DEVELOPMENT OF THERMAL ENERGY STORAGE SYSTEM FOR A CUBICAL BUILDING USING PCM

Submitted by:

Kottakota chaitanya – 20UME043

Niladri Datta – 20UME041

Faculty Advisor:

Dr. Dipak Chandra Das

Department of Mechanical Engineering

ACKNOWLEDGEMENT

We would like to express my thankful gratitude to our project guide Mr. Dipak Chandra Das, Assistant Professor, Department of Mechanical Engineering, NIT Agartala, for his cooperation, suggestion, active support and immense help.

We are extremely fortunate to be involved in such an exciting and challenging project. It gave us an opportunity to work in a new environment of Fluent. This project has increased our thinking and understanding capability.

Lastly, we would like to convey our sincere gratitude to Dr.Pritam Das, HOD, Associate Professor, Department of Mechanical Engineering, NIT Agartala.

Yours faithfully,

____

Kottakota chaitanya (20UME043)

____

Niladri Datta (20UME41)

Department of Mechanical Engineering, NIT Agartala.

DECLARATION

We declare that this written submission represents our ideas in our own words and where others'
ideas or words have been included, we have adequately cited and referenced the original sources.We also declare that we have adhered to all principles of academic honesty and integrity and havenot misrepresented or fabricated or falsified any idea/data/fact/source in our submission. Weunderstand that any violation of the above will be cause for disciplinary action by the Institute andcan also evoke penal action from the sources which have thus not been properly cited or from whomproper permission has not been taken when needed.

Name of Members and Signatures:

NILADRI DATTA:
____

KOTTAKOTA CHAITANYA:
____

Date: ______________________________________

CERTIFICATE

It is certified that the work contained in the Project titled “ENERGY STORAGE SYSTEM OF A CUBICAL BUILDING USING PCMs” by Kottakota Chaitanya and Niladri Dattais getting carried out under our supervision and that this ongoing work has not been submittedelsewhere for a degree.

Signature of Guide

____

.Mr. Dipak Chandra Das.
Assistant Professor
Dept. of Mechanical Engineerig
NIT Agartala

Introduction

The world is rapidly adopting renewable energy alternatives at a remarkable rate to address the ever-increasing environmental crisis of CO2 emissions. RES offers enormous potential to decarbonize the environment because they produce no greenhouse gases or other polluting emissions. However, the RES relies on natural resources for energy generation, such as sunlight, wind, water, geothermal, which are generally unpredictable and reliant on weather, season, and year. To account for these intermittencies, renewable energy can be stored using various techniques and then used in a consistent and controlled manner as needed. Several researchers from around the world have made substantial contributions over the last century to developing novel methods of energy storage that are efficient enough to meet increasing energy demand and technological breakthroughs. The different types of energy storage systems which are in practical use these days are mentioned below with the help of a schematic diagram

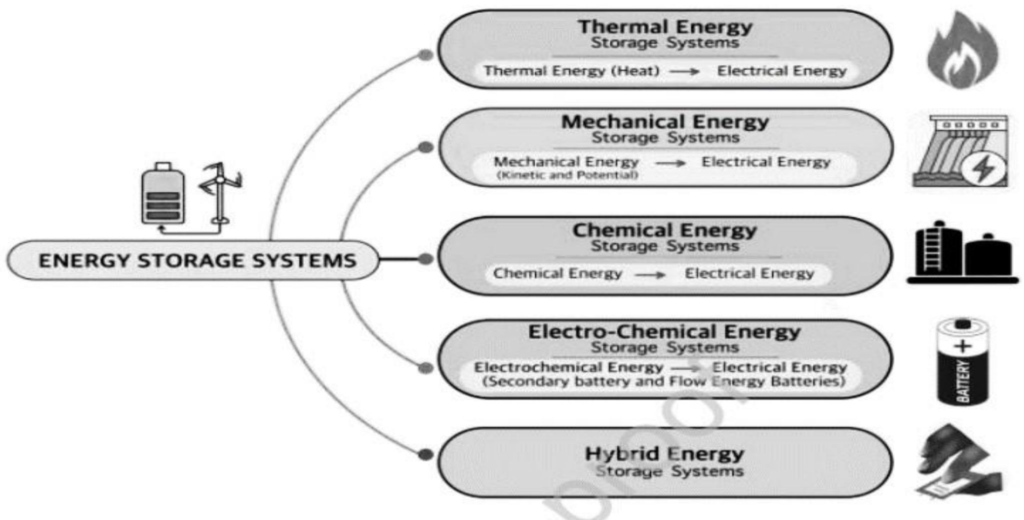


Fig no.1

In this report we are going to focus our studies on thermal energy storage system.

Classification of Thermal Energy Storage:

TES systems are specially designed to store heat energy by cooling, heating, melting, condensing, or vaporising a substance. Depending on the operating temperature range, the materials are stored at high or low temperatures in an insulated repository; later, the energy recovered from these materials is used for various residential and industrial applications, such as space heating or cooling, hot water production, or electricity generation, depending on the operating temperature range. Thermal energy storage systems can be classified into the following categories as shown in the below diagram

