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A Review on Revolution of Flat Plate Collector for Solar Water Heater

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Abstract: Energy is the significant need of the world either for nutrition or for development of the society. The power bank of the earth is the sun, which has tremendous amount of energy in it and will never exhaust. The conversion of solar energy to thermal energy is the function of collector. Flat plate collector (FPC) are cost effective and more convenience in all collectors. The paper reveals the different design of the flat collectors used to enhance the efficiency of the collector. Effect of using phase change material, nanofluids, heat pipe, different geometry of the tubes and absorber discussed. This review deals with the suggestion for the research work in flat plate collector.
Keywords: FPC Design; Solar Collectors; different collectors for SWH; Design of SWH

I. INTRODUCTION

Energy is the most important and a key factor in day-to-day life. The keen interest is towards the solar energy which is a pure green energy and available in plenty. The energy of Sun used to heat the water, which is the great need of each human being for various purposes. During review it is found that the various solar water heating system were made by many researchers with relatively high efficiency and reasonable cost, but the system does not meet the requirement of other countries due to climatic conditions and many other reasons. Today environment is the major issue and the awareness regarding the environment is increasing this promote solar and renewable energy system in world and decreases the dependencies' on fossil fuels.

The solar water heating system consist of riser tubes, absorbers a dark surface plate, insulation and glazed glass. The system when exposed to the sun, the absorber absorbs the solar radiation and transfers a part of it to the fluid flowing over/under it [3-7]. The more is the collector area more will be the energy, but the law of thermodynamics state that no machine can gives 100% output therefore we even cannot get the 100% percent conversion. Now, the design goals were to have the collector that can convert the maximum solar energy to heat energy with a lesser amount of losses; and cost. The objective for the review of solar water heating system is to get the various designs available and invented by researchers at one place to get the idea of possible development in it with the future of design in Solar Water Heater (SWH). The review is limited to the flat plate collector and other similar to it.

There are two broad categories of SWH (passive and active), each of them operating in either direct or indirect mode. The active systems give 35%–80% efficiency higher than those of the passive systems [3].

II. LITERATURE REVIEW

Many researchers have done the various experiments to prove their design and to increase the use of solar energy by applying different techniques of design. The review comprises the details of researcher design and the techniques they uses

A. Integrated Collector Water Storage(ICWS)

This is a simple type of solar water heater, which consists of storage tank, absorber plate and the glass. This is the oldest solar water heater and used for farm field [2]. The development goes on then with various new design and development [2-8]. This improved design gives the better thermal efficiency and better energy collection in ICWS system. The preceding discussion gives the brief idea of the integrated system with photovoltaic system, phase change material, concentrator collector with integrated storage system. The researcher [8] made a simple design of the ICWS for domestic purpose with a cost of `2500 only with a temperature output of 60^0C in Jaipur Rajasthan, India. The Effective basin area of solar water heater is 0.14 m^2. The vertical height and length of the solar water heater are 200 mm, 700 mm and 1000 mm respectively, wooden(10 mm thickness) structure is used to prepare the outer body and the collector was covered by a clear glass and insulation. The Fig 1 and 2 shows the schematic view of the BSWH design. The Experimental result shows that these types of solar water heater are enough for the family of 4 persons. It gives the good thermal efficiency but thermal losses is more at night. [9] Gives the report on the thermal performance of ICWS with absorber surface. Fig. 3. Shows the schematic diagram of the system it has rectangular shape with capacity of 100 liters, the tank is made of GI sheet of

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gauge 20. The depth of corrugated surface is 0.0004 m and 0.001m. The design include the night insulation cover to restrict the night losses. The corrugated absorber surface gives the high temperature with no increase in cost.

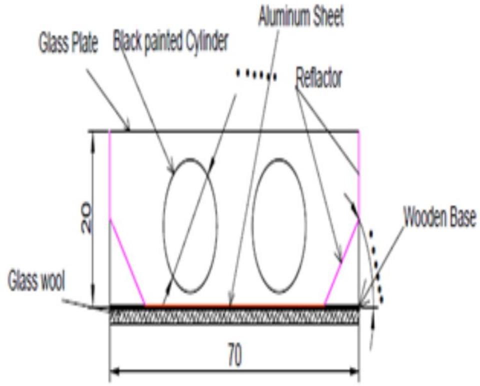

Fig.1 Line Diagram of Experimental Solar water heater (Front View) [8]

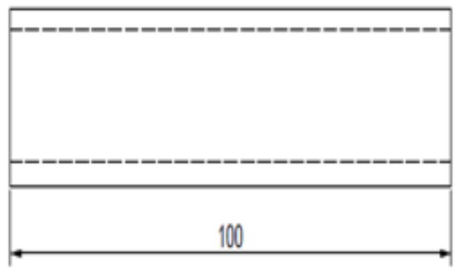

Fig. 2 Line Diagram of Experimental Solar water heater (Side View) [8]

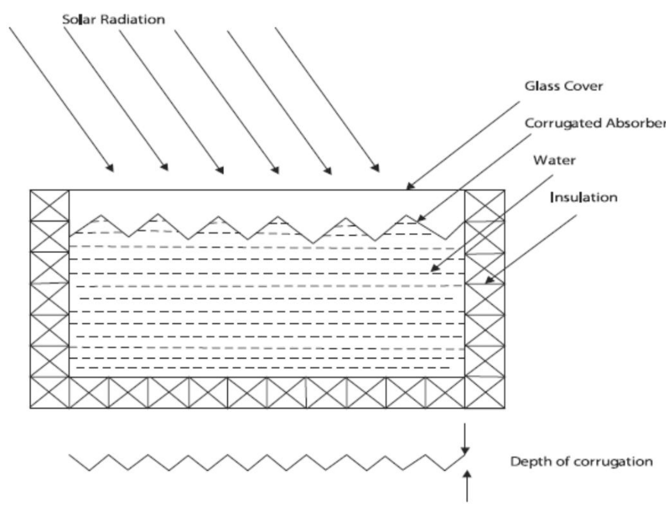

Fig.3. Cross section schematic of rectangular solar water heater with corrugated surface [9]

1) *Integrated collector-Storage Solar water heater (ICSSWH) with PV panel:* Solar water heater with better efficiency and less heat losses always gives the most allowable system. The Photovoltaic (PV) cells use to convert the approximately 20% of incident radiation to electric energy [10]. [11] uses a combination of photovoltaic – thermal (PVT) module with an integrated collector storage solar water heater to investigate the effect of PV cell on tank, water mass and the collector area on this new system. The proposed gives the higher energy output as compared to the standard system. Fig 4 gives the schematic diagram and fig 5 & 6 shows the result of the PVT system. The use of PV panel is not the new trend but the use of PV with thermal collector gives the pre heating of the water [11-17]. The PVT system is also known as the hybrid system and gives the better enhancement to the temperature of the fluid [13, 14, 17].

