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Studies of Rock Bed Solar Thermal Storage System for Space Heating Applications

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Abstract
We know that demand of energy storage system is increasing day by day. This experiment deals with the storage of thermal energy with rock bed storage system. Radiator and rock bed storage system both act as heat exchanger in this experiment.100 watt of rock bed storage system is taken and its heat power lies between110 watt 125 watt. Tullu pump, radiator, fan all are used in discharging of heat energy with rock bed storage system. In this experiment energy is stored in day and provides back energy and is used in night.
This experiment also describes how to store heat energy by the help of rock bed storage system and calculate heat power of rock bed in both case with fan and without fan. There are two working cycle used in this experiment 1st cycle deals with charging process and 2nd cycle deals with discharging process. Now a days this experiment is applied as space heating application. Rock bed storage system, solar water heater using in1st step and 2nd step radiator, Tullu pump, fan, solar panel all are deals with rock bed storage system during discharging process. The main purpose of this experiment is to provide backup energy storage system at night with rock bed storage system.
Keywords: *Solar water heater, Rock bed storage system, Tullu pump, Radiator, Fan, Solar panel.*

INTRODUCTION

Energy storage system is one of the best device which store the energy such as mechanical energy, electrical energy, chemical energy, electrochemical energy, thermal energy, and renewable source of energy. Now a days energy storage system is widely used because it stores energy and used as useful work in future.

The device which store the energy is called accumulator.

The main concept of energy storage system is to store all type of energy such as renewable and non-renewable source of energy. Energy storage system is also deals with the storage of kinetic energy, potential energy, gravitational energy, etc. Storing energy allows to balance the supply and demand of energy.

Energy storage such a natural process is as earlier as the universe itself - the energy available at Energy the starting formation of the universe has been stored in stars as like as the sun and is currently to be used by humans directly (e.g. during solar heating), or indirectly (e.g. by increasing crops or exchange into electricity in solar cells)

As a fixed activity, energy storage has existed as pre-history, though it was frequently not openly accepted as such. An example of purposeful mechanical energy storage is the utilize of logs or boulders as protective measures in prehistoric forts—the logs or boulders were composed at the top of a hill or wall, and the energy hence stored used to damage invaders who came within series.

P.CHANDRA et al.1996 [1] describes that characteristics of rock bed with the help of air. In this experiment air is used as the heat transfer medium. All the parameter such as pressure drop, co-efficient of volumetric heat, heat transfer rate, heat transfer between air and rock bed, depends upon the rock size and air flow rate. Pressure drop is exhibited with the help of rock bed porosity. Both

inlet air and starting stage rock bed temp in the range of variable in low temperature. Its application is to store energy in the rock bed storage.

D.M. CRANDALL et al. 2003 [2] describes the charging of solar thermal energy into rock bed storage for the purpose of space heating. In the standard rock bed or routing of flow segments cooler as compare the inlet air during charging. They preserve stratification by the help of rock bed storage beds. By the help of this way generates inaccessible region of higher temperature and also may reduce amount of rock bed temperature. The rock bed segmented bed contain less than 1% maximum energy. Its application is applied in space heating and energy storage in day and use in night.

HARMEET SINGH et al.2009 [3] describes about packed bed and performance analysis of rock bed storage. Packed bed storage system used as the storage of thermal energy. This is also deals with solar air heater. The volume of packed beds is deals with the help of packing materials. The packed bed is to store the thermal energy from solar air heater. Finally we conclude in this experiment rocks and pebbles are such as used as like as packed material. Its application is to storage of thermal energy by the help of packed bed system.

M.MEDRANO et al. 2009 [4] describes about active storage system and passive storage system deeply with a lot of experience and those term related to in this storage system such as information, and all details and Advantage, and disadvantage and other important facts. This type of energy storage system to give a lot of benefits and to ensure system to be more reliable and to give economic benefits. Thermal energy storage takes place in the solar power plant. Its application is to use to store thermal energy and also describe to purpose of storage thermal energy in future.

M.M.ALKILANI et al. 2010 [5] describes about all the efficient way to store solar energy by the help of hot air. Hot air is absorb by the help of sun. They are also done relative studies between the type of collection and the type of storage. The latest progress in solar thermal storage system with air as heat transfer fluid. Encapsulation and greenhouse is also an important type of energy storage material. Recent research deals with the phase change. The recent design of solar air heater reduces the cost and gives economic supports and also reduces the volume. Now a days its application is widely used in industry.

