to maximize the receiving energy. In this work, we proposed to analyze the optimum tilt angle for compound parabolic collectors CPC with different concentration ratios. There are analyzed the energy gains when the collector keeps the same position during the whole year and when the collector changes its tilt twice a year, on summer and on winter.

Table2: The optimum tilt angles for different concentration ratio, when γ = 0 and ω = 0 for summer and winter [6]

C (concentration ratio)	β (tilt angle)	Q[kWh/m²] (useful energy gain)	β (tilt angle)	Q [kWh/m²] (useful energy gain)	Q [kWh/m²] (useful energy gain)
	Summer		Winter		Year
1	Φ -23	86.065	Φ +2	11.91	97.975
1.2	Φ -23	84.258	Φ +2	12.668	96.926
1.5	Φ -23	85.747	Φ +3	14.435	100.182
1.7	Φ -23	87.035	Φ +4	15.686	102.721
2	Φ-23	89.248	Φ +5	17.419	106.667
2.5	Φ -25	91.248	Φ +4	19.771	111.019
3	Φ -21	92.923	Φ +8	21.376	114.299
3.5	Φ -18	91.658	Φ +10	22.522	114.18
4	Φ -16	89.088	Φ +13	23.396	112.484
4.5	Φ -22	78.928	Φ +15	24.089	103.017
5	Φ -21	77.676	Φ +13	24.2	101.876

R. Herrero et al [7] describe enhancement techniques for flat-plate liquid solar collectors. Tube-side enhancement passive techniques can consist of adding additional devices which are incorporated into a smooth round tube (twisted tapes, wire coils), modifying the surface of a smooth tube (corrugated and dimpled tubes) or making special tube geometries (internally finned tubes). For the typical operating flow rates in flat-plate solar collectors, the most suitable technique is inserted devices. Based on previous studies from the authors, wire coils were selected for enhancing heat transfer. This type of inserted device provides better results in laminar, transitional and low turbulence fluid flow regimes.

Mustafa AKTAŞ et al [8] describe experimental analysis of optimum fin size, which can be used in heat exchanger in solar energy systems, has been performed. For this purpose, two systems, one of which is classic and the other finned, were designed and manufactured. According to the experimental tests, which lasted for six days, the system with a fin is 7% more efficient than the classical system. Therefore, it has been concluded that it is useful to use fins in solar energy systems with a suitable sizing.

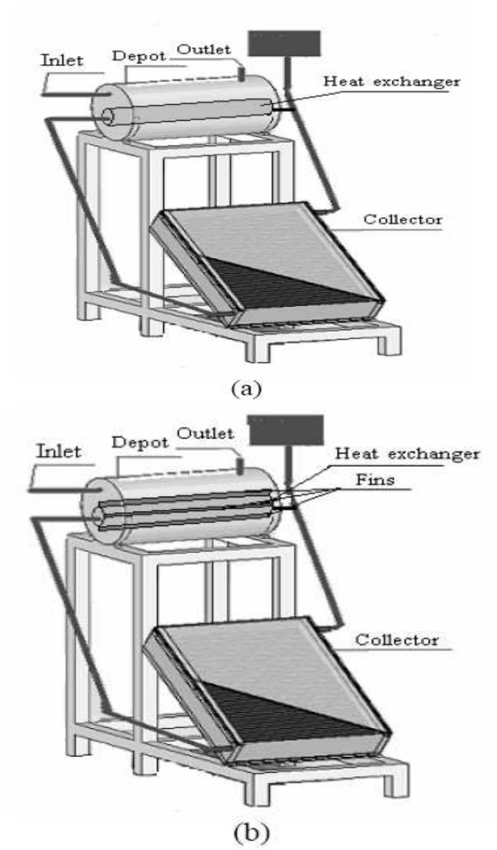

Fig .9. (a) Classical System (b). Finned System [8]

K. Sivakumar et [9] al represent the design of Elliptical heat pipe flat plat solar collector and tested with a collector tilt angle of 11° to the horizontal. Experimental analysis of the effect of condenser length/evaporator length (Lc/Le) ratio of the heat pipe, different cooling water mass flow rates and different inlet cooling water temperature were analysed. Five numbers of elliptical heat pipes with stainless steel wick has been fabricated and used as transport tubes in the collector. Copper tube has been used as container material with methanol as working fluid of the heat pipe. These heat pipes were fixed to the absorber plate of the solar collector and the performance of elliptical heat pipe solar collector has been studied and results were compared. It has been found from the experimental trials that the elliptical heat pipe solar collector having Lc/Le ratio of 0.1764 achieved higher instantaneous efficiency.

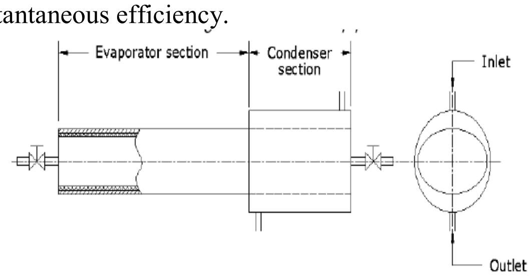

Fig.10. Detail of heat pipe.[9]

V.CONCLUSION

At Present, Solar water heating systems are installed with different configurations and arrangements. The basic technology concrete of these systems are studied and it is found that there is a need to work on the generated design procedure to select, install and monitor the solar water heating system as per the availability of solar radiation and local geographical condition.

IV ACKNOWLEDGMENT

I am kindly expressing thanks to my respected guide Prof. Pragna R. Patel and Prof. Jatin R. Patel for their valuable time and suggestions given to me.

I express my sincere thanks to the entire team of NCIET 2013, of SRPEC, for arranging this event

REFERENCE

1. Dilip Johari, Ashok Yadav, Ravi Verma "Study of solar water heaters based on exergy analysis" *Proceedings of the National Conference on Trends and Advances in Mechanical Engineering,YMCA University of Science & Technology, Faridabad, Haryana, Oct 19-20, 2012*
2. Soteris A. Kalogirou, "Solar thermal collectors and applications.", Progress in Energy and Combustion Science 30 (2004) 231–295.
3. Samara Sadrin, Maherin Hossain, Ehsanul Mohith, " Alternative solar water heater for domestic purpose"
4. P. Rhushi Prasad, H.V. Byregowda, P.B. Gangavati, "Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector" European Journal of Scientific Research, ISSN 1450-216X Vol.40 No.1 (2010), pp.144 -155, EuroJournals Publishing, Inc. 2010.
5. Wattana Ratismith, "A Novel Non-Tracking Solar Collector for High Temperature Application.", proceedings of ecos 2012 - the 25th international conference on efficiency, cost, optimization, simulation and environmental impact of energy systems june 26-29, 2012, perugia, italy.
6. Krisztina Uzuneanu, Alexandrina Teodoru, Tanase Panait ,"Optimum Tilt Angle for Solar Collectors with Low Concentration Ratio"
7. R. Herrero Martín, A. García Pinar, J. Pérez García "Experimental heat transfer research in enhanced flat-plate solar collectors" ,World Renewable Energy Congress -2011, Sweden.
8. Mustafa AKTAŞ, İlhan CEYLAN,Hikmet DOĞAN " The Thermal Effectiveness Compression Of The Classical And Finned Solar System" Isı Bilimi ve Tekniği Dergisi, 26, 2, 29-33, 2006. J. of Thermal Science and Technology ©2006 TIBTD Printed in Turkey ISSBN 1300-3615.
9. K. Sivakumar, N. Krishna Mohan and B. Sivaraman "Performance analysis of elliptical heat pipe solar collector" Indian Journal of Science and Technology