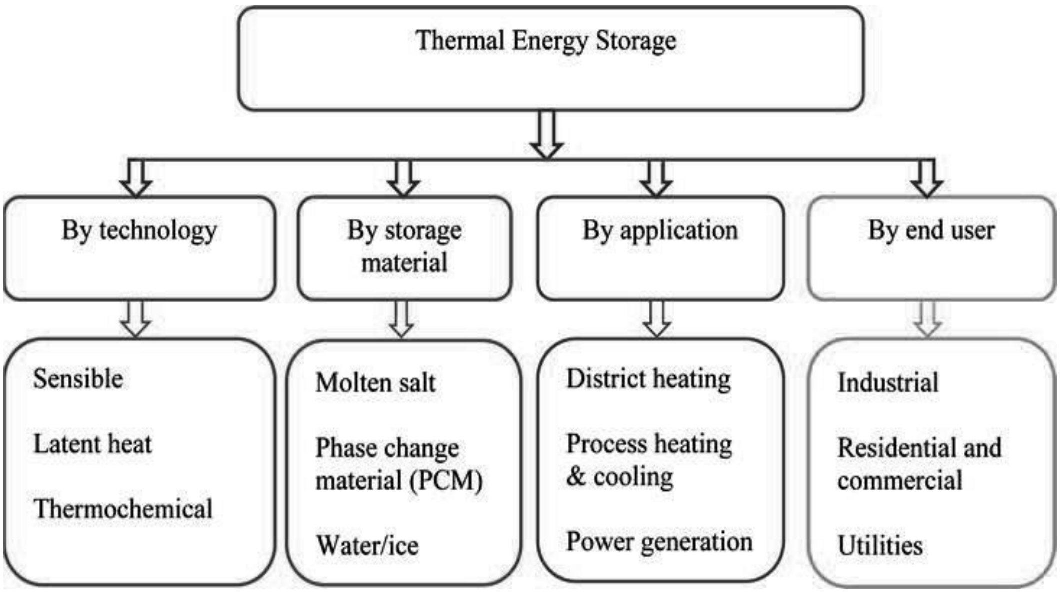


Fig no.2

There are three main types of TES systems in use these days which are

1) Sensible heat energy storage system.
2) Latent heat storage system.
3) Thermochemical storage system.

Our study concerns the use of PCM's which comes under LHTES. So, We will be discussing in details about the scope of it's usage in our report.

Latent Heat Storage System (LHS):

Latent heat storage system utilises the amount of heat absorbed or released when the storage material undergoes a phase change. The ability of storage material to undergo phase change at a constant temperature is critical to the performance of LHS systems. The following figure depicts the phase transition profile for a storage material when heat is added/removed from it. It can be observed that as the energy in the form of heat is added to the material, the consequence is an increase in temperature (sensible heating) or a change of phase (latent heating). The material in the solid phase is represented by point O. Heat addition causes sensible heating of the solid (region O-A), further melting occurs and the material is converted from a solid phase to the liquid phase (region A-B). The heat absorbed during this transition is known as latent heat of fusion. Region B-C represents sensible heating of liquid, followed by a liquid-to vapour phase change (region C-D). The absorbed heat is referred to as latent heat of vaporisation and regions D-E represents sensible heating of the vapourPoint O : Material in the solid phase, Region O-A : Sensible heating of material due to heat addition, Region A-B : Conversion of material from solid phase to liquid phase due to melting, Region B-C : Sensible heating of liquid, Region C-D : Liquid-to vapour phase change Region D-E : Sensible heating of the vapour

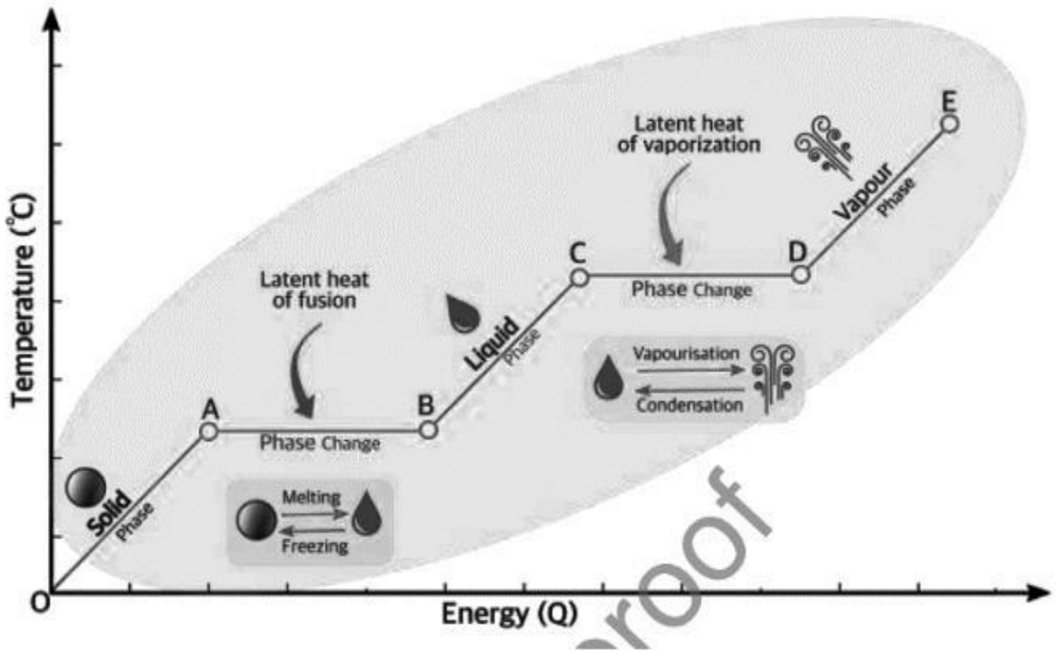


Fig no.3

LHS can take the following forms depending on the phase change type: solid-solid, solid-liquid, solid-gas, and liquid-gas and vice versa. In solidsolid transition, energy is stored as the storage material changes from one crystalline to another. This type of phase change has very little latent heat and produces very small volume changes. Solid-gas and liquid-gas phase transitions have higher latent heat but their phase transitions result in large volume changes, which are not feasible due to containment issues. When compared to liquid–gas transitions, solid–liquid transitions have a lower latent heat. However, these transformations only result in a minor volume change (of an order of 10% or less). As a result, solid-liquid transitions are commonly used in TES systems

