Thermal Heat Storage Device Using PCM

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ABSTRACT

In the renewable energy side. Sun is the mother for all sources and harnessing the solar energy in proper ways can eliminate the energy crisis of the world. To harness the solar energy, collectors are used and for low temperature application side flat plate collectors are used. In solar air heater, solar energy is collected by means of an absorbing plate and the collected heat energy is transferred to heat transferring medium such as air.Solar energy applications require am efficient thermal storage Hence, the successful application of solar energy depends, to a large extent, on the method of energy storage used. The latent heat of melting is the large quality of energy that needs to be absorbed or released when a material changes phase form solid state to liquid state or vice-versa .magnitude of the energy involved can be Demonstrate comparing the sensible heat capacity of concrete (1.0 kJ/kg with the latent heat of a phase change material (PCM), such as paraffin wax (154 kl/kg). It is obvious that any energy storage systems incorporating PCM will comprise significantly smaller volumes when compared to other materials storing only sensible heat.

KEYWORDS – PCM , Thermal – Energy , Solar, Heating , Renewable.

Introduction

Energy is the backbone of human activities. The importance of energy in economic development is very critical as there is a strong relationship between energy and economic activity. Historically fossil fuel in its solid phase, i.e wood and coal. Has been the prime source of energy. The increment in global energy demands due to population growth and 20th century industrial revolution leads fossil fuel through a transitional phase. Energy crisis and global warming lead to find an alternative way to overcome the above worsening situation. Renewable energy plays a major solution and thereby meets our energy demand and reduces the CO2 emission which reduces the greenhouse effect. It is being widely realized that for sustainable development presently used energy mediums such as fossil fuel and nuclear power have to be quickly replaced by renewable energy sources. The latter are sustainable and have the potential to meet present and future projected global energy demands without inflicting any environmental impacts. Renewable energy sources such as solar. wind. Hydropower and biogas are potential candidates to meet global energy requirements in a sustainable way.

Objective

The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps. solar engineering. And spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. This focuses on the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications.

Scope of Work

Under this project, we are going to see the effect of increase in the thermal energy storage capacity by using P.C.M. and how the usage of P.C.M. can increase the reliability of solar thermal devices. We are decided to use paraffin-wax as the P.C.M. as it has melting temperature in the desired operating temperature range.

Literature Review

Solar Water Heaters with Phase Change Material Thermal Energy Storage Medium: A ReviewAnanr Shukla, D. Buddhi, RL Sawhney

Latent heat thermal energy storage is one of the most efficient ways to store thermal energy for heating water by energy received from sun. His paper summarizes the investigation and analysis of thermal energy storage incorporating with and without PCM for use in solar water heaters. The relative studies are classified on the basis of type of collector and the type of storage used i.e. sensible or latent. A thorough literature investigation into the use of phase change material (PCM) in solar water heating has been considered. It has been demonstrated that for a better thermal performance of solar water heater a phase change material with high latent heat and with large surface area for heat transfer is required.(1)

Review on Thermal Energy Storage With Phase Change materials And Applications Atul Sharma, V.V. Tyagi, C.R. Chen:

The use of a latent heat storage system using phase change materials (PCMS is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process, PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engincenng. and spacecraft thermal control applications. The uses of PCMs for heating and cooling applications for buildings have been investigated within the past decade. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them attractive in a number of applications. This paper also summarizes the investigation and analysis of the available thermal energy storage systems incorporating PCMs for use in different applications.(2)

A Nano-Graphite/Parafin Phase Change Material With High Thermal Conductivity Min Li:

Nano-graphite (NG/paraffin composites were prepared as composite phase change materials. NG has the function of improving the thermal conductivity of the composite. The microstructure and thermal properties of the materials were examined with environmental scanning electron microscopy and differential scamming calorimetry. The results indicated that the NG layers were randomly dispersed in the paraffin, and the thermal conductivity increased gradually with the content of NG. Thermal conductivity of the material containing 10% NG were 0.9362 W/m K. (3)

Thermal Energy Storage with Phase Change Material Lavinia Gabriela SOCACIU:

Thermal energy storage (TES) systems provide several alternatives for efficient energy use and conservation. Phase change materials (PCMs) for TES are materials supplying thermal regulation at particular phase change temperatures by absorbing and emitting the heat of the medium. TES in general and PCMs in particular. have been a main topic in research for the last30 years, but although the information is quantitatively enormous, it is also spread widely in the literature. and difficult to find PCMs absorb energy during the heating process as phase change takes place and release energy to the environment in the phase change range during a reverse cooling process. PCMs possesses the ability of latent thermal energy change their state with a certain temperature. PCMs for TES are generally solid-liquid phase change materials and therefore they need encapsulation. TES systems using PCMs as a storage medium offers advantages such as high TES capacity, small unit size and isothermal behaviour during charging and discharging when compared to the sensible TES. (4)

Methodology

Latent heat storage can be achieved through liquid to solid, solid to liquid solid to gas and liquid to gas phase changes. However, only solid to liquid and liquid to solid phase changes are practical for PCMs. Although liquid gas transitions have a higher heat of transformation than solid-liquid transitions, liquid-gas phase changes are impractical for thermal storage because large volumes or high pressures are required to store the materials in their gas phase. Solid- solid phase changes are typically very slow and have a relatively low heat of transformation. Initially, solid-liquid PCMs behave like sensible heat storage (SHIS) materials their temperature rises as they absorb heat. Unlike conventional SHS materials however, when PCMs reach the temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature. The PCM continues to absorb heat without a significant rise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat. A large number of PCMs are available in any required temperature range from-5 up to 190 °CII1 Within the human comfort range between 20-30 C, some PCMs are very effective. They store 5 to 14 times more heat per unit volume than conventional storage materials such as water, masonry or rock. Utilization of solar-thermal energy storage tanks with PCM based latent heat storage technology is expected to enhance the efficiency of available solar-thermal systems. Phase change material (PCM) absorbs heat during its phase change cycle from solid to liquid during the daytime solar cycle. This latent heat stored in PCM maintains the temperature of space air warm during cold night. A phase change material (PCM) is a substance with a high heat of fusion which. melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units.

Types of P.C.M.:

1) Organic P.C.Ms , 2. Inorganic **,** 3. Eutectics **,** 4. Hygroscopic Materials.

3.,2.1 Organic P.C.Ms: Paraffin (C.H), carbohydrate and lipid derived.

- Advantages:

2) Freeze without much undercooling
3) Ability to melt congruently
4) Self nucleating properties
5) Compatibility with conventional material of construction
6) No segregation

7) Chemically stable
8) High heat of fusion
9) Safe and non-reactive
10) Recyclable
11) Carbohydrate and lipid based PCMs can be produced from renewable sources

- Disadvantages:

1) Low thermal conductivity in their solid state. High heat transfer rates are required during the freezing cycle.
2) Volumetric latent heat storage capacity can be low.
3) Flammable. This can be partially alleviated by specialist containment
4) To obtain reliable phase change points, most manufacturers use technical grade paraffin's which are essentially paraffin mixture(s) and are completely refined of oil, resulting in high costs.

3.2.2 Inorganic: Salt hydrates (M,H2O)

- Advantages:

1) High volumetric latent heat storage capacity.
2) Availability and low cost.

- Disadvantages:
    1) Change of volume is very high
    2) Super cooling is major problem in solid-liquid transition
    3) Nucleating agents are needed and they often become inoperative after repeated cycling.

1) Eutectics: c-inorganic, inorganic-inorganic compounds.

- Advantages:
    1) Eutectics have sharp melting point similar to pure substance
    1) Volumetric storage density is slightly above organic compounds
    2) Extra water principle can be used to avoid phase change degradation involving dissolving the anhydrous salt during melting to result in thickening of the liquid material so that it melts to a gel form.
- Disadvantages:

  Only limited data is available on thermo-physical properties as the use these materials are relatively new to thermal storage application.

2) Hygroscopic Materials: Many natural building materials are hygroscopic. that is they absorb (water condenses) and release water (water evaporates). The process is thus Condensation (gas to liquid) ΔH<0; enthalpy decreases (exothermic process gives off heat.