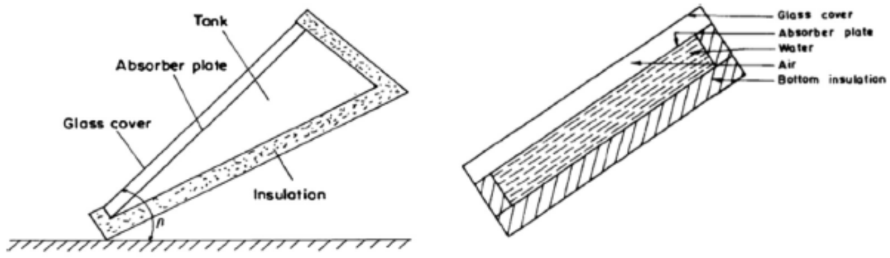

Fig 4. The ICSSWH systems for present model validating: (a) triangular storage tank (adapted from Ecevit et al. works); and (b) rectangular storage tank [11].

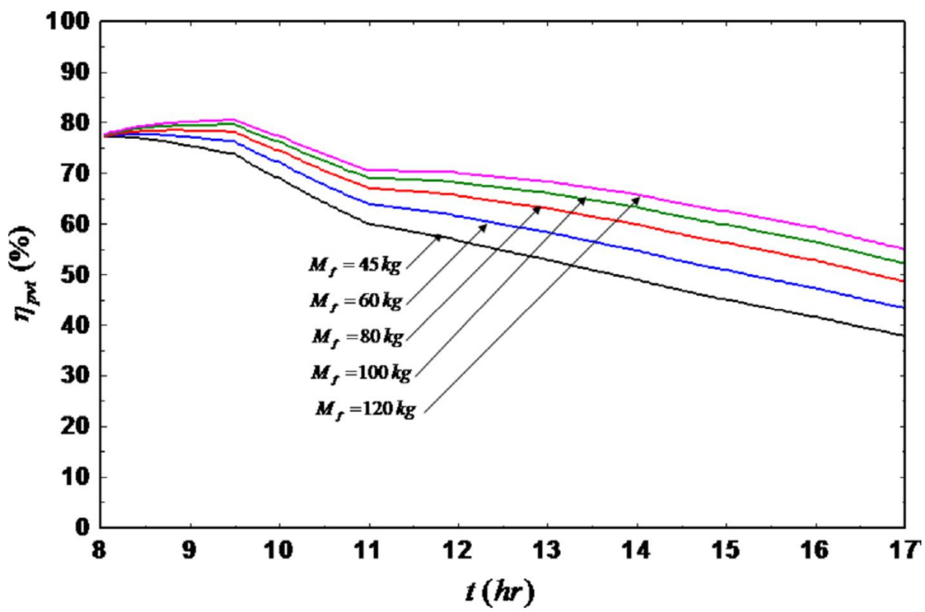

Fig 5. The effect of the tank water mass on the collector total efficiency [11]

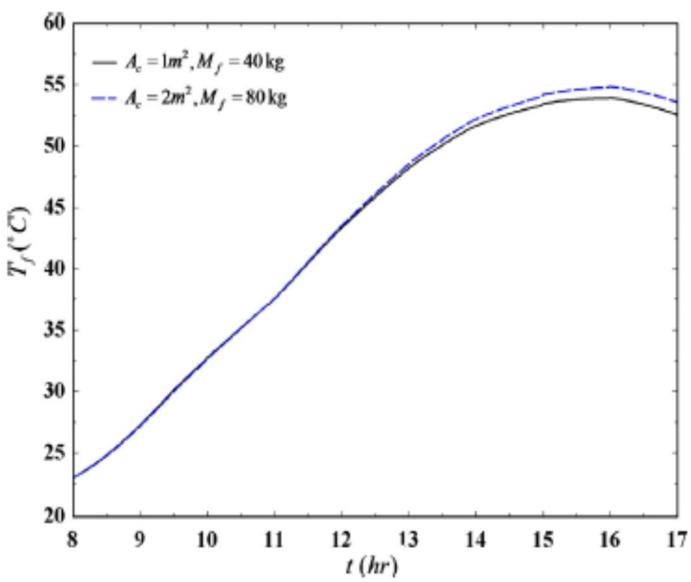

Fig 6. The effects of both the collector area and the tank water mass on the tank water temperature.[11]

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2) *Developed integrated storage solar water heater system:* Solar passive water heater are probable aspirant for boosting heat transfer [11, 18]. Cost and performance matter the most that is why [18, 19] created the design of solar water heater with low cost and with better performance. [18] Develop the integrated storage solar water heater system with a new design having a tank with black colored sands as a absorber and it is immersed into the water. The fig 7. Shows the tank of size 1.45 x 0.56 x 0.17 $m^3$with an effective area of 0.67 m^2 is used, the thickness of galvanized sheet of tank is 0.0015m. The black oil colored sand is use with the average diameters of 10 mm, there were two glass with airy distance of 0.045m between them. The important feature of this design is its large capacity with low cost [17-18]. The experimental result shows efficiency higher than 70% and the system simulated by using thermal network analysis, which shows the temperature can be increase up to 90^0C. The experiment carried out at different situation and find that the west-south situation is better for the highest temperature. Integrated storage solar water heater is the simplest design of solar water heater and with minimum cost [18-19]. Fig. 8 gives the idea about the efficiency with direction and time. The main drawback in the system is that at night, the temperature get reverse, to overcome this drawback many researcher has done numerous modifications in design, [19] did the simplest modification by extending the storage section, there were two section as shown in fig 9. Section A is the regular collector that, interact with radiation and section B (shown in fig. 10) is the insulated section which store the hot water. The total volume of the two section is 100 liter and area of the absorber is 1m^2 the design analyzed and optimize in such a way that the temperature remain maximum in both the section. Fig. 11 shows the relationship between efficiency and volume ratio (volume A/ Volume B) the maximum efficiency was at 2.33 i.e (70/30) ratio.

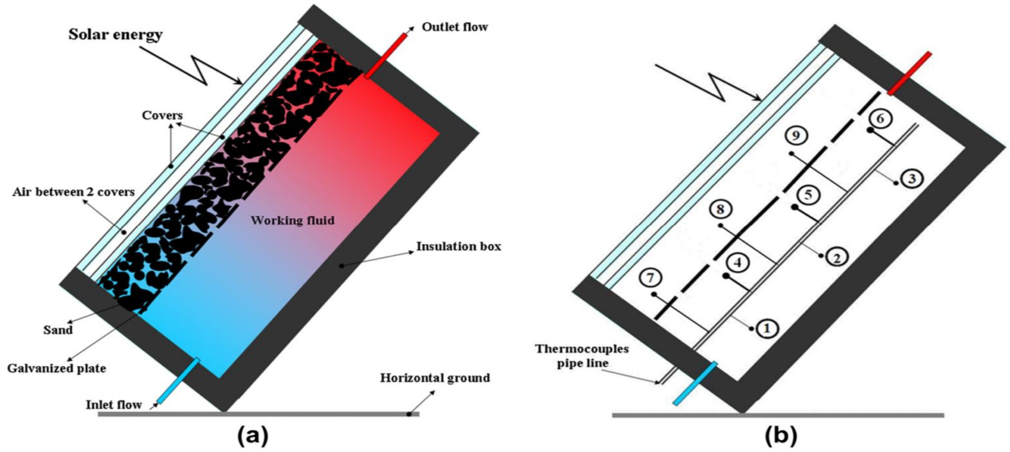

Fig. 7. The schematics of (a)the compact solar water heater and (b) the thermocouple locations[18].

