IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

Design, Development and Analysis of Umbrella Shape Solar Hot Water Device

Shailesh B. Yadav[1], Prof. G.R. Nikhade[2], Dr. D.K. Sakhre[3]

M. Tech Scholar, Dept of Mechanical Engineering, Ramdeobaba College of Engineering Nagpur, Maharashtra, India[1]

Asst Professor, Dept of Mechanical Engineering, Ramdeobaba College of Engineering Nagpur, Maharashtra, India[2]

Principal Scientist, CSIR- Central Institute of Mining and fuel Research Nagpur, Maharashtra, India[3]

Abstract: Due to the increasing population in world, the demand for energy is also increasing. There are lots of technologies to utilize the solar energy for the benefits of human society. Out of those techniques most popular technique is solar water heating. Mainly solar collectors used for heating a water are of flat type. It is used to increase the temperature of water up to 70^0C by direct solar radiation absorption. But the flat plate collector has low thermal efficiency due to less surface area. Other disadvantage of flat plate solar collector is improper thermal stratification. So to overcome these drawbacks, new solar geometry used with different tube arrangement. The main aim of this project is to fabricate a low cost solar water heater which gives hot warm water for bathing as well as washing purpose. In proposed system umbrella shape absorber geometry is used, which gives more effective area as compare to flat plate collector subjected to heat transfer. And spiral tube arrangement is being used which overcome the tracking requirement of system. And this system is quite simple in operation as well as in construction. The performance of this umbrella shape water heating system is carried out at Nagpur [21.06^0, 79.03^0] in the month of March with different combinations of selective coatings on the absorber surface, with different mass flow rate, with and without mirror conditions. After experimentation and analysis, it is found that umbrella shape solar water is more efficient as compare to flat plate solar collector. The maximum temperature achieved during the experimentation as 77.6 ^{0}C with corresponding instantaneous efficiency of 60.24% with mass flow rate of 0.192 kg/min.

Keyword: Absorber geometry, Spiral tube arrangement, Absorber coating, Cost, Thermosiphon circulation, Mirror.

I. INTRODUCTION

Currently, 80% of global energy consumption is based on fossil fuels. Although coal, oil and natural gas have been suitable companions to human development, their disadvantages have become more evident with the increasing energy consumption.Moreover, fossil fuels are non-renewable, which means there is a limited amount of these resources available for the near future.

Solar energy is becoming a popular alternative to reduce the environmental impacts. The total solar energy flux intercepted by the earth on any particular day is 6.26 x 10^{20} Joules per hour. This is equivalent to burning 360 billion tons of oil per day or 15 Billion per hour.

However, in 2013, the BP Statistical Review of World Energy reported worldwide energy consumption of 12.5 Billion per year. This means that the earth receives more energy from the Sun in just one hour than the world's population uses in a whole year.

Solar energy is a very large, inexhaustible and clean source of energy. The power from sun intercepted by earth is approximately 1.8×10^{11} MW which is many thousands of times larger than the present consumption rate on the earth of all energy sources. Thus, in principle, the solar energy has the potential of supplying a large portion of the present and future energy needs of the world.

A. Solar Thermal Collectors

A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. The term "solar collector" commonly refers to solar hot water panels. Simple collectors are typically used in residential and commercial building for space heating. In any collector device, the principle is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid. The device in which the no optical concentration is done is called as flat plate collector (FPC). The other type of solar collector is evacuated tube collector (ETC), this type of collector can be used with and without concentration.

B. Basic Flat Plate Collector (FPC)

The flat-plate collectors are the most common used collectors for residential water and space-heating applications. A typical flat plate collector is an insulated metal box with a glass or plastic cover called the glazing and a dark-coloured absorber plate. The glazing can be transparent or translucent. Translucent (transmitting light only) low-iron glass is common glazing material for flat-plate collectors because of high transmission of total available solar energy. The glazing allows the light to strike the absorber plate but reduces the amount of heat that can escape.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

