Use of Phase change material (PCM) for the Enhancement of performance of cold storage for Transportation

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report **"Use of Phase change material (PCM) for the Enhancement of performance of cold storage for Transportation"** is the bonafide work of the **VENKATA MILIND(RA1711002020153), C.S SUBRAMANYAM VELLALA(RA1711002020133), RAJDEEP SINGH(RA1711002020113), ADNAN KHAN(RA1711002020148)**who carried out the project work under my supervision.

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ABSTRACT

Temperature-sensitive items, such as sausages, milk, fish, and poultry, necessitate additional cooling energy. To conserve these products during transportation and marketing, we need an energy-efficient design of cold storage box.

- We aim to study and observe the heat flow, temperature distribution, and temperature changes in a cold box with phase change content (PCM). Our research starts with the design and fabrication of a cold box with PCM between the layers as an energy storage medium. We conducted several tests to determine the quality of the PCM material.
- We consider using phase change materials (PCMs) to store latent heat as it is one of the most effective ways to store thermal energy.
- PCMs are used to increase the thermal energy storage capacity of a variety of devices.
- As opposed to sensitive heat storage, PCM has a higher heat storage capacity and more consistent behaviour during charging and discharging.
- We have used PCM panels of 33x 25 x 3 cubic mm full of PCM material known as TN-24.
- We shortlisted the PCM based mostly upon their performance and used styrofoam for insulation and to take care of the temperature.
- We did several experiments and created totally different readings and comparisons based mostly upon the PCM's performance and selected PCM TN-45 because it showed the simplest performance, its charging time was 3 hours and discharging time was 16 and it can maintain the temperature at -23C.

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CHAPTER - 1

INTRODUCTION

1.1 PURPOSE

- Food transportation plays an important as well as a key role in a country's economy. In our day to day life, the products which are perishable such as milk, butter, curd(refrigerated products) are always shipped some days before the expiry using transport(cargo).
- Such products, which necessarily need refrigeration, need a whole different set up to transport.
- Such cargo containers which are specifically designed to carry these products are called refrigerated trucks or reefer trucks. These trucks are exactly designed as per the requirement but the big let down to these trucks is the efficiency.
- These dairy products have relatively less resistance against microorganisms such as bacteria, fungi, etc; and therefore such products could get spoiled if they are carried in the containers having slightly more temperature(closer to room temperature). And that's how refrigerated truck become a compulsion for transportation.
- To maintain these products in a fresh condition and not spoiling their quality, we made a cold storage box in order to meet the needs and demand.
- With this cold storage, we aim to preserve perishable products(diary, edible products) and essentially use the phase change materials (PCMs), to perform the temperature alteration inside the storage box.
- We found that the use of electric refrigerator in transport container was not sensible and economical.

PROBLEMS IDENTIFIED

- The need for cold trucks to transport perishable products like milk, fruits, meat, and fresh vegetables has skyrocketed.
- Certain biopharmaceutical goods must be shipped regularly, but cold storage transportation is an expensive and difficult process fraught with danger. According to studies, refrigerated warehouses and cold storages are incredibly inefficient if they aren't equipped with high-quality sealed doors. This is how energy conservation ends up causing yet another cost problem.
- When it comes to fuel, the truck's battery is in charge of the whole cooling system; the downside of a non-independent refrigeration unit is that it is entirely reliant on the truck's power supply
- If the truck's battery dies, the cold storage device can be hampered.

- As the cold truck engine shuts off, the non-independent refrigeration mechanism loses control, the cooling system shuts down, and if the doors are opened too often, the temperature inside the vehicle rises due to a significant lack of cold air from the vehicle's body.
- Engine failure is another occurrence that may occur out of nowhere, causing the temperature to increase similarly.

AIM OF THE PROJECT

Through this project, we aim to create a PCM-equipped storage box that improves cold storage performance in transportation.

CHAPTER – 2

LITERATURE REVIEW

Evaluation on performance of a phase change material based cold storage house - Changjiang Wang, Zitao He, Hailong Li, Ronald Wennerstern, Qie Sun

In this study, the author has studied the performance of a cold storage house with ice/water as PCM, experimentally and numerically. The main results of the study include:

- Water/ice is a promising material for cold thermal energy storage in high temperature cold storage house for its high latent heat density, high density, non-toxic and no corrosion.

- The water/ice layer can absorb the cold thermal energy in off-peak period and release it to run the cold storage house in busy and peak period as an economic operation solution.

- Ice/water layer can increase heat transfer resistance of wall and then reduce the energy needed.

