Experimental Study On Efficiency Of Solar Collector At Nagpur (India) During Winter

Jayant. V. Madan, Oshan. M. Sirse

Abstract: In this experimental study, the active solar water heating direct circulation systems the thermo siphon solar flat plate collector has been tested at Government medical college, (21.15ºN, 79.09ºE), Nagpur, Maharashtra, India. The various data needed are collected from Indian metrological department and during months from November to January i.e. during the winter season, the responses from the system has been studied and analyzed. The maximum temperature was obtained was around 70ºc and the minimum ambient temperature was 18ºc. The objective of the present work is to evaluate efficiency of flat plate collector in Nagpur region considering these aspects of the flat plate collector both theoretically and experimentally. A test setup is fabricated and experiments conducted to study these aspects.

Keywords: Solar Water Heater, Thermosyphon, Solar Insolation, Flat Plate Collector, collector efficiency

1. INTRODUCTION

Throughout the 21st century, our dependence on the non-conventional energy resources has drastically increased. Due to rapid depletion of energy resources, mankind has started utilizing the non-conventional energy resources like solar energy, wind energy, geothermal heat, tides and biomass. Out of these solar energy is the most abundant and can be easily acquired for use. Technology these days helps us to easily accumulate the Necessary solar radiations and convert it into usable form. The most commonly used solar water heating system for domestic needs is through natural circulation type that consists of a flat plate solar collector connected to an insulated storage tank. The sun's rays pass through the glass and are trapped in the space between the cover and plate or are absorbed by the black body. The circulating water through a conduit system located between the cover and absorber plate is heated and then carried to the storage tank. Flat plate collectors are most suitable when a temperature below 100ºC is required. These are simple to assemble; low cost; simple in design and fabrication; durable; do not require sun-tracking; can work on cloudy days; and require minimum maintenance. The performance of the thermo syphon system depends upon the size and capacity of the storage tank, the thermal capacity of the collector and the connecting pipes including fluid flow and on the pattern of hot water use. This paper deals with the efficiency of the thermo syphon solar collector in Nagpur region. For the calculation of the efficiency, various design parameters are needed. Radiation data for Nagpur was taken from the Indian Meteorological Department. The design parameter for the collector and the parameters for the water tank were calculated. The solar insolation and the angle of tilt were taken according to the geographical location of Nagpur. Experiment was performed to calculate the efficiency of the solar flat plate collector.

2. OPERATION PRINCIPLE

Water is caused by gravity to flow from cold water reservoir to the solar collector where it absorbs radiation in the form of heat energy. This result in density difference which causes heated water to flow through riser to hot water tank via common header. Thermo siphon systems generally have low flow rates through the collector, as the fluid undergoes a high temperature rise. This accounts for low efficiency of thermo siphon systems.

2.1 Schematic diagram

Figures 1.0 & 2.0 shows schematic diagram and assembly of thermo siphon solar water heater

