Thermal Enhancement of Walls Using Phase Change Materials

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Has been accepted towards the partial fulfillment

of

the requirements for the award of degree of

Master of Science in Structural Engineering

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THESIS ACCEPTANCE CERTIFICATE

It is certified that Mr. Mahmood Hussain, Registration No. 00000119609, of MS Structural Engineering batch 2015 has completed his thesis work and submitted final copy which was evaluated, and found to be completed in all aspect as per policy of NUST/Regulations. His thesis work was found to be free of plagiarism.

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Name of Supervisor: Dr. Muhammad Usman

Date: _______________________________

Signature: ______________________________

Head of Dept.: Dr. Rao Arsalan Khushnood

Date: _______________________________

Signature: ______________________________

Dean: Dr. S. Muhammad Jamil

Date: _________________________________

Declaration

I certify that this research work titled "*Thermal Enhancement of Walls Using Phase Change Materials"* is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources has been properly acknowledged /referred.

Signature of Student

MAHMOOD HUSSAIN

2015-NUST-Ms-STR-0000019609

Copyright Statement

Acknowledgments

I am grateful to Almighty Allah whose countless blessings gave me the strength to complete this research work.

I bestow my sincere thanks to my mentor and advisor Asst. Prof. Dr. Muhammad Usman, department of structural engineering, NUST Institute of civil engineering (NICE) for his advice, untiring guidance, incredible patience, and supervision. He inspired me through his punctuality, professionalism, diligence, and sincerity. I am grateful to him for his encouragement and motivation. He always urged me to achieve the best. All credit goes to him for making me a hard worker, focused and ambitious.

Dedicated to my Supervisor, Dr. Muhammad Usman and to my beloved family.

ABSTRACT

Energy demand is continuously increasing globally. Fossil fuels are a major cause of harmful gas emissions and thus causing environmental pollution. Therefore, it is a dire need to introduce innovative techniques for energy storage and reduce environmental pollution. Different studies have shown that the building sector consumes 40% share of the total energy consumption. Phase change materials (PCM) are the latent thermal storage materials that have the capacity to store a large amount of thermal energy during its phase change from solid to liquid and vice versa. Structural materials of such kind offer one of the best options for the rapid development of energy-saving materials. This study focuses on the preparation of the model wall encapsulating the locally available PCM to develop thermal energy storage with the capability of storing thermal energy within the human comfort zone. Three locally available PCMs (Glycerin, Vegetable Ghee and Ferric Chloride hexahydrated) have been tested in a controlled environment. 2x heating cycle i.e. three hours heating cycle and two hours heating cycle have been conducted to study the performance and behavior of each PCM. The experimental setup consists of 0.7-inchdiameter steel tubes, embedded in the front wall with a concrete cover of 1 inch. The embedded tubes filled with the Glycerin, Vegetable Ghee and Ferric Chloride Hexahydrated to analyze their performance above quoted heating conditions. From the investigation of test results, it was concluded that PCMs have significant improvement in thermal efficiency and also did not have any adverse effect of all the used PCM on the model. Out of tested PCMs, the best performance was given by vegetable ghee that showed a drop in temperature for all the points i.e. T3, T4, and T5.

Table of Contents

List of Figures

CHAPTER 1

1 INTRODUCTION

1.1 Background

Owing to rapid economic growth, energy demand is increasing continuously causing a depletion of the fossil fuels and renewable energy resources at the same time. The usage of fossil fuels results in the emission of harmful gases and cause environmental pollution. It is highly desired to make the best use of available energy sources to save the environment. Therefore, it is necessary to introduce innovative techniques for energy storage to make the efficient use of available energy resource[1]. As per studies, the building sector consumes 40% share of the total energy consumption. Consequently, researchers are paying more attention to the innovation of energy saving materials known as green building materials, which have energy-saving capacity viable for the construction industry [2].

With an immense increase in the annual production i.e. 11 billion metric tons; human being continues to spread the construction industry. Massive concrete construction may be favorable in modern climate zones where the intrinsic thermal properties of concrete, i.e. to store thermal energy during the day and release slowly during the night, can be effectively utilized with reduced need of artificial heating and cooling[3] .To deal with critical energy situations and to save a portion of energy in the buildings, enhancing the energy storage capacity of concrete is need vide some mechanism. Introduction of PCMs in the concrete mixes can be quoted as an example in such cases [1] [4][5][6].

PCM materials can be defined as *"Phase change, are the latent heat of storage, materials can store a large amount of thermal energy in its phase change from solid to liquid or vice versa".* Generally, thermal energy storage materials are of two types

1) Sensible heat storing

2) Latent heat Storing.

Phase change materials are broadly classified as;

a. Organic
b. Inorganic
c. Eutectic

The most widely used PCMs are organic PCMs (i.e. paraffin) due to their inert behavior. Inorganic PCMs are praised for the high latent heat of storage, reasonable thermal conductivity, non-flammable and economical nature. Their usage becomes restricted for some undesirable characteristics, for example, corrosive nature and super cooling. In the present study, inorganic as well as organic PCMs were employed with an attempt to overcome undesirable properties.

1.2 Problem Statement

Phase change material is considered an effective method to reduce the heat flux and is being used since last few decades. Walls in frame structures are exposed to sunlight and invite heat inflow which consequently results in an excessive rise in internal temperature. incorporation of PCM in walls exposed to high temperatures, heat flow may be controlled resulting in better indoor temperatures.. This research aims to the incorporation of PCMs (Ferric Chloride, Glycerin, and Vegetable Ghee) into walls for better thermal efficiency.

1.3 Research Objectives

The main objectives of current research areas follow:

1. Preparation of thermal energy storage wall for its contribution towards sustainability.
2. Study the locally available PCMs and development of a technique for the incorporation of PCMs into walls for the achievement of better indoor temperature.
3. Develop a controlled mechanism for the study of PCM and establish a comparison between all the subjective PCMs.

1.4 Thesis Organization

This thesis is organised stepwise starting from the brief introduction to the title and PCM. Second chapter includes the literature review, third chapter is composed of experimentation discussion in details, and results are presented in fourth chapter along with the discussion. Results are cited in fifth chapter along with the recommendations.

CHAPTER 2

2 LITERATURE REVIEW

2.1 General

This chapter covers a literature review regarding Phase Change Materials works which was previously investigated for walls.

2.2 Phase Change Materials (PCM)

Phase change materials are the latent heat of storage materials that can store a large amount of thermal energy in its phase change from solid to liquid or vice versa. PCMs are the latent heat of storage material and unlike sensible heat storage material; they have the capacity to store energy in their phase changing the situation without significant increase in their temperature. Classification of different PCM and the phase changing cycle are presented in Fig2.1 and Fig 2.2.

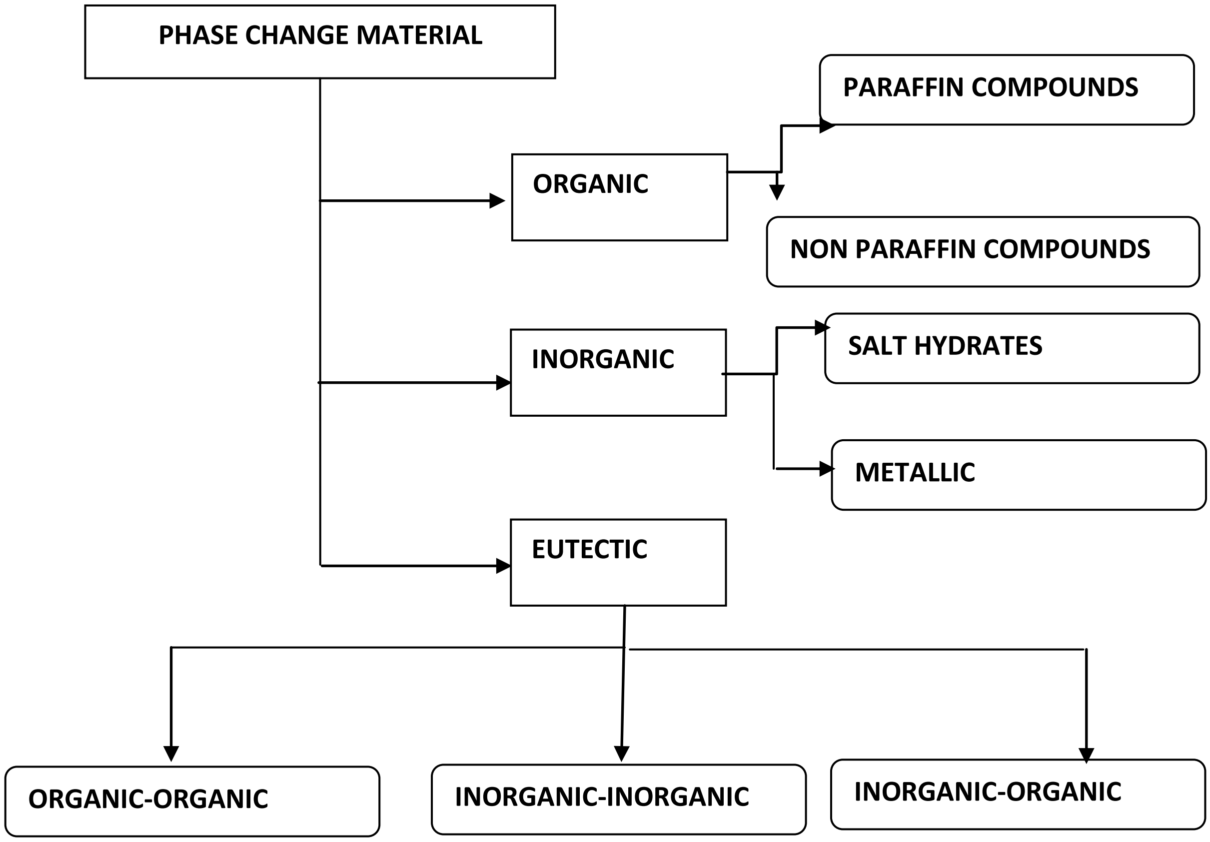


Figure 2-1: Classification of Phase Change materials

2.3 Phase Change Materials (PCM) in Literature

Phase change material (PCM) has become a necessity with the increase in energy demands. Buildings have been the major consumer of energy and hence require necessary modification in architectural and material aspect. A limited number of studies have been carried out previously for the incorporation of PCM. Small scale indoor tests were conducted using the incorporation of PCMs in Lightweight aggregate (LWA) for their performance in residential buildings. It was concluded that macro-encapsulation of paraffin LWA reduced the internal surface temperature by 4.7 Celsius and 7.5 Celsius. With a further reduction of 2.9 Celsius in the internal room temperature[3].