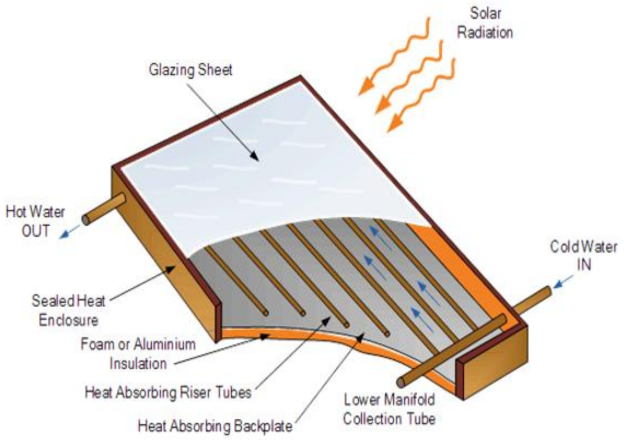

Figure I solar flat plate collector

The sides and bottom of the collector are usually insulated to minimize heat losses. The absorber is made up of copper, aluminium or steel. The thickness of absorber material varies from 0.2 to 0.7mm. There is tube attached to the absorber by means of solder or welding through which heat carrying fluid flows with pitch ranging from 5 to 12cm. The diameter of water tube usually 1 to 1.5cm.

The solar radiation incident on cover get absorb by the absorber. This heat is then transfer to the heat carrying fluid which flows through the tubes. Absorber is then covered by glass or other transparent cover to reduce the heat loss. Usually spacing between absorber and cover ranging from 1.5 to 3cm. The bottom and side are usually insulated by mineral wool, rock wool or glass wool with a covering of aluminium foil and has a thickness ranging from 2.5cm to 8cm.

C. Drawbacks of flat plate collector and advantages of proposed design

Solar flat plate collector has low thermal efficiency due less effective area subjected to solar radiation. The ratio of effective area to the base area ratio is less than 1. Besides this, in solar flat plate collector same tank is used to store both hot and cold water. So there is problem of improper thermal stratification. Apart from these drawbacks, another major reason for not utilizing solar flat plate collector is the cost of solar flat collector.

These drawbacks are overcome by the proposed umbrella shape solar hot water device. The main reason for selecting the umbrella shape absorber geometry is that, it gives more effective area subjected to solar radiation. And the ratio of effective area to base area ratio is more than 1. Apart from this, there is separate storage tank for storing cold and hot water. And water is circulated in the system by thermosiphon principal.

II. FINAL DESIGN OF SYSTEM

- Base radius of umbrella shape collector= 0.6096 m
- Height of umbrella shape collector= 0.6096 m
- Water tubes diameter= 1cm
- Number of turn around collector= 14
- Tank capacity= 50 litre
- Polythene cover thickness= 40 microns
- Header tank height= 1.2 m

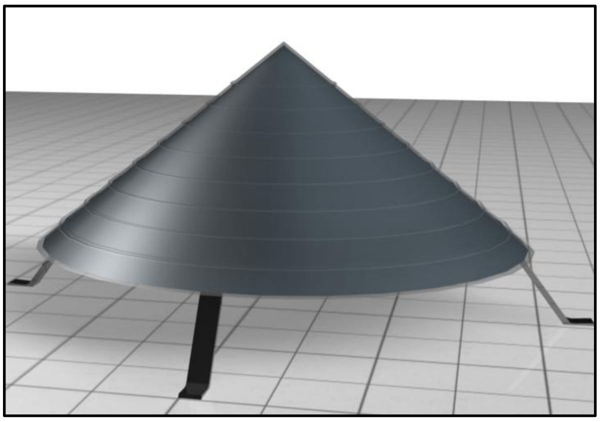
Figure II 3-D view of umbrella shape solar collector


Figure III Actual view of umbrella shape solar collector with spiral tube

Above figure shows the actual view of umbrella shape solar collector with spiral tubing.