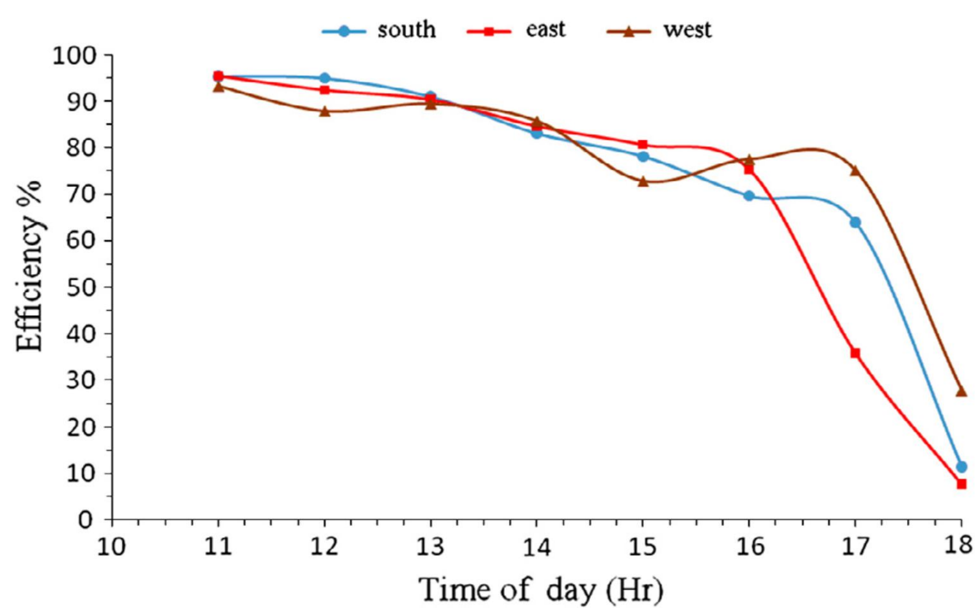

Fig. 8. The collector hourly efficiency (g), for three cases of the collector rotation.[17]

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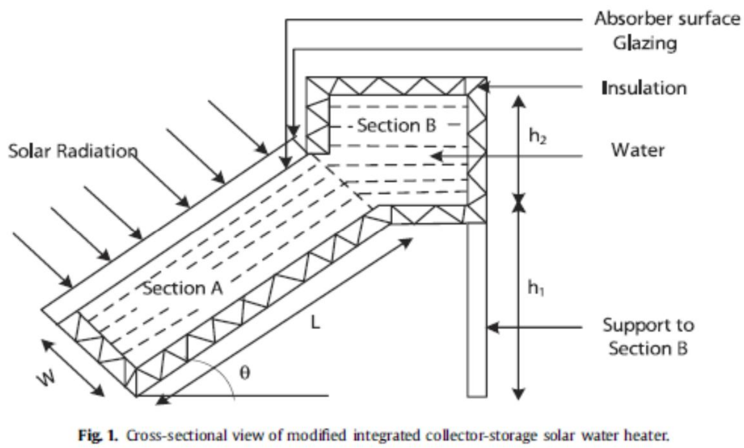

Fig 9. Cross section view of modified integrated collector storage solar water system [19]

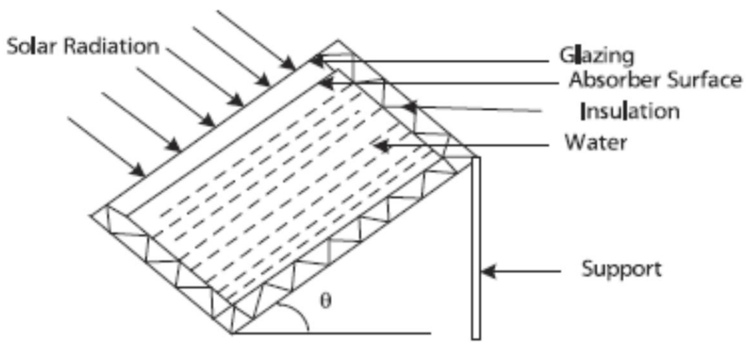

Fig 10. Cross section view of rectangular integrated collector storage solar water heater [19]

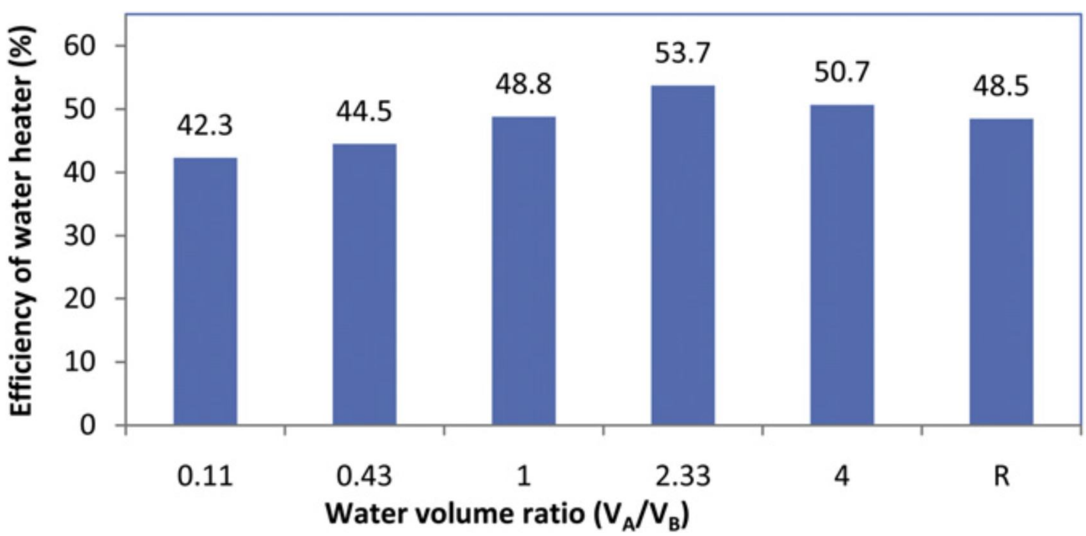

Fig. 11. Efficiency of water heater corresponding to different water volume ratios together with rectangular shape (R) ICSSWH. [19]

3) *New trends in integrated collector storage solar water heaters:* The integrated collector storage solar water heater system is a flat plate collector with compact design. This new design studied by [20] is integrated collector storage solar water heater (ICSSWH) with parabolic trough that is compare with the regular flat plate thermo-syphon unit. The important factor to be consider in ICSSWH is its depth, if the depth is more performance is low, therefore the depth of solar thermal devices that

combine with Compound Parabolic Concentrating (CPC) reflector [18, 21-23]. The parabola trough gives the momentous improve in the thermal performance. [20] Studied the decrease in depth of ICSSWH with CPC and even with less maintenance. The three designs have the symmetrical reflector with involutes curve, parabolic curve and CPC reflector with different acceptance angle; fig 12 shows the schematics diagram of the storage collector, all three design have the same thickness of insulation on backside of storage tank i.e. 18.17% [19]. Fig 13 to 17 shows the design of all 3 model and fig 17. Gives the experimental view of the entire three model, the design is suitable for flat as well as for inclined surfaces and ICS 2 shows the satisfactorily performance in respect to thermal and depth. The new trend in design is to use computational studies on the performance of ICSSWH [24-25]. The [26-27] uses the new material known as phase change material (PCM). PCM has the high thermal capacity and constant change temperature. The use of PCM in solar collector system gives the promising result with decrease in thermal loss and efficiency increases by 11% [28]. The utilization of PCM in water tank boosts thermal energy density and capacity, introduction of PCM shows the higher temperature in water storage [27-32]. Fig 18 and fig 19. Shows schematic diagram of the experiments and thermal energy storage unit [26]. The use of PCM in ICSSWH is a better option to improve the thermal performance of this solar water heater system, the only thing is to use the proper PCM material at appropriate radius [27].