- The payback period of ice/water PCM is about 4.1 years.

Evaluation on performance of cold storage box enveloped with phase change Materials - A H Dongoran and A Setiawan

- The experimental results show that adding 10 vol.% of commercial NaCl into water is able to improve the effectiveness of the release and absorption of heat by up to 73% compared with pure water.
- Numerical iteration on the flow patterns and temperature distribution of heat within the cold-box concludes that the shape and number of holes of PCM bottle are important factor in optimising performance of the cold-box. Any PCMs liquids filled into a plain plastic bottle without hole and groove demonstrates the coldest temperature compared to others.

PCM storage system with integrated active heat pipe - R. Yogev, A. Kribus

- The active heat pipe storage system to the simpler reference configuration composed of steam tubes surrounded by PCM annuli, with one-dimensional conduction heat transfer in the radial direction.
- For both systems, the same steam pipes were used, and the same amount of PCM per unit steam pipe length.
- Hence, the reference geometry of the PCM is an annulus with internal diameter 2.13 cm and an external diameter of 7.4 cm.
- The discharge of the reference system is determined using a heat balance between the solidifying PCM and evaporating steam; details are given in.
- Comparing the normalized electrical power output of the two storage configurations, both operated in constant thermal power mode (β=0).
- The heat pipe system offers a major improvement with respect to the radial conduction configuration, where the electrical power output drops by only 18% at the end of discharge, compared to 35% for the radial system Another aspect for comparison is the required heat transfer area per unit volume of storage material.
- In the case study presented here, this ratio is 46.5 m2/m3. For comparison, in the conduction-based finned tube storage system presented in, a much higher surface area was used, about 200 m2/m.

Energy and Exergy Analysis of a Multi-PCM Solar Storage System - Wisam H. Mousa, Fawziea M. Hussein, Johain J. Faraj

The following conclusion can be derived from the experimental results on the performance of a multi PCM system. With the Barium Hydroxide Octahydrate inside the first capsule and the Sodium Acetate Trihydrate inside the second capsule, some remarks can be summarized as below

- In general, the increase in the water flow rate increases the time required to melt the PCM and decreases the temperature difference of the charging water.
- The charging time is longer than the discharging time as the hot water temperature difference during melting was lower than that of the solidification.
- For the 0.5 L/min water flow rate, the charging period is 2.79 hours with an average hotwater temperature difference of 2.59 °C, while the discharging period is 2.27 hours with an average cold-water temperature difference of 5.84 °C.

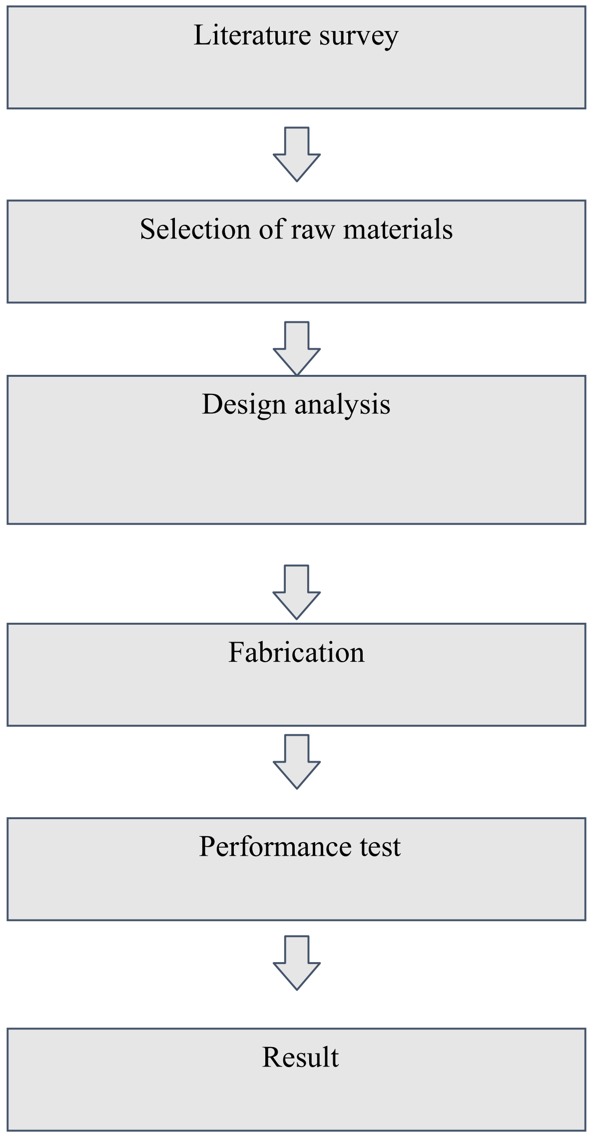
- For the 1 L/min water flow rate, the charging period is 4.84 hours with an average hotwater temperature difference of 1.44 °C, while the discharging period is 2.51 hours with an average cold-water temperature difference of 3.92 °C.
- For the 1.5 L/min water flow rate, the charging period is 5.19 hours with an average hotwater temperature difference of 1.12 °C, while the discharging period is 3.73 hours with an average cold-water temperature difference of 2.91 °C.
- The 1 L/min water flow rate gives a maximum total storage energy of 139.38 kJ and maximum total storage exergy of 17.15 kJ.
- The 1.5 L/min water flow rate gives maximum system energy efficiency of 64.82 % and maximum system exergy efficiency of 14.99 %.