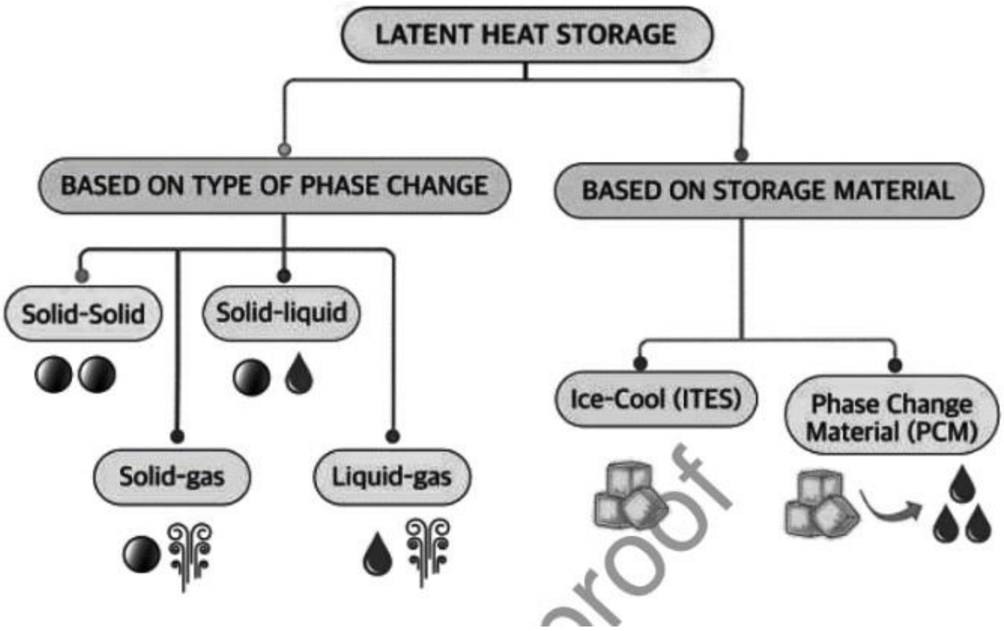


Fig no.4

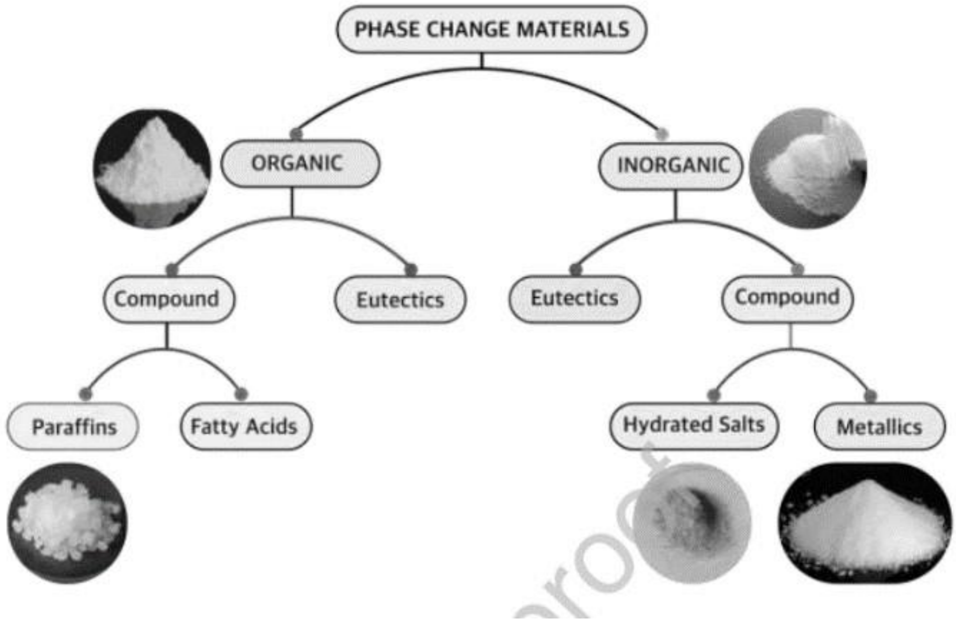
Our study concerns the use of PCM materials as a means of LTHES.

PHASE CHANGE MATERIAL(PCM):

PCM-TES refers to the use of various phase change materials depending on the required temperature range. It is an effective way of storing thermal energy and has the advantages of high thermal energy storage density and the isothermal nature of the storage process. There are large numbers of PCMs that melt and solidify at a wide range of temperatures, making them suitable for a wide range of applications. PCMs are typically divided into two categories Organic PCMs and Inorganic PCMs. Organic PCMs have high storage density with small melting and freezing temperature differences. They are classified primarily as paraffin wax

and fatty acids. Paraffin wax is a combination of hydrogen and carbon molecules (C_nH_{2n+2}), where n ranges from 20 to 40. As the chain length increases, there is an increase in the melting temperature and latent heat of fusion. Because paraffins have a high specific heat of fusion, they have a higher energy storing capacity. Fatty acids are carboxylic acids having a long aliphatic tail with the general formula CH3(CH2)2nCOOH, where n is an even number ranging from 12 to 28. They can withstand a large number of thermal (freezing and melting) cycles with no loss. Fatty acids have better phase transition properties than paraffin wax but are more expensive. Inorganic PCMs, on the other hand, have sharp melting points with high heat of fusion, high latent heat storage capacity per unit mass, and high thermal conductivity. Inorganic PCMs are classified as Salt hydrates and Metallics. Salt hydrates are inorganic salts that contain water of crystallisation. The salt hydrate is dried here to store thermal energy, and the dry salt and water are stored separately. Salt hydrates are known to have the highest storage density with little to no heat loss during storage. Metals with low melting temperatures and metal eutectics are examples of metallic PCMs. Metallics have high latent heat of fusion, high thermal conductivity, low specific heat, and low vapour pressure. Apart from these PCMs, eutectic materials have recently piqued the interest of researchers as phase change materials due to their fixed freezing/melting point. Eutectics are mixtures of two or more components that do not interact to form a new chemical compound; rather, when these compounds are mixed in specific proportions, they inhibit crystallisation process, resulting in a system with lower melting temperature than its constituents.

When heat is supplied to the PCM (during the charging cycle), it continues to absorb heat without significantly increasing its temperature until it undergoes a phase transition from solid to liquid. During the discharging period, as the ambient temperature around the liquid PCM falls, it again undergoes a phase change from liquid to the solid phase, releasing the stored latent heat. PCMs can store 5-14 times more energy per unit volume than the traditional sensible storage materials such as water, rocks and other solids. Apart from that, PCMs can store and release heat energy at a nearly constant temperature, which is another benefit. However, the low thermal conductivities of phase change materials pose a significant barrier to their use in large scale applications. A lot of research is being done to overcome this limitation, and new methodologies are bein



g

developed.