While investigation the thermal performance of PCM tests were conducted using the full-scale model as well as employing the numerical analysis techniques. In this investigation, two PCMs panels containing Capric Acid, as well as Capric acid (PCMOW) and 1-dodecanol (PCMIW) were installed on the outside and inside surfaces of the walls and roofs. It was concluded that PCMIW showed a better performance[7] .

Apart from the macro-encapsulation techniques, different other techniques have been used for the incorporation of PCM in the wall. Trombe walls have been used and found efficient in reducing the internal temperatures. These walls were made using the salt hydrates and hydrocarbons as PCMs[8].

In a research two passive storage collector walls using calcium chloride hexahydrate (melting point 29 8C) as a phase change material. It was concluded that an 8.1 cm PCM wall has slightly better thermal performance than a 40-cm thick masonry wall.[9]

Usage of PCM wall boards has also been reported in the literature. Liquid PCM are immersed in the pores using post manufacturing imbibing or at the wet stage. A new technique of incorporating the PCM at the microscopic level is also in vogue these days[10].

PCM based window shutters are also being used to achieve better internal temperature. In this case, a movable shutter made of PCM is placed inside the window. During the daytime shutter is opened to side exposed to heat, the heat is absorbed and The PCM shutter is kept open to absorb heat at night the shutter is closed and the heat from PCM radiated into the room. A temperature drop of 2 Celsius has been reported [9]

The composite solar wall has been established in order to store a large amount of heat energy in a small volume so as to make it possible to use as lightweight arrangement. The composite solar wall consists of several layers a semi-transparent cover, a closed cavity, a storage wall, a ventilated air cavity and insulating panels where two vents allow the warm air to enter inside the room.PCM bricks are incorporated in the solar wall that aims to store heat energy[8].

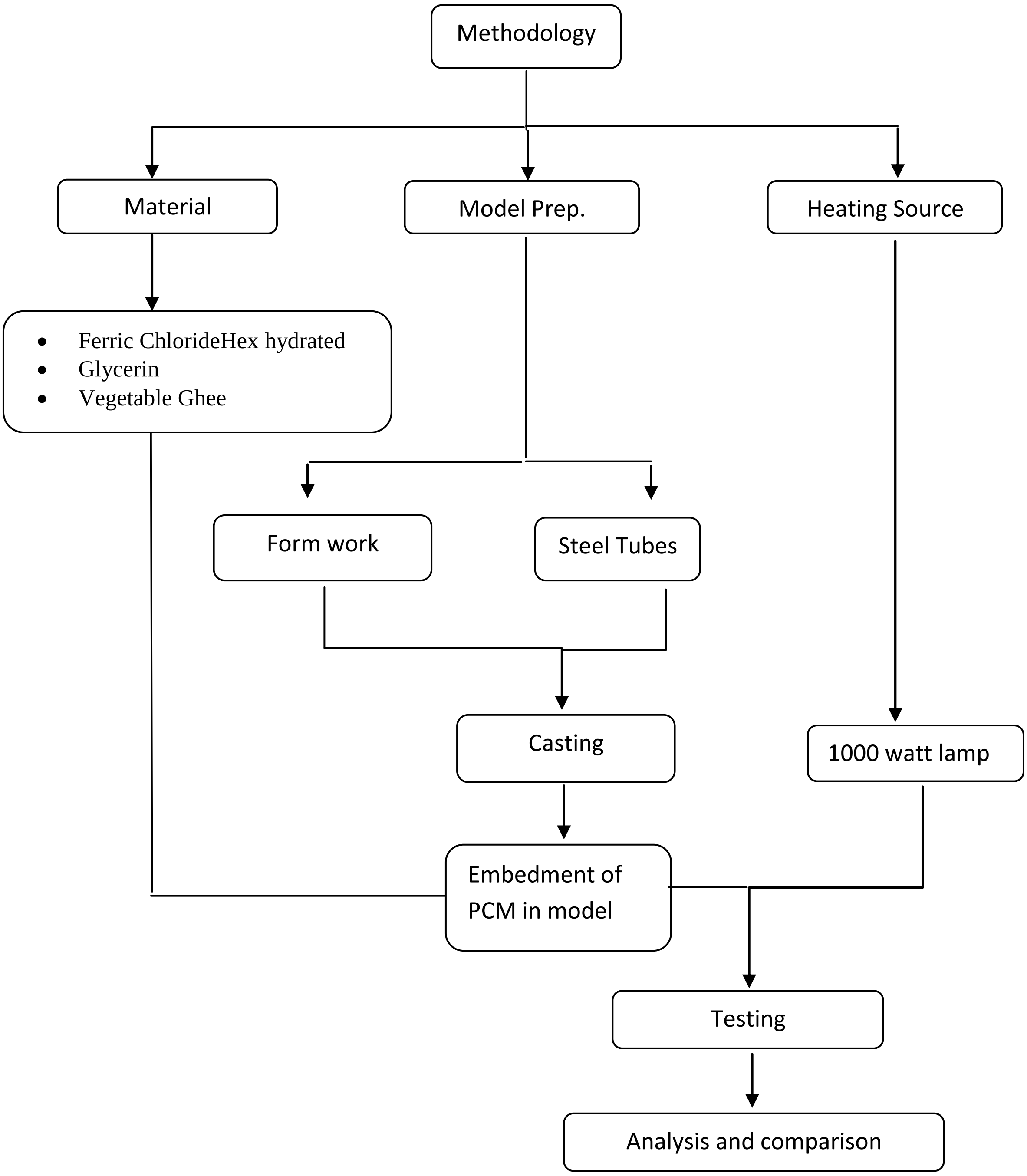
In experimental assessment of positions of macro encapsulated phase change material in concrete walls on indoor temperatures and humidity levels was examined. The results indicated that the model with PCM laminated within the concrete walls showed the better temperature control and was effective in reducing the maximum temperature by up to 4 Celsius. However, the model with PCM placed on the inner side of concrete walls showed the best humidity control and reduced the relative humidity by16% more than the control model[11]

CHAPTER 3

3 Experimental Program

3.1 Background

This chapter deals with the experimental setup for the titled research work and is divided into two phases. In the first phase, all the material used and the casting process is discussed concisely while the second phase covers the thermal cyclic loading that was carried out to make the observations.



3.2 Materials

3.2.1 Phase Change Material

While making this study utmost effort has been made to bring those materials in experimentation that are locally available economically. In this regard three choices were made;

i. Ferric chloride Hexahydrated ($FeCl_3.6H_2O$)

ii. Glycerin

iii. Vegetable Ghee

In the literature Ferric chloride, Hexahydrated and Glycerin have been reported as phase change material. However, during the identification for PCM, it was observed the locally used vegetable Ghee shows some tendencies for being used as PCM. Therefore, it was decided that the third PCM for this study shall be Vegetable Ghee.

i. Ferric chloride Hexahydrated ($FeCl_3.6H_2O$)

Ferric chloride Hexahydrated comes with a chemical formula of $FeCl_3.6H_2O$. It is available in pale yellow lumps. It has a melting point of almost 37 Celsius and boiling point of 282.5 Celsius. The latent heat of fusion is about 223 J/kg K. Ferric Chloride comes with different trade names. In this study ferric chloride of "DUKSAN" was used.

Figure 3-1: Ferric Chloride

ii. Glycerin

Glycerin comes with a chemical formula of CH_2 (OH) CH (OH) CH_2OH. It is available in a thick viscous liquid. It has a melting point of almost 19 Celsius and a boiling point of 290 Celsius. The latent heat of fusion is about 198 J/kg K. Glycerin comes with different trade names. In this study ferric chloride of "DUKSAN" was used.\\

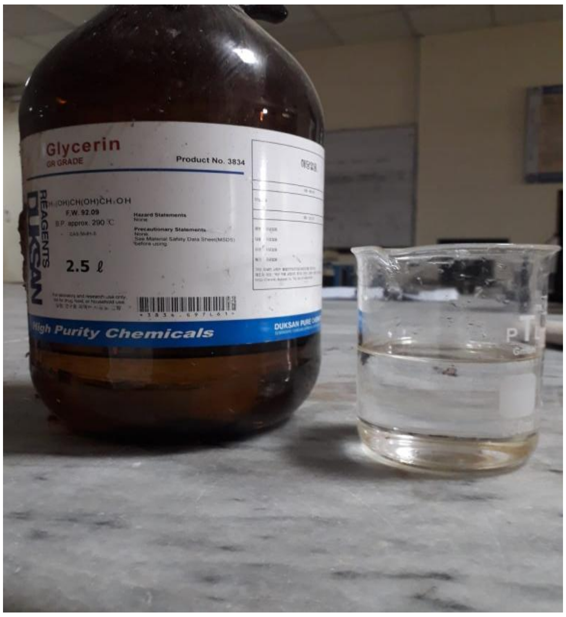


Figure 3-2: Glycerin

iii. Vegetable Ghee

Vegetable ghee comes with a chemical formula of ($C_{17}H_{33}COO$). It is available in a thick viscous liquid. It has a melting point of almost 30 Celsius and boiling point of 200 Celsius. Vegetable Ghee is available under different trade names in the market. In this study vegetable ghee with trade name of "DALDA" was used.

Figure 3-3: Vegetable Ghee

3.2.2 Formwork

The model employed for the testing of the subject PCM was a cube with the internal dimension of 2' each. The mix ratio used for the construction of this model was 1:4. The cement employed was ordinary Portland cement with 28 days compressive strength of 3000 psi. Wall of the model was 6" thick. The model was cured for 7 days so as to achieve the desired strength.

The formwork employed for the construction of the model was made of locally available plywood sheets. Since the model was to be tested for heating cycles, therefore, it was kept raised 6" with the help of a wooden platform.

Figure 3-4: Plywood formwork

3.2.3 Steel tubes

The steel tubes were used for the encapsulation of the PCM. These tubes were embedded in the face wall of the model with a frontal cover of 1”. The diameter of each tube was 0.7” with the center to center spacing of 2”. The embedded length of each steel tube was 2’. These tubes were covered by using steel caps which in turn were sealed using RTV silicon rubber sealant.

Figure 3-5: Steel Tubes and caps

3.2.4 Temperature Data Logger

A temperature data logger was devised locally so as collect all the data. For this purpose, Arduino Uno along with DS18B20 thermometers was used. Each thermometer had a temperature measuring range of -20 Celsius to 120 Celsius. The Arduino was programmed so as to get the data from these thermometers. The data so acquired was converted and saved into Excel file using a MATLAB code (ANNEXURE I). The temperature data acquired was stored against each time date for the total testing process. The time interval for taking each measurement was 10.2 seconds.