G.ZANGANEH et al.2014 [6] describes a new configuration of thermal energy storage system which deals with the help of the concentrated solar thermal power. Which to be proposed for stable outflow of the temperature of a packed bed of rock. This technique is based upon the sensible and latent heat storage both by using few amount of phase change. Fluid, solid, and molten phases shows the out flow temperature of the rock bed storage system. Thermal energy storage is deals only with sensible heat storage system. In this energy conservation equation is solved by the help of transient simulation. Its application is generally applied in many purposes in industry and also used in many purposes.

According to F.OPITZ et al. 2014 [7] packed bed saves a lot of thermal energy storage. Heat exchanger is in also used as different technical application. In this heterogeneous model of heat transfer is easily developed to the packed bed. The main advantage of the introduced model have theory based approach and allow to simulate packed bed without increasing the simulation time. Thermal energy storage applied measured data using of model calibration and also applied transfer correlation with the help of restricted application. it main application is to establishes the possibility to integrate the thermal energy storage and heat exchanger in power plant model TES/HEX of larger scale without increasing the simulation time. Hence its application is generally used in power plant.

V.P.SETHI et al.2013 [8] give the consideration of the exact and the accurate thermal model and precise of the input ofthe solar radiation and heat transfer co efficient affect the greenhouse energy storage and mass balance .Greenhouse thermal model deals with the help of heat storage system such as rock bed storage system, earth tube heat storage system, and phase change material also. Exchanger system deals with the all type of water heating system such as water thermal mass storage,

heat pipe heating system, shallow solar pond heating .Its application is to be used in many purpose and widely used in industry and used to the maintain the active and passive heating system according to their needs .Greenhouse energy deals with the both type of energy storage system used in future for many important purposes.

K.G.ALLEN et al.2015 [9] describes thermal energy storage with the help of concentrating solar power plants. In which air is used as heat transfer medium for pack bed of rocks. Which to be suitable for thermal energy storage. Pressure drop of packed bed is depend on the shape of particle, roughness, and arrangement of packing. In order to designing the rock bed storage then determine the result less costly, and existing the thermal storage system. And determine the estimate pressure drop and associated pumping power. It is expressed as in the terms of practical volume- equivalent sphere diameter then is to be easily measured. Its application is widely used in industries and also used in space heating.

In the past rock bed energy storage system deals with solar air heater. But in this experiment we used rock bed energy storage system with solar water heater.

Radiator is used in this experiment. Radiator is used to increase the effectiveness and Fan is used for cooling purpose of radiator in this experiment.

SYSTEM DESCRIPTION

Solar Water Heater

Solar water heater act as most important role in this experiment. The main purpose of solar water heater in this experiment to give the hot water in the rock bed storage system. C P V C pipe is attached to the outlet of solar water heater and connect with the rock bed storage system. By the help of solar water heater rock of rock bed storage system to be heated at in the range of temp lie between 45°c -65°c. When rock is heated at 45°c-65°c then close the valve. Solar water heater is widely used in this experiment. Solar water heater is used in industrial purposes and experimental purposes both. Mainly its work for the heat of the water which is increase the efficiency of the rock bed storage system and solar water heater is capable to maintain the temperature of rock bed storage system. Hence solar water is the most equipment according to this experiment. In this experiment role of solar water heater is to be increase the temp of rock in the rock bed storage system.

Table 1. Technical feature of solar water heater

Model	solar air heater
Capacity	50 lit

Rock bed storage system

In this experiment rock bed storage system act a vital role. Rock bed storage system is made of wood. Insulation of aluminum is done in the rock bed storage system. Rock bed storage system is the mixture of rock and water. there are two whole are situated in the rock bed storage system in which one whole is situated in the upper part rock bed storage system and other whole is situated in the lower part of rock bed storage system in the center. Rock bed storage system is full with rock and hot water. Rock bed storage system takes hot water by the help of solar water heater. C P V C pipe are connected with the inlet of rock bed storage system and also connected the outlet of rock bed storage system. Rock bed storage system deals with the storage of the heat. Hence rock bed storage system. The main purpose of rock bed storage is to increase the rate of temperature and also increase the efficiency of rock bed storage system. Rock bed storage is the key element in this experiment.

