iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** IV **Month of publication:** April 2015

DOI:

Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Experimental Investigation on the Performance of Parabolic Through Solar Collector with Magnifying Glasses

G Maruthi Prasad Yadav[1], M. Lokanath [2] , H.Raghavendra[3] K Sai Seetha Ram Reddy[4], R Satya Narayana Reddy[5]
B Hanumantha[6], P Chand Basha[7], T MD Irfanulla[8], K Pandu Ranga [9]

[1] *Assoc. Professor, Mechanical Engineering, St.Johns College of Engineering & Technology, JNTUA, INDIA*

[2&3] *Asst. Professor, Mechanical Engineering, St.Johns College of Engineering & Technology, JNTUA, INDIA*

[45678] *Final year students, Mechanical Engineering, St.Johns College of Engineering & Technology, JNTUA, INDIA*

Abstract: Now a day's consumption of hot water is increased because of our modern life style for drinking, cooking, washing, bathing etc. For heating water, we are using non-renewable energy sources which cause damage to the environment. In this present work it is suggested to increase the temperature of water by using solar energy, which is available abundantly at free of cost. The device that increases the water temperature through solar heat energy source is known as 'PARABOLIC SOLAR TROUGH COLLECTOR'. PTSC is a simple device that collects the solar radiation and focus on to copper pipe which is exactly located at the focal point of trough and their by increases the water temperature which is eco-friendly and economical. The performance of PTSC depends on the amount of rays reflected on to the copper pipe. Any attempt that improves the concentration of sun rays results in improvement of the performance of PTSC. In the present attempt it is proposed to analyze the performance of PSTV associated with magnifying lens which increases the feed water temperature and the effect of PTSC orientation and black coating on PTSC performance is analyzed. From this experiment it is obtained that the parabolic collector along with the magnifying glasses yields max output temperature and productivity. Orientation of the PTSC is suggested to position in 30^o North towards West direction to obtain maximum productivity. When parabolic collector along with magnifying lens is placed at 30° north towards the West a maximum temperature difference obtained is 28°C by which performance is improved by 42.85% than without magnifying glasses. When parabolic collector with black coating on the copper pipe is placed at 30° north towards west a maximum temperature difference obtained is 17°C by which performance is improved by 5.88% than without black coating.

I. INTRODUCTION

Humans have already used the rays of the sun to gather their energy needs. In the energy needs of today with increasing environmental concern, alternatives to the use of nonrenewable and polluting fossil fuels have to be investigated. One such possibility is solar energy, which has become increasingly popular in recent years.

Now-a-days solar energy has been strongly promoted as available energy source. One of the simplest and most direct applications of this energy is the conversion of solar radiation into heat. Hence way that the domestic sector can lessen its impact on the environment is by the installation of solar parabolic trough collectors for heating water. Although it should be said that some of these collectors have been in service for the last 40-50 years without any real significant changes in their design and operational principles. The use of solar energy is centered at present on photovoltaic and thermal solar energy conversion systems. In the first-named, solar energy is converted into electricity directly by a photoelectric cell. The obtainable outputs are, however still limited. Higher outputs can be achieved by solar thermal conversion. In this process solar energy is received and transferred by a collector system to a working fluid. Solar energy is the radiation produced by nuclear fusion reactions in the core of the sun. This radiation travels to Earth through space in the form of energy called photons. Even though only 30% of the solar power actually reaches the Earth, every 20 minutes the sun produces enough power to supply the Earth with its needs for an entire year.

The history of utilizing solar energy in recent time's dates from 1861 when Mouchout developed a steam engine powered entirely by the sun and in 1883 American inventor Charles Frits described the first solar cells made of selenium wafers.In the United States, John Ericsson designed the "parabolic trough collector" a technology which functions more than a hundred years later on the same basic design.

Albert Einstein was awarded the 1921 Nobel Prize in physics for his research on the photoelectric effect; a phenomenon central to the generation of electricity through solar cells. In 1953 AT&T laboratory scientists developed the first silicon solar cell capable of generating an electric current.

The Arab oil embargo in 1973 confirmed the degree to which the western economy depended upon there, being a cheap and reliable flow of oil. In the 1970s it was thought that through massive investment in funding and research, solar photovoltaic costs could drastically reduced, such that eventually solar cells could become competitive with fossil fuels.

