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EFFECT OF PITCH ON THERMAL PERFORMANCE OF SOLAR WATER HEATER

PATEL NEELKUMAR KANTILAL

LAKSHMI NARAIN COLLEGE OF TECHNOLOGY, INDORE

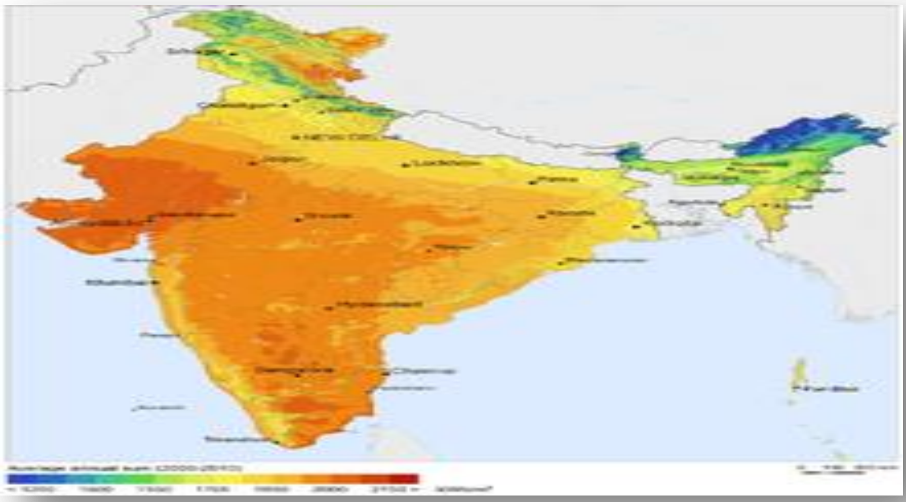
ABSTRACT

Energy is essential for living and vital for development of all. The global economy thrives on energy. Affordable energy directly contributes to increase productivity, reducing poverty and improving betterment of life. Global population is increasing day by day, which, in a way is leading to the utilization of natural resources and fossil fuels. The solar energy, wind energy and bio mass are three major sources and out of these three energy sources solar energy is the easiest source to extract useful energy because the wind energy can be useful particularly in coastal area where there is high wind velocity and energy extraction bio mass needs either chemical conversion or thermo chemical conversion process. The objective of present work is to carry out comparative study for thermal performance of the helical solar heater of various coil pitch by using Digital Thermometer at appropriate location of both experimental set up; using thermocouple the change in water temperature for 20 litre water will be carried out simultaneously in case of two set up will be fabricated.

Introduction

Strictly speaking, all forms of energy on the earth are derived from the sun. However, the more conventional forms of energy, the fossil fuels received their solar energy input eons ago and possess the energy in a greatly concentrated form. These highly concentrated solar energy sources are being used as such at a rapid rate that they will be depleted in not-too distant future.

There are four primary sources of energy viz., petroleum, natural gas and natural-gas-liquids, coal and wood. Excepting wood, all these common sources have finite supplies. The life-time is estimated to range from 15 years for a natural gas to nearly 300 years for coal. Therefore, as these non-renewable sources are consumed, the mankind must turn its attention to longer-terms, permanent type of energy sources. The two most significant such sources are nuclear and solar energy. Nuclear energy requires advanced technology and costly means for its safe and reliable utilization and may have undesirable side effects. Solar energy, on the other hand, shows promise of becoming a dependable energy source without new requirement of a highly technical and specialized nature for its wide spread utilization. In addition, there appear to be no significant polluting effects from its use.



All countries in the world receive some solar energy. This amount varies from a few hundred hours per year as in the northern countries and the lower part of South America, to four thousands hours per year as in the case in most of the Arabian Peninsula and the Sahara Desert. In estimating the amount of solar energy falling on the earth, let us consider first of all the natural deserts of the world. This area is about 20 x 10^6 km^2 with average solar isolation of 583.30 W/m^2 /day (500 gm cal/cm^2/day). Another 30 X 10^6 Km^2 receive about 291.65 W/m^2/day (250 gm cal/cm^2/day). Let us ignore all the areas of sea and the rest of the land. Therefore, the amount of solar energy received by this 50 x 10^6 km^2 is 162.2 X 10^{12} kWh/day, assuming eight hours of sunshine, or approximately 60 X 10^{15} kWh/year, Using 5%, this energy will result in 300 X 10^{13} kWh and comparing this with the estimated world energy demand in the year 2000 (50 X 10^{12} kWh/year), it can be seen that it is 60 times what the world will require then. Solar energy, which is the ultimate source of most forms of energy used now, is clean, safe and exists in viable quantities in many countries.