- Vaporization (liquid to gas) AH0; enthalpy increases (endothermic process) absorbs heat (or cools). Whilst this process liberates a small quantity of energy, large surfaces area allows significant (1-2 "C) heating or cooling in buildings. The corresponding materials are wool insulation, earth clay render finishes.

3.3 Selection Criteria for P.C.M.:

Thermodynamic Properties:

1. The phase change material should possess:
2. Melting temperature in the desired operating temperature range High latent heat of fusion per unit volume.
3. High specific heat, high density and high thermal conductivity.
4. Small volume changes on phase transformation and small vapour pressure operating temperatures to reduce the containment problem Kinetic properties.
5. High nucleation rate to avoid supercoiling of the liquid phase.
6. High rate of crystal growth, so that the system can meet demands of heat recovery from the storage system.
7. Chemical properties
8. Chemical stability
9. Complete reversible freeze/melt cycle.
10. No degradation after a large number of freeze melt cycle
11. Non-corrosiveness, non-toxic, non-flammable and non-explosive material.

Property or Characteristic.	Paraffin Wax	Non paraffin Organics	Hydrated salts	Metallica
Heat of Fusion	High	High	High	Med.
Thermal conductivity	Very Low	Low	High	Very High
Melt temperature (°c)	-20 to +100	5 to 120	0 to 100	150 to 800
Latent Heat (kJ/kg)	200 to 280	90 to 250	60 to 300	25 to 100
Corrosive	Non Corrosive	Mildly Corrosive	Corrosive	Varies
Economics	$$	$$$ to $$$$	$	$$ to $$$
Thermal cycling	Stable .	Elevated Temp. Can Cause Decomposition.	Unstable over Repeated cycles.	Stable.
Weight	Medium	Medium	Light	Heavy.

3.1 Table: Comparison between phase change mater

3.4 Paraffin Wax:

Fully refined paraffin wax is hard having white crystailline maternal derived from petroleum and it is refined by means of a carefully controlled selective solvent process into different melting point grades. The refined paraffin we have exceptional gloss and resistance. Its degree of purity and low order makes many applications Paraffin waxes predominantly composed of normal straight chain of hydrocarbons. They vary from 18 to 40 carbon atoms and the chain length determines average melting point, resistant to acids an alkaline substances. In chemistry, paraffin is the common name for the alkane hydrocarbon having general formula CnHzn 2 paraffin wax is related to solids having n-20 to 40. The solid paraffin called paraffin wax is C20H42 to C40H82. The fuel name in Britain has paraffin. which is now called as kerosene in U.S.A and Australia. The name is derived from Latin partum (barely) affine which means lacking in reactivity or highly in reactive. Paraffin is the alternative for kerosene. Its melting point is above 470C to 640C. Its density is 0.9gm/cm3. It is insoluble in water but soluble in ether like benzene and some esters It is unaffected by reagents and combustible. The electrical resistivity is very high. It is an effective neutron moderator used by James Chadwick to identify neutron. Paraffin wax is having specific heat 2.14 to 2.9 j/kg K. Its latent heat of fusion is 20) 220 j/kg.

3.4.1 Uses

Liquidities paraffin state is used as a fuel. Paraffin wax has wide application like it is used as laxative; it is used in paints and pigments, dyes. inks, in medicine, in lavatories, cosmetics, making candies and coating tor wax paper. Paraffin is used as a sealant for jars, cans. and botties. It acts as anticaking agent moisture repellent and dust binding coating for fertilizers. I is used as solid propellant for hybrid rocket motors. it used on handrails.