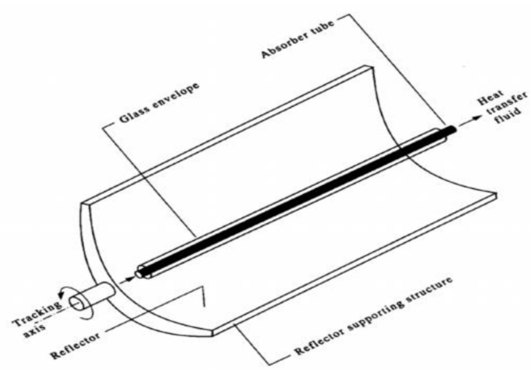
By the 1990s, the reality was that the costs of solar energy had dropped as predicted and the huge PV market growth in Germany and Japan from the 1990s to the present has boosted the solar industry. Furthermore, such large PV productions are creating steadily lowering costs. Meanwhile, the heating of water by solar energy is an increasingly cost effective means of lowering gas and electricity demand.

Due to the nature of solar energy, two components are required in order to have a functional solar energy generator. These two components are a collector and a storage unit. Whilst the storage unit is required because of the non-constant nature of solar energy, as during cloudy days the amount of energy produced by the collector will be quite small. The storage unit can hold the energy produced during the periods of maximum radiation and release it when it is needed or the productivity drops.

A. Parabolic Trough Solar Collector

A parabolic trough solar collector uses a reflector in the shape of a parabola which is mostly a mirror, or an anodized aluminum sheet depending on the required applications to reflect and concentrate the solar radiations towards a receiver tube located at the focus line of the parabola. The absorber tube may be made of mild steel or copper and is coated with a heat resistant black paint for the better performance. The receiver absorbs the incoming radiations and transforms them into thermal energy, which is being transported and collected by a fluid medium circulating within the receiver tube. The heat transfer fluid flows through the absorber tube, gets heated and thus carries heat. The temperature of the fluid reaches up to 400º C. Depending on the heat transfer requirement different heat transfer fluids may be used.

1) *Working Principle:* The Solar radiations coming parallel to the focal line of the parabola (reflector) collects at the surface of reflector and concentrate it to the focal point F as shown in figure.7. If the reflector is in the form of trough with parabolic cross section, the solar radiation focuses along a line. In concentrating collectors the term concentration ratio (C) is a very important parameter. It is defined as the ratio of the collector area at which radiation collects to the area (absorber) at which these radiations are concentrated. Concentration ratio is defined as the ratio of the collector area to the absorber area. So with the decrease in the absorber area the concentration ratio increases and hence more quickly the high temperatures are reached. So higher concentration ratio means higher temperature can be achieved. The schematic diagram of the parabolic trough solar collector with absorber tube, tracking mechanism and support structure is shown.



Parabolic Trough Solar Collector System

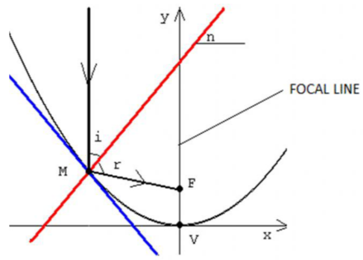
B. Parabolic Trough Solar Collector System Components

The main components of parabolic trough solar collector system are:

1) Reflector: A parabolic reflector reflects and concentrates all the sun's rays to the receiver tube which is at the focal point of the parabola. The reflectors are parabolic shaped mirrors with a reflectivity of 96%. The mirror is a second surface silvered glass mirrors with reflective silver layer coating on the back side of the glass. A special multilayer paint coating protects the silver on the back side of the mirror for the better performance of the reflector.

2) Absorber tube: An absorber tube is a linear receiver located at the focus line of parabolic reflective surface at the focus line of parabolic reflective surface, with means of transferring the absorbed solar energy to a heat transfer fluid. It has glass to metal seals and metal bellows to accommodate for differing thermal expansions between steel tubing and glass envelop. It has a vacuum type enclosure to reduce the heat losses. The selective coating on the steel tube has a good solar absorbance. The getters are metallic compounds which are used to absorb gas molecules are installed in the vacuum space to absorb hydrogen and other gases that permeate through annulus over time.

