Phase Changing Material (PCM)

CL-204: Heat Transfer

Group 7(Project No.5)

By

Kaushik (22110113)

Ankit Singh (22110025)

Om Gupta (22110174)

Pankaj (22110177)

Chanchal Yadav (22110055)

Under the guidance of

Mr. Bishwajit Saha

Indian Institute of Technology, Gandhinagar

Project Statement

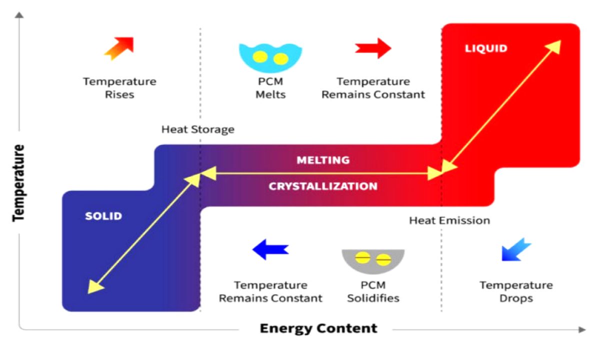
This project is about creating a system to control temperatures using unique materials called phase change materials (PCMs). We want to see how well these PCMs can keep temperatures steady inside insulated containers. By comparing setups with PCM insulation to those without, we want to understand if PCM-based solutions can effectively regulate temperatures in different situations. Through careful experiments and analysis, we aim to learn how PCM technology could be used practically to manage temperatures in various settings.

Basic Introduction

Phase change materials (PCMs) are substances capable of storing and releasing large amounts of thermal energy during phase transition. This unique property makes them invaluable for various applications, particularly temperature regulation systems.

1. Modes of Heat Transfer using PCM:

PCMs operate based on the principle of latent heat storage, where they absorb or release heat energy during the phase transition process. The three main modes of heat transfer involved in PCM-based systems are conduction, convection, and radiation. During the phase change, the PCM absorbs or releases heat from its surroundings, stabilizing the system's temperature.



2. Necessary Calculations:

Calculations involved in PCM-based systems include determining the amount of PCM required to maintain a desired temperature range and considering factors such as the specific heat capacity of the PCM, the latent heat of fusion, and the material's thermal conductivity. Additionally, calculations may involve estimating the heat transfer rates and the system's overall efficiency.

1. **Efficiency Calculation:**

$$\eta = \frac{Useful\ Energy\ Output}{Input\ Energy} \times 100\%$$

2. **Heat Transfer Calculation:**

$$Q = m.L$$

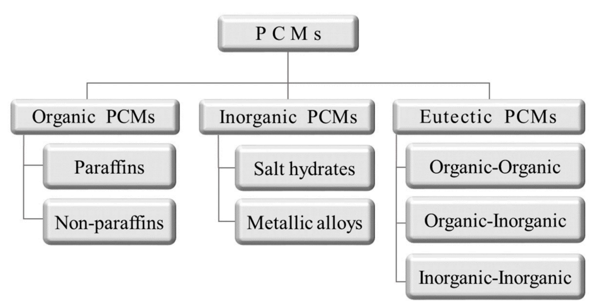
$$\Delta T = \frac{Q}{mc}$$

3. **Heat Capacity Calculation:**

$$C = mc + mL$$

4. **Temperature Distribution Calculation:**

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$$



5. **Latent Heat Calculation:**

   $L=\frac{Q}{M}$

6. **Newton's Law of Cooling:**

   $q=hA(T_w - T_\infty)$

7. **Heat Conduction:**

   $Q=-kA\frac{dT}{dx}$

3. Why PCM Must Be Used (with and without PCM):

Using PCM offers several advantages over traditional temperature regulation methods. PCM minimizes temperature fluctuations, leading to improved thermal comfort and energy efficiency. Without PCM, temperature control may rely solely on active cooling or heating methods, which can be less efficient and costly in energy consumption.

4. Advantages of PCM:

- Thermal energy storage: PCMs can store and release large amounts of heat energy during phase transitions, providing effective temperature regulation.

- Temperature stabilization: PCM-based systems help maintain consistent temperatures, reducing the need for frequent heating or cooling.

- Energy efficiency: By reducing temperature fluctuations, PCM systems can lower energy consumption and operating costs.

- Space-saving: PCM technology allows for compact and versatile designs, making it suitable for various applications with limited space.