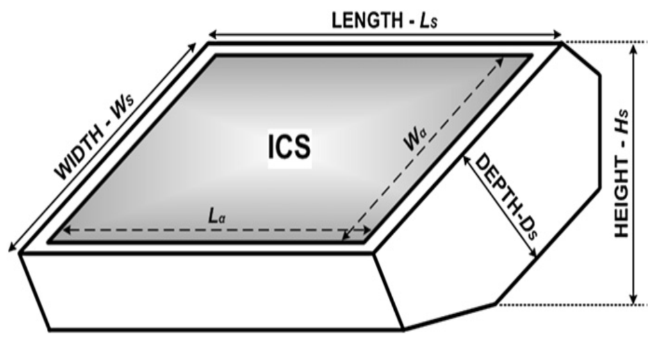

Fig. 12. Dimension description of the ICS experimental models.[19]

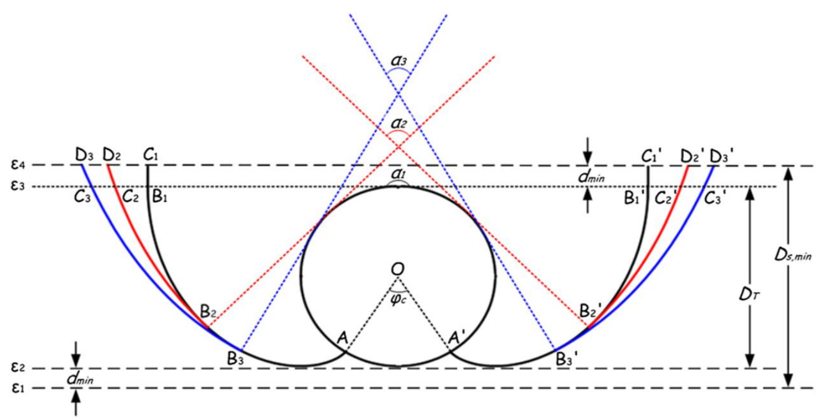

Fig. 13. Design of the CPC type ICS models. [20]

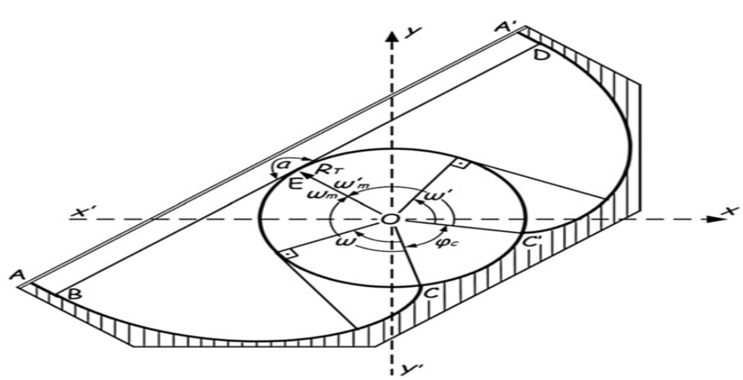

Fig. 14. Cross section of the experimental model ICS 1.

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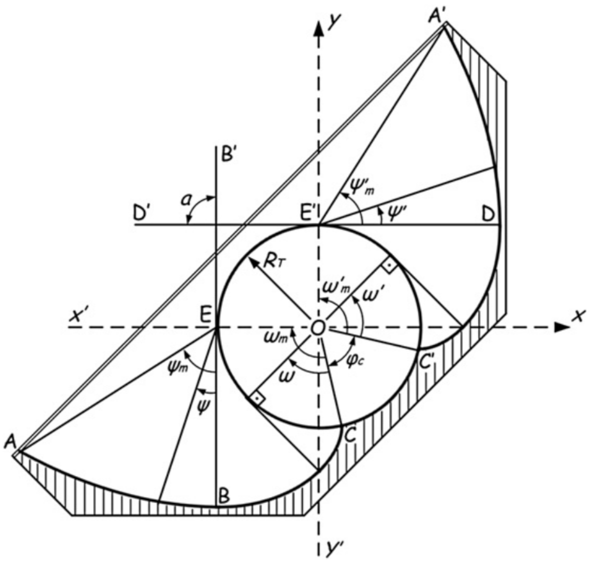

Fig. 15. Cross section of the experimental model ICS 2.[20]

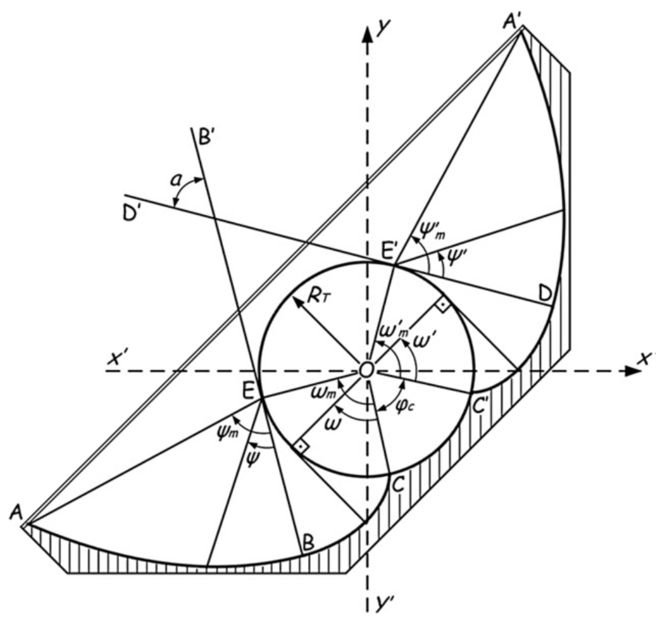

Fig. 16. Cross section of the experimental model ICS 3. [20]

Fig. 17. Experimental ICS models mounted at the test field.[20]

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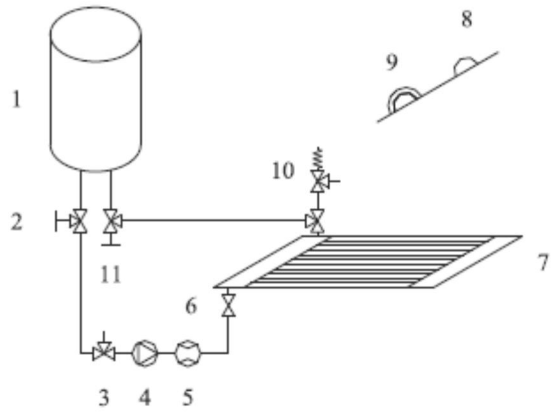