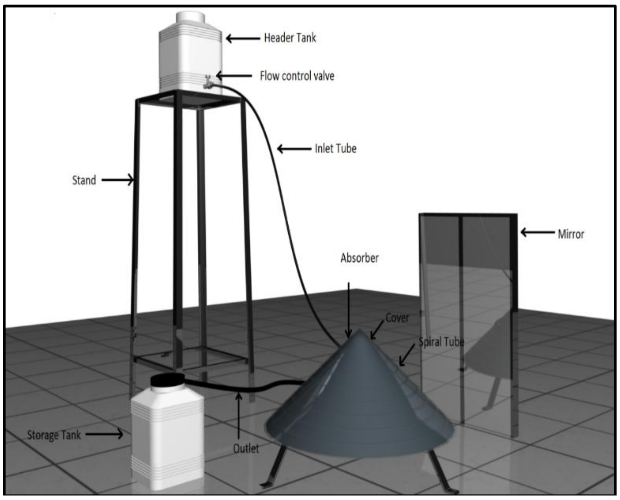

Figure IV 3-D view of total system design

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

Vol. 3, Issue 10, October 2016

Umbrella shape absorber geometry is made up of galvanized steel sheet of thickness 0.3 mm. Water tubes which are wound around the absorber are made up of copper. The absorptivity of galvanized steel is 0.7.

Above Fig 2 shows the total view of umbrella shape solar hot water device. It consists of umbrella shape absorber over which spiral tubes are wound. Absorber is then covered transparent cover to reduce the heat loss due to convection. Besides this, there is header tank which store cold water. There is control valve at the header tank to regulate the water flow in the tube. Water tube is connected to control valve which is then follows spiral fashion on umbrella shape absorber. And at the end water tube is connected to the hot water storage tank where ho water get stored. Apart from this, mirrors are also provided to analyze the performance with respect to without mirror condition.

III. DESIGN OF EXPERIMENT

Parameters which are considered for design of experiment are absorber coating, mass flow rate of water, with and without mirror. These parameters are taken to determine the effect of these parameter on the performance umbrella shape solar collector. Performance of the system is concluded on the basis of water outlet temperature and instantaneous efficiency. Experimentation is done for with and without using the mirror. Performance of the system is also compared by varying the mass flow rate by means of changing the tap angle. Experimentations are done for 30^0, 45^0, 60^0, 90^0 tap open condition.

Table1 shows the experiment design for 30^0 tap open. After this, same experimentation is repeated for 45^0, 60^0 and 90^0 tap open condition.

Table I experiment design for 30^0 tap open

Sr. No.	Absorber coating material	30^0 tap open	Accessories
1	Copper powder+ Black paint	0.19 2kg/min	Mirror
2	Graphite powder + Black Paint	0.192 kg/min	Mirror
3	Black Paint only	0.192 kg/min	Mirror

Table II property of coating material

Sr. No.	Absorber coating material	Absorptivity
1	Copper Powder	0.85
2	Graphite Powder	0.7
3	Black Paint	0.98

Table II shows the radiative property of coating material. Experimentation is carried out from 9.00 am to 4.00 pm. Besides this, thermocouples and pyranometer are used to measure temperatures (Collector, water outlet) and solar intensity.

Figure V Actual view of umbrella shape solar hot water device

Figure V shows the actual umbrella shape solar water heating system.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