5. Real-Life Applications:

PCM technology has applications in diverse fields such as construction, automotive, textiles, electronics, and renewable energy systems. Examples include:

- Thermal insulation in buildings to reduce heating and cooling loads.

- Thermal management in electronic devices to prevent overheating.

- Thermal comfort solutions in clothing and bedding materials.

- Solar energy storage for heating and cooling purposes.

6. PCM - Why Choose Paraffin Wax:

Paraffin wax is a widely used PCM due to its desirable properties, such as high latent heat of fusion, low cost, availability, non-toxicity, and chemical stability. These characteristics make it an ideal choice for various temperature regulation applications, ranging from household products to industrial processes.

7. Challenges:

Despite its advantages, PCM technology also poses challenges such as:

- Limited thermal conductivity. Some PCMs exhibit relatively low thermal conductivity, which may impact their effectiveness in rapidly transferring heat.

- Temperature range limitations: The temperature range over which a PCM remains in its desired phase may be narrow, requiring careful selection for specific applications.

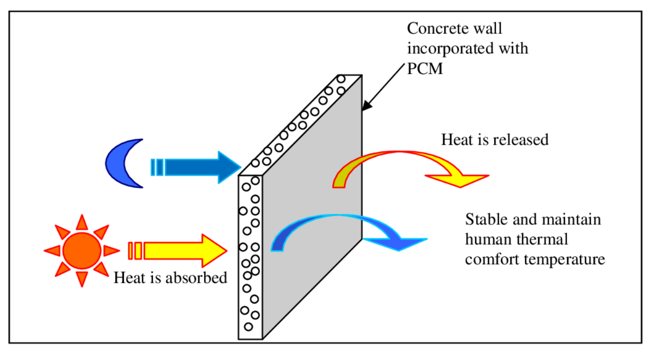
- Compatibility issues: Compatibility with other materials and components within a system must be considered to prevent degradation or performance issues.

8. Conclusion:

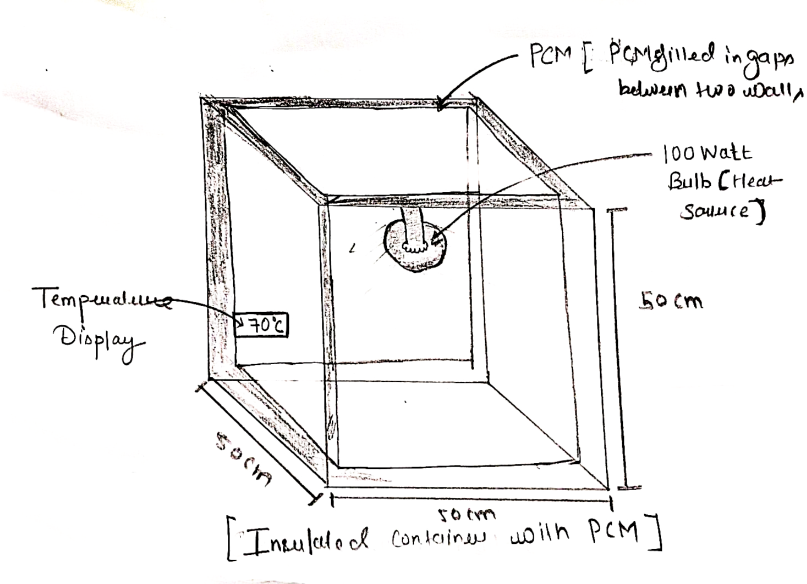
In conclusion, PCM technology, particularly utilizing paraffin wax, offers promising solutions for temperature regulation in various applications. By understanding the underlying principles, advantages, and challenges associated with PCM systems, we can explore innovative approaches to address the evolving needs of thermal management in diverse industries.