3) Glass covers tube: A concentric tubular glass cover surrounding the absorber with a gap of 1-2 cm with glass to metal seal to create vacuum so as to minimize the conduction, convection, and radiation losses. Glass



tube is nearly transparent to the radiations of short wavelength (coming from sun) and opaque to the radiations of long wavelength (emitted by the absorber). Transmittance of the glass tube can be increased by decreasing the iron content from the glass material. Evacuated glass tube also used which reduce heat losses more efficiently than the simple glass tube. Also the spacing distance between the glass tube and absorber tube affects the heat los

4) Support structure: Steel supported structure is there in the back of the reflector mirror so as to provide strength to the collector so as to provide mechanical strength to the collector to withstand the wind loads. The main emphasis is to reduce the weight of the support structure and also to reduce the structure deformations so that trough focuses the sun more effectively.

5) Tracking mechanism: In a Tracking mechanism the trough is usually aligned on a north-south axis, and rotated to track the sun as it moves across the sky each day. Alternatively the trough can be aligned on an east-west axis; this reduces the overall efficiency of the collector, due to cosine loss, but only requires the trough to be aligned with the change in seasons, avoiding the need for tracking motors.

The parabolic trough solar collector system uses water or thermal oil as heat transfer fluid in industry for the power generation applications. A heat transfer fluid is heated up as high as 393°C as it circulates through the receiver and returns to a series of heat exchangers in the power block in case of thermal oil, where the fluid is used to generate high-pressure superheated steam at 100 bar, 371°C. The superheated steam is then fed to a conventional reheat steam turbine/generator to produce electricity. In the direct steam generation

II. SUGGESTED EXPERIMENTATION

A. Parabolic trough solar collector is to be placed in various directions by increasing 30° every time towards east to get the maximum output.

B. Performance of Parabolic trough solar collector is to be investigated by applying a black coating on the copper pipe.

C. Performance of Parabolic trough solar collector is to be investigated by installing magnifying glasses to PTSC for concentrating the max solar radiations.

III. EXPERIMENTAL SETUP

Experimental setup of parabolic solar trough collector with magnifying glasses

This project consists of mainly 5 parts

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A. Water tank

A cylindrical tank having diameter of 40 cm having open on top side to pour water it acts as an inlet and at the bottom placing a hole having diameter of 3 cm. From the bottom a pipe is attached between tank and to parabolic collector, the pipe which is used to join the tank and collector is surrounded with a black tape to absorb heat from the sun. The capacity of the tank is up to 15 liters.

B. Parabolic collector

It is a device which heat up water with solar energy. It is designed in parabola shape, it consists of mirrors to reflect the sun light towards a particular point it should be designed in such a way. A pipe is to be fixed at that particular point light which is reflected from mirror has to fall on the pipe. We used copper metal pipe, because it absorbs more amount of heat when compared to other metals. Two valves are provided to the copper pipe to control the flow rate one is at inlet and the other is at out let. At inlet we had place a thermometer to know the inlet temperature of the water, on other side i.e., at outlet a pressure guage and thermometer is fixed to know the how much of heat is absorbed by water and by what pressure the water is coming out from the pipe. This parabolic collector is kept in east-west direction facing towards north side, it give more effective temperature than remaining faces. The water coming from the outlet will be up to 50^0 C based on the surrounding temperature and water inlet temperature. If the temperature of inlet is less the outlet temperature is also less, because the water in the pipe flows constantly hence the temperature rises up to certain temperature.

C. Magnifying Glass

A magnifying glass is a combination of lenses used to magnify an object. For getting optimal output of PTSC, five magnifying glasses of ɷ90mm and with 3x focus are installed to it. For our convenience and better performance adjustable stand is fixed to the PTSC.

A magnifying glass is a combination of lenses used to magnify an object. A magnifying glass enables people to magnify almost anything (e.g. books, newspapers etc.,).The magnifying glass was invented in 1250 by Roger Bacon.

1) *Lens size:* Magnification power is a result of the amount of curvature in the magnifier lens. As the lens size increases, the amount of curvature in magnification power of the lens. As the lens size decreases, the amount of curvature in the lens increases, resulting in higher magnification power of the lens. As the Lens size of the magnifier lens decreases, the magnification power of the magnifier increases. This is a result of the amount of curvature in the magnifier (lens). The size of most round magnifying lenses is between 1 inch and 5 inches. The size of most rectangular or square lenses is also between 1 inch and 5 inches. It is very important to understand the relationship between the size of the magnifying lens and the magnification power of the magnifying lens. As the size of the round, rectangular or square magnifying lens increases, the magnification power decreases. And, as the size of the round, rectangular or square magnifying lens decreases, the magnification power increases. (Example: A round magnifying lens that is 5 inches in diameter has a magnification power of approximately 2x; however, a round magnifying lens that is 1 inch in diameter has a magnification power of approximately 10x.). Magnification power is created by the curvature of the magnifying lens.
2) *Focal Length:* Focal length is the distance from the magnifying lens to the object behind the lens when the object is in focus. To put it another way, the optimal distance between the object being magnified (when it is in clear focus) and the magnifying glass is the focal length. As the magnification power increases, the focal length decreases; conversely, as the magnification power decreases, the focal length increases. The stronger the optical power of the magnifying lens, the shorter the required distance between the magnifier and the object behind the lens.
3) *Types of Lenses:* Along with understanding the lens size, magnification and focal length, it is important to choose the appropriate type of glass material or composition of the optical lens to meet your needs. A magnifying glass lens can be made of glass or acrylic (plastic) material. The adjustable stand in L-shape is prepared according to our desired load capacity.