IV. DATA ANALYSIS

A. **Temperature variation with time for mirror and without mirror for copper powder and black paint coating condition**

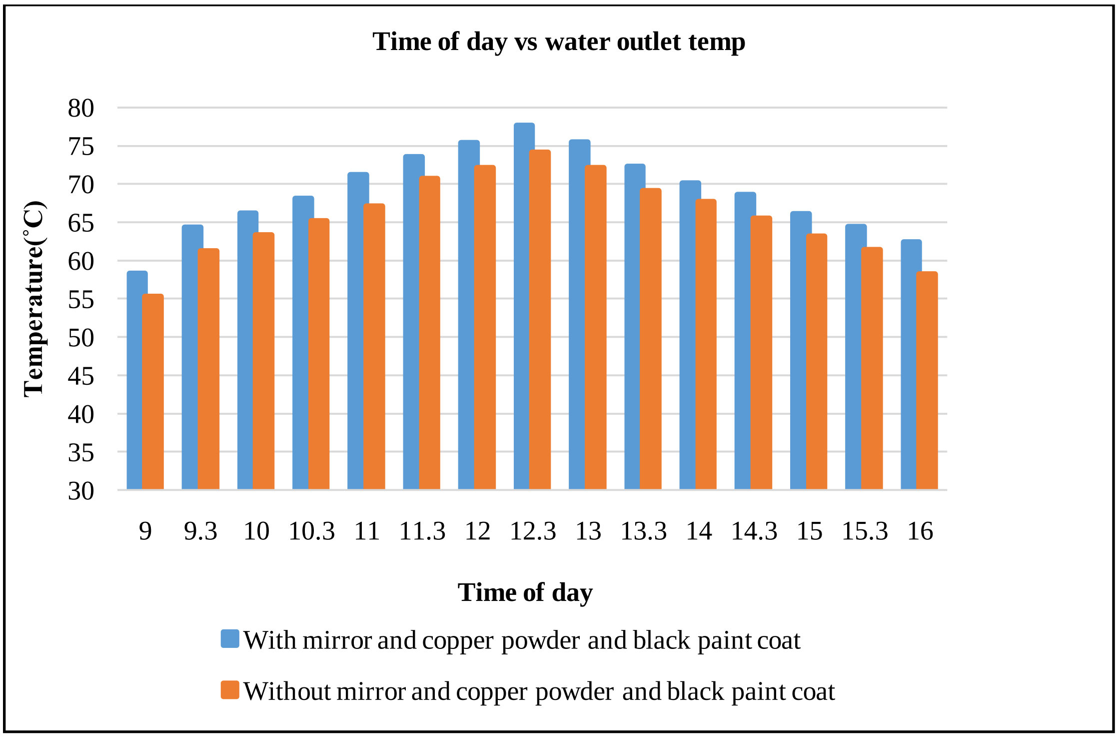

Figure VI Graph showing time of the day vs. water outlet temperature

B. **Instantaneous Efficiency variation with time for mirror and without mirror for copper powder and black paint coating condition**

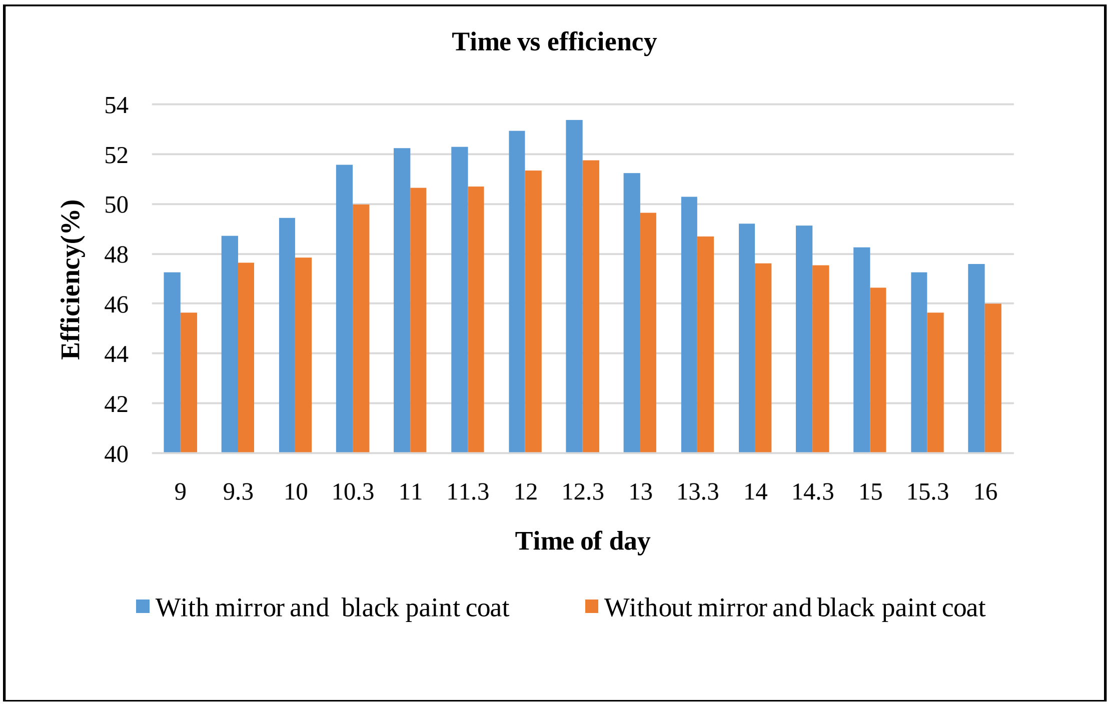

Figure VII Graph showing time of the day vs. instantaneous efficiency

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

C. Variation in instantaneous efficiency with time and mass flow rate for with mirror and with copper powder and black paint coating