CHAPTER - 4

METHODOLOGY

To complete this project, we used the following methodology:

- In order to fully understand refrigerated containers, we conducted extensive analysis and gathered feedback from a variety of logistics and transportation offices.
- About 85% of employees accepted that the refrigerated containers are not cost-effective, environmentally safe, or easy to run.
- We reviewed a number of research papers, journals, and publications on PCM and came to the conclusion that it can improve cold storage capacity.
- After multiple researches, we finalised all the raw materials.
- Until beginning of the design work, we ran multiple dimensions calculations to ensure that each part would fit perfectly.
- We developed the 3-D version using CATIA software after the original concept was finalised.
- Following the specification, we fabricated everything in accordance with the design.
- We then put our storage box into a performance inspection.
- As a result, we concluded the outcomes.


Literature survey
Selection of raw materials
Design analysis
Fabrication
Performance test
Result

4.1 TERMINOLOGY

PCM classification

- Phase change products are divided into two categories.
- a)organic
- b)inorganic.
- Inorganic compounds display a latent Thermal Energy Storage capacity (volumetric) twice that of the organic compounds . Organic compounds have a tendency to melt, be non-corrosive, non-toxic, and environmentally friendly. It is one of the main benefits of organic compounds that may be used as a significant heat storage medium.

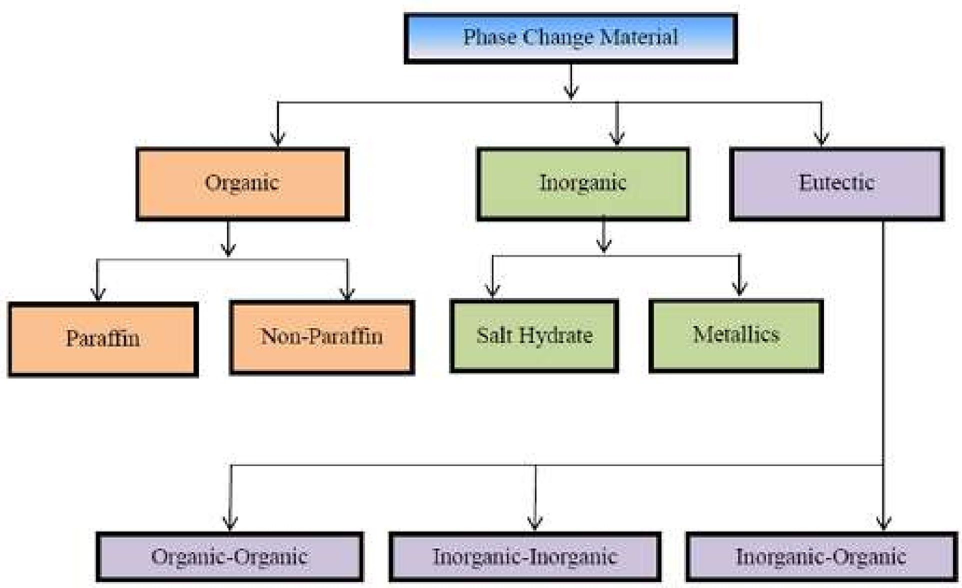


Fig.4.1.1- Phase Change Material Classification

Paraffin

- Due to its availability, relatively inexpensive, and non-corrosive nature, paraffin is one of the most heavily researched phase change materials in thermal energy storage systems.
- Paraffin is usually made of straight long chain alkanes, and its thermal release and melting point are determined by the chain length. Even though there are some advantages, the limitations, like the low thermal conductivity and mild flammability, narrowed its use to small scale and low temperature implementations.