The drawbacks in using solar radiation as energy, as have been pointed out, are that it cannot be stored and it is a dilute form of energy. This is however, an outdated argument since the energy can be stored by producing hydrogen, or by storing in other mechanical or electrical storage devices, the energy can be concentrated in solar furnaces, for example which can achieved temperatures in the region of 5000^0 C.

Solar Water Heater

A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber panel coated with selected coating transfers the hat to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and are delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to 80 C (Maximum) in a good sunny day. The total system with solar collector, storage tank and pipelines is called solar hot water system. Broadly, the solar water heating systems are of two categories. They are: closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from bore wells or from freezing temperatures in the cold regions. In the other type, either thermo syphon or forced circulation system, the water in the system is open to the atmosphere at one point or other. The thermo syphon systems are simple and relatively inexpensive. They are suitable for domestic and small institutional systems, provided the water is treated and potable in quality. The forced circulation systems employ electrical pumps to circulate the water through collectors and storage tanks. The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, annual solar radiation, etc. The solar water heating systems are economical, pollution free and easy for operation in warm countries like ours.

Solar water heating systems for domestic, industrial and commercial application are at present available. Except in the hilly regions and in the northern latitudes, the potential for domestic water heaters is somewhat limited. In commercial establishments however, there is great potential especially in hotels, hospitals, guest, tourist bungalows, Canteen etc. For industrial applications, solar water heating system can meet the low and medium temperature process heat requirement hot water up to 90^0 C, hot air up to 110^0 C and low pressure steam up to 140^0 C. These are especially useful in engineering, textile, chemicals, pharmaceutical, food processing, and sugar, dairy and other industries. Hot water systems have relevance for many agricultural and village industries also, such as for handloom fabrics, seri-culture, leather tanning and handmade paper. Pharmaceutical industry demands steam from coal and electricity.

Salient Features of Solar Water Heating (SWH) System

Solar Hot Water System turns cold water into hot water with the help of sun’s rays.

- Around 60^0C – 80 ^{0}C temperatures can be attained depending on solar radiation, weather conditions and solar collector system efficiency.
- Hot water for homes, hostels, hotels, hospitals, restaurants, dairies, industries etc. can be installed on roof-tops, building terrace and open ground where there is no
- shading, south orientation of collectors and over-head tank above solar water heating system SWH system generates hot water on clear sunny days (maximum), partially clouded (moderate) but not in rainy or heavy overcast day.
- Only soft and potable water can be used.
- Stainless Steel is used for small tanks whereas Mild Steel tanks with anticorrosion coating inside are used for large tanks.
- Solar water heaters of 100-300 liters capacity are suited for domestic application.
- Larger systems can be used in restaurants, guest houses, hotels, hospitals, industries etc.
- **Fuel Savings:**
- A 100 liters capacity SWH can replace an electric geyser for residential use and saves 1500 units of electricity annually.
- **Avoided utility cost on generation**
- The use of 1000 SWHs of 100 liters capacity each can contribute to a peak load shaving of 1 MW.
- **Environmental benefits**
- A SWH of 100 liters capacity can prevent emission of 1.5 tons of carbon dioxide per year.
- **Life:** 15-20 years.

Literatures Review related to Solar Water Heater

Budihardjo, G.L. Morrison studied the thermal performance of water-in-glass evacuated tube solar water heaters and is evaluated using experimental measurements of optical and heat loss characteristics and a simulation model of the thermo syphon circulation in single-ended tubes.

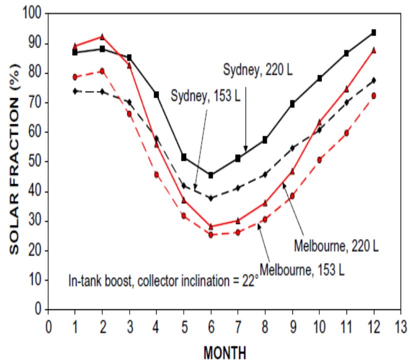


Fig. 3.1 Monthly solar fraction of single-tank systems with in-tank boost, collector inclination = $22^0$and different system sizes in Sydney and Melbourne.