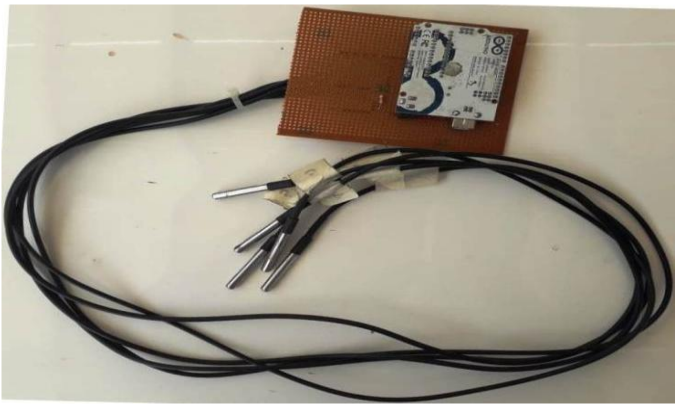


Figure 3-6: ArduinoUNO with thermometers

3.2.5 Heat Source

The heat source used for this study was 1000 watts fluorescent lamp. The lamp was mounted on to an aluminum coated cylinder so as to achieve a height of 1'. The arrangement of heating was made in such a way so as it focuses on the center of the subject model.

Figure 3-7: Heat source (1000W)

3.2.6 Insulation

Since the frontal wall of the model was filled with the PCM, therefore, front of the wall was covered from all the four sides except the front. This covering was done using Plywood sheets with an inner lining of aluminum foil so as to optimize the efficiency of heating source. Any other space was filled with a thermocol sheet. The top open surface of the model was also insulated using thermocol sheet.

Figure 3-8: Insulation

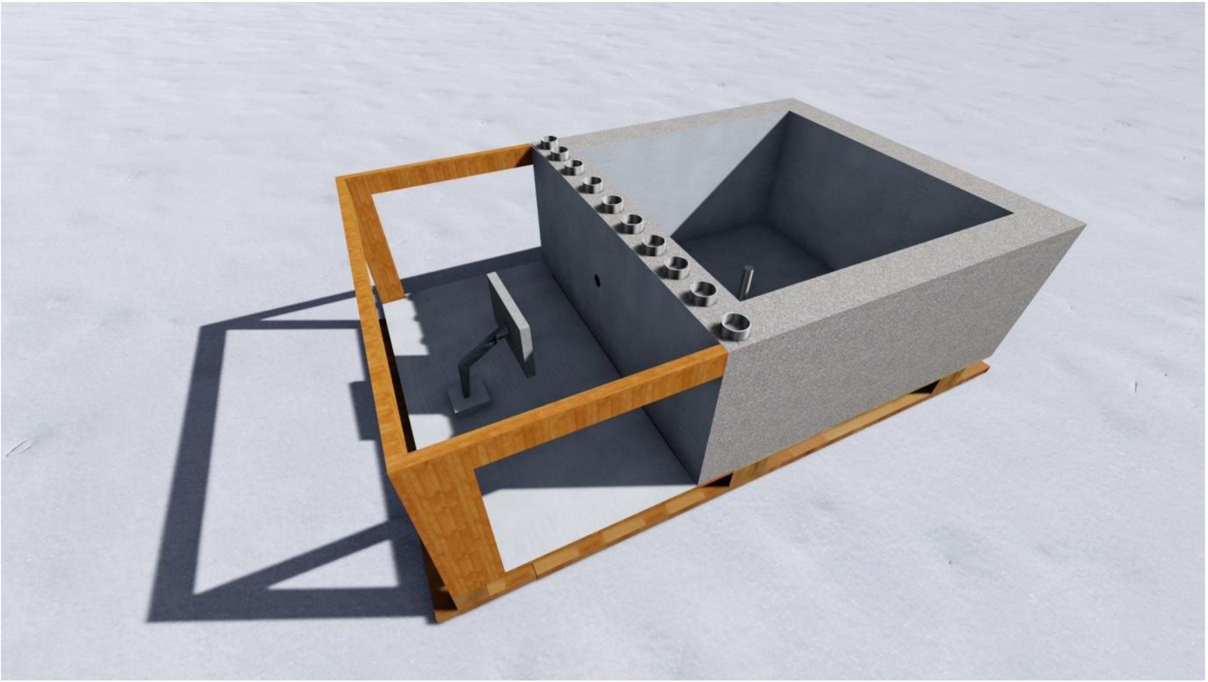


Figure 3-9: Schematic Arrangement

3.3 TESTING

3.3.1 Material Testing

3.3.2 Model Testing

Since, all the structures are prone to repeat thermal loading, therefore, while making this study consideration was made to cover this aspect. The testing, in this study, was cyclic thermal loading. One complete cycle includes the heating and then cooling of the subject model. The testing was carried out using different available of PCMs and for a different set of cycles. Primarily following cycles were selected;

i. **Three Hours cycle**: three hours of heating following three hours of cooling.

In each heating session the model was heated using 1000 Watts Halogen lamp placed inside the insulation at the position and location motioned in the previous section. After three hours of heating, the model was allowed to cool down for three hours under the prevalent environment. This cycle was repeated. The total time length of each cycle was 6 hours and the total time for each test was for 12 hours.

In order to study the performance of PCM following combinations were made;

I. Without Tubes
II. Glycerin
III. Vegetable Ghee
IV. Ferric chloride Hexahydrated.

Model without tubes was tested under the same conditions and was selected as the baseline for the comparison of the performance of PCM.

The temperature was noted at the point with the temperature data logger described in the previous sections. The temperature was recorded at a gap of 10.2 sec. The corresponding time when the reading was taken and temperature value was stored into the excel file. All these values were plotted using MATLAB in time vs. temperature graph.

ii. **Two Hours Cycle**: two hours of heating following four hours of cooling.

In each heating session the model was heated using 1000 Watts Halogen lamp placed inside the insulation at the position and location motioned in the previous section. After two hours of heating, the model was allowed to cool down for four hours under the prevalent environment. This cycle was repeated. The total time length of each cycle was 6 hours and the total time for each test was for 12 hours.

In order to study the performance of PCM following combinations were made;

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CHAPTER 4

4 RESULTS

4.1 Background

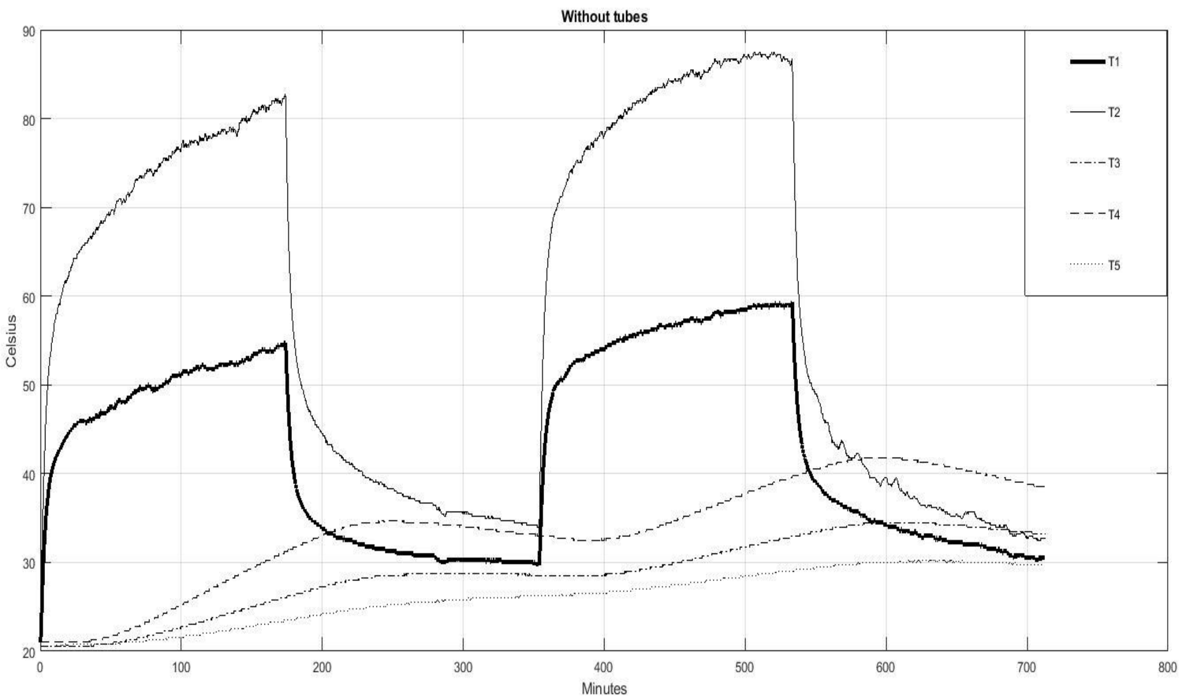
This chapter deals with the experimental results for the setup made for the testing of the efficiency of the PCMs for the titled research work. The tests were conducted under two broad classifications based on the time given for the test namely; three hours and two hours cycles. The results are discussed as follows:-

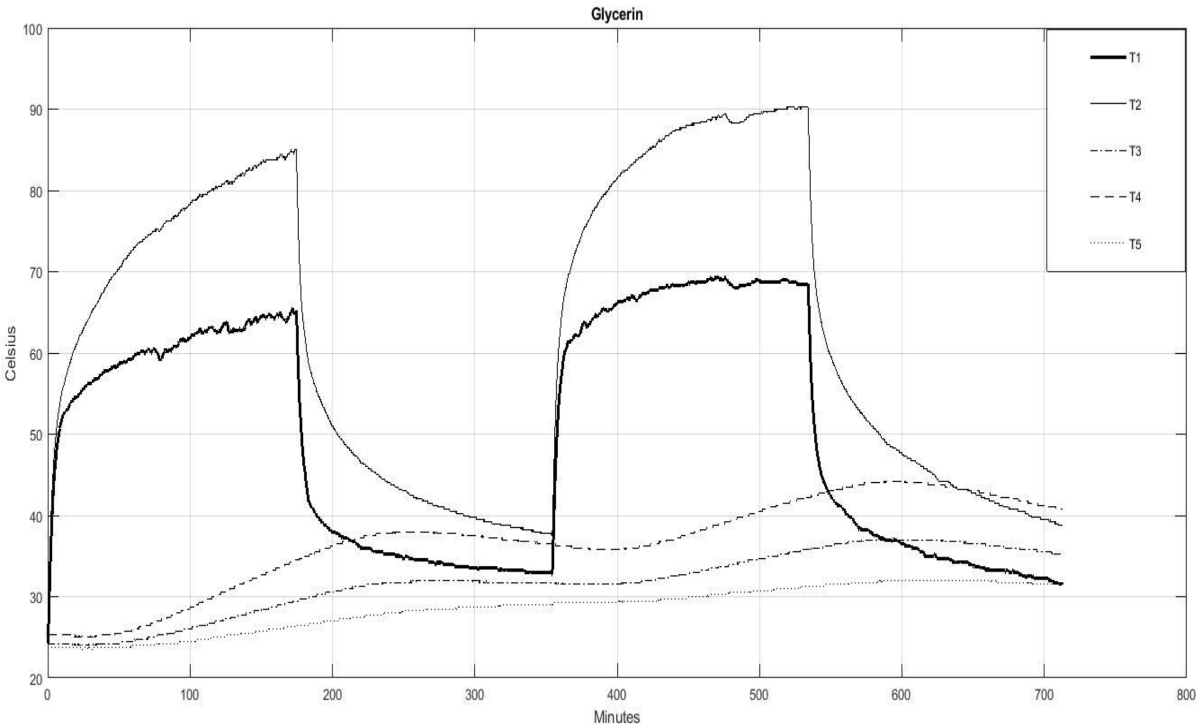
4.2 Results

As mentioned in chapter 3, the temperature for the model was noted at five (5) different points. Temperature sensors for T1 and T2 were meant to measure the external surface temperature whereas temperature sensor for T3 and T4 measured the temperature values on the internal face of the model. The fifth temperature sensor T5 measured the temperature inside the model (the air temperature).