Non-Paraffin

- A number of non-paraffins, such as fatty acids, alcohol, and glycol, are best suited for thermal energy storage. Nevertheless, all non-paraffins have one distinct drawback: its flammability, which requires special handling in high-temperature environments.

Inorganic Salt and Salt Composites

- Salt hydrates have been the most highly explored PCM due to their greatest capabilities in terms of comparatively high thermal conduction, value, and stable activity.
- Several researchers have proposed inorganic salt composites as a potential PCM storage application due to greater energy density, heat of fusion, and cheaper prices.
- KOH, NaOH, Na2CO3, NaNO3, KNO3, among others, have been frequently used for research.
- Fluoride salts have a high heat potential, but still they are the optimal option for Phase Change Substance salt selection, in terms of value and material compatibility. The same is true for KOH, which has a high value or cost effectiveness but can cause high corrosion of the material being contained.

5.3 COMPONENTS AND SPECIFICATIONS

1. PHASE CHANGE MATERIALS (PCMs)

- When a system goes through a phase transition, PCM plays a vital role in absorbing or releasing large amounts of heat.
- These are installed in a wooden box that functions as an adiabatic wall.
- The 4-PCM panels are mounted, one on either side, of the box's interior.
- These are designed to absorb all the heat produced during the phase shift.

- These operate on a single-charge basis and adjust the temperature continuously for many hours (12 hours attained after testing). The minimum temperature to be achieved by PCM is -23C.

2. WOODEN BOX

- The wooden box is the system's exterior, and it stores the whole PCM setup. The wooden box measures 350x300x15 cubic mm in size.

- This arrangement functions as an adiabatic wall, which acts as an insulator, preventing heat from escaping the device when it is in the phase change state. Everything is contained within this wooden box, including the PCM, sheet metal box, and styrofoam.
- The battery, temperature reader and thermocouple are mounted on the wooden box's exterior.

3. SHEET METAL BOX

- Sheet metal refers to any metal that can be moulded into flat parts of different thicknesses.

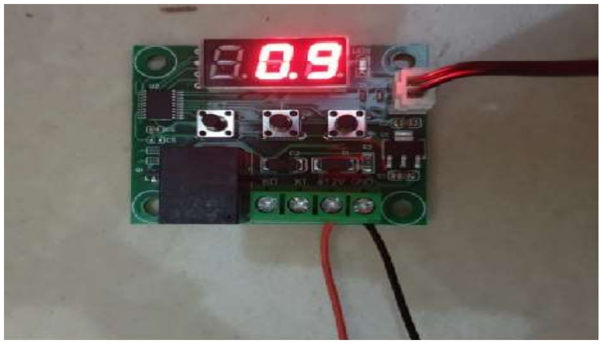
- This sheet metal is used in the device and is shaped into a box of dimensions 175x320x1 cubic mm, which is kept inside the wooden box and mounted in the middle.
- This sheet metal box acts as a diathermic wall, which is used to change the temperature and distribute heat.
- This is the compartment that contains the product and conducts the phase change using PCM.

4. TEMPERATURE SENSOR OR THERMOCOUPLE

- This sensor measures the temperature. It is constructed of two metals that are joined at one end. A voltage is produced when the junction of two metals is heated or cooled. This sensor is connected to the temperature reader and displays the temperature.

5. TEMPERATURE READER

* This temperature reader calculates the product's temperature as well as the



PCM temperature at the same time, which is usually needed for analysis. It measures temperature using a thermocouple or temperature sensor connected to a power source (battery).

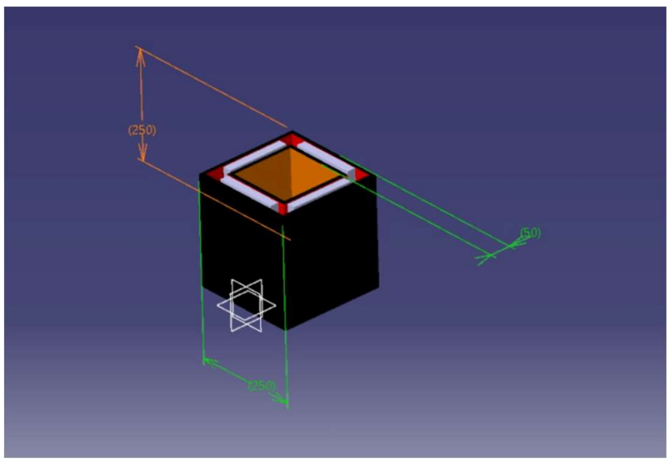
6. BATTERIES

The battery is used to power the temperature reader, which displays the PCM's temperature.