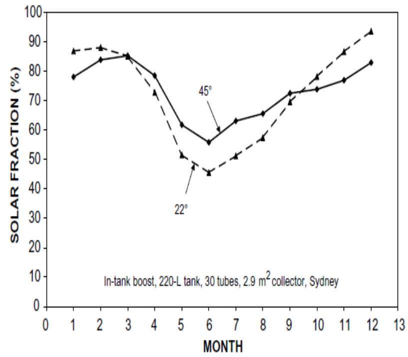


Fig3.2 Monthly solar fraction for 220 L single-tank system with in-tank boost in Sydney for north-facing collector with inclinations of 22^0 and 45^0.

Y. Taheri, Behrooz M.Ziapour,K.Alimardani investigated a new techniques for solar water heater using black coated sand and all experiments results, the collector averaging daily efficiencies achieved higher than 70%.

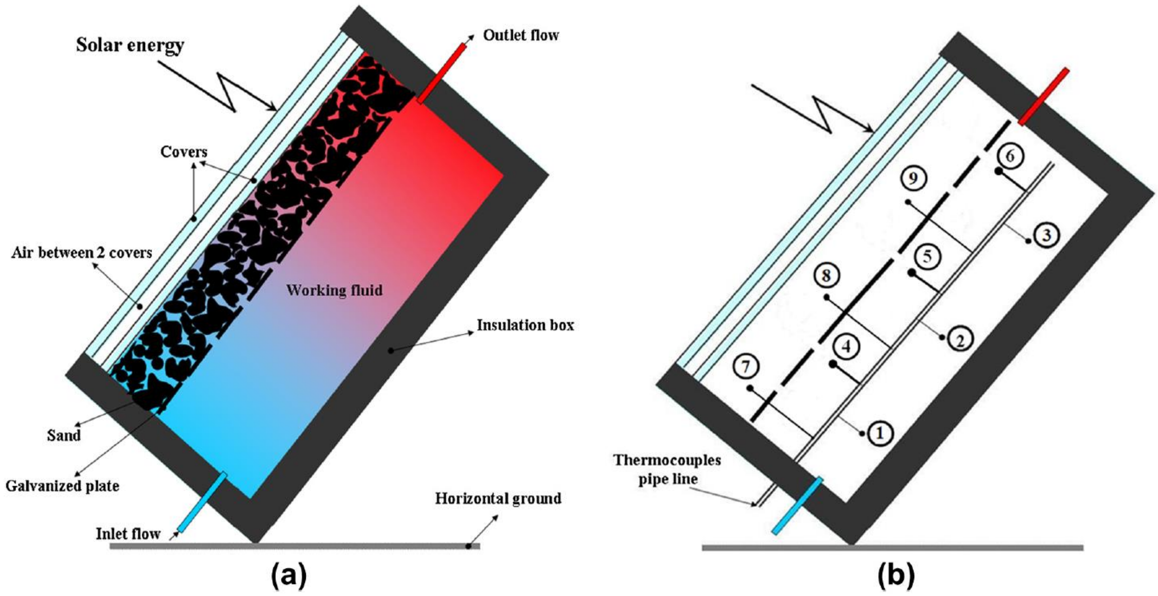


Fig 3.3 The Schematic of the test device with thermocouples at different locations

Table 3.1 Validation of the results using comparison between the experimental and the theoretical absorber plate values

Hour	τ_a Eq. (16)	$AC\,I_T$ (kJ/h)	Q (kJ/h) Eq. (2)	η (%) Eq. (1)	T_a (°C) Exp.	T_P (°C) Exp.	T_P (°C) Eq. (19)	Deviation (%)
South (2 August)								
16.00	0.9819	1933.0	1347.32	69.7	25.80	41.3	41.77	1.13
17.00	0.9806	1497.0	958.09	64.0	27.78	43.24	42.67	1.33
18.00	0.9795	928.5	105.85	11.4	25.40	43.92	44.55	1.43
East (3 August)								
16.00	0.9814	1769.2	1298.61	73.4	24.73	41.68	41.23	1.09
17.00	0.9801	1246.3	447.42	35.9	27.79	43.3	43.84	1.24
18.00	0.9792	690.4	52.95	7.7	27.53	43.72	42.73	2.27
West (4 August)								
16.00	0.9824	2019.5	1567.15	73.4	28.68	41.51	41.97	1.12
17.00	0.9812	1573.9	1183.56	35.9	27.97	43.55	42.93	1.43
18.00	0.9799	1091.2	303.34	7.7	27.00	44.71	43.71	2.23

N.M. Nahar focused on effect of selective surface on the performance of solar water heater the overall efficiency of the heater is 57%. The predicted performance at various Indian stations revealed that hot water is required at most places for domestic use only during winter season and it can provide 100 l of hot water at an average temperature of 50–70 ^{0}C, which can be retained to 40–60 ^{0}C till next day morning use.