D. Black Coating On Copper Pipe

A black body is an ideal body which allows the whole of incident radiations to pass into it and absorbs with in itself. This property is valid for radiation corresponding to all angle of incidence. By means of this phenomenon the attraction of radiation of PTSC is increased. By coating black paint on the copper pipe causes a great absorption of radiation. The black paint because of its high absorbing nature rises the water temperature by collecting maximum amount of radiations

E. Temperature Sensors

A thermometer is a device that measures temperature or a temperature gradient. A thermometer has two important elements: the temperature sensor (e.g. the bulb on a mercury-in-glass thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer).

There are various principles by which different thermometers operate. They include the thermal expansion of solids or liquids with temperature, or the change in pressure of a gas on heating or cooling. Radiation-type thermometers measure the infrared energy emitted by an object, allowing measurement of temperature without contact.

Thermometers are widely used in industry to control and regulate processes, in the study of weather, in medicine, and scientific research.

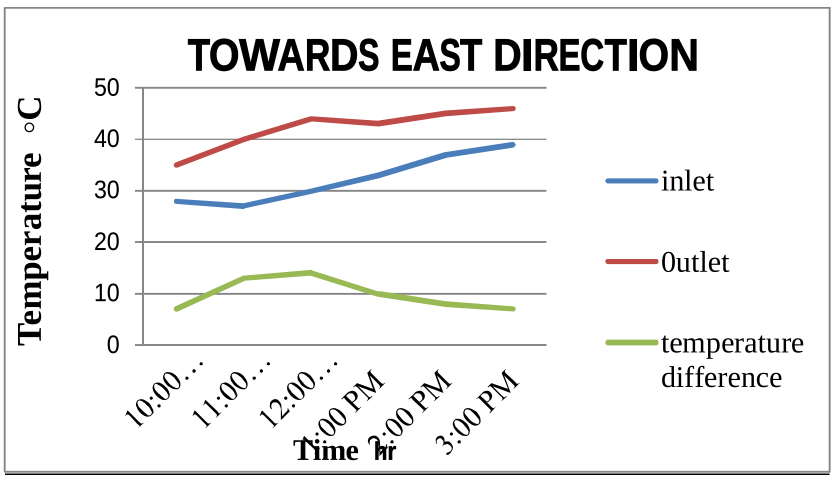
IV. WORKING PROCEDURE

A. Parabolic collector in various directions

1) Firstly 3000 ml of water which is at normal atmospheric temperature is taken in the storage tank which is placed at a height of 200 cm from the ground.
2) From the bottom of the tank a pipe is passed to the parabolic collector which contains a regulating valve to control the inlet water flow from the tank into the parabolic collector.
3) Parabolic collector is kept in such way that inlet and outlet are placed east-west direction.
4) The flow rate of water is maintained with the help of the regulator in such a way that the water obtained at the both outlets is equal to inlet water.
5) The collector should be maintained in such a manner that the reflected sun rays has to fall on the copper pipe. At the inlet of collector a thermometer is placed to know the inlet temperature of the water which is coming from water tank, it should be at surrounding temperature. At outlet of copper pipe another thermometer is placed to know the outlet temperature of the water which is coming out. The outlet temperature of the water depends upon various parameters like inlet temperature and atmospheric temperature.
6) Note down the readings in a tabular column in 6 consecutive directions varying 30º every time from east towards south.