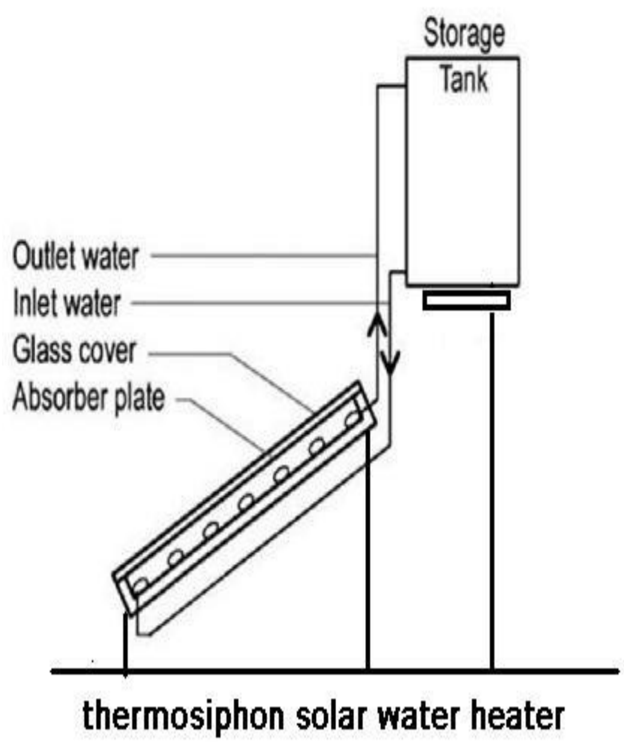

Figure: 1.0

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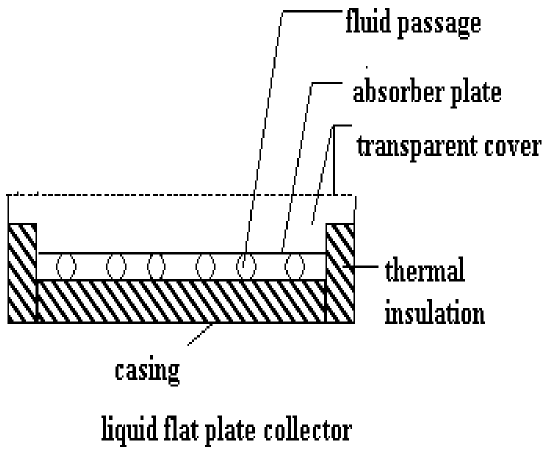
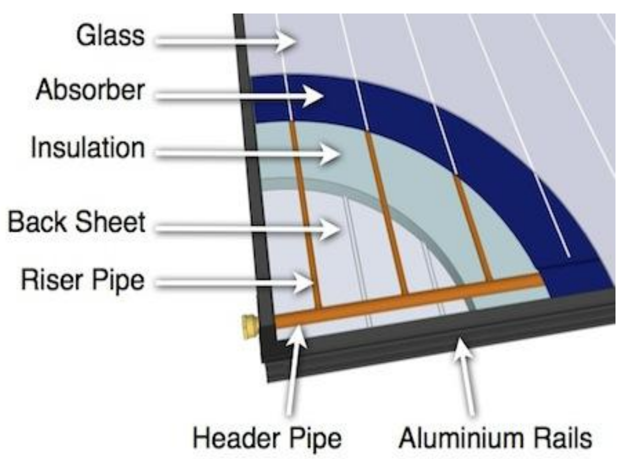


Figure: 2.0

3. COMPONENTS OF SOLAR WATER HEATING SYSTEM

3.1 Solar collector

A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation Solar flat plate collector



Glass: Toughened glass (glazing) protects the absorber from the outside environment while allowing through >90% of sunlight.
Absorber: A thin sheet of Aluminum is coated with a highly selective material that is extremely efficient at absorbing sunlight and converting it in to usable heat
Insulation: The insulation helps reduce heat loss from the sides and back of the collector. Made from ultra-light weight melamine foam this material is chosen to greatly reduce the weight of the collector.
Back Sheet: An aluminum alloy sheet seals the back of the panel and adds to the rigidity of the collector.

3.2 Water tank

water tank serves to store hot water from solar collector the tank is insulated so that there should be minimum loss of heat .the size of water tank is determined by the quantity of water to be heated.

4. DESIGN ANALYSIS

4.1 Testing method

The storage was filled with 100 liters of water and working fluid tubes were filled with working fluid through the working fluid tank. The working fluid is supplied from the working tank which flows inside the tubes in the collectors and then to the solar water storage tank A part of incidence solar radiation on the glass cover is reflected back to atmosphere and remaining is transmitted inside the solar collectors and the solar radiation is absorbed by the working fluid. Due to the absorption of solar radiation, working fluid temperature increases and the working fluid starts emitting long wavelength radiation which is not allowed to escape to atmosphere due to presence of glass cover. Thus the temperature above the working fluid inside the solar collectors becomes higher. The insulation provided at the bottom and all the sides of solar collectors and glass cover serves the purpose of reducing direct convective losses to the ambient which further becomes beneficial for rise in working fluid and solar collectors temperature respectively. The heated working fluid moves upward due to decrease in density whereas the colder working fluid settled at the lower portion due to more in density. After 3 hours the temperature of water(working fluid) at outlet is measured.