4.2.1 Three Hours Testing Cycle

The results plotted for each combination are plotted as follows;




Glycerin
100
90
80
70
60
50
40
30
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Celsius
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Minutes
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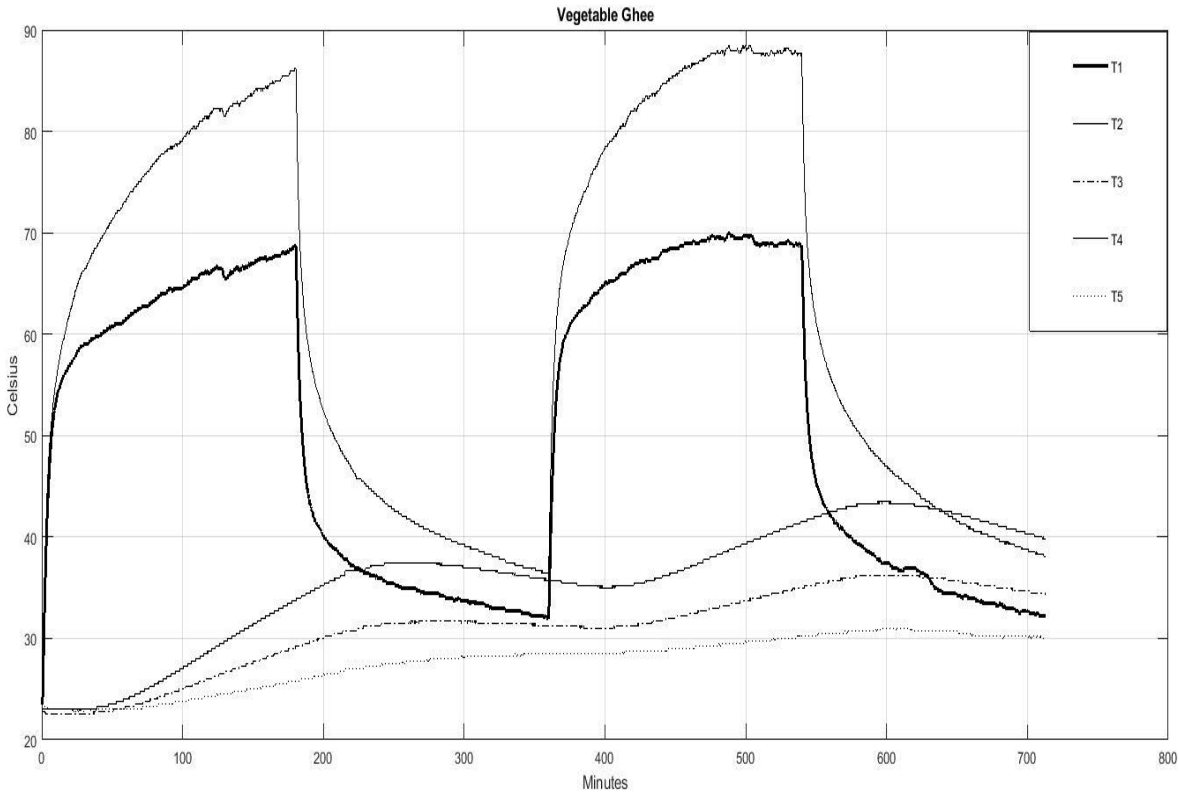
T2
T3
T4
T5


Vegetable Ghee
90
80
70
60
50
40
30
20
Celsius
0
100
200
300
400
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700
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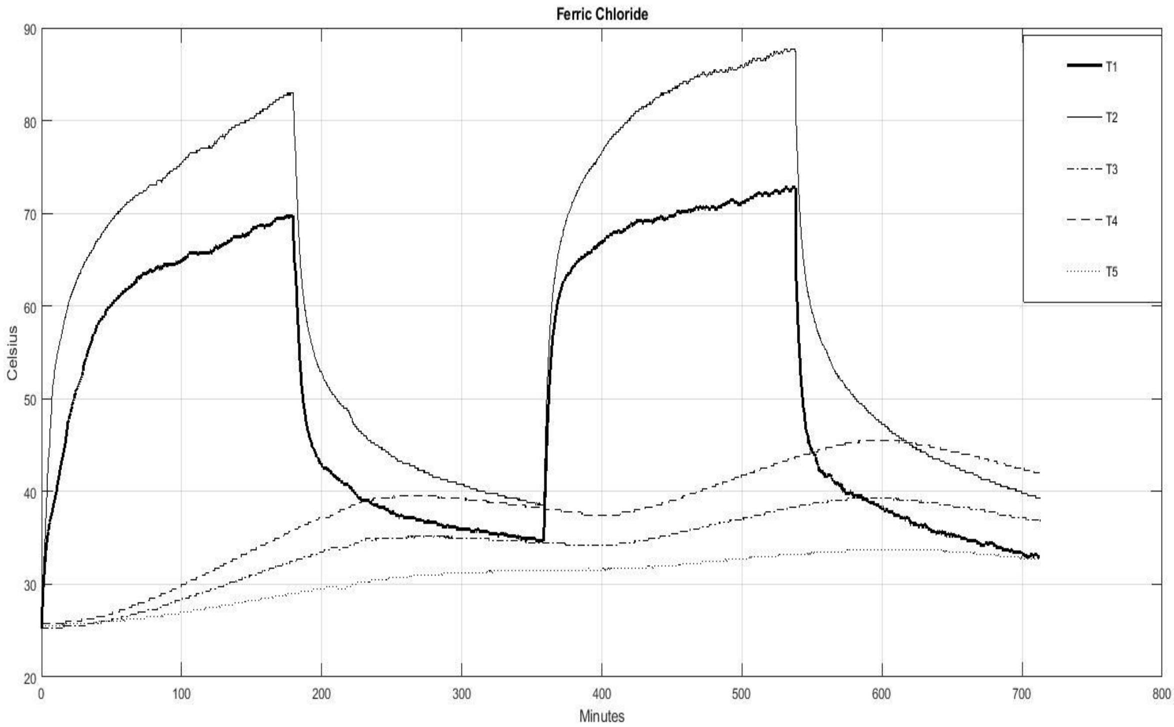
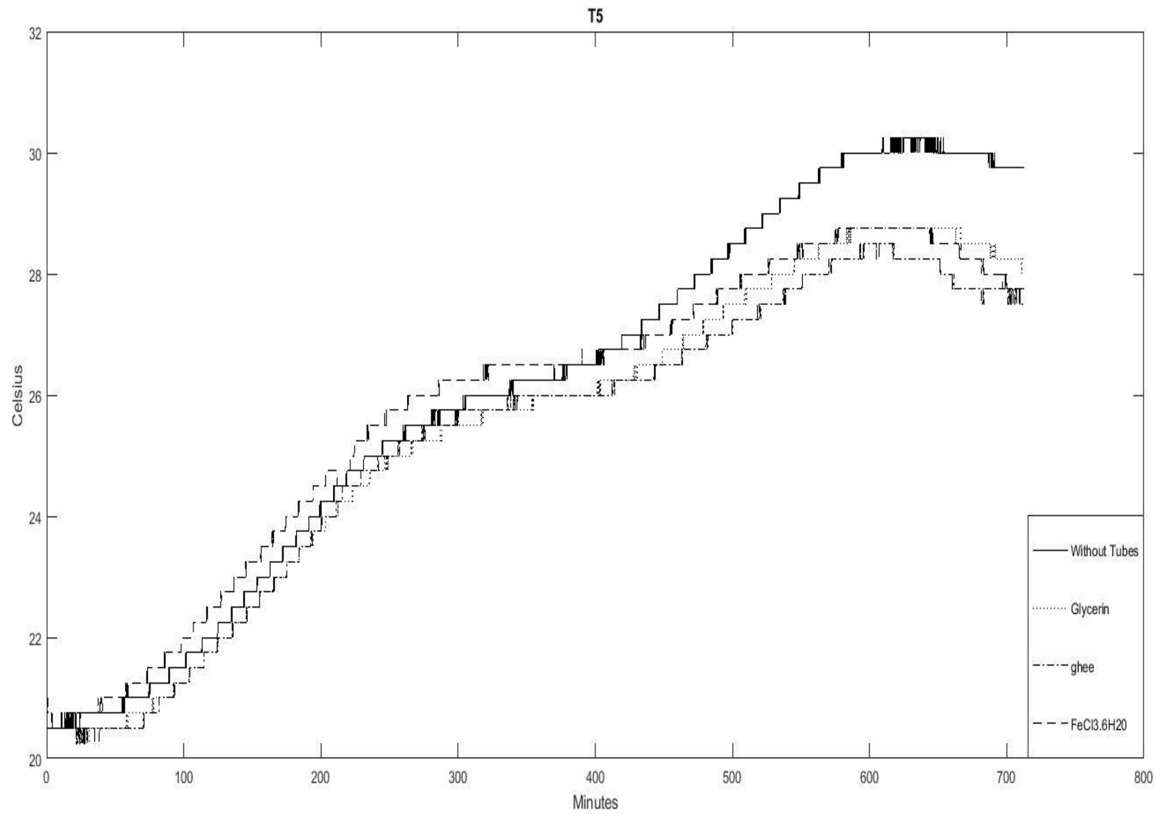
Minutes
T1
T2
T3
T4
T5