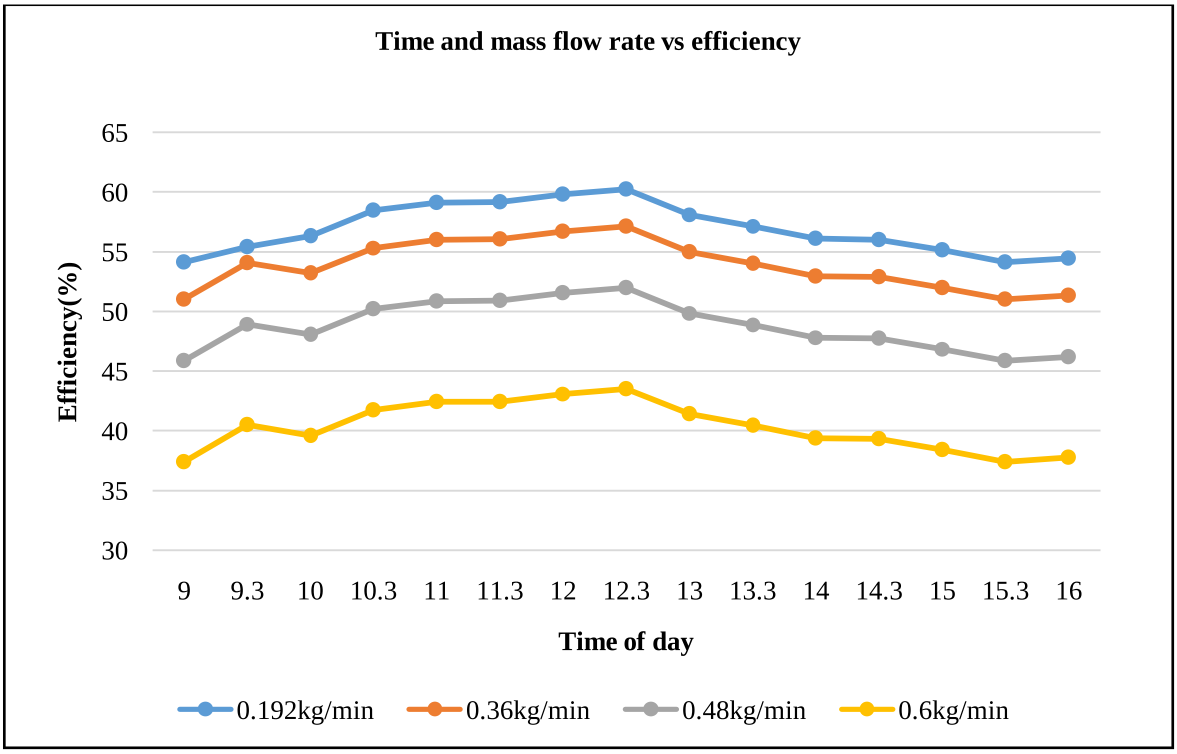

Figure VIII Graph showing time of the day vs. efficiency

D. Variation in efficiency with coating on collector

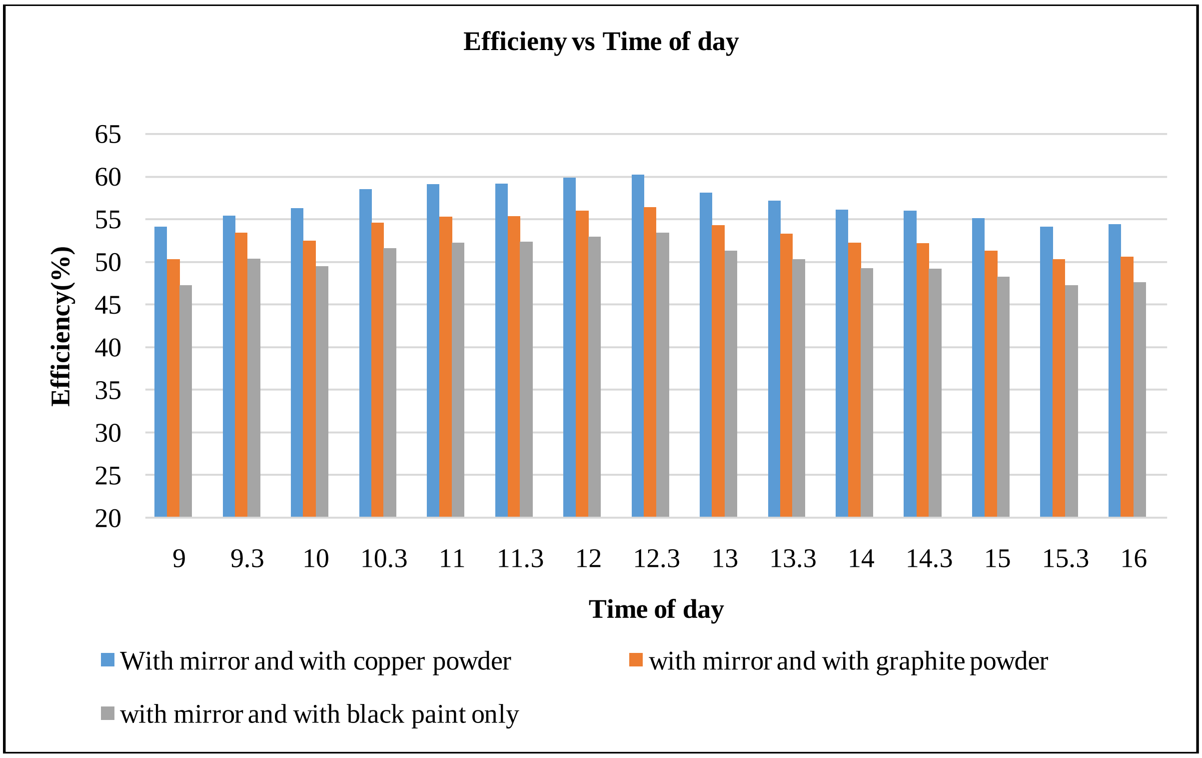

Figure IX Graph showing time of the day vs. efficiency

DOI 10.17148/IARJSET.2016.31010

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

E. Variation in water outlet temperature and efficiency with time for flat plate solar collector and umbrella shape solar water heater