Table 2. Technical feature of Rock bed storage system

Model	Rock bed storage system
Wt. of water in rock bed storage system	25 L
Wt. of rock in rock bed storage system	48 Kg
Avg.Size of rock bed storage	1. 2 Ft long
	2. 1 ft width
	3. 2 ft depth
Size of hole at the inlet of rock bed storage system	3/4 inch.
Size of hole at the outlet of rock bed storage system	3/4 inch.
Temp. of water of rock bed storage system	60°c - 80° c
Temp. of rock of rock bed storage system	45° c - 65° c

Tullu Pump

Tullu pump is one of the most important device which to be used as repel the water in the range 1 ft

to 30 ft height. In this experiment Tulu pump act a vital role and also very useful for this experiment. Tullu pump placed between the outlet of rock bed storage and inlet of radiator. C P V C pipe are connected the rock bed storage and radiator between this Tullu pump is placed. In this experiment Tulu pump is to be used to take the water with the outlet of rock bed storage system and repel the water to the inlet of radiator continuously. Flow of water is continuous used in this system. Tullu pump is key element in this experiment. Tullu pump also used in many purposes apart from this experiment .hence it is one of the most important equipment.

Table 3. Technical feature of Tullu pump

Model	Tulu pump
Size of head	15 m
Size of drive	.05 KW
Voltage	230 v
Type	Ac
LPH	240

Radiator

Radiator is a type of heat exchanger. Radiator is an automotive cooling system and widely used for cooling purposes. Radiator changes the rate of temperature. Fluctuation of heat and temperature is possible at the inlet of radiator temperature and outlet of radiator temperature these observation is possible with the help of thermocouple which to be used as temperature measurement in the radiator. Radiator of car 800 is to be used in this experiment. Radiator is one of the most important device and widely used in many other purposes. In this experiment radiator acts a vital role and it is the key element of this experiment. Fins use in radiator is made of aluminum. Inlet of radiator is connect with the Tullu pump and outlet of radiator is connect with the rock bed storage system. Flow of water is continuous hence water to be cooled continuously by the help of radiator in this experiment. Radiator connected with Tulu pump and rock bed storage system by the help of C P V C pipe. Radiator is one of the most imperative device in this experiment and also very essential for this experiment.

Miscellaneous Equipment

Table 4. Details of Miscellaneous Equipments

Name	Size	Quantity
C P V C pipe	20-30 ft	3
M A B T	3/4*1/2 inch.	2
F A B T	3/4*1/2 inch.	3
F A B T	1 inch.	1
ELBOW	3/4 inch	6
T SHAPE	3/4 inch	2
G.I socket	3/4 inch	1
Solution	29.5ml	1
And Cap	3/4 inch	2
Clip	1/2 inch	4
Clip	3/4 inch	4
Nipple	Convert 1/2 inch to 3/4 inch	4
Valve	3/4 inch	2

EXPERIMENTAL SET UP AND PROCEDURE

Experimental set up

We had chosen rock bed storage system. C P V C pipe radiator, Tullu pump, fan, valve, is used in this experiment. All the important equipment such as rock bed storage system and radiator are kept on the radiator stand and rock bed storage stand. At first we deals with the outlet of solar water heater the C P V C pipe is connected with the outlet of solar water heater after it C P V C pipe is connected with the inlet of rock bed storage system and valve is used to control the flow of water when rock bed storage system is filled with water then close the valve. After it C P V C pipe is also connected with the outlet of radiator. Rock bed storage system is filled with rock and water both. C P V C pipe is also connected with the outlet of radiator. After it c p v c pipe is connected with the Tullu pump. After it Tullu pump is connected the inlet of radiator.

Fig.1. Connecting C P V C pipe and Tullu pump in a system

Experimental Procedure

Step 1:- At first attach the C P V C pipe to the outlet of the drum of solar heater .The main work do

in this step to reach hot water to the rock bed storage system. When rock bed storage is filled with water then valve is closed.

Step 2:- Rock bed storage system filled with rock and water whole system is heated with the help of solar water heater. Rock is heated till when temperature of rock lies between 45˚c to 65 ˚ c. Reading of temperature of rock bed storage system continuously. Temperature is measured in this step by the help of thermocouple.

Step 3:- In this step the hot water of rock bed storage system is released thorough the C P V C pipe and to reach hot water to the Tullu pump. Tullu pump repel the water to the inlet of radiator.

Step 4:- In this step measure the temperature at the inlet of radiator continuously and note the temperature. In this step temperature is measured by the help of thermocouple.

Step 5:- In next step water deals with the radiator and fan and then observe the temperature of radiator. Temperature of radiator is measured with the help of infrared thermometer.

