COMPARISON OF BUILT-IN-STORAGE AND NATURAL FLOW TYPE SOLAR WATER HEATERS

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Abstract

This paper compares experimental results of the performance tests of a Built-in-Storage Type Solar Water Heater (BSWH) and the Natural Flow Type Solar Water Heater (NFSWH) performed at IUT campus, Dhaka, Bangladesh during the rainy season.
Both of these solar water heaters were mainly made of wood, G.I. Sheet, steel frame, and some valves and piping. The BSWH is 114 litres in capacity, 1.265m^2 of collector surface area, and 10 cm. in depth and the NFSWH has a cylindrical tank of 900 mm length and 600 mm diameter having a capacity of 150 litres, the collector has a surface area of 1.84 m^2 and depth of 200 mm.
The readings were taken on hourly basis starting from 8 AM to 5 PM. The BSWH can heat 114 litres of water to a maximum temperature of 56^{0}C and 59.5^{0}C absorbing 2510.4 Wh/m^2 and 2573.1 Wh/m^2 heat energy during August and September respectively, whereas the NFSWH can heat 150 litres water to a maximum temperature of 60^{0}C and 61^{0}C absorbing 2355.75 Wh/m^2 and 2527.45 Wh/m^2 heat energy in the same day. For BSWH the daily rise of water temperature was about 12^{o}C in August and about 14 ^{0}C in September and for NFSWH the rise was about 16^{o}C in August and about 18^{0}C in September. The daily average heat energy absorbed by BSWH is about 1276.2 Wh/m^2 and for the NFSWH it is about 1667.14 Wh/m^2. The efficiency of the BSWH varies from 36.95 to 41.9 percent and that of for NFSWH 38.24 to 46.5 percent. These differences in heat energy absorption and the efficiencies are because of the fact that loss of heat increases rapidly with the rise of water temperature and the weather conditions also affect the total performance. On a very clear bright sunny day, the maximum efficiency can be obtained with a maximum mean water temperature.

Introduction

The BSWH consists of one or more metal water tanks painted with a heat absorbing black coating and placed in an insulating box or container with a glass or plastic cover that admits sunlight to strike the tank directly. The batch system's storage tank is the collector as well.

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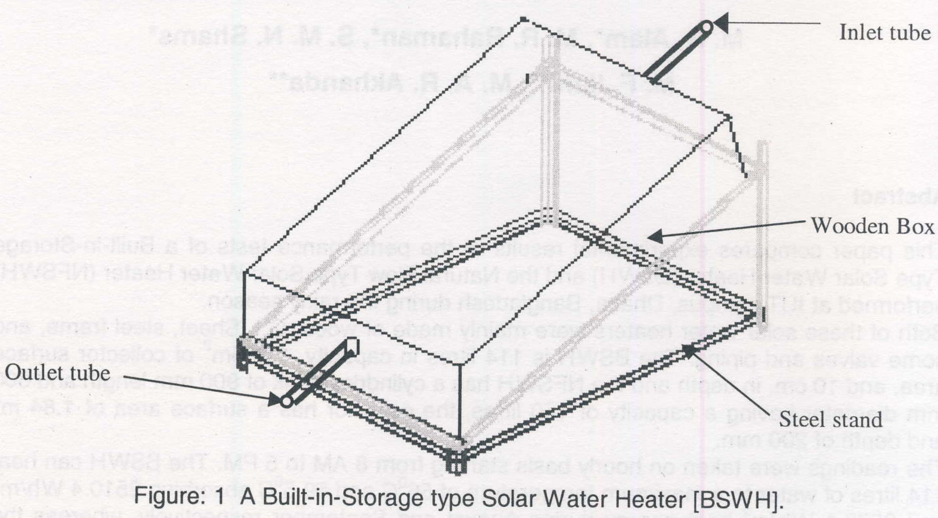

Figure: 1 A Built-in-Storage type Solar Water Heater [BSWH].