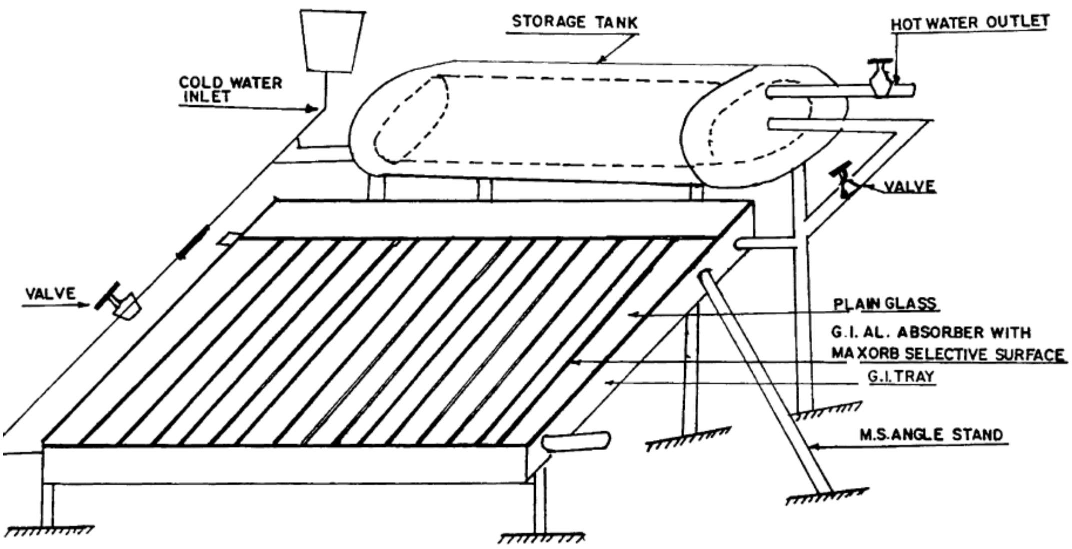


Fig 3.4 Schematics of Natural Circulation Type Solar Water Heater

Table 3.2 Average meteorological parameters at Jodhpur (1991-2000)

Month	Air temperature (°C)		RH at 07:38 a.m. (%)	RH at 02:35 p.m. (%)	Rainfall (mm)	Rainy days (number)	Wind speed (km h^{-1})	Sunshine (h)
	Maximum	Minimum						
January	25.1	10.3	65	28	6.3	1	3.0	8.8
February	28.0	12.4	58	21	3.5	0	3.5	9.3
March	33.4	17.8	45	17	2.0	0	4.2	9.4
April	38.5	22.7	40	15	11.0	1	5.1	10.4
May	41.3	27.2	50	20	7.3	1	7.8	10.4
June	39.9	27.9	64	34	60.6	3	8.9	9.7
July	36.0	27.0	78	52	124.0	6	7.8	7.0
August	34.0	25.7	81	58	130.0	6	6.3	7.0
September	35.0	23.8	76	45	45.4	3	4.2	9.2
October	36.1	19.8	60	25	12.3	1	2.2	9.4
November	31.5	14.7	56	22	1.2	0	2.0	9.3
December	27.6	11.1	62	26	0.1	0	2.0	8.9
Mean/total	33.9	20.0	61.3	30.2	403.4	22	4.7	9.1

K.K. Chong, K.G. Chay, K.H. Chin studied solar water heater using stationary V-trough collector. Integrating the solar absorber with the easily fabricated V-trough reflector can improve the performance of solar water heater system. In this paper, optical analysis, experimental study and cost analysis of the stationary V-trough solar water heater system are presented in details.