Fig no.5

LITERATURE REVIEW AND SCOPE OF WORK:

[1] **Wang***et al* (1999):

The experiment done by wang is mainly to develop a 1D-physical model for latent heat thermal energy storage system using a PCM with different PCT distribution. The phase change time of composite PCM's for the constant temperature boundary condition. By theoretical investigation under the assumption of neglecting the sensible heat, the optimum linear PCT distributions which are corresponding to minimum phase change time are derived.

[2] **Saito** *et al* (2001):

An analytical and experimental investigation was performed on a heat removal process of the TES capsule, using Glauber's salt (Na2SO4. 10H2O) transient heat flux at the capsule wall was measured for various cooling conditions. An apparatus for accurate measurement of the heat floe through TES capsule was designed. The experimental results on heat flux were compared with numerical calculation using the analytical method mentioned and they agreed very well with each other.

[3] **Barba and Spiga** (2003):

The paper is aimed at analysing the behaviour of encapsulated salt hydrates, used as LES in a heat transfer system of a domestic hot water tank. The discharge process of PCM is analyzed analytically and its effectiveness is assessed, for a constant surface temperature conditions in three different geometrical conditions. Summarizing the final results of the experiment for different proposed geometric configuration. Finally, since the duration time is inversely proportional to the thermal diffusivity, the thermal conductivity of the PCM should be as high as possible.

[4] **WEI** *et al* (2005):

In this paper, they mainly studied numerically and experimentally of rapid heat discharge for a thermal energy TES system employing PCM FNP-0090. In numerical studies, the PCM was encapsulated in four different capsules (sphere, cylinder, plate, tube) for investigating the effects of geometrical phenomena. Spherical capsule showed the best heat release performance among four types of investigating capsules. Finally, they came to now the heat release performance in the order of sphere, cylinder, plate, and tube.

[5] **Pimez- Lumbard** *et al* **(**2007):

They analyzed the available information concerning energy consumption in building and particularly related to HVAC system. The global contribution from building towards energy consumption, both residential and commercial, has steadily increased reaching figmes between 20% and 40% in developed countries, and has exceeded, the major sectors: industrial and transportation. For this reason energy efficiency in building is today a prime objective for energy policy at all levels.

[6] **Kurnia** *et al* (2013):

Kurnia and his team had developed a conjugate mathematical model for PCM and HTF. This study evaluates numerically various configurations of PCM TES devices, e.g., U-tube, U-tube with inline fins, U-tube with staggered fins and a novel festoon design. The results indicate that our novel festoon channel design yields improved heat transfer rate for both charging and discharging stages. Different arrangements of PCM significantly offsets the heat transfer performance: Placement of high melting point improves heat transfer but it slightly under perform during charging.

[7] **Alvarez** *et al* (2013):

Carried out studies which aims to overcome the drawbacks of PCM based night cooling applications by developing innovative integrated solutions of PCM in the building structure based on:

a) Placing the PCM in the form of mechanically ventilated air layers which allows a significant increase of the convective heat transfer co-efficient.

b) The use of encapsulation that use the convective heat transfer coefficient and optimize the use of significant amounts of PCM reading by building in summer region.

[8] **Soames** *et al* (2013):

Published a paper which provides a comprehensive review on previous studies related to the evaluation of how, and where, PCM's are used in passive LHTES systems. It was concluded that PCM passive
LHTES system can contribute to

(i) increase indoor thermal comfort

(ii) improve building develop performance and to increases system efficiency

(iii) decreases the conditioning power developed (iv) reduce energy consumption among others.

[9] **Kousksou** *et al* (2014):

In their paper had given an updated review of the state of technology and installations of several energy storage technologies were presented and their various characteristics were analyzed. The analysis included their storage properties, current state in the industry and feasability for future the main characteristics of energy storage technologies suitable for renewable energy system.

[10] **Royo** *et al* (2019):

Made a study that assesses in detail the thermal performance of latent heat thermal storage for industrial integrations. By evaluating the thermal profiles, charging/discharging tires, portion of PCM solidified/melted and gas flow temperatures. At present, working with PCM as a thermal storage and recovery system at high temperatures is both promising and challenging.

SCOPE OF WORK:

After going through all the literatures, a numerous amount of journals and carefully studying thermal energy storage system model using PCMs made by our seniors, me and my partner decided to make modifications in the existing model and focus our studies in increasing the efficiency of the present existing model keeping in my mind the conditions of the state Tripura. Also the PCM that previous batch had used is not suitable to the weather conditions and the availability in Tripura. So selection of an appropriate PCM for our project is made on the basis of the research and other parameters like kinematic properties, chemical properties etc.,

Selection of PCM:

The climate of Tripura exhibits a strong seasonal rhythm. The state is characterized by a warm and humid tropical climate with the summer season extending from March to the half of October. The temperature difference between day and night of Tripura is generally between 10 - 16°C which is perfect for the PCM to be used. The average temperature of Tripura is roaming around 22-28°C so a PCM of the melting point of 24°C is selected for the experimentation. So for the selection of suitable PCM for our experiment the following materials are considered based on different properties of the materials shortlisted below

Name	Type of PCM	Melting tempreture	Latent heat	Density	Specific Heat	Thermal conductivity
Plus ice PCM S25	Hydrated salt	25	180	1530	2.2	0.54
PCM Latest TM 25T	Hydrated salt	24	175	1480	2	1
Plus Ice PCM S27	Hydrated salt	27	183	1530	2.2	0.54
HS24	Hydrated salt	24	218	1510	2.42	0.55
Plus Ice PCM A25H	Organic solution	25	226	785	2.15	0.18

On the basis of the above mentioned properties and after carefully analyzing the cost and availability we have decided to opt for Plus Ice PCM A25H as the energy storing material.