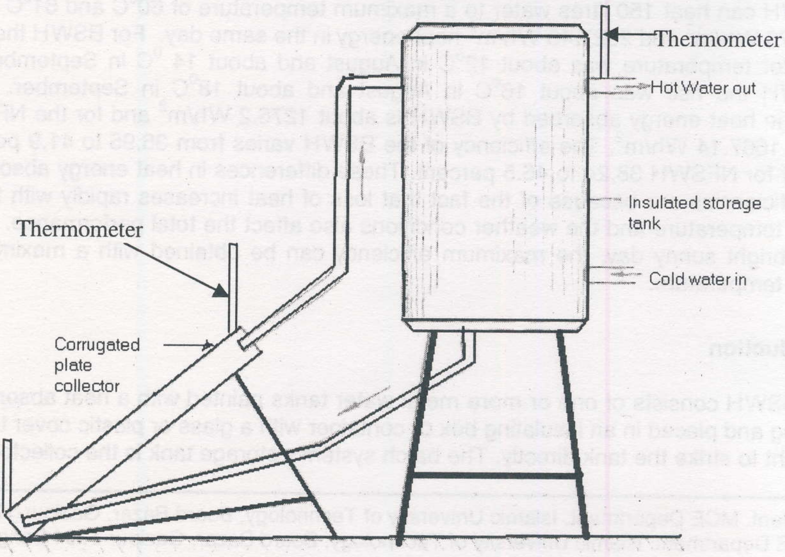

Figure : 2 A Natural Flow type Solar Water Heater [NFSWH]

These systems will use the existing tank pressure to circulate water through the system. Each time a hot water tap is opened, heated water from the batch system tank is removed and replaced by incoming cold water. [3]

The thermosyphon system uses a corrugated plate collector and a separate storage tank that is located higher than the collector. The storage tank, located above the collector receives heated water coming from the top of the collector into the top of the storage tank. Colder water from the bottom of the storage tank will be drawn into the lower entry of the solar collector to replace the heated water that was thermosyphoned upward..[3]

A comparative evaluation of the performance of three BSWH of equal volume were conducted by Ecevit et al.[13] in 1990. The rectangular and triangular with one-baffle plate heaters were 43 percent and 40 percent efficient respectively. Garg [11] in 1975 carried out year round performance test on rectangular heater of capacity 90 litres which can supply water at a mean temperature of 50 to 60 ^{0}C in winter and 60 to 70 ^{0}C in summer. Chinnapa et al [12] in 1973 studied pressurized BSWH and found that 30-50 gallons of water could be supplied a day at 48.5^{0}C and the efficiency was 46 percent.

Although the geographical position of Bangladesh shows that this country is blessed with sufficient amount of solar energy throughout the year, the work on BSWH is still in its infancy in Bangladesh. Researchers of this country have carried out very limited work on BSWH. Akhanda et al [10] in 1995 carried out performance studies on BSWH of 115 litres water capacity with a mean water temperature of 44 ^{0}C. The Pioneer work on BSWH was carried out by Chuan [16] in 1976, Tanishita [14] in 1970. All those works and comparisons were on BSWH only but this paper compares the performance of BSWH with NFSWH, as it was not done before for the same condition of weather and the geographical locations.

Experimental Apparatus

Figures 1 and 2 show the schematic diagrams of the BSWH and NFSWH respectively. In BSWH the storage tank and solar collector are combined and built as one unit as shown in Fig.1.This BSWH has corrugated absorber plate. The tank is of 138cmX91cmX10cm dimension with a capacity of 114 litres. It is fabricated from 20-gauge GI sheet, one at the bottom and the other is absorber plate at the top which is corrugated [7].

In NFSWH the storage tank is separated from the collector. The storage tank has cylindrical shape with 900 mm length and 600 mm diameter having a capacity of 150 litres, the dimension of the collector is 2300mm×880mm×200mm.They are joined by plastic pipe with proper insulation. The tank is placed at a height of 1860mm above the ground level [6]. This was fabricated by G.I. sheet.