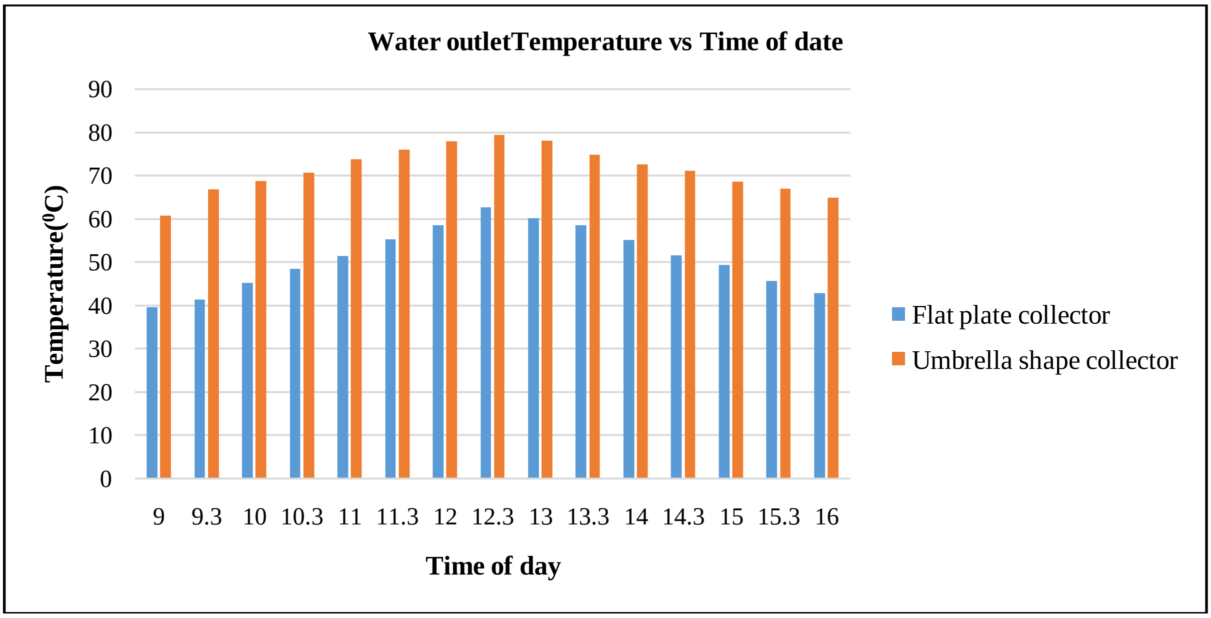

Figure X Graph showing time of the day vs. water outlet temperature

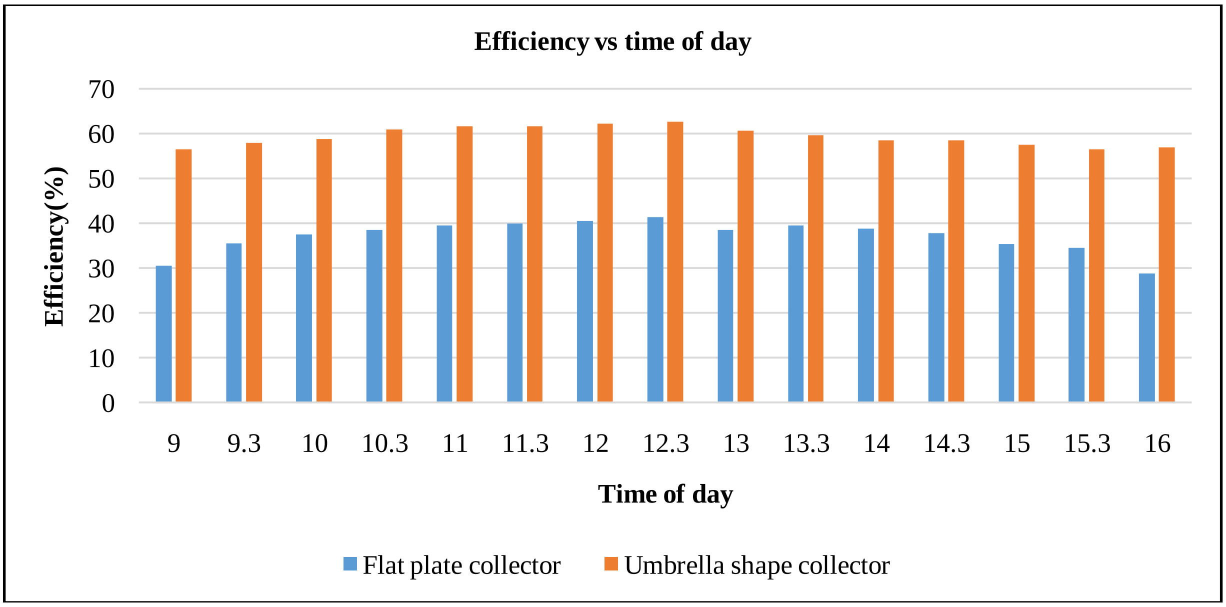

Figure XI Graph showing time of the day vs. efficiency

From above graphs it is seen that maximum water outlet temperature and maximum instantaneous obtained when absorber surface coated with copper powder and black paint and for 300 tap open (0.192 kg/min) of mass flow rate. From the graph it is seen that umbrella shape solar hot water device is more efficient on cost basis for without using mirror condition. Because there is not much difference in the performance of collector. Besides this, as compare to flat plate collector efficiency of umbrella shape solar water heater is more efficient as compare to flat plate collector.