On 21th march 2015 the set-up was placed in such a that inlet of copper pipe in north-30◦ towards west direction with the atmospheric temperature 29^{0}C water is sent to parabolic collector from the tank with an initial temperature of 26^{0}C. At the outlet of the collector the temperature is noted as 35^{0}C.From 9:00AM to 11:00AM the temperature of water goes on increasing towards the afternoon session. At 12:00PM to 1:00PM maximum temperature of 47ºC is observed. Maximum temperature difference of 16ºC is noted

V. RESULTS AND DISCUSSIONS



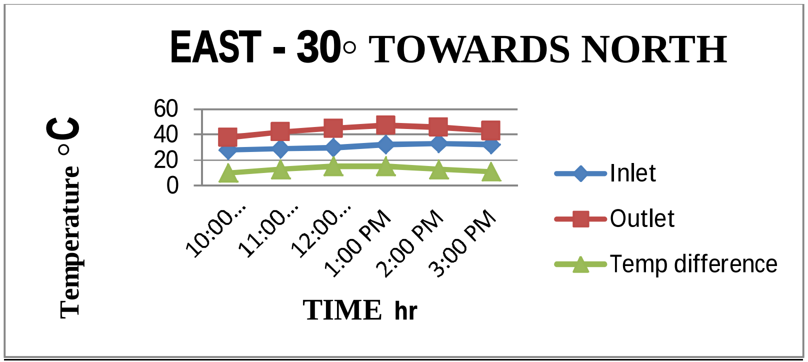
Graph 1: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is placed towards east

Graph-1 shows the effect of day light hours that how temperature difference of parabolic collector between inlet and outlet varies when it is placed towards east directions. It is observed from the graph that as time progress temperature difference increases initially up to the time ranging from 12:00PM to 2:00 PM and decreases thereafter for all directions. A maximum temperature difference of 14^{0}C, 13^{0}C, 10^{0}C and 8^{0}C are obtained when copper pipe is placed inlet towards east and outlet towards west.

Initially at morning sessions from 9AM to 10AM the temperature difference varies slowly. This temperature difference gradually increased between 1PM to 2PM which becomes 11.16% higher than in mornings.

Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

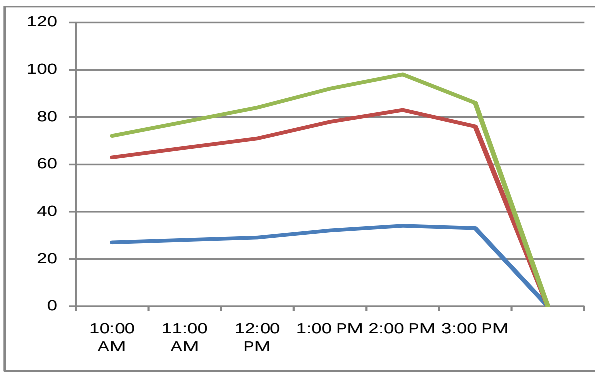
Graph 2: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 30º east towards north



Graph 2 shows the effect of day light hours that how temperature difference of parabolic collector between inlet and outlet varies when it is placed 30º east towards north directions.

It is observed from the graph that outlet temperature increases uniformly from 9:00 am to 1:00 pm and their after decreases uniformly.

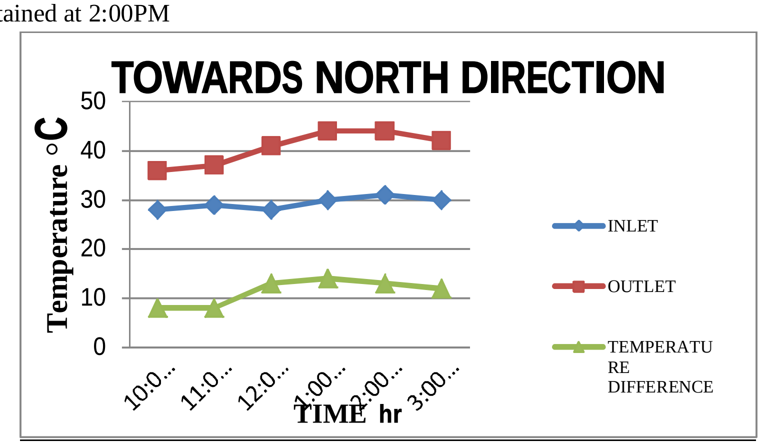
A maximum temperature difference of 15^{0}C, 13^{0}C, and 11^{0}C are obtained in 30º east towards south.



Graph-3: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 60º east towards north.

From the graph-4 it is observed that inlet temperature increases with time from10:00 AM to 2:00 Pm and decreases thereafter. Also it is observed that outlet temperature increases uniformly whereas the inlet temperature increases slowly up to 12:00PM and from there it increases rapidly.

