American International University- Bangladesh
Department of Electrical and Electronic Engineering
EEE: Renewable Energy Technology Laboratory

Title: Familiarization with Solar Thermal System

Abstract:

In this experiment, the active solar water heating direct circulation systems using the thermo-syphon solar flat plate collector will be tested at AIUB Campus 2. The objective of the present work is to evaluate efficiency of flat plate collector in Dhaka, Bangladesh considering the aspects of the flat plate collector both theoretically and experimentally.

Introduction:

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 experiment deals with the efficiency of the thermo-syphon solar collector in Dhaka. For the calculation of the efficiency, various design parameters are needed. Radiation data for Dhaka is taken from the Bangladesh Meteorological Department. The design parameters for the collector and the parameters for the water tank are calculated. The solar insolation and the angle of tilt are taken according to the geographical location of Dhaka. Experiment will be performed to calculate the efficiency of the solar flat plate collector.

Theory and Methodology:

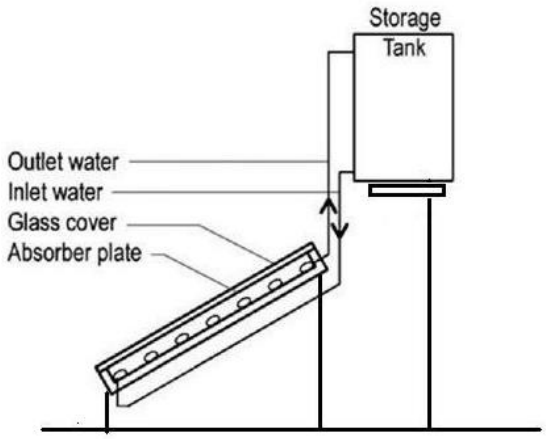


Figure 1: Thermo-syphon Solar Water Heater

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-syphon systems generally have low flow rates through the collector, as the fluid undergoes a high temperature rise. This accounts for low efficiency of thermo-syphon systems.

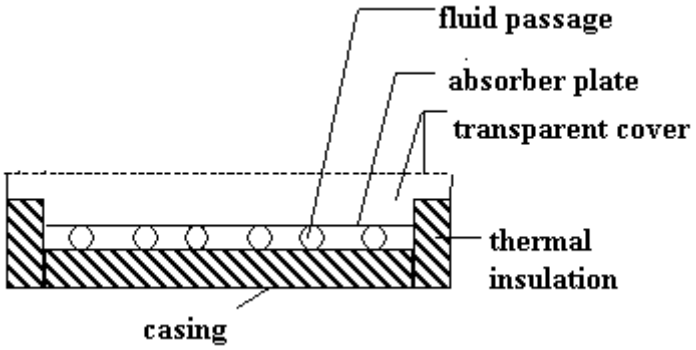
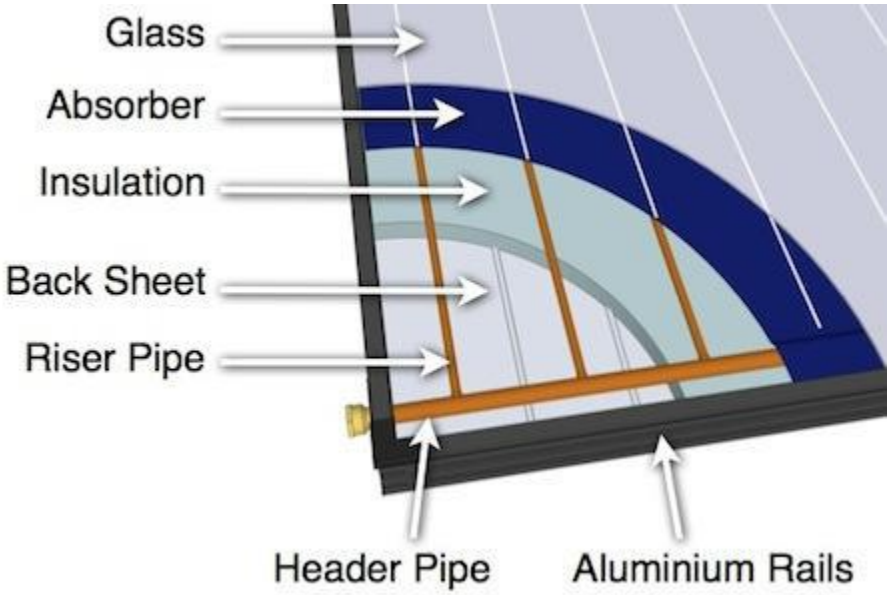