Table I. THERMOPHYSICAL PROPERTIES OF THE ORGANIC PCM

Property	**Value**
Melting Temp (°C)	25.0
Freezing Temp (°C)	23.0
Latent Heat (kJ/kg)	226
Liquid Density (kg/m³)	785
Liquid Specific Heat (kJ/kg K)	2.15
Solid Specific Heat (kJ/kg K)	2.02
Liquid Thermal Conductivity (W/mK)	0.18
Base Material	Inorganic
Congruent Melting	Yes
Flammability	No

EXPERIMENTAL SETUP FOR THE PROPOSED MODEL

SETUP DESCRIPTION

The proposed model consists a cubical building with dimensions of 1.0×1.0×1.0 m3 with an extension on one of it's sides which consists of an inlet hole attached with a fan which is used as a suction for blowing cold air from outside to inside.There are outlet holes created on the opposite side of the wall which open up the room to the outside atmosphere.Thermometers are placed in both the inlet and outlet holes to measure the temperature change.Inside the cubical room we have placed a PCM which is placed on top of a container which is kept at an angle to the horizontal axis so that the cold air from outside hits the PCM materials in an effective manner.The container containing PCM materials is kept at an elevated height using a stand .In the roof of the cubical building we have placed a solar panel which is used to capture the solar energy and this solar energy is transferred to the PCM using a heat pump which connects the solar panel placed on the roof with the container of the PCM material.

WORKING PRINCIPLE

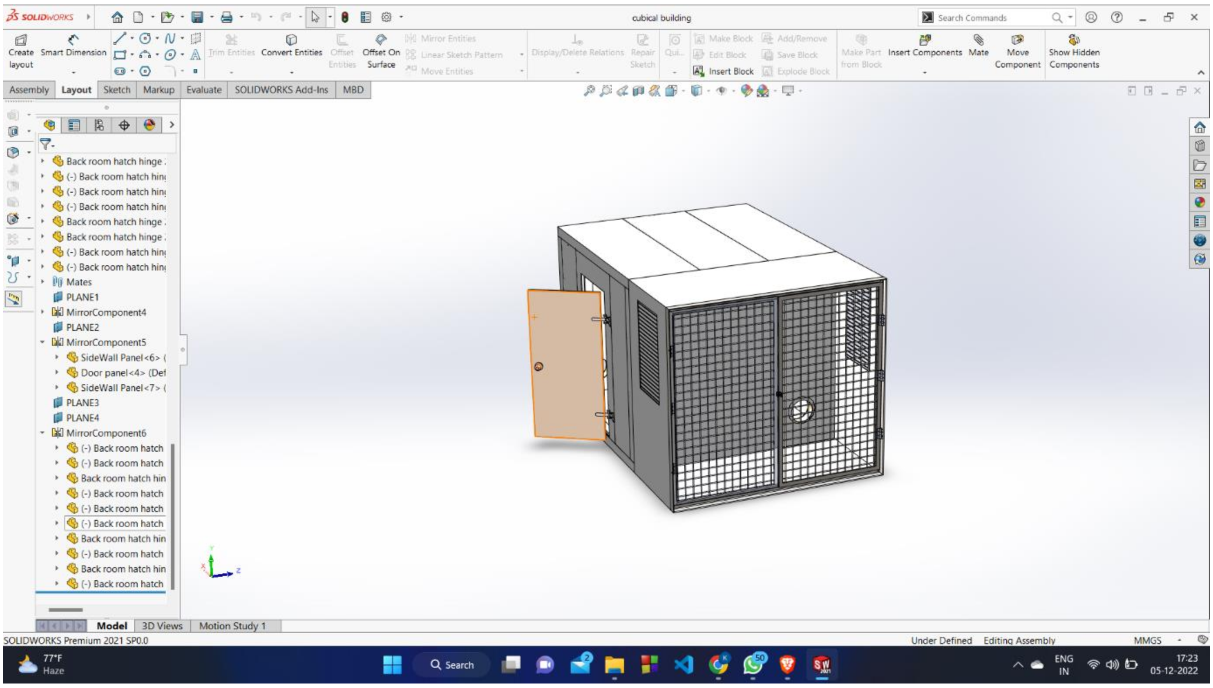
During the daytime the solar energy is captured by the solar panels .The heat captured is transferred to the PCM material using the heat pipes connected.This heat is used to melt the PCM during daytime which results in the changing of phase of the PCM thereby storing the energy.During the night the fan is used as a blower which blows the cold air from outside .The cold air is used to convert the melted PCM into it’s solid phase thereby rejecting the heat energy stored during the day time thereby maintaining a constant temperature inside the room throughout the day.The temperature readings during the day and nighttime are recorded using the thermometers placed at the inlet,outlet and inside the room.It’s expected to maintain same temperature throughout the entire time of research inside the cubical block.The PCM we have used in this case is plus ice pcm A25H.