For BSWH water temperature at different depths in the storage tank is measured with five thermocouple probes made of iron-constantan (type J) placed inside the tank [7]. For NFSWH two thermometers are placed at inlet and outlet of the collector and one is used for storage tank outlet.[6]

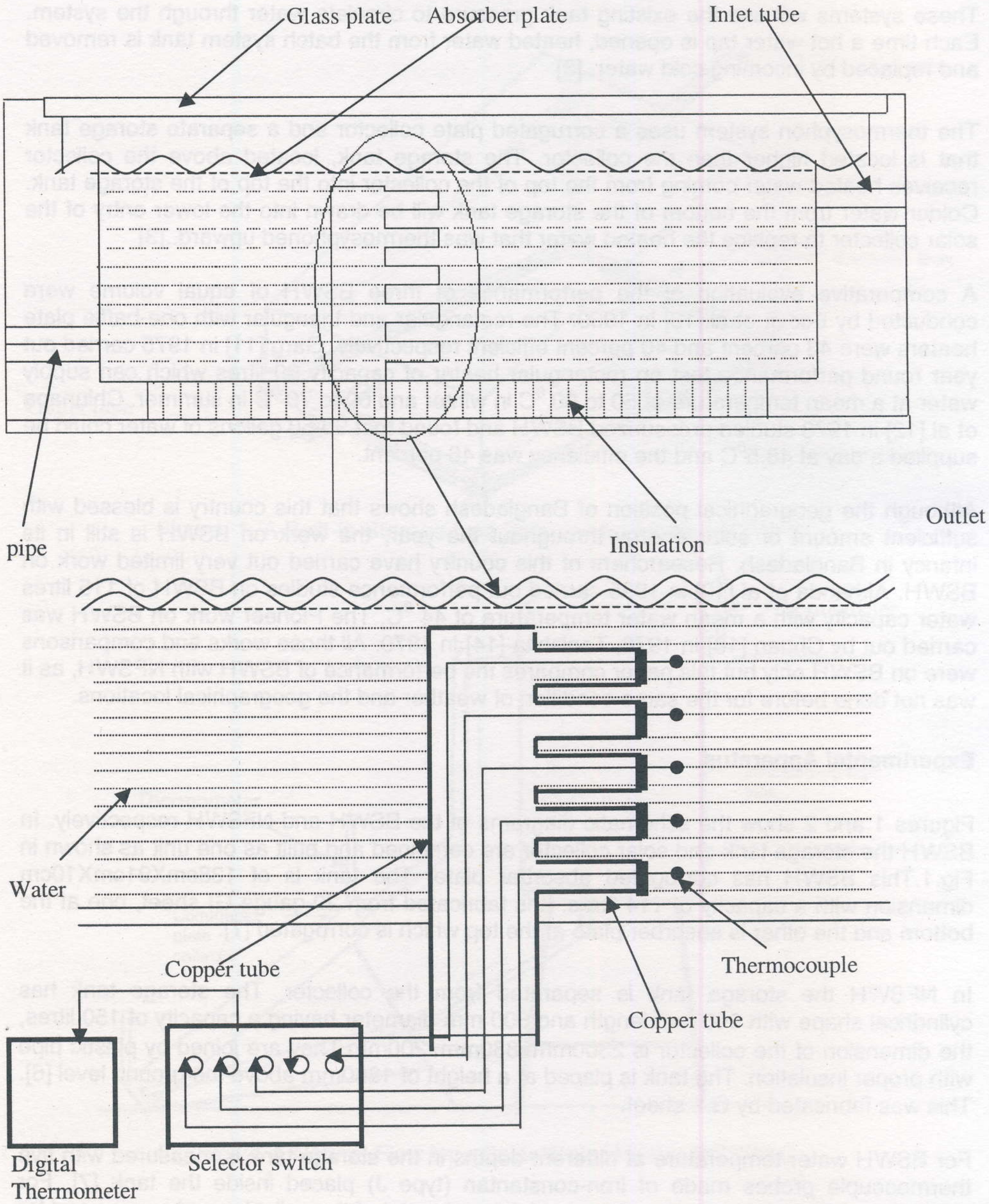

Figure : 3 Experimental Set up

The following procedures were followed:

1. The solar water heaters were filled with water.
2. For BSWH five thermocouple probes (type J) are placed inside the tank at a distance 2 cm apart from each other.
3. For BSWH system the collector is held at a fixed angle (23.5^0)
4. For BSWH the temperature of water at different depths were measured by using a selector switch.
6. The readings were displayed in a digital thermometer
7. A Solar Integrator measured the intensity of solar radiation.
8. The same procedures were repeated for several times.

The following precautions were made during the time period when the experiments were carried out

1. The piping that connects to and from the NFSWH was highly insulated because on a cold night when no one is drawing hot water, the water in the pipes is standing still and vulnerable to freezing. . The water in the BSWH itself will not freeze because there is adequate mass to keep it from freezing. [1,4]

2. Since the tank that is storing the heated water is installed outside, there will be heat loss from the tank during the night. An insulating cover is placed on the heater in the evening to minimize this. [3,5]

3. Careful selection of site was made so that trees, buildings or other obstructions cast no shade on the collectors between 8 a.m. and 5 p.m.[2,3]

Results And Discussions

Figure 4 shows the variation of heat energy absorbed, mean water temperature and ambient temperature recorded every hour from 8 AM to 5 PM on August 31,2002 for BSWH and fig.5 shows the variation of heat energy absorbed, ambient temperature, reservoir outlet and collector outlet temperature recorded every hour from 8 A.M to 5 P.M on the same day. From figures 4 and 5 it is obvious that the mean water temperature increases at a faster rate and reaches a maximum value at the maximum ambient temperature around noon. Both mean and ambient temperatures then decrease at slower rate. As the ambient temperature increases the mean water temperature also increases. The rise of water temperature in the collector is more in the forenoon than in the afternoon. As the ambient temperature increases, the mean water temperatures for both heaters also increase and final mean water temperatures reach maximum values at around noon every day as expected.

In the morning hour from 8 to 9 AM the BSWH can raise the mean temperature of water by 6°C whereas for the NFSWH it is 4°C at the same time period of the same day. The temperature difference between mean water temperature at 5 PM and 8 AM on August 29,2002 is 12°C for the BSWH and 16°C for NFSWH. The average temperature difference

To reduce heat losses from the collector by radiation and convection of BSWH, a glass cover of 142 cm X 101 cm X 5 mm with an optimum air gap of 25.4 mm is used. The glass rests on a wooden frame of 153cmX106cmX5.04 cm [7] For natural circulation system the thickness of the glass plate is 3mm and has a dimension of 1065mmX760mm [9].

Both of these heaters are blackened with boiler paint in order to increase the absorption of short wave solar radiation. A wooden frame supports this plate and to avoid leakage of water, rubber gasket is used in between the frame and the G.I. sheet [6,7].

Both the water heaters are held rigidly on two steel stand structures, which provide setting of these collectors at any desired inclination between 0 to 40 degree for thermosyphon system and at a fixed angle (22.5^{o}) for BSWH [6,7]. Two G.I. pipes of 25.4mm OD are fitted for cold-water entry and hot water exit at the front and the backsides of the tank respectively.
The glass wool is used as insulation having a thickness of 2.86cm at the bottom surface and 2.54cm at the sides of the BSWH. The insulation is contained in a wooden casing having external dimensions of 153cmX106cmX25.04cm[7]. For NFSWH the quantity of insulation was 80mm at the bottom, 40mm in the side of the collector 40 mm in the periphery, 80mm at the top and bottom of the storage tank. [6,9]