Step 6:- In this step water reach to the outlet of the radiator and temperature of water is measured continuously by the help of thermocouple.

Step 7:- In this step outlet of radiator is joined with the inlet of rock bed storage system.

Step 8:- It is the final step of the experiment finally becomes a closed system and flow of hot water continuously in the closed system and maintain the temperature. Experiment is done till when temp. of rock bed storage and temp. of inlet and outlet of radiator and temp. of radiator shows equal value of temperature. Maintain the temp. of whole closed system at the 35˚c to 45˚c.

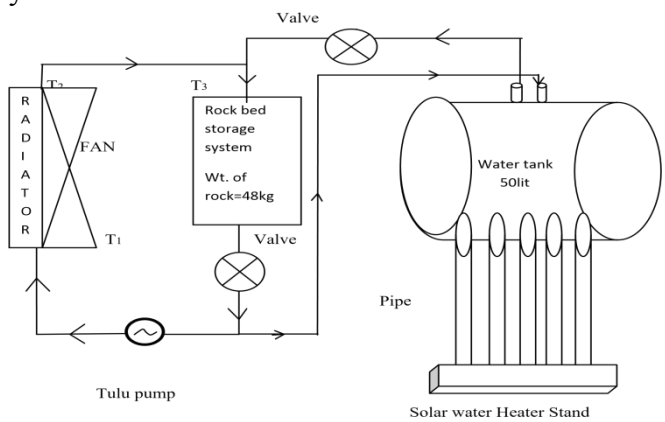

Fig.2. Block diagram of experimental setup

Observation and Graphs

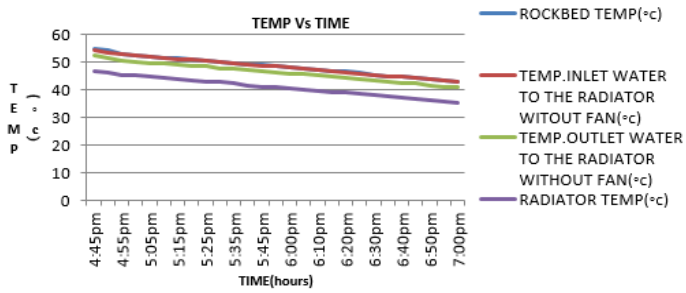

Fig.3. Profile of temperature b/w Rock bed storage temp, inlet temp of radiator, outlet temp of radiator and radiator temp on 15th July 2015.

When experiment was conducted from 4.45 pm to 7.00 pm at given values then, we got Fig.3 and Fig.4.

Temp. of rock =49°c
Amount. Of water =25 lit
Flow rate of water =800ml/60 sec
Wt. of rock =48Kg

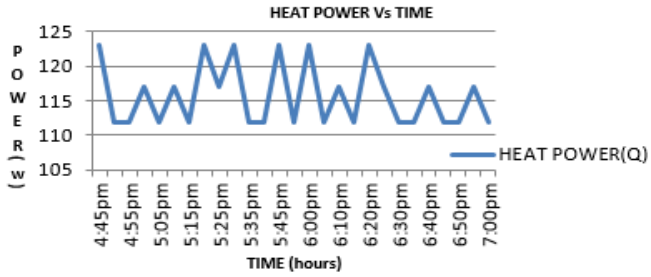

Fig.4. Variation of heat power of Rock Bed Storage system with respect to time on 15th July 2015.

When experiment was conducted from 12.00 pm to 4.00 pm at given values , then we got Fig.5 and fig.6.

Temp. Of rock =66°c
Amount of water =25 lit
Flow rate of water =800ml/60 sec
Wt. of rock =48Kg

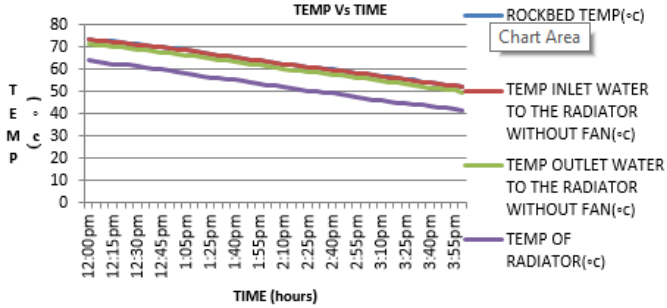

Fig.5. Profile of temperature b/w Rock bed storage temp, inlet temp of radiator, outlet temp of radiator and radiator temp on 20th July 2015.