Fig. 18. Schematic diagram of the test rig. (1.Water storage; 2,11. Temperature sensor; 3. Three-way valve; 4. Pump; 5. Flow meter; 6. Valve; 7. All-glass vacuated tubular solar collector; 8. Pyranometer; 9. Shaded pyranometer; 10. Safety valve).[26]

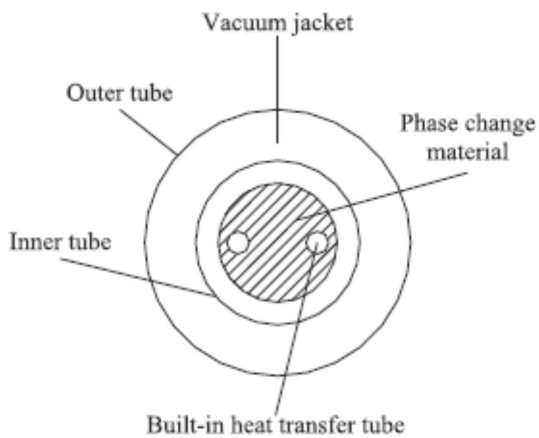

Fig. 19. Schematic diagram of thermal energy storage unit using $Ba(OH)_2.8H_2O$ as PCM.[26]

B. Zig Zag Collector Design

the Maximum temperature with less loss is the aim of every researcher and [33] experimentally analyzed the flat plate collector with zigzag pattern and at different flow rates. [33 -35] arrange the riser tubes of FPC (flat plate Collector) in zig zag pattern to attain the maximum solar radiation and to gain maximum temperature. Fig 20 shows the zigzag pattern of collector, in series and mixed mode the mixed flow collector increases the contact surface area and change in tube material of higher conductivity and that of using Nano-material can give better temperature result. [34 -36] arrange the riser tube in Z configuration which give the maximum performance as compared with conventional FPC. The new developed design is the Zig Zag design of riser tubes in FPC [20, 21]. This type of collector is suitable for both domestic and industrial purpose. The fig.20. Shows that the riser tube is arrange in the tubular arrangement [20, 21]. The design parameters of the zig-zag flat plate collector is similar to regular flat plate collector the only change is there are three header tubes, it is less utilized as its performance is approximately equivalent to the conventional design.

C. Micro tubes Flat plate Collector

Flat plate collector is always the point of research due to its surface area more is area more can be the energy storage but to get the maximum energy losses are to minimize, [37] uses the FPC with low cost and high efficiency micro heat pipes array. The FPC will contain 300 micro heat pipe per $1m^2$ of diameter 0.4- 1.0 mm. These pipes are gravity assisted with a two stage closed thermo-syphon with a liquid reservoir, it can transmit the heat at high rates over considerable distances with a minute temperature difference in a very little time [37].Fig 21. Shows the section of micro flat plate heat pipe of size 1500 x 26 x 2 mm with micro grooves and channel connected by stiffening rib. The cost of the micro tubes is less as it is made of aluminum alloy. Fig 22. Shows the charging circuit which charge the tube by using methanol in it. The experiment set up consist of a flat plate collector with heat pipes and a

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well-insulated water tank of 150L capacity equipped with an electric heater, a thermostat, a circulating pump, control valves, safety instruments and a measuring system. The system gives excellent isothermal characteristics. Heat pipes eliminate the welding and scale formation while it gives 88% efficiency with low cost. [38] suggest that the pipe inclination angle have a substantial effect on heat transfer inside the wickless heat pipe. Similarly [39] shows that the increase in number of wickless heat pipe gives a significant effect on the collector efficiency. [40] examine the heat pipe for three different geometry that are circular, elliptical and semi-circular. The result shows that the elliptical geometry gives better performance than the other does. The wickless heat pipe can transmit heat at high frequencies over substantial distances with small temperature differences. It behave like thermal diode. Fig 23. Shows the schematic diagram of the evacuation and charging rig of wickless heat pipe and Fig 24. Cross sectional views of the prototype wickless heat pipe flat plate solar collector [40].

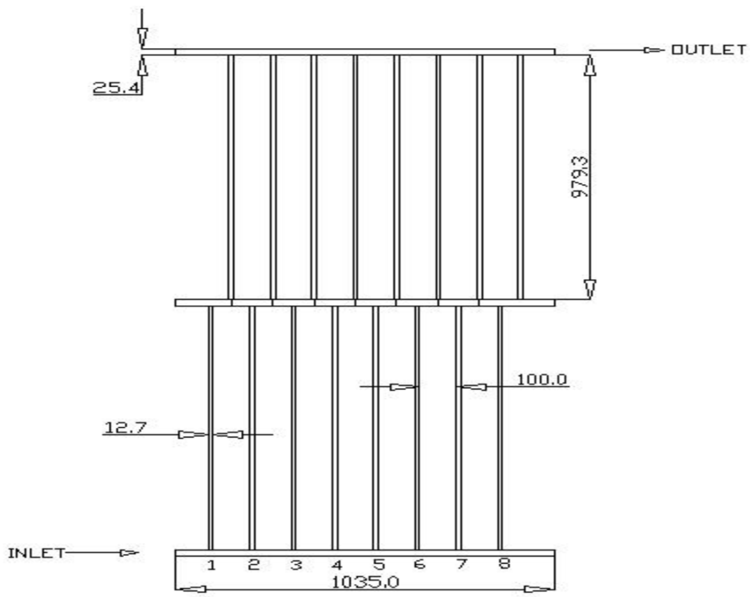

Fig. 20. Sectional view of zig zag Flat Plate Collector (FPC) [21].

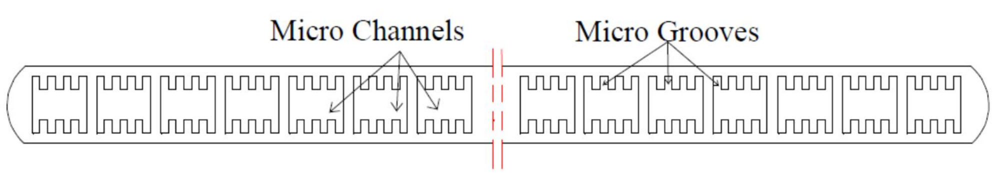

Fig 21. Section of micro flat plate heat pipe [37]

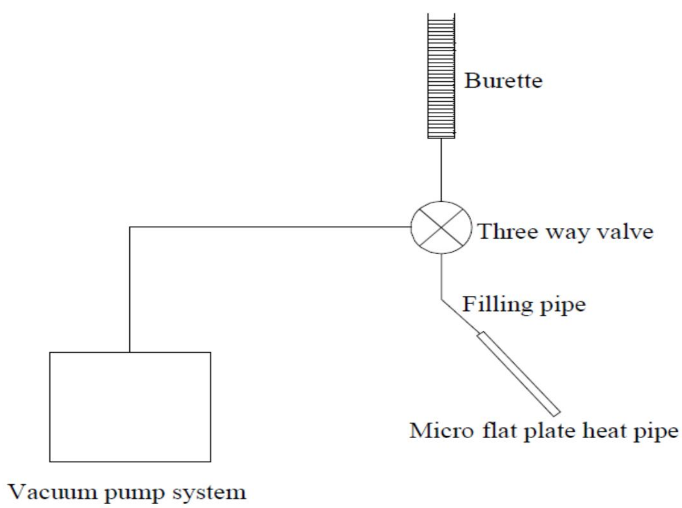

Fig.22. Schematic diagram of the evacuation and charging [37]