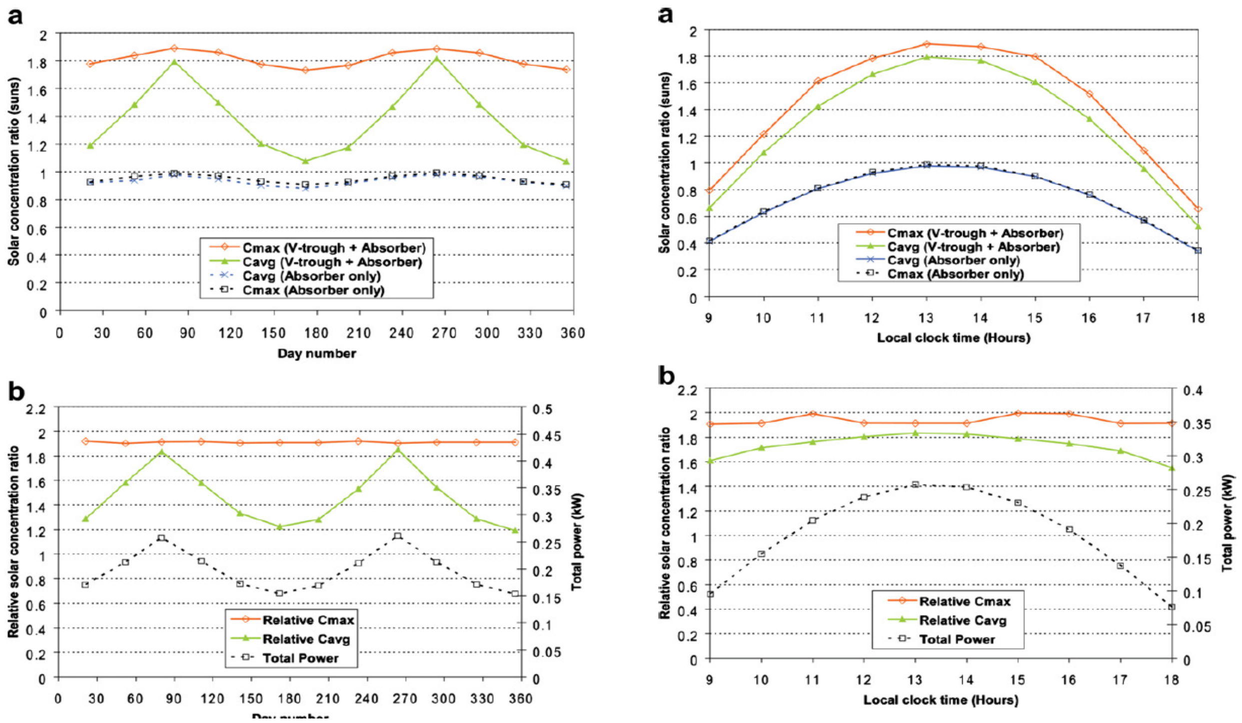


Fig 3.5 Effect of V trough on Solar Concentration Ratio

Rakesh Kumar, MarcA.Rosen carried out thermal performance of integrated collector storage solar water heater with corrugated absorber surface. In this investigation, the surface of the absorber is considered to be corrugated, with small indentation depths, instead of plane. The modified surface has a higher characteristic length for convective heat transfer from the absorber to the water, in addition to having more surface area exposed to solar radiation. The corrugated surface based solar water heater is determined to have a higher operating temperature for longer time than the plane surface.