Figure 2: Solar Flat Plate Collector

Components of Solar Water Heating System:

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.



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 w

Back Sheet: An aluminum alloy sheet seals the back of the panel and adds to the rigidity of the collector.

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.

Pre-Lab Homework:

Study about Solar Thermal Systems and Flat Plate Collector.

Apparatus:

Computer installed with RETScreen4 Software and necessary system requirements.

Experimental Procedure:

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.

Measured Parameters:

- Volume of water to be heated, v = 0.1m3
- Average time of heating = 3 hours
- Average insolation (Dhaka) = 4.64 kWh/m2/day
- Ambient temperature = 21.6 ºc (Winter), 28.9 ºc (Summer)
- Water inlet temperature = 21.6 ºc (Winter), 28.9 ºc (Summer)
- Water outlet temperature = 70ºc
- Length of collector = 1m
- Width of collector = 2m

Water Tank:

Volume of water + volume of air space
100 liters + 100 x 0.5 = 150 liters
Length of tank = 1m
Volume (v) = $\pi r^2 l$
Diameter of inner tank = 0.35m
Diameter of outer tank = 0.4m

Solar Insolation:

Average value of solar insolation in Dhaka is – 4.64 kWh/m^2/day

Collector Tilt Angle:

Dhaka, Bangladesh is located at northern hemisphere at coordinates 23.8103° N, 90.4125° Eso, panels have to point towards south direction. Determining angle of tilt needs taking latitude of location and adding 15º for winter season and subtracting 15º for summer season.

Calculation and Results:

The efficiency of the flat plate collector with an alternative working fluid are calculated as Overall efficiency of the system = (heat gained by water /input solar energy)

Where

v =volume of water
Ti = temperature of water at inlet
To = temperature of water at outlet
G= solar insolation
cp =specific heat of water
ḿ = mass flow rate of water per second

I. **Volume of water in tank**

v=100 $litres$ or v=100$*10^{-3}m^3$ or v=26.4172 $gallons$
ḿ= 220.46 pounds (Converted from gallons to lbs)

II. Temperature of inlet and outlet

Ti=21.6℃ (Winter) =70.88 °F
To=70 °C=158 °F
T$ime\ required$=3 $Hours$=10,800 sec

III. Solar insolation heat input

G= 4.64*10^3$*$3*3412.14
Hence Qin= 47497 BTU

IV. Heat gained by water during 3 hours

$Qout$= ḿ $*cp*\Delta T$
ΔT=158°F−70.88°F=87.12°F

cp=1.0 BTU
ṁ= 220.46 lbs
$Qout$= 19206.4752 BTU
$\acute{\eta}$=$Qout/Qin$
$\acute{\eta}$=19206.4752/47497
$\acute{\eta}$=40.4372%≅40%

Discussion and Conclusion:

The flat plate collector efficiency using water as a working medium during month of November to January i.e. during winter season in AIUB, Campus 2 is around 40% . Since hot water is circulated by thermos-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] Madan, Jayant V., and Oshan M. Sirse. "Experimental Study On Efficiency Of Solar Collector At Nagpur (India) During Winter.", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 4, ISSUE 08, AUGUST 2015 ISSN 2277-8616

[2] 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