Rain is one of the most important factors, which may damage the system. If the rain is heavy, especially with hails it may cause damage to the glass and if water goes into the collector box it may damage the insulation. To overcome these problems one removable shade is used for uncertainties. By using this safety cover the glass sheet is kept more or less dust free to get more incident energy from the sun. The dimension of the safety cover is 165cmX116cm for the built-in-storage type solar water heater and that for 240cm×100cm for the natural circulation system. [6,7,9]

Test Procedure

The water heaters were installed at places with no obstructions to sunshine during the day. The tanks were filled before 8.00 AM in the morning with fresh water by opening the gate valves provided in the inlet pipe of the heater. Five thermocouples were used to measure the water temperature at five different levels in the tank of BSWH, which were already inserted through the bottom of the tank. [7]
For NFSWH three thermometers were used to measure the temperature at different positions, one for the inlet of the tank, one for the inlet of the collector and another for the outlet of the collector. [8]

One thermometer was used to measure the temperature of the ambient air. These measurements were taken at beginning and during the day at one-hour intervals. Also the intensity of total solar radiation was measured on the plane of the BSWH and the NFSWH at the same time and on the same day.

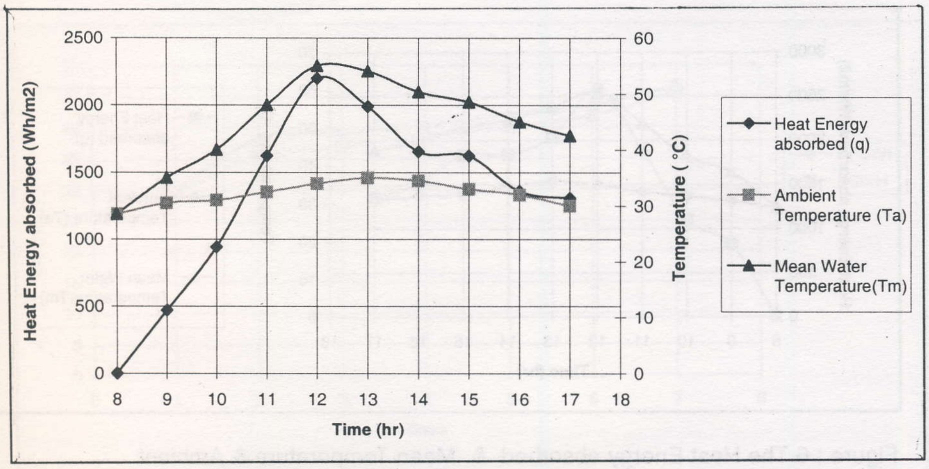

Figure : 4 The Heat Energy absorbed, Mean water Temperature & Ambient Temperature on Augaust 31,2002.[BSWH]

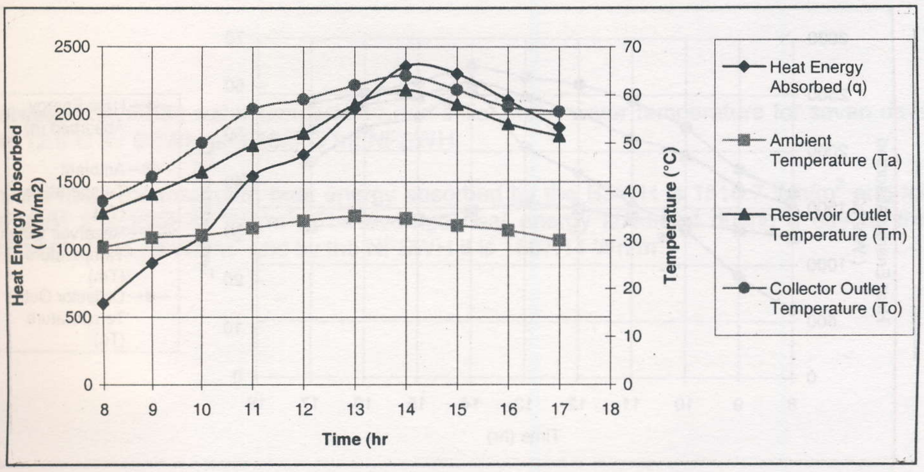

Figure : 5 The Heat energy absorbed,Ambient,Reservoir outlet and Collector outlet Temperature on Augaust 31,2002.[NFSWH]