5. MEASURED PARAMETER

- Volume of water to be heated, v = $0.1m^3$
- Average time of heating = 3 hours
- Average insolation (Nagpur) = $480w/m^2$
- Ambient temperature = 18ºc (winter season)
- Water inlet temperature = 18ºc (winter season)
- Water outlet temperature = 70ºc
- Length of collector = 1m
- Width of collector = 2m

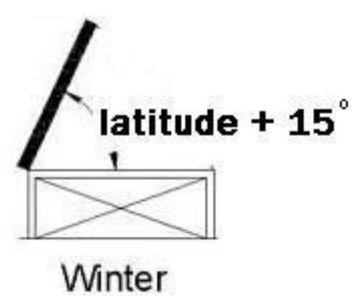
6. WATER TANK

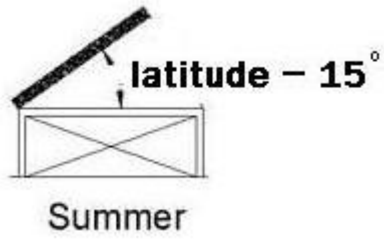
Volume of water + volume of air space
100 liters + 100x0.5 = 150 liters
Length of tank = 1m
Volume (v) = $\pi r^2 l$
Diameter of inner tank = 0.35m
Diameter of outer tank = 0.4m

7. Solar insolation

Average value of solar insolation in Nagpur during winter season $4.8\ Kw\ hr$ (data by Indian metrological department)

8. ANGLE OF TILT FOR COLLECTOR





Nagpur, Maharashtra, India. Located at northern hemisphere at coordinates 21.15ºN, 79.09ºE so, panels have to point towards south direction. Determining angle of tilt taking latitude of location and adding 15º for winter season and subtracting 15º for summer season
Angle of tilt for solar collector = 21º + 15º = 36º

9. EFFICIENCY CALCULATION

The efficiency of the flat plate collector with an alternative working fluid was calculated as Overall efficiency of the system = (heat gained by water /input solar energy)
Where$v$ =volume of water
T_i = temperature of water at inlet
T_o = temperature of water at outlet
G= solar insolation
cp =specific heat of water
ṁ = mass flow rate of water per second

I. Volume of water in tank

$v = 100\ litres$
$v = 100 * 10^{-3} m^3$
$v = 26.4172\ gallons$

II. Temperature of inlet and outlet

$T_i = 18℃ = 64.4\ °F$
$T_o = 70\ ℃ = 158\ °F$
$time\ required = 3\ hours = 10{,}800\ sec$

III. Solar insolation heat input

$G = 4.8\ Kw\ hr$
$G = 4.8 * 10^3\ w\ hr$
$G = 4.8 * 10^3\ w\ hr * 3\ hours$
$G = 9{,}600\ w\ hr$
$G = Q_{in} = 32{,}736\ BTU$

IV. Heat gained by water during 3 hours

$Q_{out} = m * cp * \Delta T$
$\Delta T = 158°F - 64.4°F = 93.6°F$
$cp = 1.0\ BTU$
$\dot{m} = (\dot{v}\ in\ ft^3) * 62.42$
$\dot{m} = 220.30\ lbs$
$Q_{out} = 20.62 * 10^3\ BTU$

$$\acute{\eta} = \frac{Q_{out}}{Q_{in}}$$

$$\acute{\eta} = \frac{20.62 * 10^3}{32{,}736}$$

$\acute{\eta} = 62.98\% \cong 60\%$

EFFICIENCY OF THE SYSTEM

The flat plate collector efficiency using water as a working medium during month of November to January i.e. during winter season in Nagpur region , was around 60% respectively.

CONCLUSION

Maximum outlet temperature = 73ºC
Maximum recorded efficiency = 65%
Since hot water is circulated by thermo siphon principle (through evaporation and condensation), ideal final temperature of hot water should be 100ºC in the absence of any heat loss. Thus, further increase in number of tubes and emissivity of glass cover is likely to improve on the water outlet temperature which might get also be affected by ambient temperature, So as to get maximum efficiency of the system.