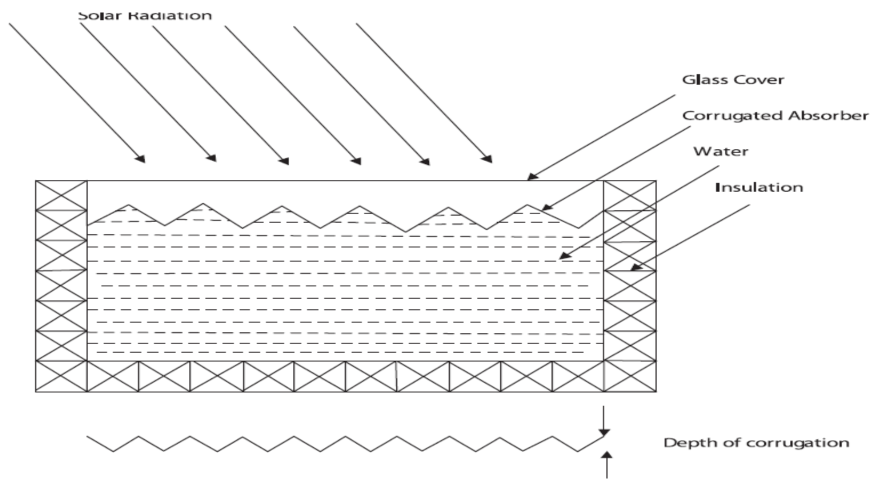


Fig 3.5 Cross section of Rectangular Solar Water heater with corrugated Surface

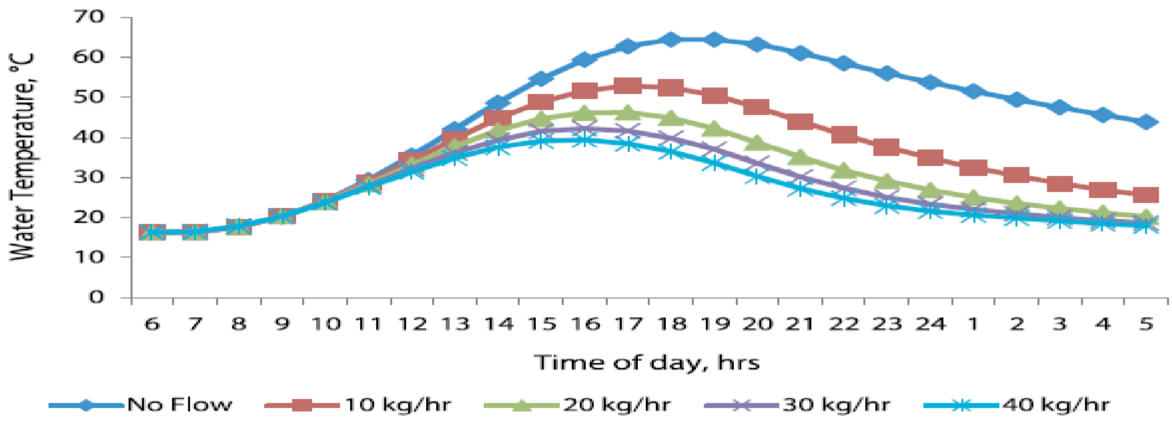


Fig 3.6 Daily Variation of Water temperature with Flow Rate

Hussain Al-Madani performed experiment on cylindrical solar water heater the efficiency of the cylindrical solar water heater was calculated. The maximum value during the experimental period was found to be 41.8%. This reveals a good capability of the system to convert solar energy to heat which can be used for heating water. An economic analysis has reveals that the cylindrical solar water heater compared with the flat plate collector is cost effective.