V. CONCLUSION

Experimentation has been carried out for six different conditions with four different mass flow rate. Also the effect of height on the performance of umbrella shape solar water heating is also considered. Experiment was conducted for 7hr in one day during sunshine hours. The major findings from the experiments are summarized as follows.

1. It is found that using umbrella shape solar water heating system without mirror is more efficient as

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 10, October 2016

compare to using with mirror on cost basis. Because there is only 2-30C increase in water outlet temperature while using with mirror. So using Umbrella shape solar water heating system without mirror, resulting into saving in cost of collector.

2. It is also concluded that using the umbrella shape solar water heater with copper powder and black paint coating gives more efficiency as compare to graphite and black paint coating. The maximum efficiency with copper powder and black paint coating is obtained as 60.24% for mass flow rate of 0.0032 kg/s.
3. Regarding to solar flat plate collector, it is concluded that efficiency of umbrella shape solar water heater is 15-20% more as compare to solar flat plate collector.
4. Apart from performance, the cost of umbrella shape solar water is comparatively low as compare to solar flat plate collector. Cost of fabrication is around Rs.6500/- only. Which is quite comparable to flat plate collector.

REFERENCES

1. D. Sarma1, R. Gogoi, B. Nath, S. Konwar,C.L. Meitei, “Design, Fabrication and the Experimental Performance Evaluation of Flat Plate Solar Water Heater specifically for Jorhat, Assam” International Journal of Engineering Trends and Technology (IJETT) – Volume 12 Number 7 - Jun 2014
2. Alok kumar, “Performance of solar collector by using semi-circular cross section tube” International journal of engineering research and general science, Volume 2, Issue2, Feb 2014, pp. 33-37.
3. Ilze Pelece, Imants Ziemelis , “Water heating effectiveness of semi-spherical solar collector” Renewable energy, 2012 pp. 185-189.
4. M. Jamil Ahmad* and G.N. Tiwari, “Optimization of Tilt Angle for Solar Collector to Receive Maximum Radiation” The Open Renewable Energy Journal, 2009, 2, 19-24.
5. Billy Anak Sup, “Effect of absorber plate material on flat plate collector efficiency”. (Thesis submitted by faculty of mechanical engg, to university Malaysia Pahang.
6. Jayant. V. Madan, Oshan. M. Sirse, “Experimental Study on Efficiency of Solar Collector at Nagpur (India) During Winter” International Journal Of Scientific And Technology Research Volume 4, issue 08, august 2015.
7. Fabio Struckmann, “Analysis of flat-plate solar collector” 2008 MVK160 Heat and Mass Transport, May 08’ 2008, Lund, Sweden.
8. Yakoob Kolipak, “Thermal analysis of solar flat plate collector” International Journal of Research and Computational technology, Vol. 7, Issue 5, Dec 2015.
9. Zeinab Sayed Abdel Rehim, “A new design of solar water heater” Proc. Indian Acad. Sci. (Chem. Sci.), Vol. 110, No. 3, June1998, pp. 373-384.
10. S P. Sukhatme, Solar Energy: Principle of Thermal collection & Storage, McGraw Hill Education, New Delhi, India, 200`7.
11. Sunil.K.Amrutkar1, Satyshree Ghodke2, Dr. K. N. Patil3, “Solar Flat Plate Collector Analysis” IOSR Journal of Engineering (IOSRJEN).
12. Bapuji Pullepu, K. Ekambhavanan, A. J. Chamkha, “Unsteady laminar free convection froma vertical cone with uniform surface heat flux” nonlinear analysis modelling and control, 2008, Vol. 13, No. 1, 47-60.
13. Atish Mozumder, Anjani Kumar Singh, “An Integrated Collector Storage Solar Water Heater and Study of Its Temperature Stratification” Open journal of applied science, Jan 2013, pp. 112-115.
14. H. Vettrivel1 and Dr. P. Mathiaragan2, “Experimental Study on a Flat Plate Solar Collector” International Journal of Mechanical Engineering and Research, Volume 3, Number 6 (2013), pp. 641-646