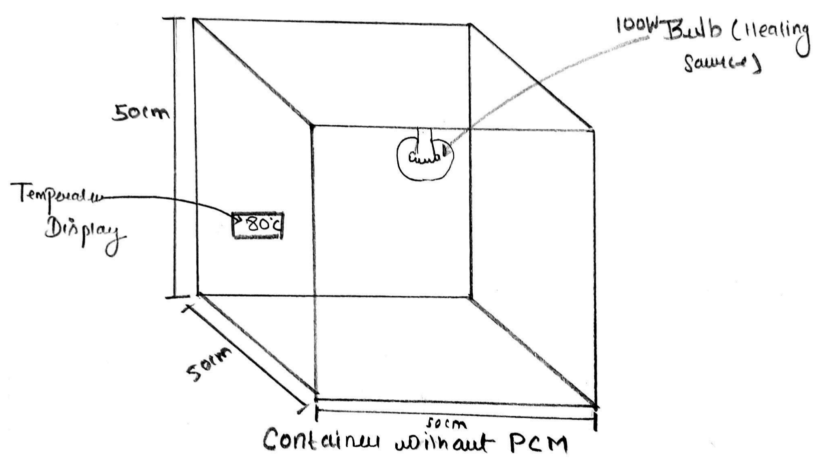
Proposed Work Plan:

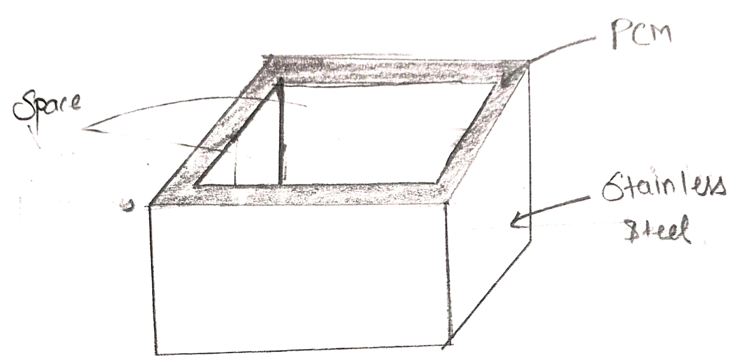
The proposed work plan encompasses a systematic approach to investigate the efficiency of phase-changing materials (PCM), particularly paraffin, in thermal storage applications compared to conventional containers. The project will commence with an extensive review of relevant literature to understand the properties of PCM and its applications in thermal energy storage. Subsequently, an experimental setup will be established, involving procuring or designing two identical containers—one with paraffin PCM and the other without PCM. A 100-watt bulb will serve as a standardized heat source for both containers, while temperature sensors will be installed to monitor and record temperature changes within each container. Controlled experiments will be conducted, exposing both containers to the heat source for predetermined durations, and temperature data will be continuously collected and analyzed at specified intervals. The thermal performance of PCM and non-PCM containers will be compared based on temperature stabilization, heat retention, and energy storage capacity. By interpreting experimental results and discussing findings with existing literature, the project aims to provide insights into the effectiveness of paraffin PCM in enhancing thermal storage efficiency. Recommendations for further research and potential applications of PCM-based thermal storage technologies will be outlined, thereby contributing to advancements in sustainable energy solutions.



Schematic Diagram







Cost analysis

Item name	Quantity	Cost (INR)
Paraffin	3 kg	400
Structural Material(Aluminum)	12 (0.5mx0.5m)	2000
100-watt bulb	5	110
Display	2	400
Temperature Sensor	2	700
Insulation material	12 (0.5mx0.5m)	300
Cooling fan	2	500

Total Estimated Cost: INR 4500 (approx)

Objectives

Our objectives for this project are twofold. Firstly, we aim to compare the temperature profiles between setups with and without the phase-changing material (PCM). Through careful experimentation and data collection, we will analyze and contrast the temperature trends in each setup to assess the impact of PCM on temperature regulation.

Secondly, we seek to evaluate the efficiency of the experimental setup. By quantifying factors such as temperature stabilization, thickness of PCM material, heat retention, and energy storage capacity, we will assess the overall effectiveness of the PCM-based thermal storage system compared to conventional setups. This analysis will provide valuable insights into the practicality and performance of PCM technology in thermal management applications.

References

[1] Phase transition (2023) Wikipedia. Available at: link (Accessed: 12 February 2024).

[2] *Potential applications of phase change materials for batteries' thermal management systems in electric vehicles*, *Journal of Energy Storage*. Available at: link (Accessed: 12 February 2024).

[3] T.-C. Ling and C.-S. Poon, "Use of phase change materials for thermal energy storage in concrete: An overview," Construction and Building Materials, vol. 46, pp. 55–62, Sep. 2013. [Online]. Available: link

[3] Govindasamy, D., & Panwar, V. (2021). Effect of variation in thickness of phase change material on temperature across the composite building wall. Materials Today: Proceedings, 46, 10221–10226. Available: link