Fig 3.7 Cylindrical Solar Water Heater

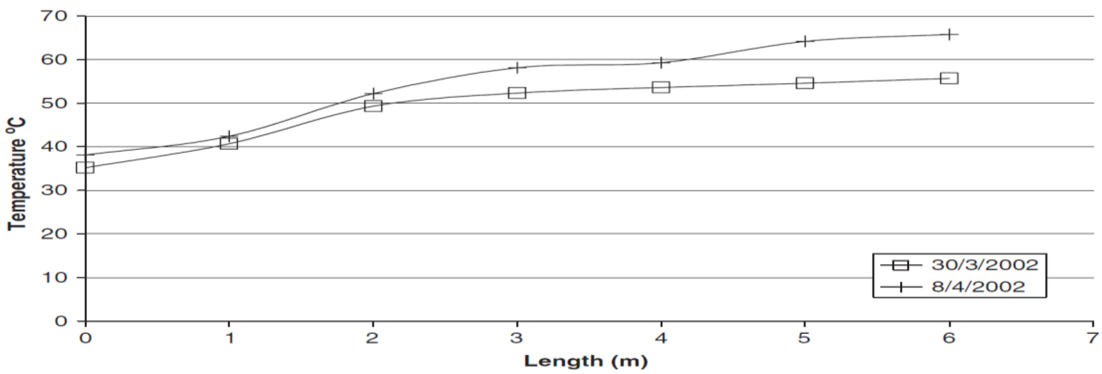


Fig 3.8 Temperature Variation along Length of Solar Water Heater

Experimental Set up

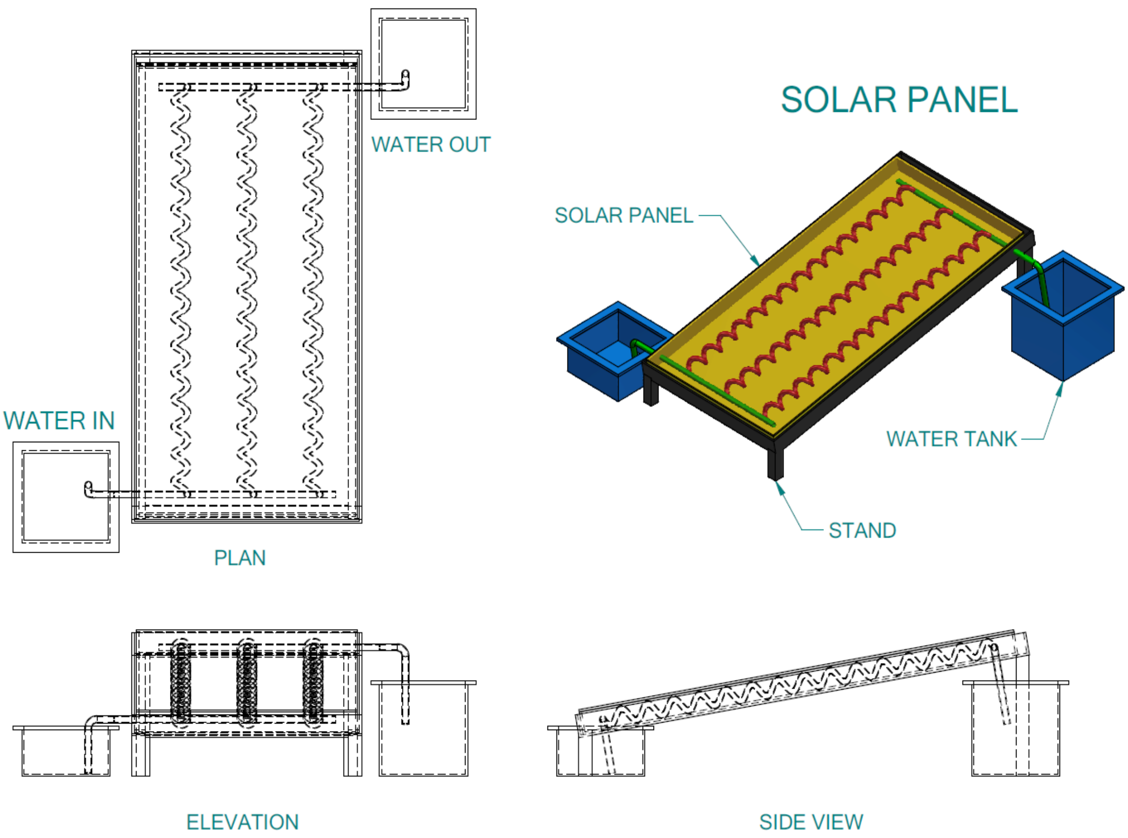


Fig 4.1 Proposed Experimental Set up with Helical Tube Solar Water Heater

Detail of Set up

In the present experimental setup following parts may be used

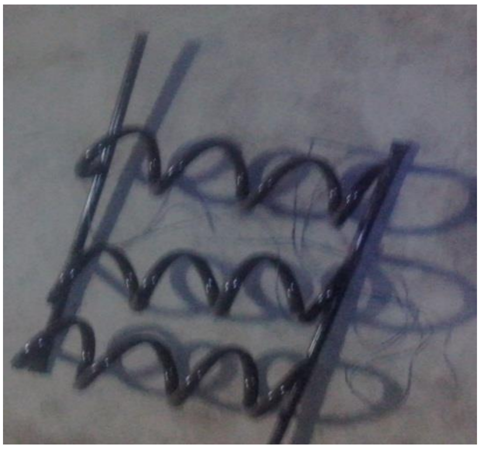
1. ½ inch copper pipes with 20 gauge of sheet of 1 m length.
2. ½ inch helical copper pipes with 20 gauge of sheet of 0.3 m length approximately.
3. 2 mm thick MS sheet with 0.35m X 0.5 m X 0.05m as Solar heater (Helical Tube).
4. Plain glass with above mention size and 3 mm thick
5. Digital Temperature indicator
6. Helical copper coil with 3inch ID

Constructional Detail

In the present work in the first phase copper pipes of three in quantity and ½" diameter and 1 m length twisted into helical shape of pitch 2" and 4" respectively. The three pipes of same pitches are fabricated to 0.5 m copper pipes at top and bottom for water in and water out. The whole assembly placed in the wooden boxes of 10" X 20" and 12" X 18" with 3 mm transparent glass sheet.


LCD
MULTI-STEM THERMOMETER
WITH EXTERNAL SENSING PROBE
Digital Thermometer User's Manual
ST-9269
Multi - Thermometer

Helical coil



Working

In the present work the water tank of 20 lt capacity consists of tape for flow control is connected using flexible pipe to the solar water heater and measuring flask of 1000 ml capacity is placed at outlet of solar water heater and Digital Thermometers are placed in a measuring flask.

In the first phase solar water heaters of 2” and 4” pitch are placed in north-south postion and then then thermocouples are at inlet and out let of solar water heaters and finally with the the help of tape water is allowed to flow through copper pipes of solar water heater.