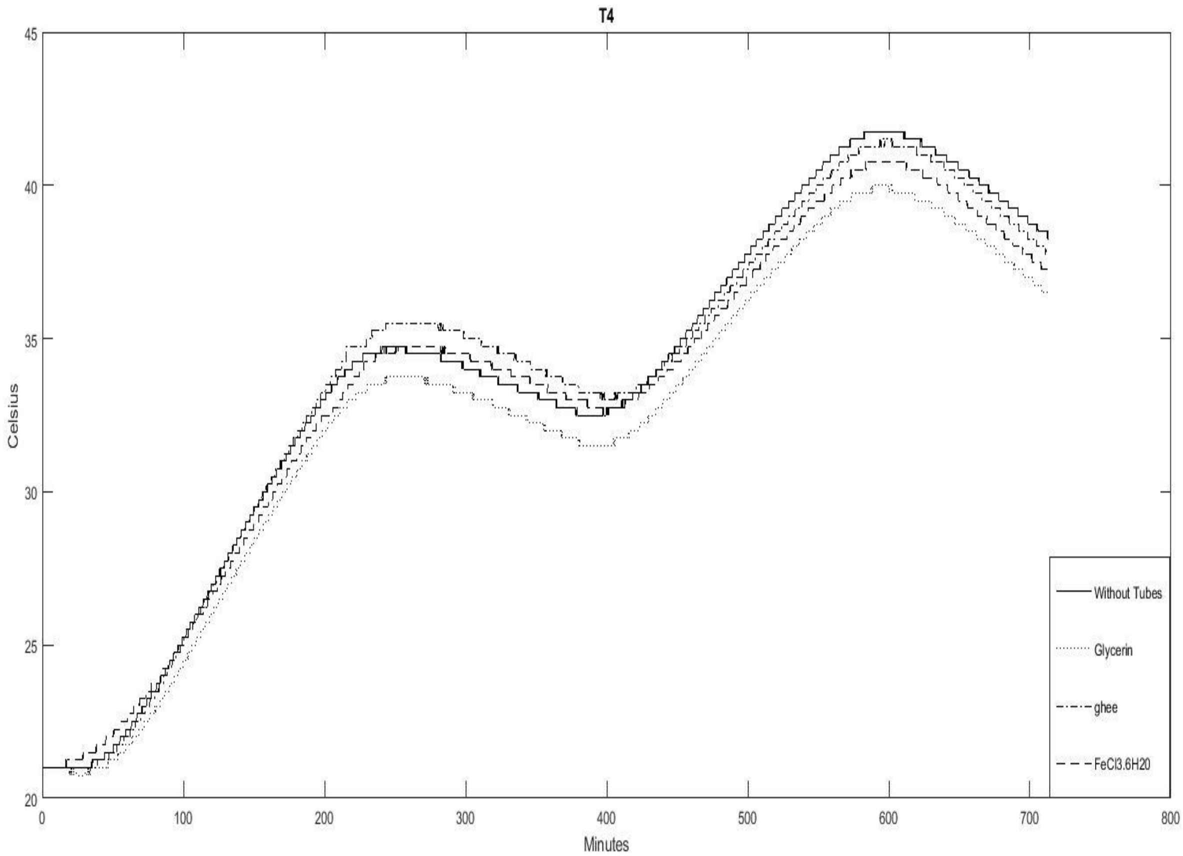


Based on the results cited above the following is deduced;



At this point, the maximum temperature is achieved for the case with hollow tubes. As can be seen the plot for the hollow tubes is at the top. The best performance, in this case, is given by ferric chloride. In this case, the model was subjected to 3 hours of thermal loading. Moreover, Ferric chloride has a melting point of 30 Celsius. It may be seen the ferric chloride shows a steady low temperature after the completion of the first heating phase. This steady low temperature can be seen throughout the test.

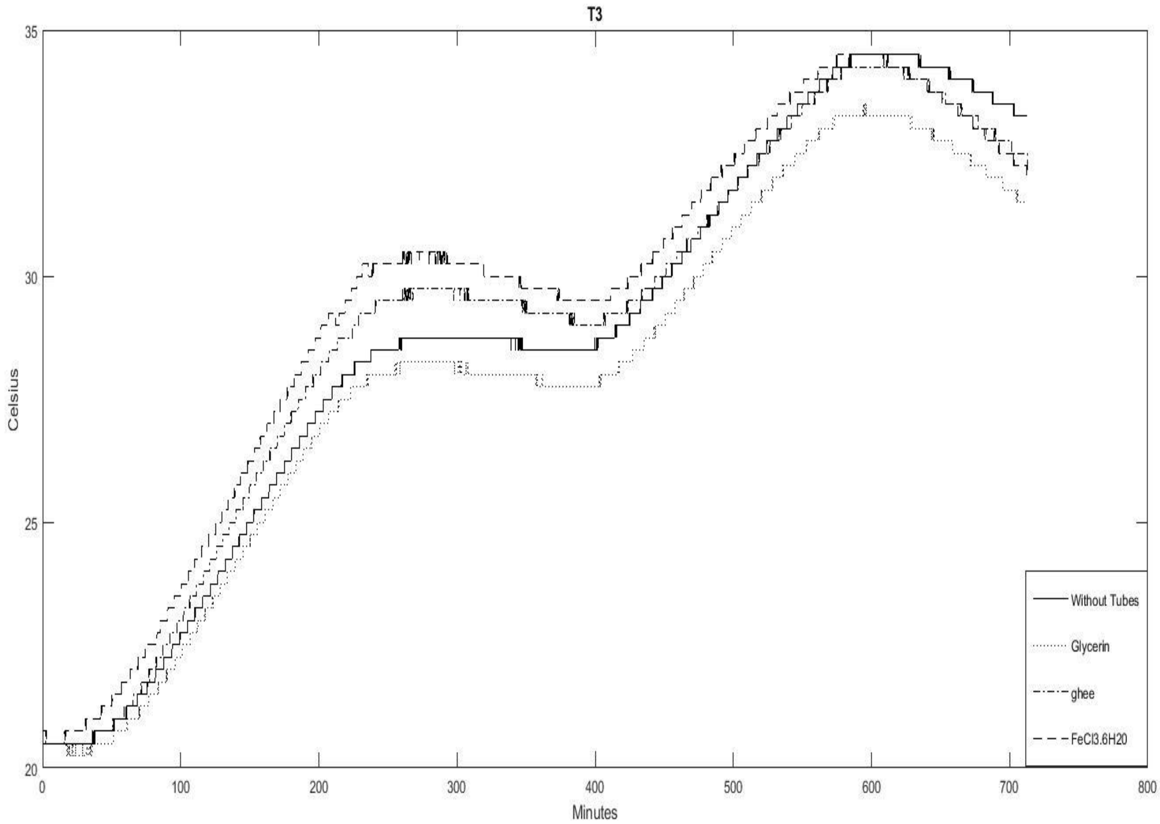
Vegetable Ghee can be seen performing well in comparison with the case with no PCM added. Owing to its melting point it also performs well in the temperature range above 30.Glycerin may be seen performing well for two sets of temperature ranges i.e. after 100 minutes and after 450 minutes.



At this point, the minimum temperature is achieved for the case with Glycerin. As it can be seen the plot for the Glycerin is at the bottom.

The best performance, in this case, is given by Glycerin. In this case, the model was subjected to 3 hours of thermal loading.

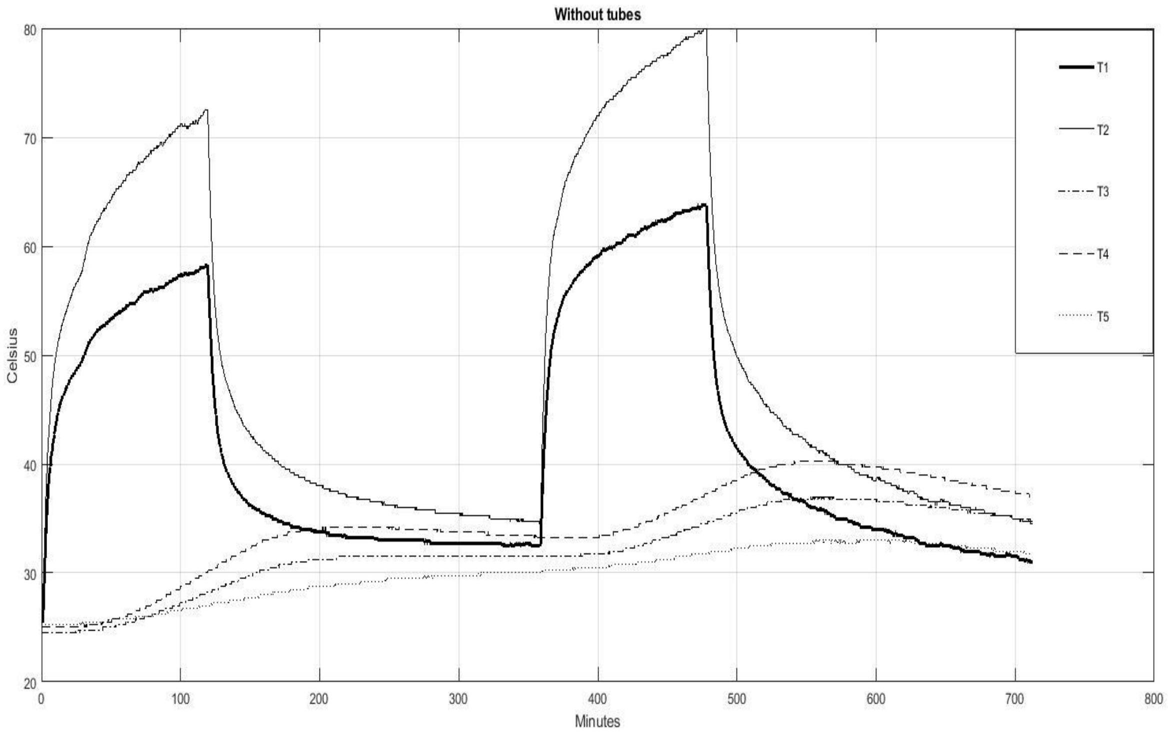
Vegetable Ghee can be seen performing well in comparison with the case with no PCM added. Owing to its melting point it also performs well in the temperature range above 30.