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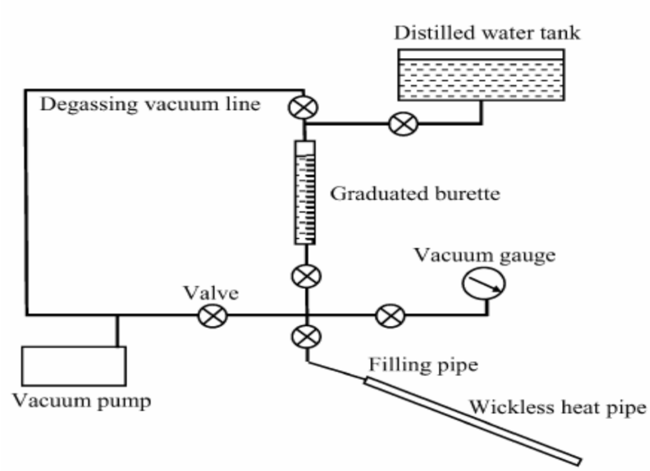

Fig.23. Schematic diagram of the evacuation and charging rig [40]

D. Variable Geometry of Riser Tube

The flat plate collector is the medium to supply the thermal energy at adequate temperature. [45-46] studied the performance of few profile shapes namely, trapezoidal (R=0.2)[45-46,48], rectangular and rectangular profile wit step change in thickness (RPSLT) (R=0.5). Fig 25. shows the detail of new absorber plates design, analysis and optimization of these shapes shows that the trapezoidal profile is a better choice but it is difficult to manufacturing. The other choice is the RSPLT profile as it gives higher performance with fewer difficulties in fabrication.

The solar energy is depend on the surface area the more the surface area the more is the energy collection therefore [46] increases the surface area by using the semicircular type tube in the collector. Here the absorber is not modified but the tube is modified with more surface area; fig. 26 Shows the schematic view of semi-circular tube, which gives the idea that semi-circular cross section gives increasing absorber area of tube due to which heat gain increases drastically [46,48]. Fig. 27 shows effect of semi-circular tube over heat. The semicircular tube absorbed more heat than regular circular tube.

To improve the thermal performance of collector many different ideas were invented one this is changing the geometry of tube this will add the absorbing area to the collector, which will lead to the gain in surface temperature [48]. The absorber area and surface is important parameter in designing the collector [47, 48]. Therefore [48] experimentally checked the performance of the four different geometry namely circular, triangular, elliptical and square tubes been illustrated in fig. 28. Triangular tubes shows more efficiency then other tubes. [49] Changes the material of absorber and analyzed the results of temperature at different radiation condition.

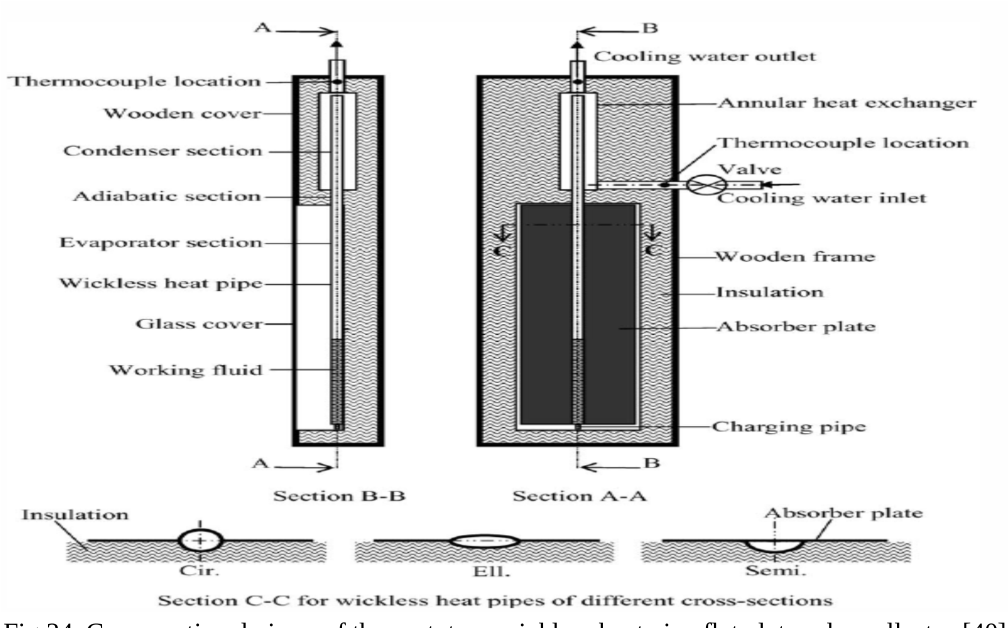

Fig 24. Cross sectional views of the prototype wickless heat pipe flat plate solar collector [40]

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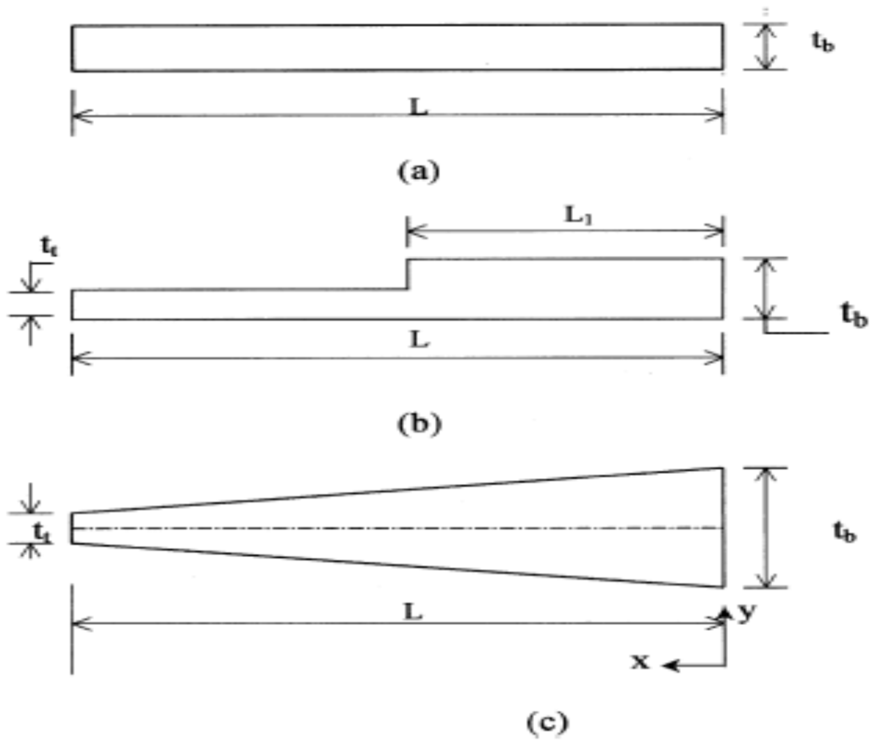

Fig. 26. Flat plate collector with semi-circular cross sectional tube [47].