The maximum temperature at the outlet attained is 49^0 c and is obtained at 2:00PM.. The maximum temperature difference obtained is 14^{0}C and is obtained at 2:00PM



Graph 4: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is towards north.

From the graph 1 it is observed that inlet temperature increases with time from10:00 AM to 2:00 PM and decreases thereafter. Also it is observed that outlet temperature increases slowly from 9:00 AM to 1:00 PM whereas the inlet temperature decreases

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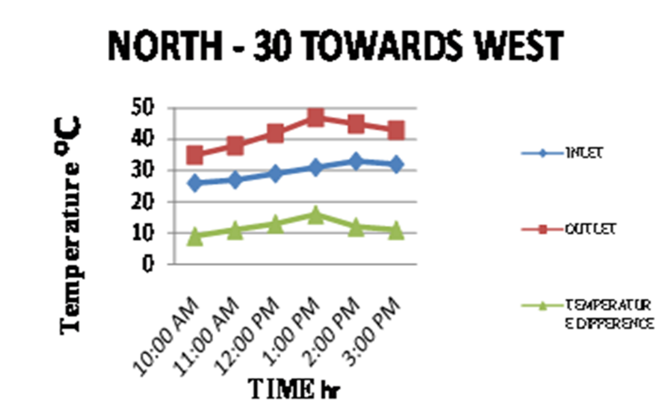
and increases slowly up to 12:00PM and from there it increases rapidly.

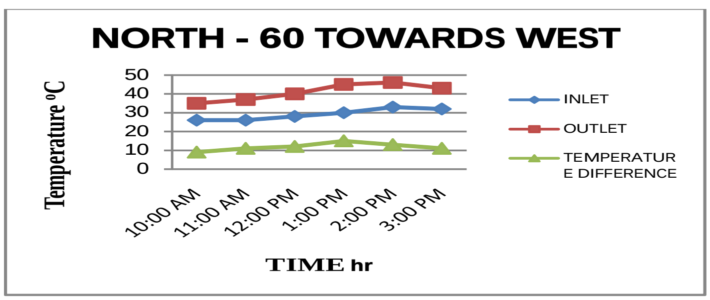
The maximum temperature at the outlet obtained is 44^0 c and is obtained from 12:00 PM to 2:00PM. The maximum temperature difference obtained is 14^0C and it is obtained at 1:00PM



Graph 5: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 30º north towards west.

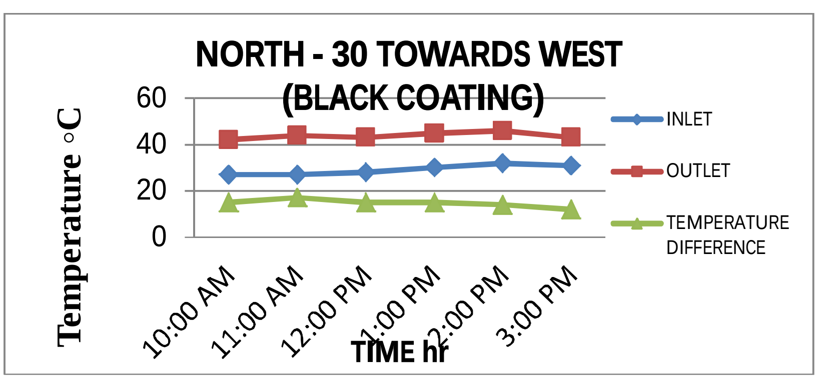
From the graph 1 it is observed that inlet temperature increases with time from9:00 AM to 2:00 PM and decreases thereafter. Also it is observed that outlet temperature increases slowly from 9:00 AM to 11:00 AM and their after increases rapidly whereas the inlet temperature increases uniformly up to 2:00 PM and from there it decreases.

The maximum temperature at the outlet obtained is 47^0 c and is obtained from 12:00 PM to 1:00PM. The maximum temperature difference obtained is 16^0C and it is obtained at 1:00PM



Graph 6: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 60º north towards west.