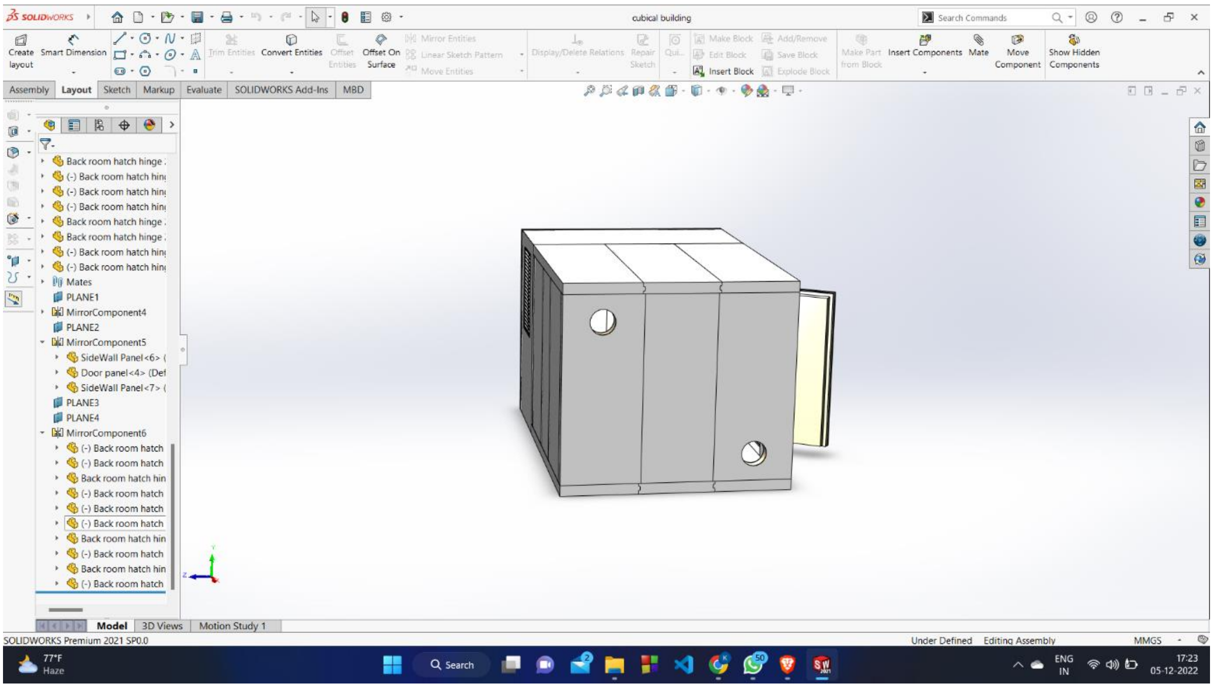
DIMENSIONING

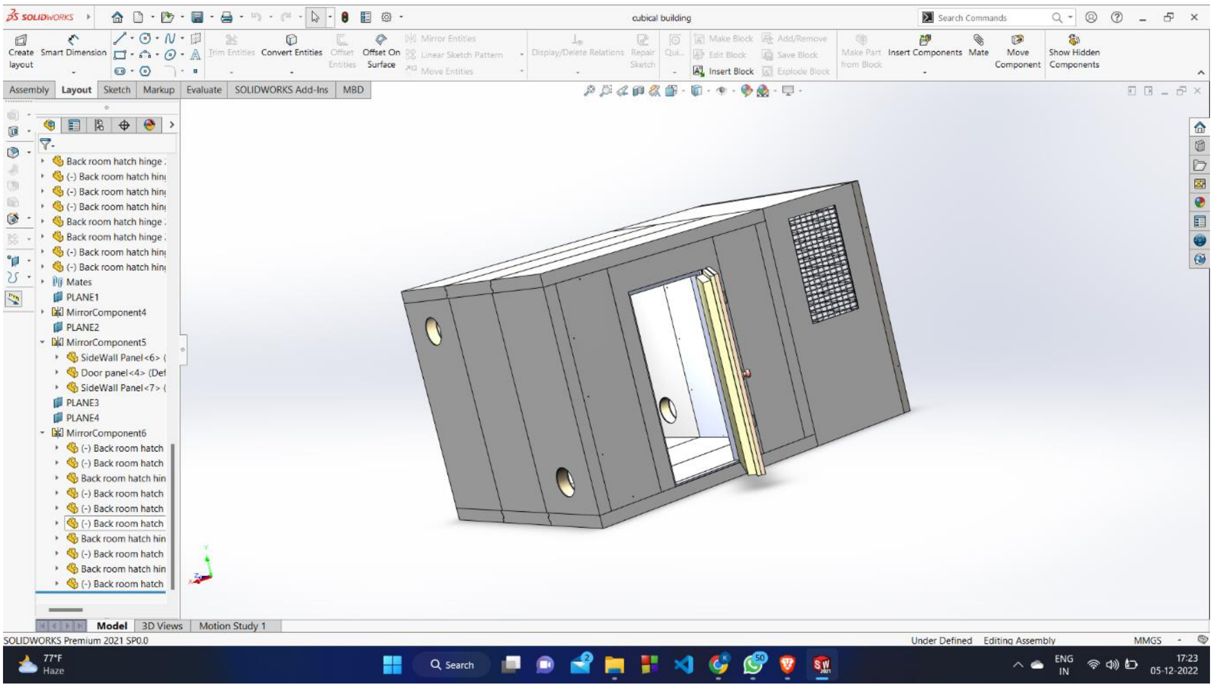
Dimensions of the building-1.0×1.0×1.0 m^3
Thickness of the walls-20 mm
Inlet hole radius -5 cm (positioned at the bottom right corner)
Outlet hole radius-3 cm(both the holes placed diagonally opposite to each other and on the opposite wall of the inlet hole)
Horizontal Position of the PCM from the inlet wall-
Position of the pcm from the base of the building-
Position of the pcm from the orthogonal plane passing through the centre of the room-
Position of the fan from the orthogonal plane passing through the centre of the room-

Solid works model:

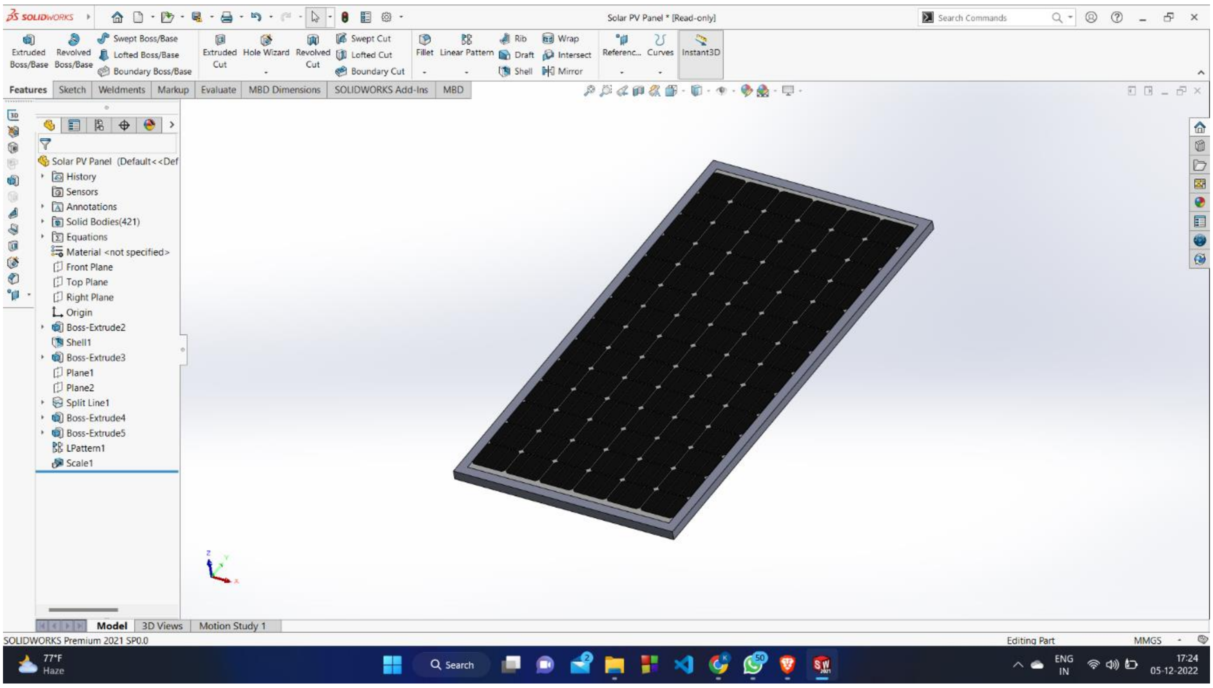
CUBICAL BUILDING WITH INLET AND OUTLET HOLES



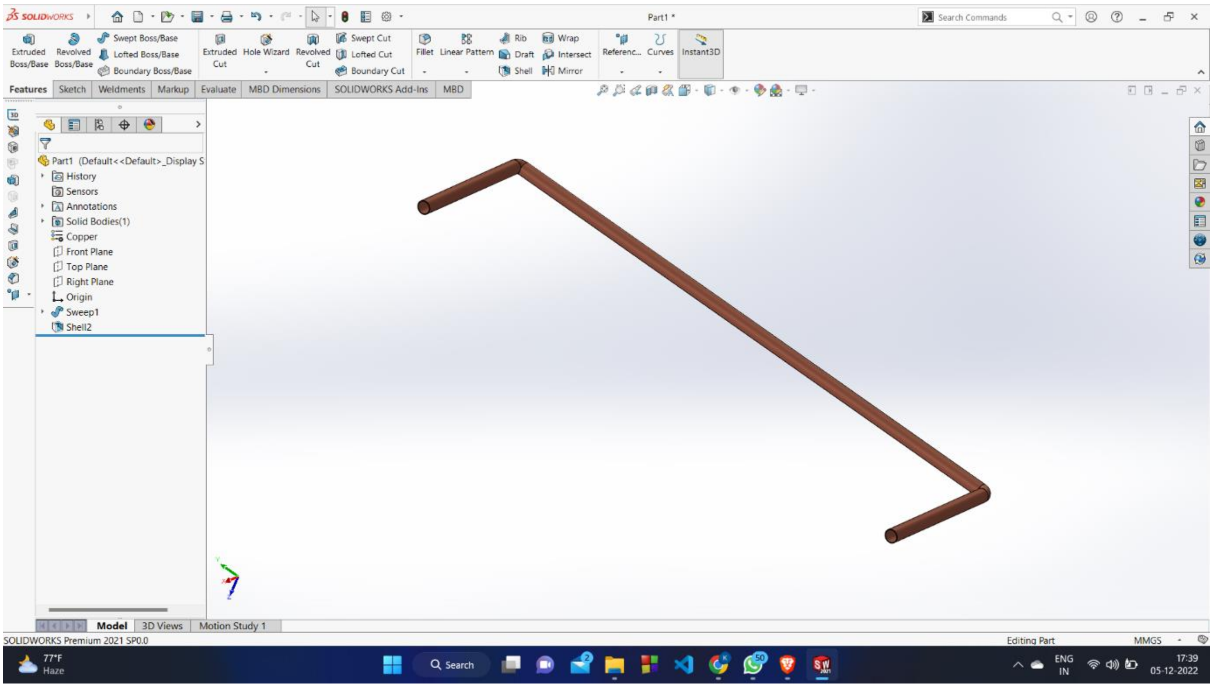




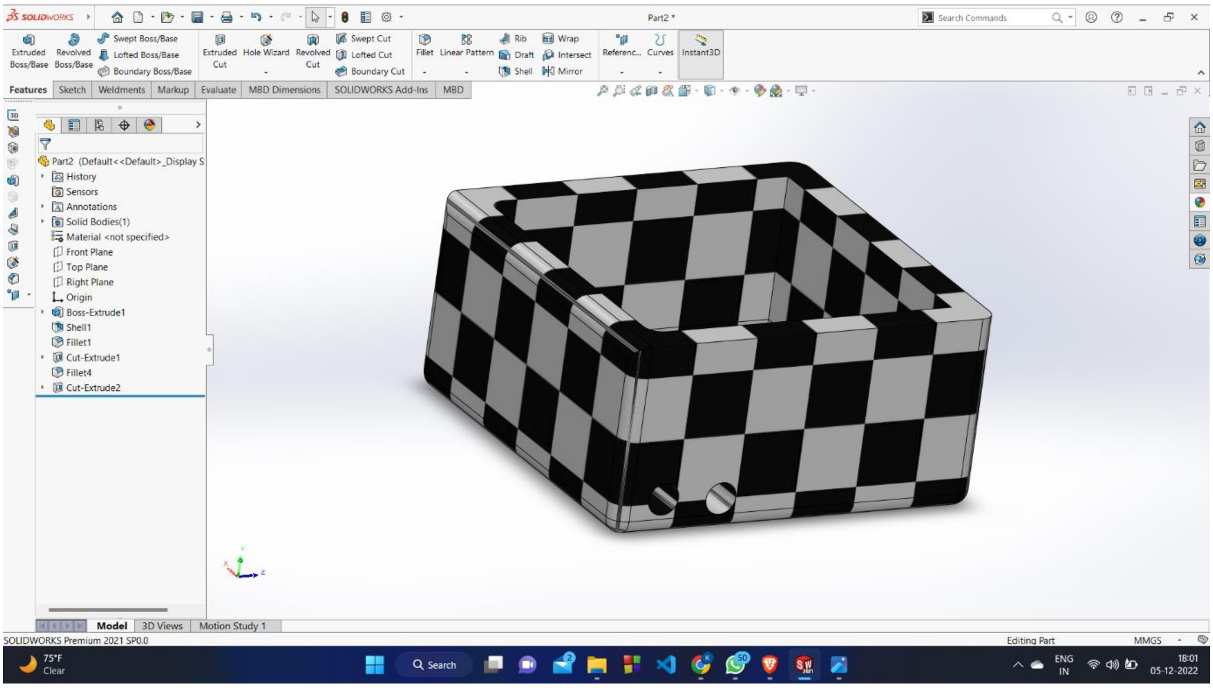
SOLAR PANELS

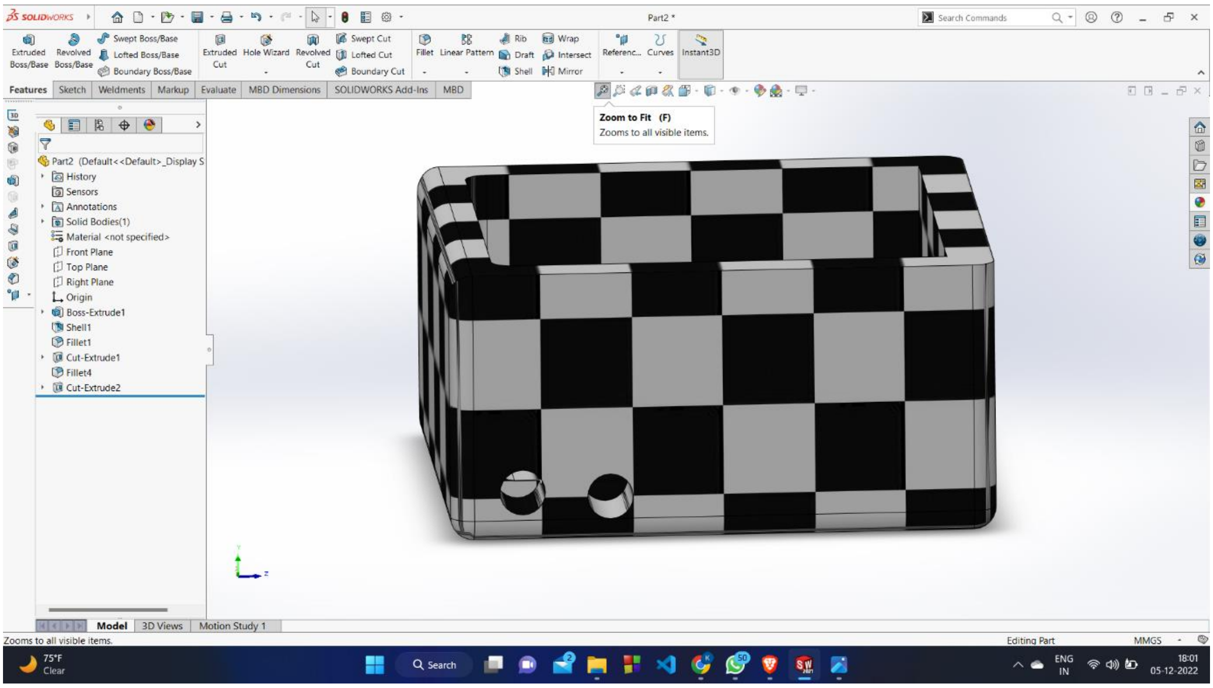


HEAT PIPE



PCM CONTAINER





NOMENCLATURE:

RES = Renewable energy system.

TES = Thermal energy storage.

PCM = Phase change material.

LHTES = Latent heat thermal energy storage.

LHS = Latent heat storage system.

PCT = Phase change temperature.

HTF = Heat transfer fluid.

HVAC = Heat, ventilation, and air conditioning.

CONCLUSION

After going through all the papers and carefully examining the previous model we have decided to make changes and modifications in the previous existing model made by our seniors and make a more sustainable model which suits the climatic conditions of our state and hence aim to produce more efficient and better results thereby affecting the lives of the people living in similar climatic conditions across the country.

REFERENCES

1. STUDY ON PHASE CHANGE TEMPERATURE DISTRIBUTIONS OF COMPOSITE PCMS IN THERMAL ENERGY STORAGE SYSTEMS JIANFENG WANG*, GUANGMING CHEN AND FEI ZHENG.