3.5 Paraffin Wax Graphite Flakes Composites

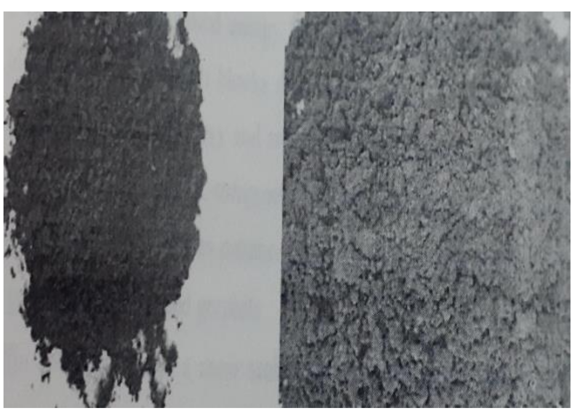

Fig. 3.2 Appearances Of Graphite Flakes

Fig. 3.3 Appearances OF Composite

Organic PCMs are more chemically stable than inorganic PCMs, they melt congruently, and super cooling is not a significant problem. For phase change heat storage, only when the heat release rate during phase change is higher than the heat dissipation speed to the environment, can the ambient temperature be changed. So the low thermal conductivity of organic PCM should be improved to increase the utilization coefficient of the stored energy. The heat storage 'release rate of organic PCM is low consequently, which blocks the effect of practical application in solar energy storage, waste heat recovery and so on. The carbon materials are introduced into organic PCMs to form PCM composites and improve the thermal conductivity Thermal conductivity of PCM was enhanced using different graphite matrix, such as exfoliated graphite and expanded graphite.

Paraffin and NG formed a Nano scale compound, and Nano-layers of NG are dispersed in paraffin in a random orientation. The distributed NG enhanced the heat transmission and improved the performance of energy storage technologies in term of efficiency in PCM. The phase change temperature of paraffin was slightly influenced by NG content. The phase change temperature of the NG/paraffin composite PCM was slightly less than that of paraffin.

Heat Calculation.

1. Solar irradion, I = 5 kwh/m^2 day

   = 0.625 kw/m^2 (assuming 8 hrs of solar radiation)

   I = 625 w/m^2

2. Collector area, A = l x w

   = 0.35*0.60 m^2

   A = 0.21 m^2

3. Total heat incident on collector area, Q_i = I * A

   = 625*0.21

   = 131.25

   Q_i = 130 w (approx.)

4. Transmissivity of Glass Cover, τ = 0.81
5. Absorptivity of Absorber, α = 0.87
6. Total heat absorbed by absorber, Q_a = Q_i * τ * α

   = 130 * 0.81 * 0.87

   = 91.61

   Q_a = 90 w (approx.)

Fig- 1 Calculation

7. Heat lost by convection and radiation : Q_L

I. Overall heat (loss) transfer coefficient: [5]

$$U_t = \left[\frac{M}{\left(\frac{c}{T_{pm}}\right)\left(\frac{T_{pm}-T_a}{M+f}\right)^{0.252}} + \frac{1}{h_w}\right]^{-1} + \left[\frac{\sigma(T_{pm}^2+T_a^2)(T_{pm}+T_a)}{\frac{1}{\varepsilon_p+0.0425M(1-\varepsilon_p)}+\frac{2M+f-1}{\varepsilon_c}-M}\right]$$

Where,

c = (204.429*(cos β)$^{0.252}$) / $L^{0.24}$

= 405.62

β = Solar rays incident angle=45˚

T_{pm} = 58˚ c = 331 k

T_a = 37˚ c = 310 k

$$f = \left(\frac{9}{h_w} - \frac{30}{h_w^2}\right)\left(\frac{T_a}{316.9}\right)(1 + 0.091M)$$

f = 0.3859

h_w = 5.7 + 3.8 * ∞

= 5.7 + 3.8* 4

h_w = 20.9 w/mk

= 5.67 *10^{-8} w/m^2k

= 0.92 =0.88

U_t = 6.749 w/m^2k

Fig- 2 calculation

II. Heat lost by convection and reradiation:

Q_L = U_t * (T_c-T_a) * A

= 6.749 * (331-310) * 0.21

= 29.76 W

Q_L = 30 w (appx)