DESIGN AND FABRICATION

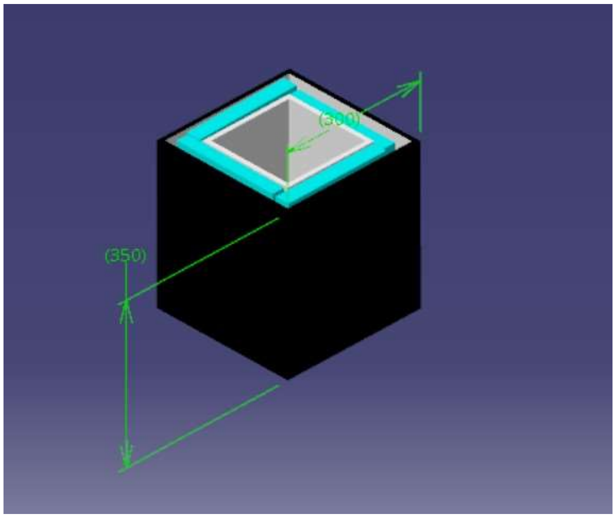
We designed the PCM storage box using CATIA software, which is used for parametric and non-parametric modelling and to design, analyze, simulate, and sometimes manufacture products. CATIA was only chosen for design because of its flexibility, and this software is used in the majority of automotive sectors for design development. Using this software, we designed the exterior and interior of storage box. Design is made in two parts which are as follows:
1.Intial Design
2.Final Design

INTIAL DESIGN



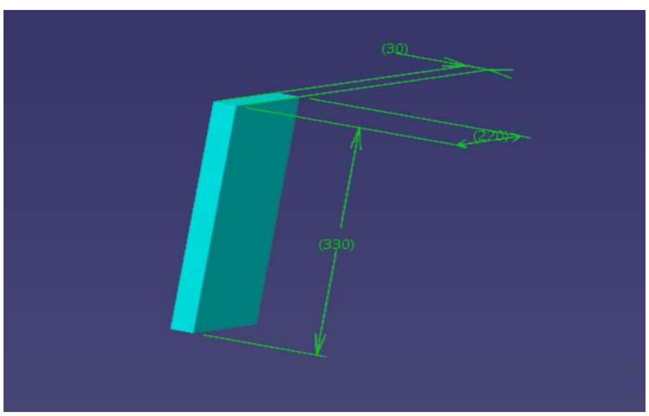
- We allocated the positions for PCM panels and the sheet metal box in the initial design.
- When the system lacked adequate insulation, we modified the design.
- We then gave sufficient space for styrofoam between the diathermic and adiabatic walls.

FINAL DESIGN
EXTERIOR DESIGN

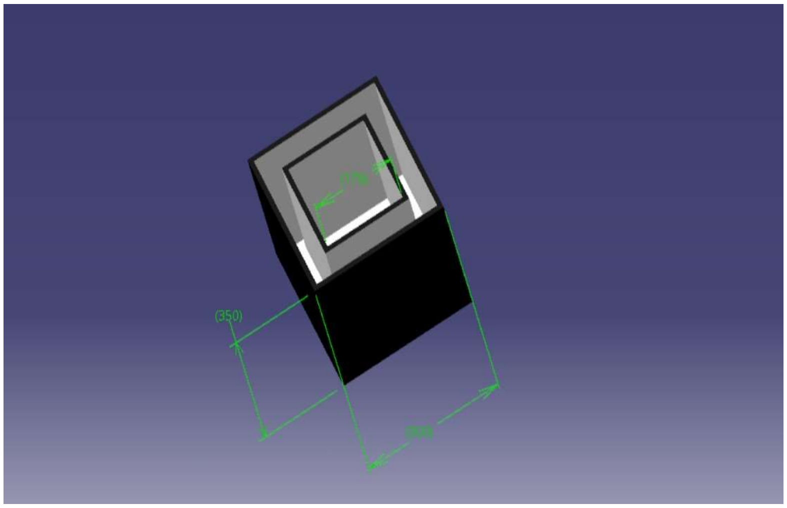


PCM DESIGN

PCM is designed in CATIA as per the dimensions required to fit inside the insulated wooden box.



INTERIOR DESIGN
The storage box's interior is designed in such a way that the interior will allocate the 4-PCM plates, styrofoam, and the sheet metal box with minimal allowances, resulting in effective insulation.