2. ON HEAT REMOVAL CHARACTERISTICS AND THE ANALYTICAL MODEL OF A THERMAL ENERGY STORAGE CAPSULE USING GELLED GLAUBER'S SALT AS THE PCM. AKIO SAITO, SEIJI OKAWA, TADAFUMI SHIN TANI, RYUICHIRO IWAMATO.

3. D ISCHARGE MODE FOR ENCAPSULATED PCMS IN STORAGE TANKS. A. BARBA, M. SPIGA.

4. STUDY ON A PCM HEAT STORAGE SYSTEM FOR RAPID HEAT SUPPLY. JINJIA WEI, YASUO KAWAGUCHI, SATOSHI HIRANO, HIROMI TAKEUCHI.

5. A REVIEW ON BUILDINGS ENERGY CONSUMPTION INFORMATION. LUIS PE´REZ-LOMBARD, JOSE´ ORTIZ, CHRISTINE POUT.

6. IMPROVED DESIGN FOR HEAT TRANSFER PERFORMANCE OF A NOVEL PHASE CHANGE MATERIAL (PCM) THERMAL ENERGY STORAGE (TES). JUNDIKA C. KURNIA, AGUS P. SASMITO, SACHIN V. JANGAM, ARUN S. MUJUMDAR.

7. BUILDING INTEGRATION OF PCM FOR NATURAL COOLING OF BUILDINGS. SERVANDO ÁLVAREZ, LUISA F. CABEZA, ALVARO RUIZ-PARDO, ALBERT CASTELL, JOSÉ ANTONIO TENORIO.

8. REVIEW OF PASSIVE PCM LATENT HEAT THERMAL ENERGY STORAGE SYSTEMS TOWARDS BUILDINGS' ENERGY EFFICIENCY. N. SOARES, J.J. COSTA, A.R. GASPAR, P. SANTOS.

9. ENERGY STORAGE: APPLICATIONS AND CHALLENGES. T. KOUSKSOU, P. BRUEL, A. JAMIL, T. EL RHAFIKI, Y. ZERAOUL.

10. HIGH-TEMPERATURE PCM-BASED THERMAL ENERGY STORAGE FOR INDUSTRIAL FURNACES INSTALLED IN ENERGY-INTENSIVE INDUSTRIES. PATRICIA ROYO, LUIS ACEVEDO, VICTOR J. FERREIRA, TATIANA GARCÍA-ARMINGOL, ANA M. LOPEZ-SABIRON, GERMAN FERREIRA.