REFERENCES

[1] (P.Vijay,K.RajaSekhar,E.Srikanth Reddy,"An Analytical Review On Solar Water Heater", International Journal of scientific research and management (IJSRM)||Volume||1||Issue|| 2 ||Pages|| 90-93||2013||ISSN (e): 2321-3418P.Vijay, IJSRM volume 1 issue 2 May 2013 [www.ijsrm.in]Page 90)

[2] (Mangesh.A.Pachkawade,Pritam.R.Nimkar,Balu.K.Chavhan,DESIGN AND FABRICATION OF LOW COST SOLAR WATER HEATER,Issue 3, Vol.6 (November 2013),ISSN 2249-6149.ISSN 2249-6149ISSN 2249-6149)

[3] (R.A.Gansler,S.A.Klein,&W.A.Beckman," Investigation of minute solar radiation data", solar energy,vol.55,No.1,pp 21-24,1995)

[4] (M. Batallas, H. Yih and P. Singh, Ph.D,"determining the performance of polyurethane foam Pipe insulation for high temperature service",AB T2P 4L4)

[5] (Vindhya Vasiny Prasad Dubey, Raj RajatVerma, PiyushShankerVerma, A.K. Srivastava,"international journal of research in Aeronautical and mechanical engineering",urameissn (online): 2321-3051) (Ankit.Patel,"Design and optimization of Shell and Tube Heat Exchanger"Volume : 3 | Issue : 8 | Aug 2013 | ISSN - 2249-555X)

[6] (William rahmeyer,"Dynamic flow testing of check valves",

[7] (GayathriVijayakumar, Sanford A. Klein,William A. Beckman,"ANALYSIS OF SHORT-TERM SOLAR RADIATION DATA",University of Wisconsin-Solar Energy Laboratory)

[8] (NattapornChaiyat, "Upgrading of Low Temperature Solar Heat with Cascade Vapour Compression and Absorption Heat Pump", Vol.3, Issue.4, Jul - Aug. 2013 pp-1923-1934 ISSN: 2249-6645)

[9] (P.Vijay,K.RajaSekhar,E.Srikanth Reddy,"An Analytical Review On Solar Water Heater",International Journal of scientific research and management (IJSRM) ||Volume||1||Issue|| 2 ||Pages|| 90-93||2013|| ISSN (e): 2321-3418)

[10] (Nosa Andrew Ogie, IkponmwosaOghogho, and Julius Jesumirewhe "Design and Construction of a Solar

Water Heater Based on the Thermosyphon Principle", Ashdin Publishing Journal of Fundamentals of Renewable Energy and Applications Vol. 3 (2013), Article ID 235592)

[11] (P. Sivakumar, W. Christraj2, M. Sridharan and N. Jayamalathi,"performance improvement study of solar Water heating system",ARPN Journal of Engineering and Applied Sciences,vol. 7, no. 1, january 2012 issn 1819-6608)

[12] (Solar water heating guidebook, Version 1, October 2006, Introduction)

[13] Solar energy, Suhas.p. sukhatme Tata McGraw-Hill Education, 1996

[14] Uses of solar energy for water heatingBedriDragusha, BesimVeselaj, XhevatBerisha Issue 3, Volume 3, 2009

[15] Thermo Siphon Solar Water Heater International Journal of Engineering and Technology Volume 3 No. 3, March, 2013 ISSN: 2049-3444

[16] Solar energy utilization by G.D.rai.

[17] Solar radiation analysis (pg no . 39-36)

[18] Solar collectors-flat plate air heating (pg no . 156-190)

[19] A simple formula for estimating global solar radiation in central ariddeserts of IranAli A. Sabziparvar_College of Agriculture, Bu–Ali Sina University, Azadegan Blvd., Chrmsazi St., Hamedan 65174, Iran

[20] Performance Analysis of Solar Water Heater Shahidul Islam Khan, Asif Islam*
Smart Grid and Renewable Energy, 2011, 2, 396-398

[21] Design and fabrication of low cost solar water heaterMangesh.A.Pachkawade,Pritam.R.Nimkar,Balu. K.ChavhanIssue 3, Vol.6

[22] Shell and tube heat exchanger design by VB Language for education purpose Chandrakant b. Kothare