8. Useful Heat, Q_U = Q_a - Q_L

Q_U = 60 W

9. Energy Balance:

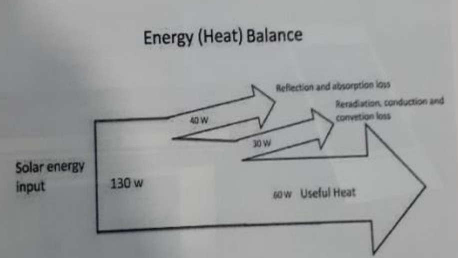

*Fig*5.1 : Sankey Diagram

Fig- 3 Calculation

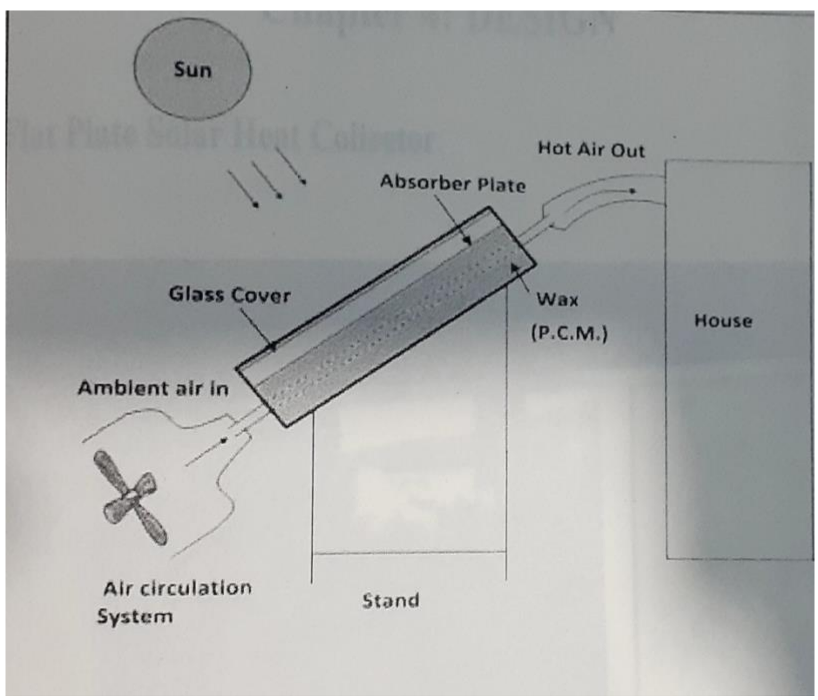

Fig.3.4 Block Diagram

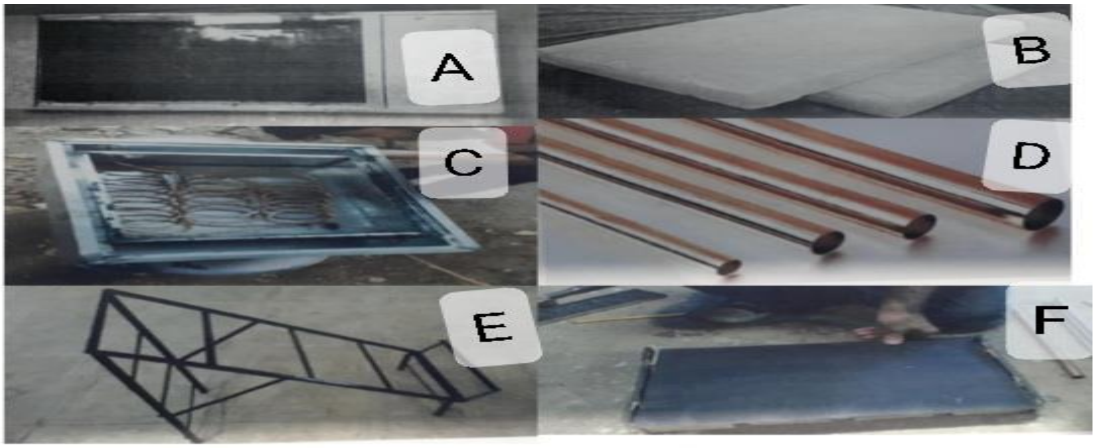

Fig.4 A – Box , B – Paraffin Wax Cube , C – Duct , D Copper Pipes , E – Support Structure, F – Absorber Plate

3.6 Ambient conditions:

i. At day time (while storing heat):

1. Ambient air temperature = 25 °c
2. Collector temperature = 65 °c
3. Wax temperature = 55 °c

ii. At night (while using stored heat):

1. Ambient air (inlet air to collector) temperature 12°
2. Collector outlet air temperature = 22 °c.

Fig. 5 Summary Of Project Manufacturing

Step 1 :First of all the inner container is constructed. The container is made from G.I. sheets by sheet metal work.