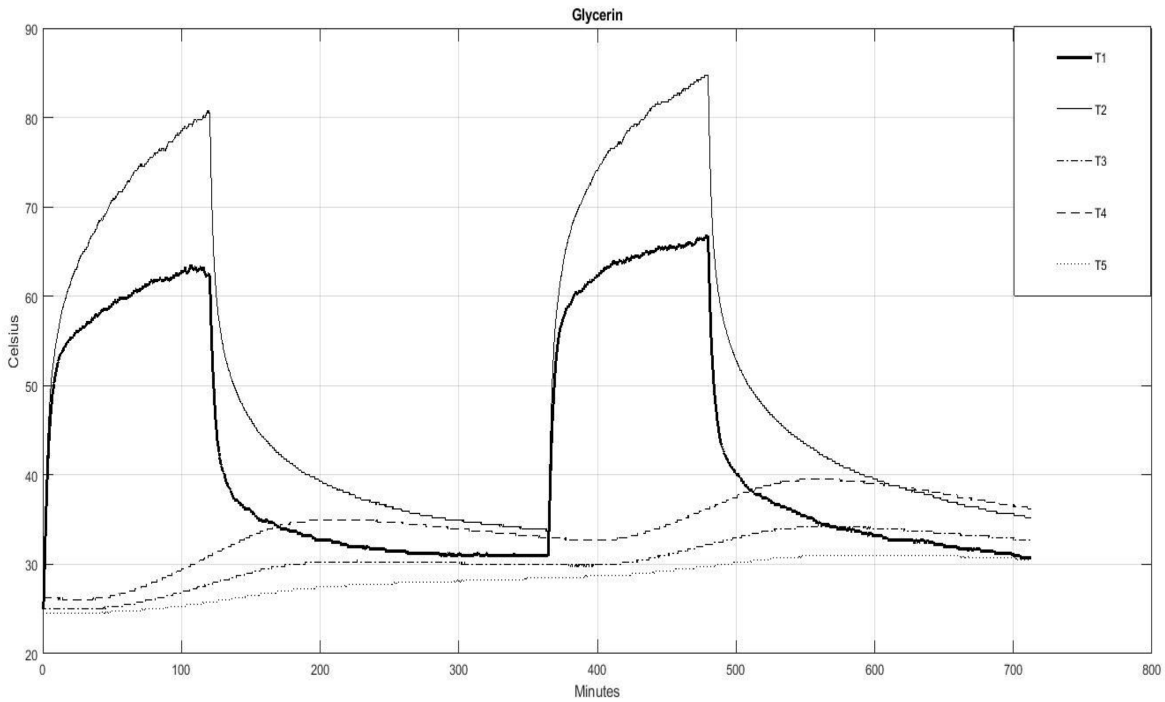


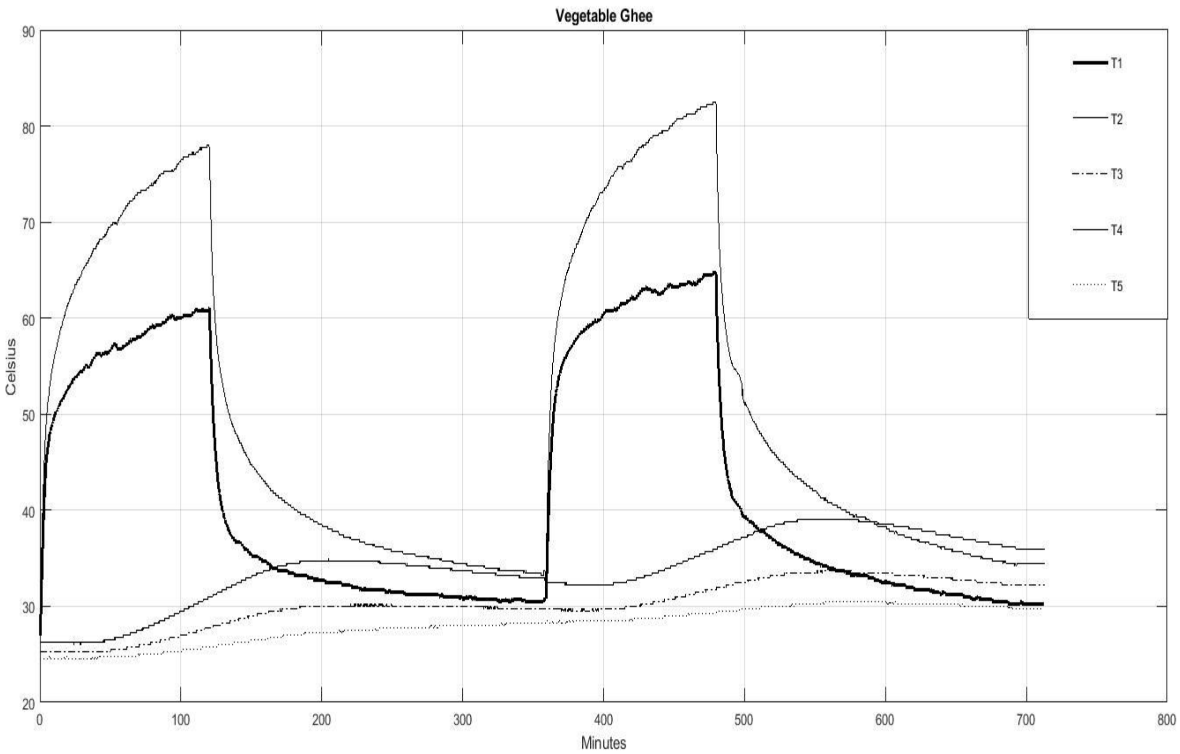
At this point, the minimum temperature is achieved for the case with Glycerin. As it can be seen the plot for the Glycerin is at the bottom. The best performance, in this case, is given by Glycerin. In this case, the model was subjected to 3 hours of thermal loading. Vegetable Ghee can be seen performing well in comparison with the case with no PCM added. Owing to its melting point it also performs well in the temperature range above 30.

4.2.2 Two Hours Testing Cycle

The results plotted for each combination are plotted as follows;






Vegetable Ghee
Celsius
Minutes
T1
T2
T3
T4
T5
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80
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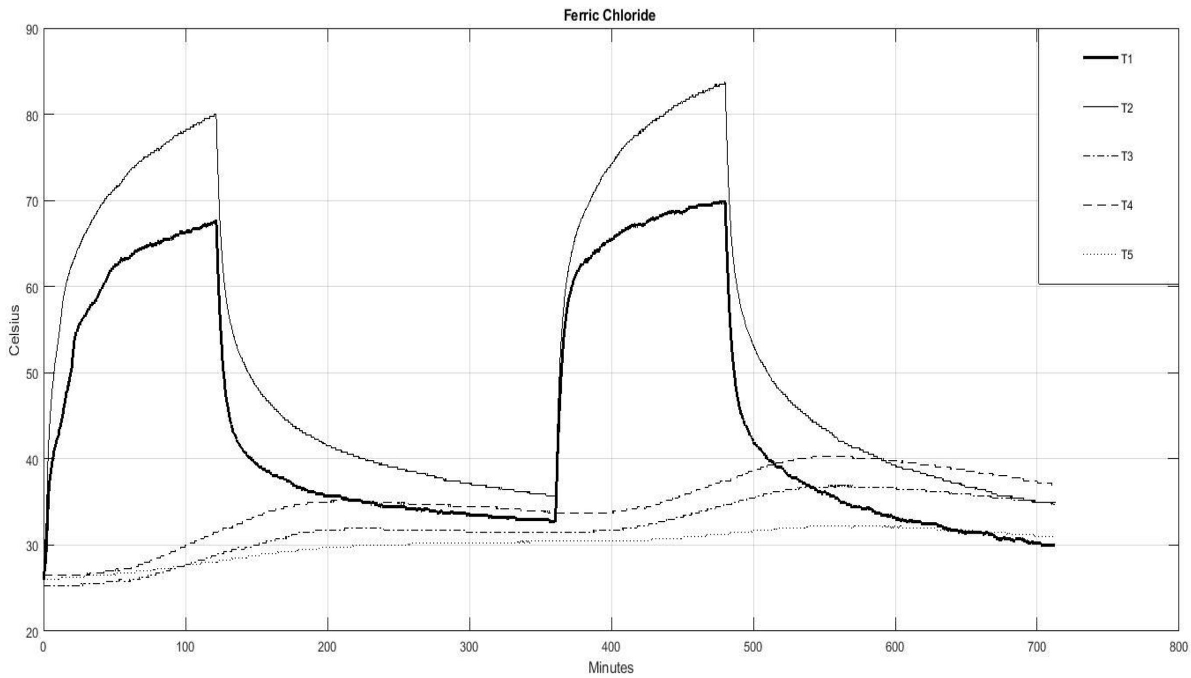
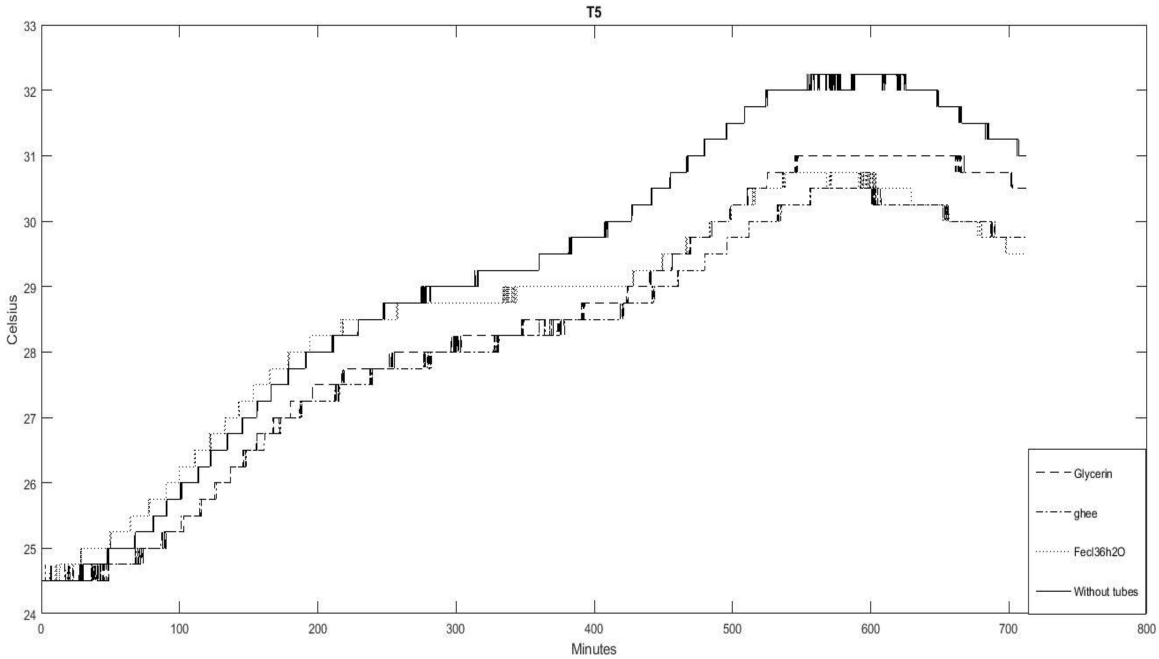

Ferric Chloride
Celsius
Minutes
T1
T2
T3
T4
T5
90
80
70
60
50
40
30
20
0
100
200
300
400
500
600
700
800

Based on the results cited above the following is deduced:

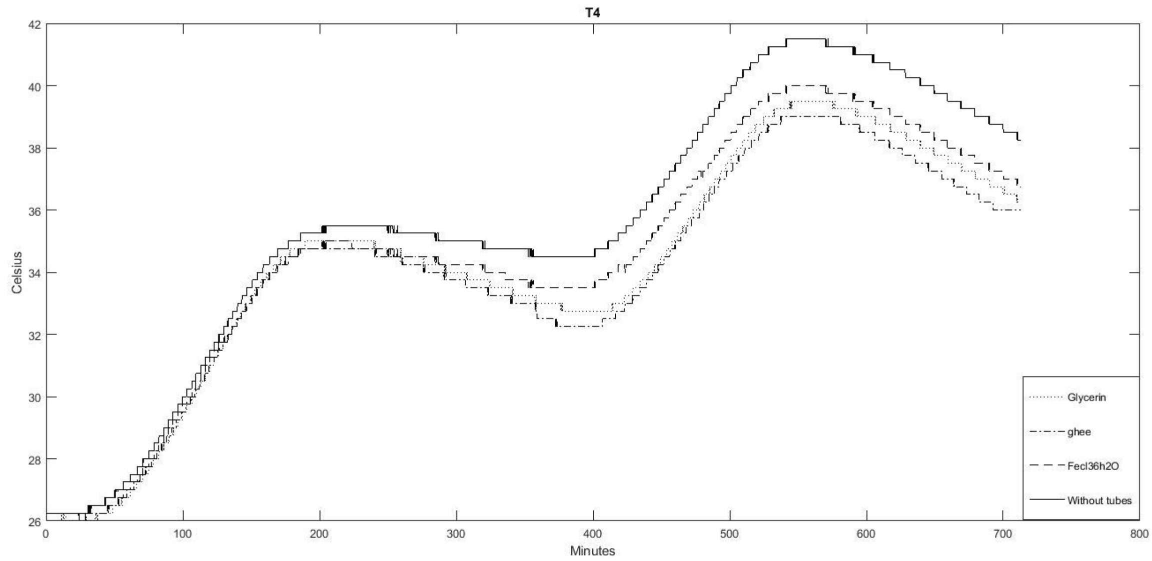
Over the completion of tests i.e. 12 hours, all the incorporated PCM have shown positive results. The decrease in temperature over the completion time of the test is almost 5 Celsius. Ferric chloride, in this case, shows the best performance. Initially, the temperature rises and after the melting point for ferric chloride is achieved there is a tendency in the reduction of temperature.

On the other hand, it may be observed that the performance of vegetable ghee and that of glycerin was very effective in the first half of the test i.e. till 400 minutes. The performance drops down with the increase in the temperature and becomes less effective at the time of completion when compared with Ferric Chloride.



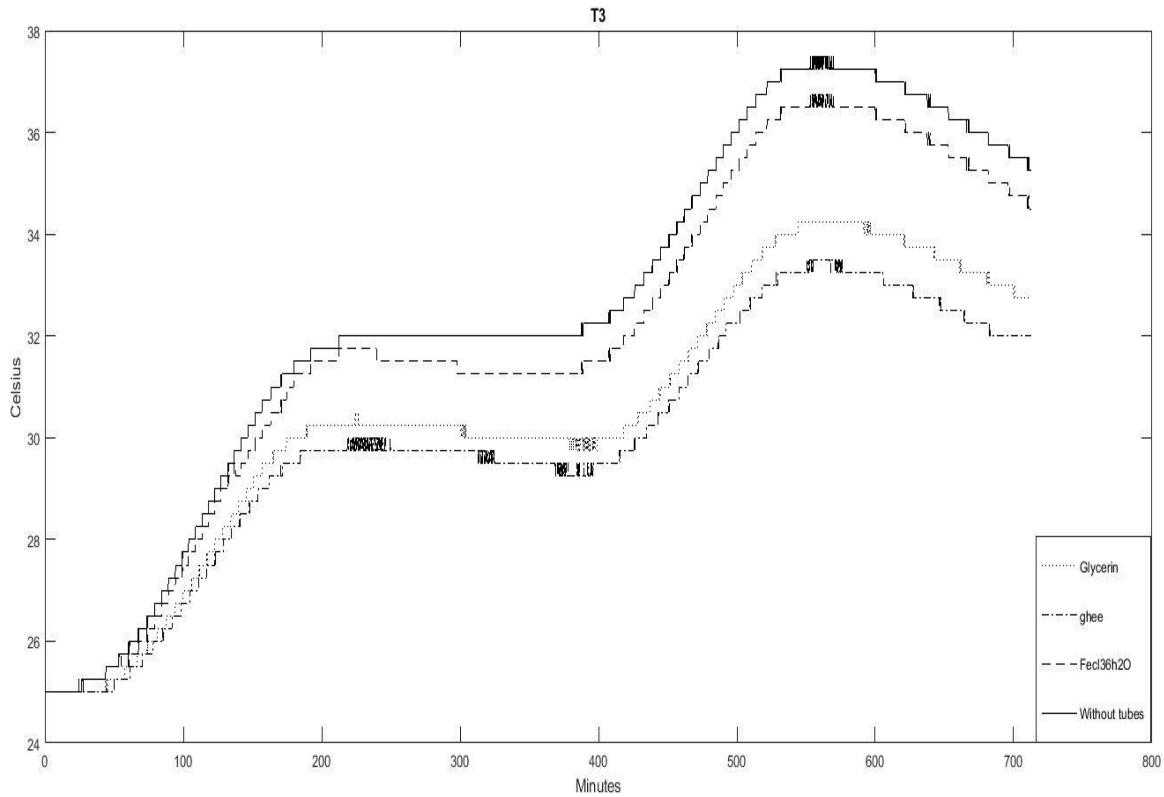
In this case, it can be seen that vegetable ghee and glycerin have been performing very well from the beginning till the completion of the test. Both Glycerin and Vegetable Ghee show almost analogs performance Ferric Chloride, in this case, has attracted more heat initially but this becomes at par at with the case that has no PCM incorporated.

Vegetable ghee may be seen as performing much better and it also shows much better tendencies to lose heat when the cooling phase starts.



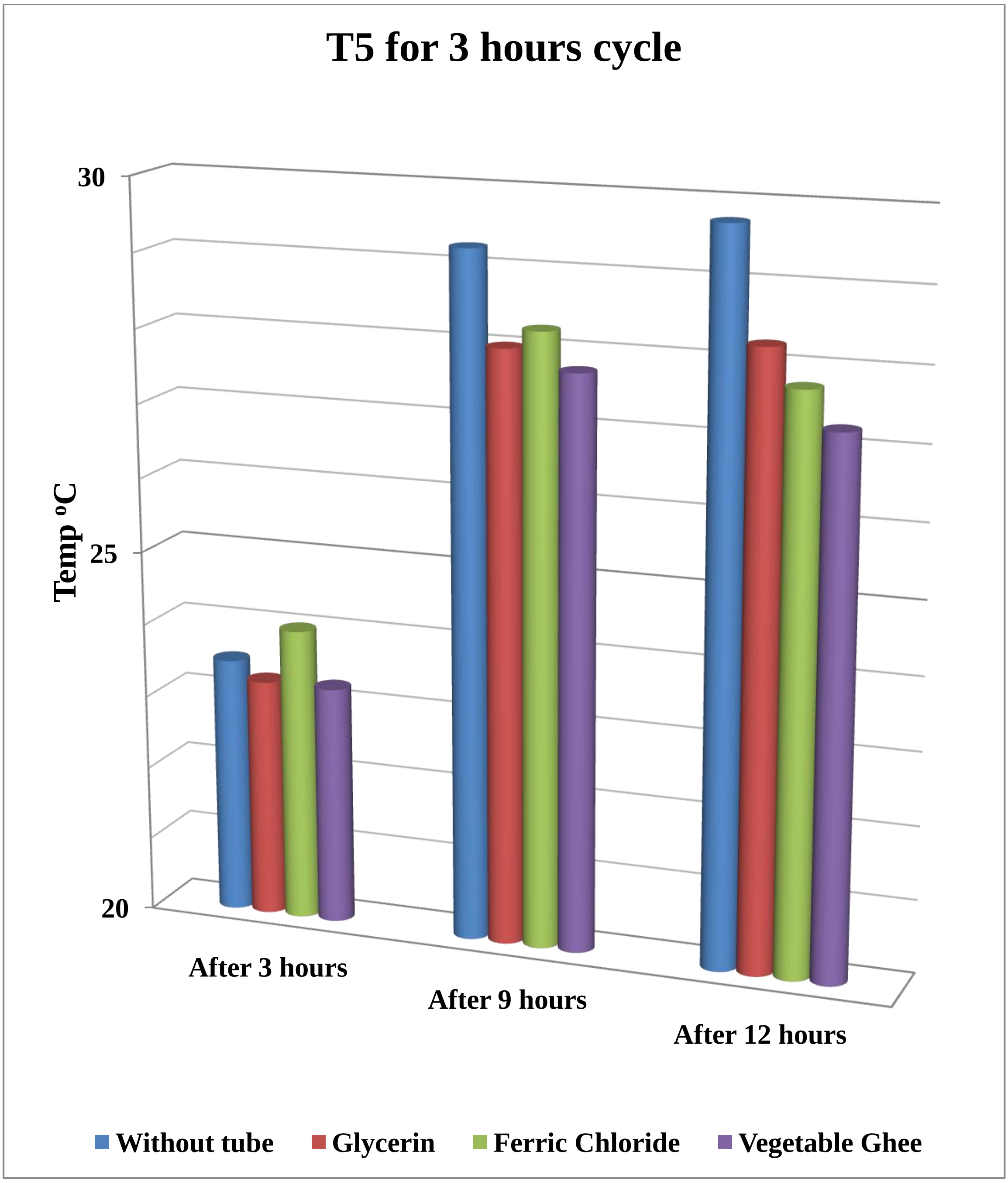
A continuous low temperature is noted for vegetable ghee. Ferric Chloride tends to attract more heat in the temperature ranges of almost 30 Celsius. On the further rise in temperature, a ferric chloride shows much lower temperature.