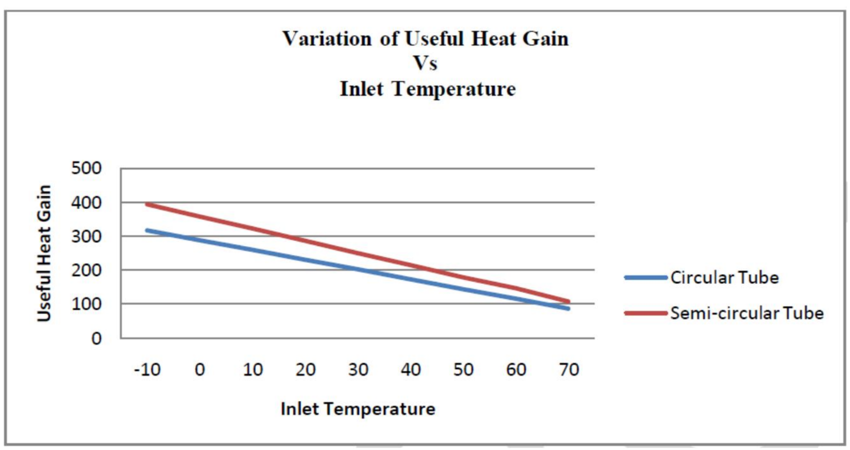

Fig.27 graph of inlet vs heat gain [47]

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Fig . 28. Different cross-section of the tubes [48]

E. Twisted Tape Design

Some researcher find that the heat transfer between tube and water is insufficient and there is a need of an idea that will increase the heat transfer between tube and water. [51-65] analyzed the issue of poor heat transfer coefficient at water tube surface and the solution to improve is it to insert the twisted tape in the tube. The conventional fin in tube shows the very low Reynolds number under thermosyphon effect [51]. This lead to the era of increasing the heat transfer enhancement from tube to water [51-65]. Fig 29. Shows the schematic view of twisted tape collector, many researcher studied the different parameters of twisted tape as the swirl flow increase the heat transfer coefficient but to get the optimum value the different parameters was discussed. [62] Investigate experimentally the heat transfer, friction factor and thermal performance of thermo syphon solar heater collector with helical and left right twisted tape and the ratio of twist is 3. [64] used twisted tape with working fluid as air and the parameters used were clearance ratio and Reynolds number. [65] experimentally studied the twisted tape with transition flow and parameter studied were twist ratio, volume, concentration of nanoparticle and Reynolds number.

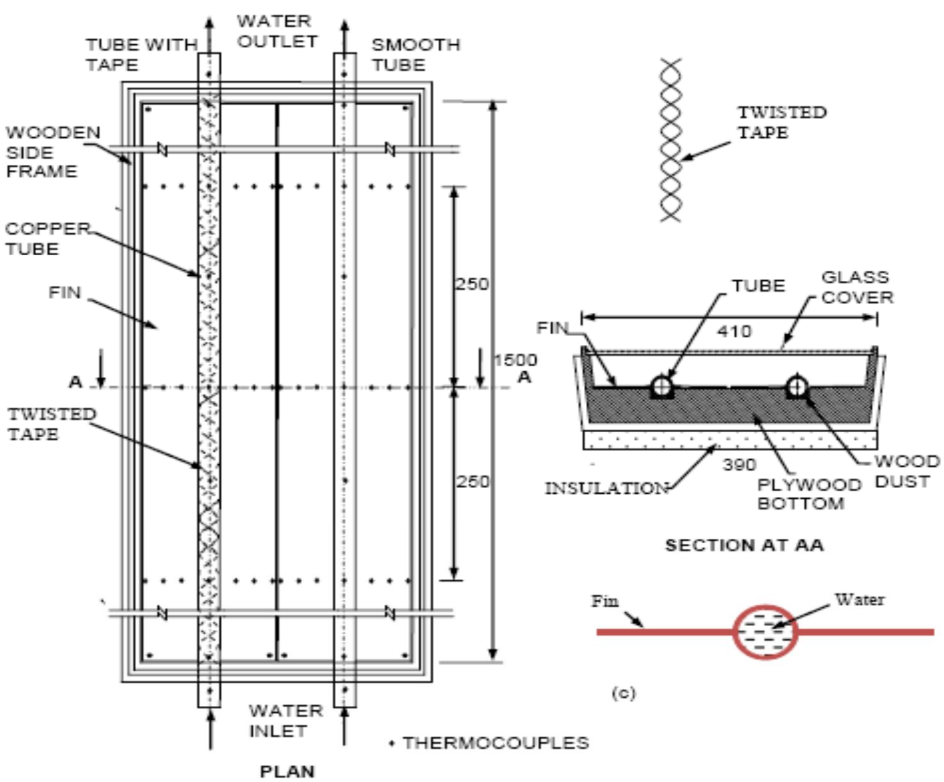

Fig. 29. Schematic view of twisted strip system [51].

F. Nano Fluid in Flat Plate collector

Solar collector can be define as a heat exchanger because it convert the solar radiation energy to thermal energy. The direct absorption solar collect (DASC) is a type of solar collector which uses fluid as absorbing medium instead of absorber plate[66-69]. Fig. 30. Shows the schematic diagram of DASC. Many development has been taken place in this type of collector the recent achievement in DASC is the use of nano fluid which is the simple way of increasing the efficiency of new and the existing flat plate collector. It provide a boost to heat transfer rate [71-73]. There are different parameters to be considered for the nanofluids such as the settlement of nano particles, cost, pressure drop, foaming effect as it affect the viscosity of the fluid [74-75]. [76] performed the experiment for investigating the performance of collector using Al_2O_3 / water nano fluid (wit and without Triton X-100 surfactant) (surfactant is the additive used to stable the nano fluid) as heat transfer agent. Nano particle used were of size 15-nm diameters at weight concentration of 0.2% and 0.4 %. The experiment shows that the use of triton X-100 stable the nano fluid for long time and the efficiency of the collector also increases but the temperature limit were 60^0C. The research continue with different nano fluid and with different parameters i.e. pH effect on performance. Nano fluids are advanced fluid that have the capability to increase the thermal concentration and improve the heat transfer rate the only drawback is the cost of nano fluids.