1. Then holes are drilled on it for passing copper pipes through it.
2. Copper pipes of equal length are fixed in holes.
3. Pipes are fixed to box using sealant.
4. Sealant is also applied at corners to prevent leakage.

Step 2:

1. Nano graphite powder is added into the paraffin wax
2. This homogeneous mixture is filled into the container.

Step 3:

1. Outer container is constructed by using G.I. sheets.
2. Insulation of polystyrene is applied to avoid heat loss to the surrounding.

Step 4:

1. Air circulation system is provided.
2. Fan takes the atmospheric air as input and passes it through copper pipe in upward direction.
3. Hot air comes out from the device.

Step 5:

1. Black colour coated absorber plate is mounted on inner container with the help of nut and bolt.
2. A rubber band is kept in between the absorber plate & inner container which act as gasket to make system leak proof.

Step 6:

1. The transparent glass cover is inserted over the absorber plate.
2. It acts as a polythene house, hence it reduces a radiant heat losses.

Step7:

1. All parts are assembled and mounted on support structure.
2. Support structure is made up of mild steel with T and L shape angle.
3. Support structure provides 45 angle to the heat storage system.
4. Overall system is placed on support structure.

Working Principle of Model:

In areas like Solapur we have come across situations when temperature is above 350 c at day time and it goes below 15° c. Normal human body feels comfort between the temperature of range of 21 to 23 in winter nights. So, the heat energy available at day time in winter can be stored and effectively used at night time for the room space heating.

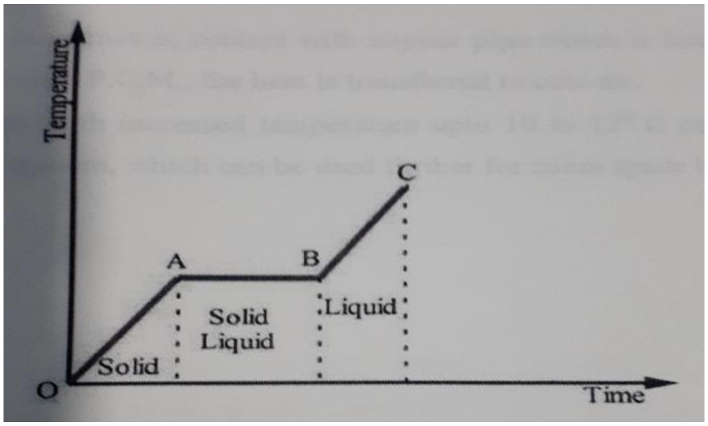

Fig. Heating Curve

1. Solar energy reaches to the earth in the form of heat radiations.

2. The direct and indirect rays fall on flat plate collector.

3. This heat energy enters into the collector through glass cover.

4. Some portion of the incident radiant energy is reflected back to the atmosphere from glass cover of the collector.

5. Radiant energy entered into the collector is absorbed by the black absorber plate. As the absorptivity of. black color is high, most of the radiations get absorbed.

6. This absorbed energy is stored into the P.C.M. which is present below the absorber plate.

7. P.C.M absorbs heat in two forms i.e sensible heat and latent heat.

- Sensible Heating: When P.C.M. absorbs heat, its temperature starts increasing above ambient temperature till it reaches melting point
- Latent Heat: The melting point of P.C.M. ranges from 50 to 550 c

8. Due to this, phase of P.C.M. changes form solid to liquid state.

9. At night we pass cold air with the help of air circulation system into heat storage system.

10. When cold air comes in contact with copper pipe which is hot due to contact with molten state P.C.M., the heat is transferred to cold air.

11. Then, this air with increased temperature up to 10 to 120 C come at outlet of heat storage system, which can be used further for room space heating.