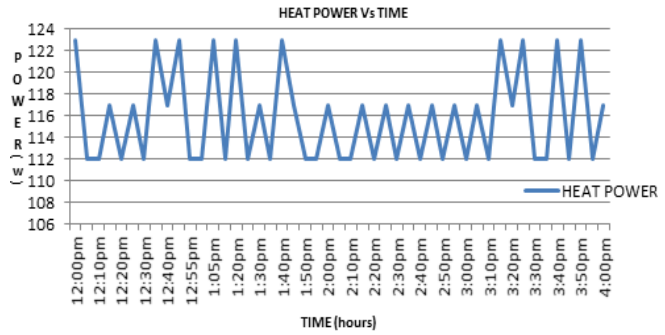

Fig.6. Variation of heat power of Rock Bed Storage system with respect to time on 20th July 2015.

Calculation

Theoretical calculation

Theoretical calculation without fan

GRPR= gβ (T1- T2) L^3/α.ν*Pr …..... (1)

Here,

g = 9.8

β = 1/15+273

ΔT = 4℃

L = 0.3m

α =25.722*10^-6

ν = 17.95*10^-6

P_r= 0.698

For Laminar Flow

h1=1.4 (ΔT/L) ^0.25……. (2)

Here

h1= theoretical value of convective heat co-efficient without fan

Theoretical calculation with fan

Re = u*L/ν …….. (3)

Re < 5 *10^5 laminar flow

In both case with fan and without fan found laminar flow hence value of convective heat coefficient approx. equal.

3.4.2. Experimental calculation

Calculation of convective heat co-efficient without fan (h_1)

At first we calculated total surface area

Total number of fins = 200

Width = 32 cm

Length (l) = 4 cm

Number of pipes =18*2 =36

Total Length (L) =29 cm

Diameter of pipe (d) =0.8 cm

Radius of pipe(r) =0.4 cm

Total surface area (A) = (Total no. of pipes)*2πrL+ area of fins …… (4)

Now calculate heat power (Q)

Q = m*C* ΔT…….. (5)

Here ΔT= Temp. Difference between inlet and outlet of radiator.

Now calculate the value of convective heat co-efficient (h1) without fan

h1 = Q/ (A.ΔT)…….. (6)

Here,

ΔT= Temp. Difference between Rock bed storage system temperature and ambient temperature.

Now calculate the value of convective heat co-efficient (h2) with fan

h2 = Q/ (A.ΔT)……. (7)

Power of fan = VI……. (8)

RESULT

Convective heat co-efficient

Table 5. Calculation of convective heat co-efficient in tabular form

GRPR	5.2 *10^6
Theoretical value of convective heat co-efficient without fan (h1)	2.67 w/m^2-deg
Theoretical value of convective heat co-efficient with fan (h2)	Approx. equal to value of h1 because flow is laminar
Re	9.8*10^4
Heat power (Q)	112 watt-125 watt
surface area (A)	4.66 m^2
Experimental value of (h1)	1.10 w/m^2-deg
Experimental value of (h2)	1.73 w/m^2-deg

Power of fan

Table 6. Calculation of fan in tabular form

Current of fan	2.79 A
Voltage of fan	9.12 V
Power of fan	25.34 W
Capacity of fan	600 CFM
Time / minute	1111 ft/ min
Time / sec	18 ft/ sec
Area of fan	0.54 ft^2
Velocity of fan	5.5 m/s

CONCLUSION

This experiment is conducted with the help of Radiator and to check the performance of rock bed storage system at the continuous flow of water and then to study about the hotness of rock in the rock bed storage system. As like as rock is heated then the temperature of rock bed storage system is increased. Finally we conclude the capacity of rock bed storage system is high and also it's more efficient. Rock bed storage system is generally preferred to save the solar energy, is to be used in future in many purposes. In this experiment rock is used for absorption of heat which is easily and widely available. At the circulation of water between the rock bed storage and radiator by using of Tullu pump then study about the consideration of temperature between the temperature of rock bed storage system and the temperature of inlet and outlet of the radiator. The main purpose of the experiment is done till when to become the equal the temperature at rock bed storage system and the inlet and outlet of radiator. Those time is taken, is to complete the experiment which gives the back up of 2 - 3 hours at night time gives and maintain the temp at least in the range 30°c - 40°c. There is a need to optimize the size of rock bed storage system, size of Tullu pump, and hotness material also for the working of 24 hours of rock bed storage system.

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