From the graph 1 it is observed that inlet temperature increases with time from 9:00 AM to 1:00 PM and thereafter increases rapidly up to 2:00 PM and decreases thereafter. Also it is observed that outlet temperature increases slowly from 9:00 AM to 11:00 AM and their after increases rapidly whereas the inlet temperature increases uniformly up to 2:00 PM and from there it decreases. The maximum temperature at the outlet obtained is 46^0 c and is obtained from 12:00 PM to 1:00PM. The maximum temperature difference obtained is 15^0C and it is obtained at 1:00PM

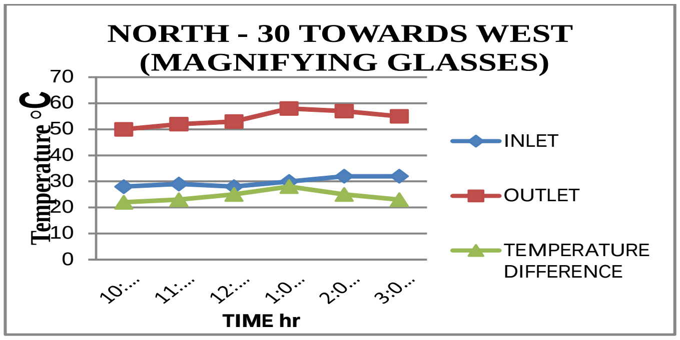


Graph 7: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 30º north towards

west coated with black paint on copper pipe.

From the graph 1 it is observed that inlet temperature increases with time from 9:00 AM to 2:00 PM and decreases thereafter. Also it is observed that outlet temperature decreases slowly from 9:00 AM to 10:00 AM and their after increases uniformly whereas the inlet temperature increases uniformly up to 2:00 PM and from there it decreases.

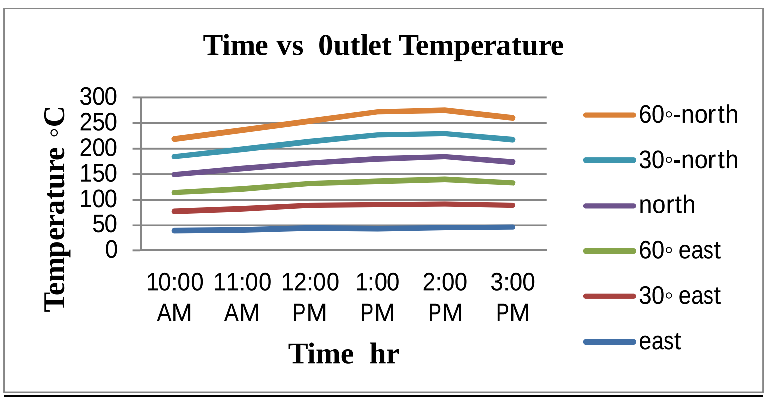
The maximum temperature at the outlet obtained is 46^0 c and is obtained from 1:00 PM to 2:00PM. The maximum temperature difference obtained is 15^0C and it is obtained at 12:00PM to 1:00PM



Graph 8: Effect of Time on temperature at the inlet, outlet and temperature difference when solar collector is 30º north towards west when magnifying glasses are installed to system

From the graph 1 it is observed that inlet temperature increases with time from 9:00 AM to 3:00 PM. Also it is observed that outlet temperature increases rapidly from 9:00 AM to 1:00 PM and their after decreases.

The maximum temperature at the outlet obtained is 58^0 c and is obtained from 12:00 PM to 1:00PM. The maximum temperature difference obtained is 28^0C and it is obtained at 1:00PM.



GRAPH-9: Effect of Time on outlet temperature of parabolic solar collector when placed in various directions

It is observed that out temperature increases slowly and uniformly in all directions from09:00AM to 11:00 AM and thereafter temperature difference increases rapidly according to effectiveness of the direction. Also it is observed that temperature decreases uniformly and slowly up to 3:00PM.

The maximum temperature difference obtained is 16◦c at the 30◦ north is obtained at 01:00PM. The maximum temperature difference is obtained at 12:00 pm in east to north directions and there by maximum temperature difference is obtained at 1:00 PM from north. After 2:00 PM temperature difference goes on decreasing from 30^o north to west.

VI. CONCLUSIONS

After conducting performance evaluation tests on PTSC with magnifying glasses and black coating the conclusions are summarized as follows:

A. The performance of the PTSC integrated with the magnifying glasses provides better performance compared with the PTSC without integration. The performance is higher by integrating PTSC with magnifying glasses than that of the performance without magnifying glasses by temperature difference of 12^{o}C

B. When the orientation of parabolic collector is at 30^{o}North –west direction a maximum temperature difference of 16^{o}C is noted than in other directions.