Results

Cycle	Time	Temperature (° c)		
		Absorber Plate	P.C.M.	
Heat Storage	9:00 am	29	25	Sensible Heating
	12:00 pm	59	48	
	3:00 pm	64	55	Latent Heating
	6:00 pm	34	53	
Heat Utilization	9:00 pm	30	52	Latent Heating
	12:00 am	28	51	
	3:00 am	26	51	
	6: 00 am	24	28	Sensible Cooling

Fig. Observation Table

Result:

The experiments conducted on project apparatus shown us that the temperature of air coming out from the setup has increased up to 10°c.

- The total heat incident on collector area is 130 w, out of that heat absorbed by the absorber is 90 w.
- 30 w heat is lost due to convection and radiation.
- So useful heat obtained is 60 w.

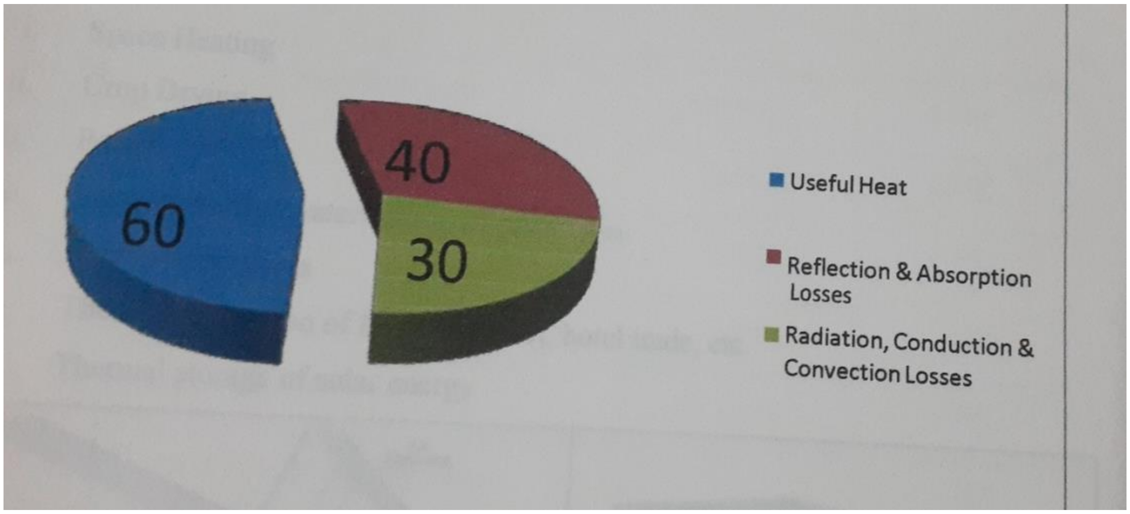

Fig. Pie – Chart Representing Breakdown Of Energy

Conclusion

1. In this project we found that the paraffin wax is best suited as PC.M. for domestic solar space heating. This project can be use for storage of heat during day time &which can be use at night time effectively.
2. Use of this device reduces heating load which is previously done by conventional energy sources Reduced energy demand reduces facilities carbon footprint
3. Due to use of Nano graphite particles, thermal conductivity of P.C.M. has been greatly improved. As a result of this Efficiency of system has been increased.

APPLICATIONS

1. Space Heating
2. Crop Drying
3. Poultry
4. Heating and hot water: using off-peak rates
5. Solar power plants
6. Thermal protection of food: transport, hotel trade, etc.
7. Thermal storage of solar energy.

FUTURE SCOPE

There are some points which can be improved in the future design of the solar Thermal heat Storage Using P.C.M. which are listed below.

1. Other better ways of storing thermal energy has to be looked in detail in order to minimize the cost without compromising on the performance. Comparison of performance has to be analyzed for different energy storage techniques.
2. Heat energy obtained from the sun is has to be optimized by choosing proper flow rate air passing through copper pipe
3. Solar tracking system can be installed to improve the efficiency of the system.
4. By deeply studying the proper proportion of Nano graphite particle and paraffin wax we can further improve the efficiency of solar thermal heat storage system.

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