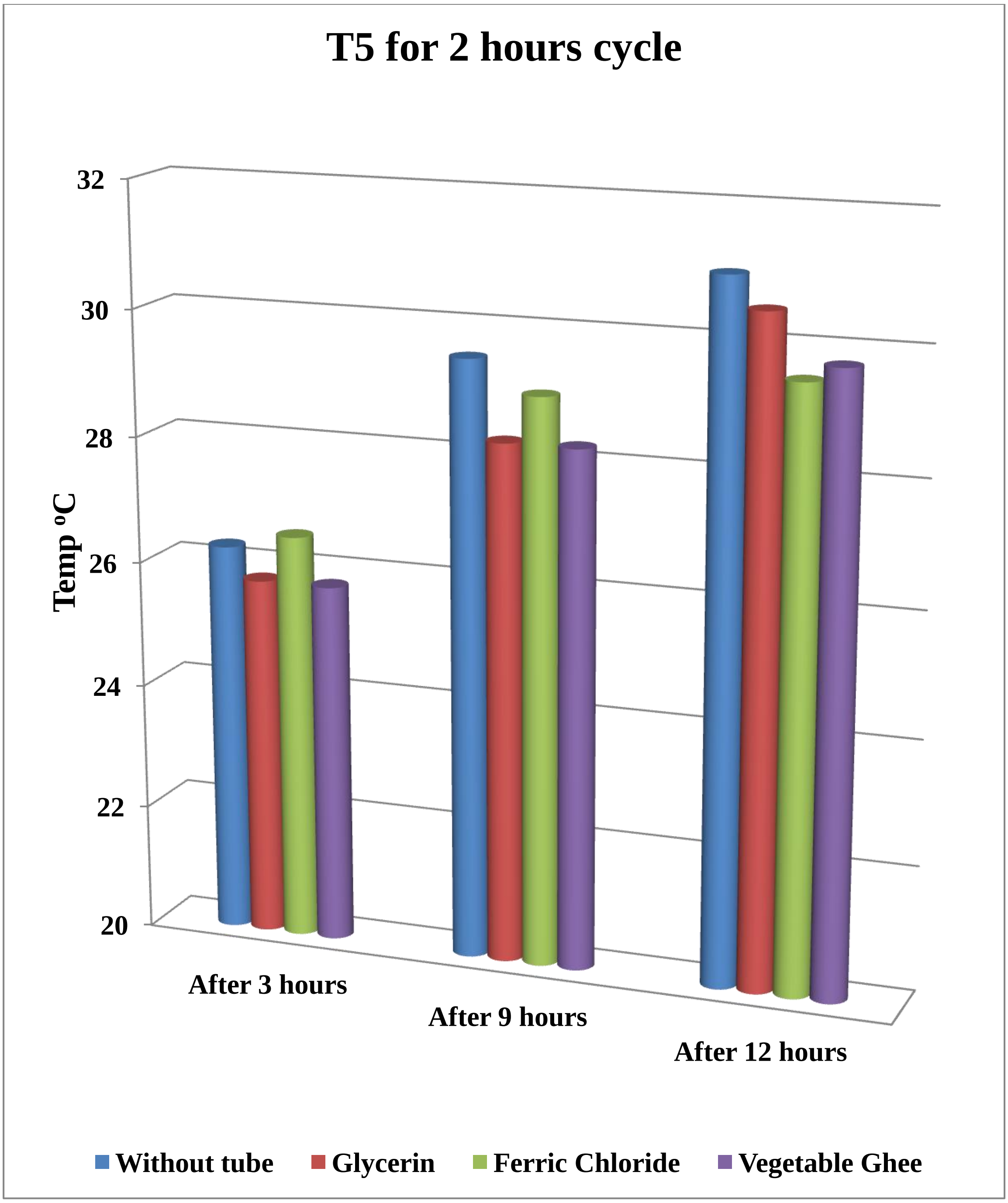
Glycerin also shows lower temperature for the heating in the first phase but its tendency to lose heat is lower in comparison with Vegetable Ghee.



Vegetable ghee and Glycerin tend to attract less heat in throughout the testing phase.

Ferric chloride also shows slow temperature rise for the heating in the second phase. However, in the first phase rise in temperature is same as of the case without PCM.


T5 for 3 hours cycle
30
25
20
Temp ºC
After 3 hours
After 9 hours
After 12 hours
Without tube
Glycerin
Ferric Chloride
Vegetable Ghee


T5 for 2 hours cycle
32
30
28
26
24
22
20
Temp ºC
After 3 hours
After 9 hours
After 12 hours
Without tube
Glycerin
Ferric Chloride
Vegetable Ghee

CHAPTER 5

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Background

This chapter deals with the outcomes of the experimental data. Suggestion regarding the way forward for future research shall also be made.

5.1.1 CONCLUSIONS

Since all the PCM are designed to maintain a temperature cozy and workable for the inhabitants. In this experimental work, an attempt has been made to find the locally available PCMs that are not only readily available but are also economical.

The model established was tested for temperature variations at five points. Out of these five points three, namely T3, T4, and T5, were of utmost importance since they were measuring inside temperatures. The graphs plots for the temperature for these three points have been discussed in the previous section.

From the discussion made previously following can be deduced;

I. Two PCMs namely Ferric Chloride Hexahydrated and Vegetable ghee performed well and when compared to the case with no PCM a temperature drop on the inner side was observed. However, Glycerin worked and sensible heat storage material and showed reduced temperature.

II. Out of all these available PCMs best performances was given by vegetable ghee that showed a drop in temperature for all the points i.e. T3, T4, and T5.

III. Vegetable ghee has a melting point of almost 35 Celsius that is the bearable prevalent temperature in the local environment. Over the completion of test i.e. 12 hours all the incorporated PCM have shown positive results and maximum temperature loss of 2.25 Celsius was reported.

IV. All the tests were carried out on the same model and embedded tubes. It has been observed that no adverse effect was given by any of the PCM.

V. Increase in the cooling temperature results in better performance of PCM. Thus may result in better energy efficiency.

5.1.2 RECOMMENDATION

In this study, only one PCM was used while conducting the test. Since each PCM has a certain melting point that defines its efficacy. This combination of PCM may be changed using staggering techniques.

From all above the following is recommended;

I. Location of PCMs may be changed so as to get better results. In this study, all the tubes were placed 1" inside from the face prone to heating. Any change may prove fruitful.

II. Instead of using the same PCM in all the tubes different PCMs in different tubes or different PCMs in the same tube may be incorporated.

III. Instead of Steel tubes, some plastic tubes with better properties may be used.

IV. Better insulation and controlling techniques may be adopted.

****

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ANNEXURE I

```
function dummy11 %% function start by name
delete(instrfind); %% delete com port
cc=serial('COM7','BaudRate',9600); %% comm port assignment
 fopen(cc); %% open comm port
A={};a={};j=1;k=num2str(j);xlRange = k;
sheet=1;
filename = 'temp_data.xlsx';
% fclose(cc);
% fopen(cc);

f = figure('Visible', 'off','color',[0.4 0.4
0.4],'Position',[360,500,950,600]); %% Layout GUI

hsttext = uicontrol('Style','text','BackgroundColor','[0.4 0.4
0.4]','ForegroundColor','green','FontWeight','bold','FontSize',25,'Position
',[200,400,450,130],'String','Temprature And Pressure Monietring System ');
%% text box for system name

huitext = uicontrol('Style','text','BackgroundColor','[0.4 0.4
0.4]','String','Please Push Following Buttons to Analyze Real Time
Graphical Sensor
Data','ForegroundColor','red','FontSize',15,'FontWeight','bold','Position',
[200,380,450,50]);  %% text box for Heading
hsttext11 = uicontrol('Parent',f,'Style','edit','BackgroundColor',[0 0.5
1], 'Position',[500,225,100,50],'ForegroundColor',[0 0
0],'FontSize',18,'Visible','on'); %% EDIT box to display value
hsttext13 = uicontrol('Parent',f,'Style','edit','BackgroundColor',[0 0.5
1], 'Position',[500,170,100,50],'ForegroundColor',[0 0
0],'FontSize',18,'Visible','on'); %% EDIT box to display value
hsttext14 = uicontrol('Parent',f,'Style','edit','BackgroundColor',[0 0.5
1], 'Position',[500,115,100,50],'ForegroundColor',[0 0
0],'FontSize',18,'Visible','on'); %% EDIT box to display value
hsttext15 = uicontrol('Parent',f,'Style','edit','BackgroundColor',[0 0.5
1], 'Position',[500,60,100,50],'ForegroundColor',[0 0
0],'FontSize',18,'Visible','on'); %% EDIT box to display value
hsttext16 = uicontrol('Parent',f,'Style','edit','BackgroundColor',[0 0.5
1], 'Position',[500,5,100,50],'ForegroundColor',[0 0
0],'FontSize',18,'Visible','on'); %% EDIT box to display value

set(f,'Name','PLANT_1')
movegui(f,'center')
h1button = uicontrol('Parent',f,'Style','togglebutton','String','TURN ON
SYSTEM','Position',[270,280,332,50],'Callback',@callbackfn2); %% turn on
system
h2button =
uicontrol('Parent',f,'Style','togglebutton','String','TEMPERATURE(C).D1',
'Position',[270,225,220,50]);%% TOGGLE BUtton to show temprature text
h3button =
uicontrol('Parent',f,'Style','togglebutton','String','TEMPERATURE(C).D2',
'Position',[270,170,220,50]);%% TOGGLE BUtton to show pressre text
h4button =
uicontrol('Parent',f,'Style','togglebutton','String','TEMPERATURE(C).D3',
'Position',[270,115,220,50]);%% TOGGLE BUtton to show differ pressure text
```

```
h5button =
uicontrol('Parent',f,'Style','togglebutton','String','TEMPERATURE(C).D4',
'Position',[270,60,220,50]);%% TOGGLE BUtton to show differ pressure text
h6button =
uicontrol('Parent',f,'Style','togglebutton','String','TEMPERATURE(C).D5',
'Position',[270,5,220,50]);%% TOGGLE BUtton to show differ pressure text


set(f,'Visible','on');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%




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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function callbackfn2(hObject,eventdata)
set(h1button,'Visible','on','BackgroundColor','green');
set(h2button,'Visible','on','BackgroundColor','green');
set(h3button,'Visible','on','BackgroundColor','green');
set(h4button,'Visible','on','BackgroundColor','green');
set(h5button,'Visible','on','BackgroundColor','green');
set(h6button,'Visible','on','BackgroundColor','green');
r=0;
while(get(h1button,'Value')==1)

%sound(w,Gs)
 data =fscanf(cc);
     IncomingString = char(data);
IncomingString = strsplit(IncomingString,',');
      Heel= IncomingString(1,1);
      Heel1= IncomingString(1,2);
      Heel2= IncomingString(1,3);
      Heel3= IncomingString(1,4);
      Heel4= IncomingString(1,5);
      d=str2double(Heel);
       d1=str2double(Heel1);
        d2=str2double(Heel2);
         d3=str2double(Heel3);
        d4=str2double(Heel4);
        k=num2str(j);xlRange = k;
       a=char(datetime('now'));
       A{1}=a; A{2}=d;A{3}=d1;A{4}=d2;A{5}=d3;A{6}=d4;
       xlswrite(filename,A,sheet,xlRange);

%%disp(d);
%  disp(d1);    disp(d2);    disp(d3);
 TEMP=d
 TEMP1=d1
  TEMP2=d2
 TEMP3=d3
TEMP4=d4
```

```
set(hsttext11,'Visible','on','String',TEMP);
set(hsttext13,'Visible','on','String',TEMP1);
set(hsttext14,'Visible','on','String',TEMP2);
set(hsttext15,'Visible','on','String',TEMP3);
set(hsttext16,'Visible','on','String',TEMP4);




  pause(0.5);
    j=j+1;

end
```