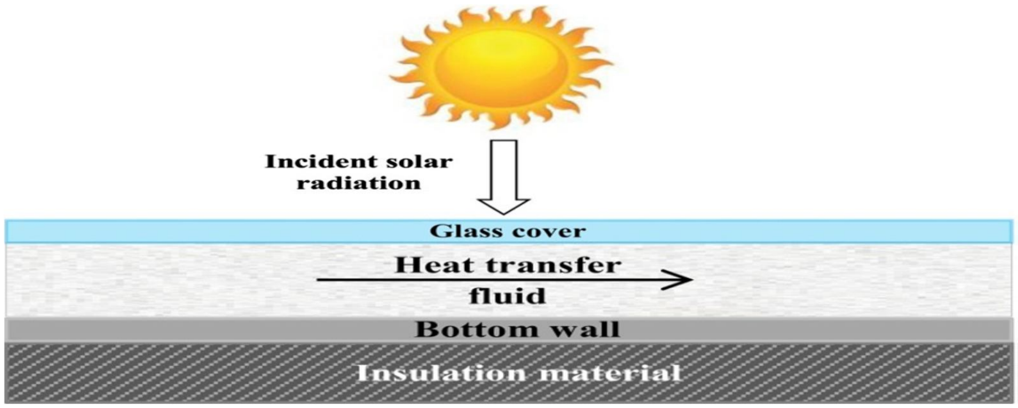

Fig. 30. Schematic drawing of a direct absorption solar collector (DASC).[70]

III.CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

The review discussed various flat plate collector and their parameters. The review finds that the maximum works were incorporated on the development of the geometrical parameters of collector to get the better thermal efficiency and heat transfer rate. The research work selected in this paper shows the increase in interest for this topic, which give the birth to the new and innovative ideas for the industry to compete with the future. The review caught the attention on some research work where costs were the main parameters for study were the cost of the solar water system [78-82]. As cost were not the parameter for our review, there were some interesting new technologies, that gives promising results with innovative materials, concentration of radiation, different geometries, integrated solar thermal collector, heat pipe collector which can be the future collector, hybrid collector i.e. PV solar collector, heat transfer through nano particles and the use of twisted tape to get the swirls effect for increasing the heat transfer. These shows the future of solar collector in the coming year is bright. The highlight is shown in table I.

TABLE FUTURE WORK FOR DIFFERENT TYPES OF COLLECTOR

Topic	Enrichment and Future work
Integrated collector water storage	• To study the ICWS system with solar tracker. • To check the performance of the collector with different phase material. • To study the performance with large capacity of storage. • To study the system with two or more storage tank. • To study the performance of collector with two glass. • To study the Hybrid ICWS with different geometry of tank. • Study of system with Transys, mathematical model and different optimization technique to get the best possible ways for development with different parameters.

Zig Zag Collector	• The zig zag pattern can be studied with swirl flow tubes. • To study the effect of tubes in coils. • To reduce the size of collector with zig zag tube and other parameters of collector.
Micro Tubes	• To study the heat pipe with the simulation techniques. • To generate the mathematical model
Innovation in absorber plate and riser tube	• To study the performance of collector with absorber and with concentrator or reflector. • To study the effect of increase and decrease in pitch of riser tubes. • To study the different absorber material for low cost
Nano Fluids	• To study the unstablity of nanofluids • To study the behavior of nanofluids with temperature greater than 60^0C. • To compare the different nano fluids and their effect. • To study the long term stability of the nanofluids. •
Decrease in Heat Loss	• To reduce the top loss. • To reduce the heat loss by convection and radiation. • To study the collector with double glazed glass. • To study the air gap between collector to get the less losses. • To study the different inert gas effect instead of air between two top glazed glass.
Heat Transfer rate	• To study the heat transfer rate with twisted tape at various angle of twisting. • To study the performance
Low cost and Maintenance	• To study the FPC with cheap material like polymer, PVC etc. • To study the optimization of collector on cost basis. • To study the effect of scale formations occur in riser tubes. • To study how to reduce the scale formation in riser tubes.

The new technique of simulation gives the deep study of collector with the help of latest software like EES, TRANSYS, MATLAB, CFD etc, to understand the losses and even the efficiency of collector soon, and by this the development ratio of new collector design can be increase to get the optimum value.

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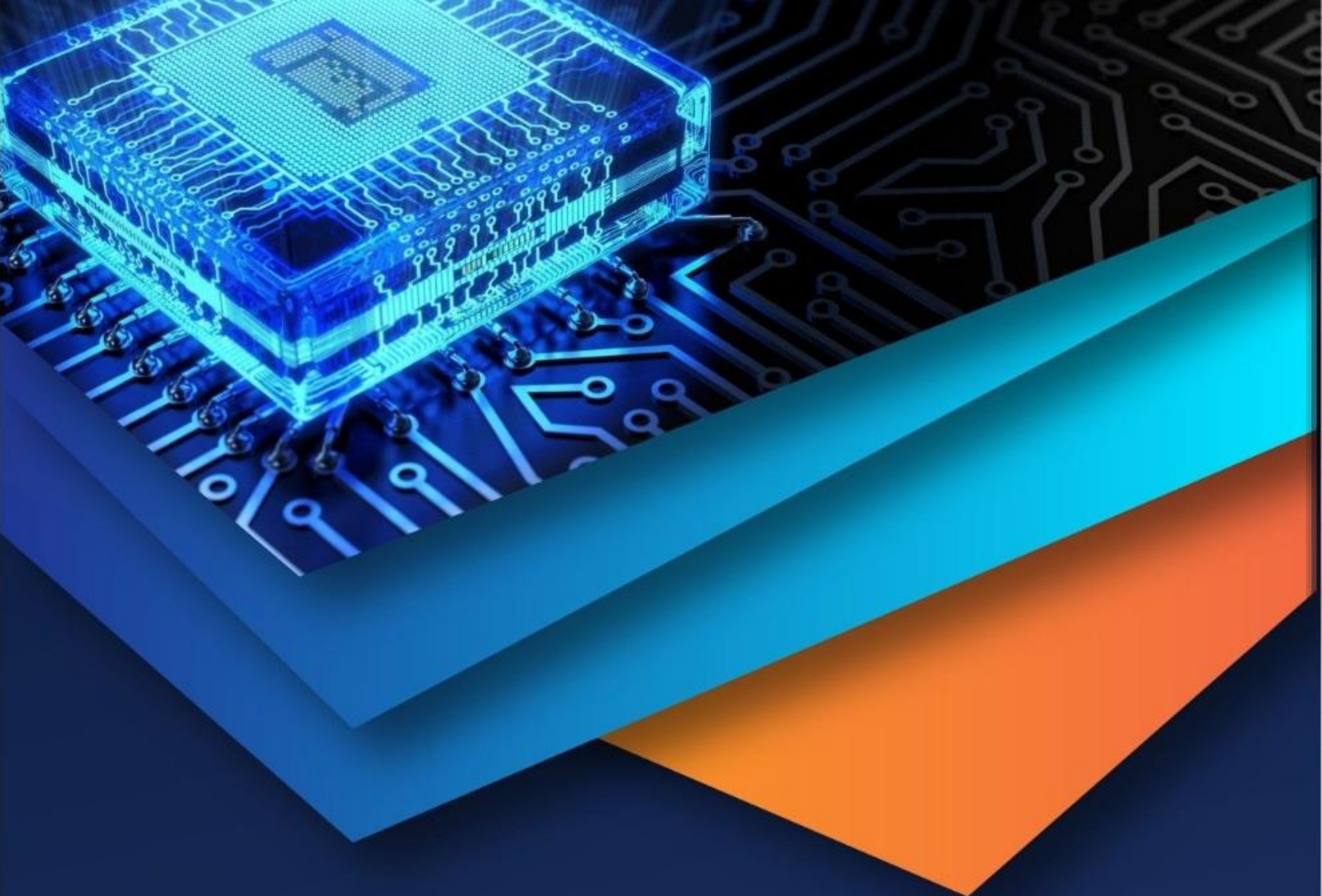

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