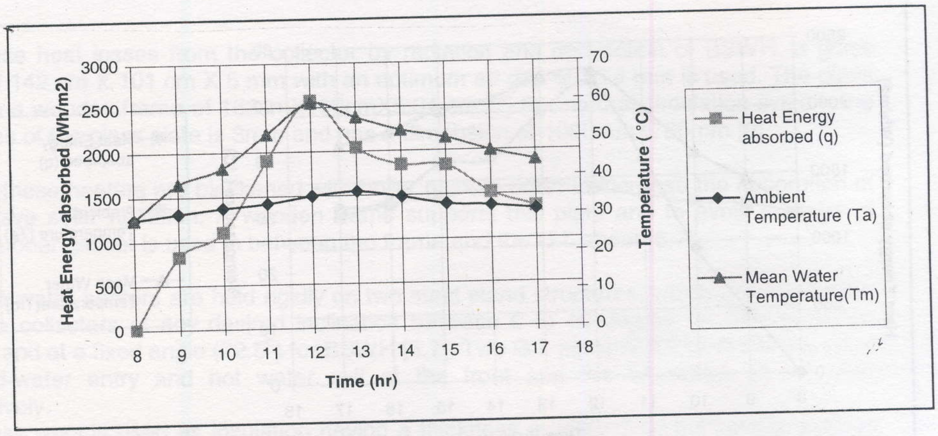

Figure : 6 The Heat Energy absorbed & Mean Temperature & Ambient Temperature on September 07,2002.[BSWH]

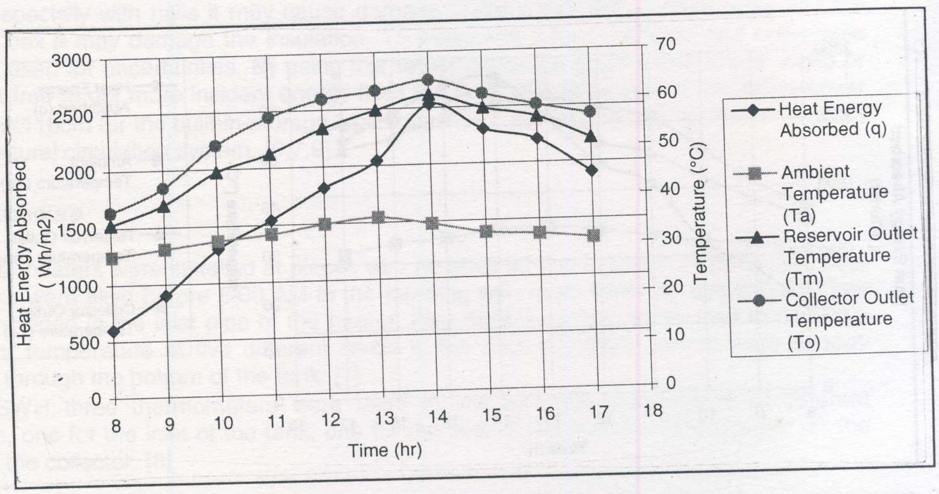

Figure : 7 The Heat energy absorbed,Ambient,Reservoir outlet and Collector outlet Temperature on September 07,2002.[NFSWH]