Result and Discussion

Observation Table

	Helical 4”			Helical 2”				
TIME (hh:mm)	$T1_{in}$ (°C)	$T2_b$ (°C)	$T3_{out}$ (°C)	$T4_{in}$ (°C)	$T5_b$ (°C)	$T6_{out}$ (°C)	Time required to fill 1000 ml tank Helical	Time required to fill 1000 ml tank Straight
11:20	41	62	50	42	64	49	292	353
11:35	41	65	49	41	66	50	292	353
11:50	41	68	52	42	69	53	292	353
12:00	42	71	53	42	71	55	292	353
12:30	41	73	57	41	72	56	292	353

Result Table

Mass Flow Rate	Mass Flow Rate	Qo Helical 4”	Qo Helical 2”	Qi Helical 4”	Qi Helical 2”	η Helical 4”	η Helical 2”
0.003	0.003	0.095	0.107	0.294	0.681	32.25	15.69
0.003	0.003	0.1147	0.095	0.294	0.681	38.98	13.94
0.003	0.003	0.130	0.154	0.294	0.681	44.34	22.66
0.003	0.003	0.190	0.178	0.294	0.681	64.50	26.15
0.003	0.003	0.229	0.178	0.294	0.681	77.97	26.15

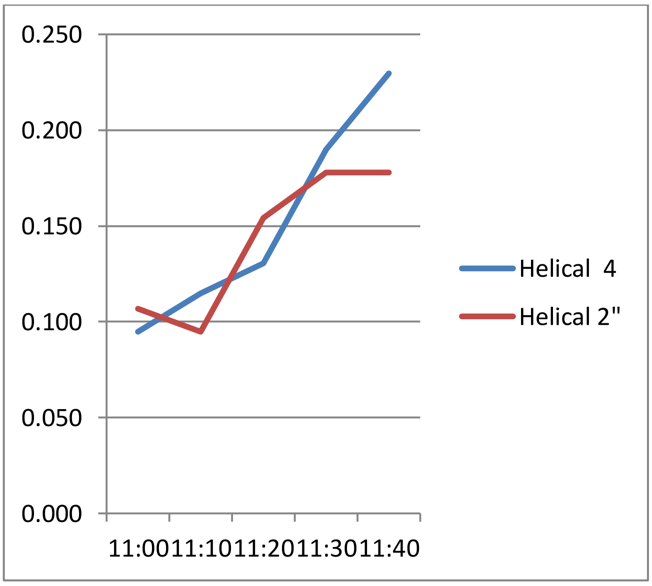


Fig Variation in Heat gain with respect to Time

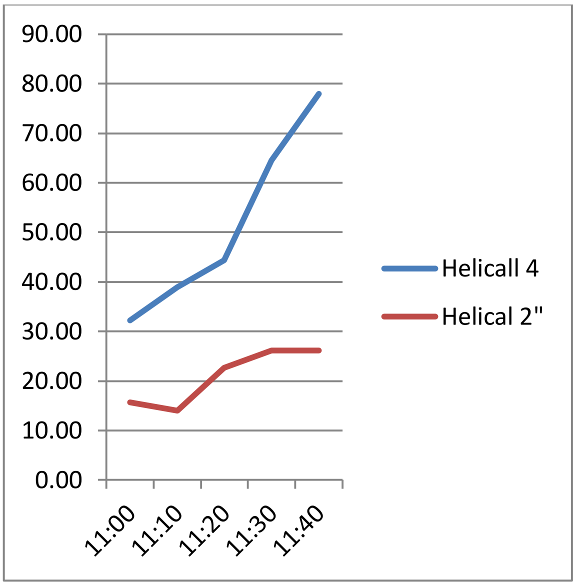


Fig Variation in Efficiency with respect to Time

The following important points have been focused as a part of result obtain through comparative studies of Helical solar water heater with pitch 2” and 4”.

1. The 2”Helical water heater is more compact compare to 4” for same tube length.
2. The outlet temperature is more in case of 4”.
3. The more time is required to fill the 1000 ml water tank in case of 4” solar water heater.
4. The thermal efficiency is more in case of 4” helical solar water heater compare to 2” helical solar water heater.
5. More rate of heat transfer in 4” helical solar water heater compare to 2” helical solar water heater.

Conclusion

The major conclusion is due to helical shape with more pitch i.e 4” more turbulance is created in the flow also due to more retaintion time the rate of heat transfer increases and so more hot water can be achieved also system is compact compare to conventioal solar water heater system.

Future Scope

This work can be extended for more level of experimentation and by increase in length of pipe and make this system viable from commerial point of view.

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