C. When the parabolic collector is at East-West direction collector is less effective as it can be determined by the maximum temperature difference obtained here is 14^0C where as when its orientation is changed to 30^0 north-towards West direction its effectiveness due to resultant maximum temperature difference obtained here is 16^0C.

D. When parabolic collector along with magnifying lens is at 30 ^{O} north towards the West a maximum temperature difference obtained is 28 ^{O} C by which performance is improved by 42.85% than without magnifying glasses

E. When parabolic collector with black coating on the copper pipe is at 30^OC north towards west a maximum temperature difference obtained is 17 ^{O} C by which performance is improved by 39.30% than without black coating.

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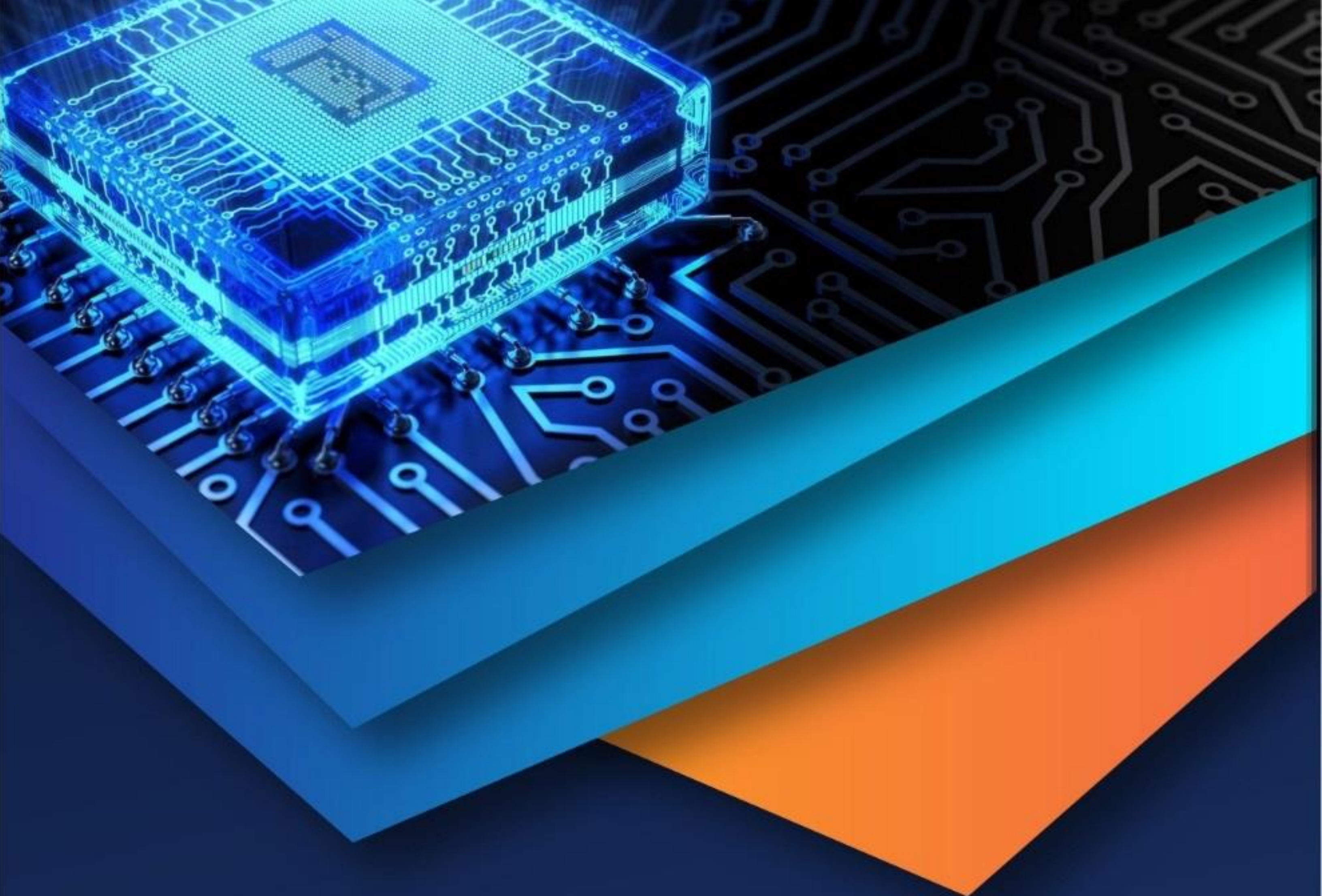

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