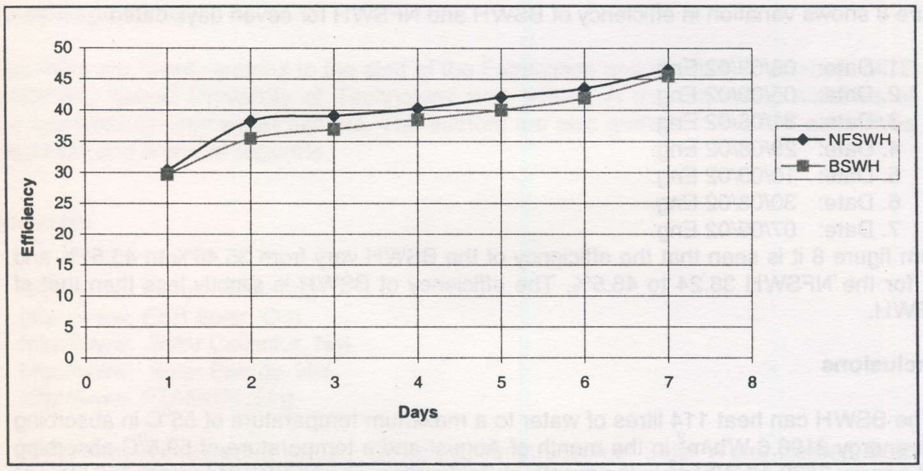

Figure : 8 Variation of efficiency of BSWH and NFSWH in Different Days

between final mean water temperature and initial mean water temperature for seven days are 12.5°C for BSWH and 15.5°C for NFSWH.

In one hour, the maximum heat energy absorbed by the BSWH is 1516.7 Wh/m^2 and for NFSWH it is 2355.75 Wh/m^2. The average heat energy absorbed during a day by the BSWH is 1086.68 Wh/m^2 and by the NFSWH it is 1667.14 Wh/m^2.

Figure 8 shows variation in efficiency of BSWH and NFSWH for seven days dated

1. Date: 06/09/02 Eng.
2. Date: 05/09/02 Eng.
3. Date: 31/08/02 Eng.
4. Date: 29/08/02 Eng.
5. Date: 10/09/02 Eng.
6. Date: 30/08/02 Eng.
7. Date: 07/09/02 Eng.

From figure 8 it is seen that the efficiency of the BSWH vary from 35.46% to 45.51% and that for the NFSWH 38.24 to 46.5%. The efficiency of BSWH is slightly less than that of NFSWH.

Conclusions

1. The BSWH can heat 114 litres of water to a maximum temperature of 55^0C in absorbing heat energy 2196.6 Wh/m^2 in the month of August and a temperature of 59.5^0C absorbing heat energy 2573.16 Wh/m^2 in the month of September. The NFSWH can heat 150 litres of water to a maximum temperature of 60^0C in absorbing heat energy 2355.6 Wh/m^2 in the month of August and a temperature of 61^0C absorbing heat energy of 2410.3 Wh/m^2 in the month of September.

2. The daily average heat energy absorbed by BSWH is about 1276.2 Wh/m^2 and 1498.9 Wh/m^2 in the months of August and September respectively and that for NFSWH it is 1667.14 Wh/m^2 and 1815.6 Wh/m^2 in the months of August and September respectively.

3. The efficiency of BSWH is found 36.95%, 38.46%, and 41.9% in the month of August and 35.46%, 40.02% and 45.51% in the month of September. The efficiency of NFSWH is found 39.1%, 40.3% and 43.5% in the month of August and 38.24%, 42.1% and 46.5% in the month of September.

Nomenclature

A Projected area of the collector surface, m2

Cp Specific heat of water at constant pressure, kJ/kg K

I Solar insolation, W/m2

m Mass flow rate of water, kg/s

q Heat energy absorbed by water per unit area of the collector, W/m2

Ta Ambient temperature, 0C

Tm Mean water temperature, 0C

ΔT Rise in temperature of water, 0C

η Efficiency of the BSWH & NFSWH

Acknowledgements

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APPENDIX

Heat energy absorbed (q) = (m Cp ΔT)/A
Efficiency (η) = q/I

(Contd.)

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