FABRICATION
The fabrication of Storage box is done in 3-stages which are as follows:
1. Insulation box (Exterior)
2. PCM selection
3. Interior (sheet metal box fabrication)

1. INSULATION BOX (EXTERIOR)
- The exterior of the storage required a robust material that could also act as a heat and cold insulator. We chose cypress wood after conducting extensive testing.
- Cypress wood is resistant to dust and water.
- It is very stable and long-lasting.
- We selected the cypress wood to make the exterior of the storage box because it met all the requirements.

TOP VIEW OF INSULATION BOX

SIDE VIEW OF WOODEN INSULATION BOX

2. PCM SELECTION

	Organic Paraffin	Organic Non-Paraffin	Inorganic Salt Hydrates	Inorganic Metal Eutectics
Melting Temp. (C)	-12 to 187	<150	20 - 140	30 - 125
Latent Heat (J/m^3) x 10^6	190 - 240	140 - 430	250 - 660	300 - 800
Density (Kg/m^3)	~810	900 - 1800	900 - 2200	~8000
Thermal Conductivity (W/mC)	~0.25	0.2	0.6 – 1.2	~20
Toxicity	No	Some Are	Highly	Some Are
Corrosion	Low	Some Are	Highly	Some Are
Congruent Melt	Yes	Some Do	Most Do Not	Yes
Supercool	No	No	Most Do	No

- We considered four PCMs and found that TN-24, an inorganic salt (hydrate), was the most effective in terms of both cost and efficiency.
- TAN 90 Chemical Solutions manufactures these panels at NCCRD (National Centre for Combustion Research and Development), IIT MADRAS.
- We inserted the chemical form of PCM into panels that are fabricated to our specifications, i.e., 33x25x2.5 cubic mm.

- We gave these measurements so that the panels can fit perfectly in the storage box.

P.C.M PANELS

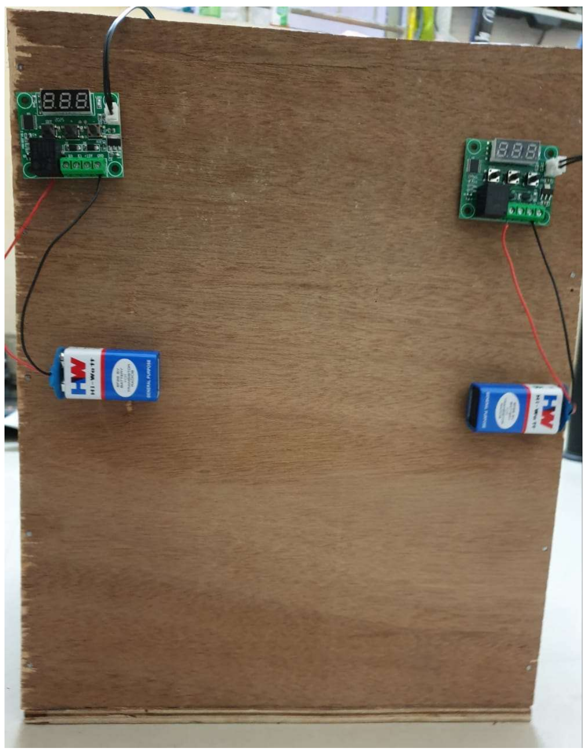
- After that, we installed the PCM panels in the storage box.

3. INTERIOR (SHEET METAL BOX FABRICATION)

- The storage box requires an adiabatic wall to conduct heat flow and temperature change, so we placed a sheet metal box between the PCM panels to accommodate the place for the product.
- The sheet metal box has dimensions of 175x320x1 cubic mm and we designed it to fit seamlessly between the panels.
- For more insulation, we installed styrofoam after installing the sheet metal box between PCM panels.

WORKING

- All the components are placed in the storage box, and the temperature reader and battery are connected to the storage box.
- The temperature reader is connected with two thermocouples or temperature sensors.
- To test the temperatures, a thermocouple is placed in the PCM and another in the sheet metal box.



Temperature sensors, Batteries connected to the storage box

5.3 EXPERIMENTATION

5.3.1 PROCESS OR METHOD

FREEZING IN REFRIGERATOR

- We took a glass of water and kept it in the refrigerator inside the freezer window.
- Inside the liquid and PCM, we installed the temperature sensors.
- The procedure took 4 hours to complete.
- We also registered the temperature and time.
- We recorded the temperature v/s time values, and created a graph.

FREEZING IN P.C.M STORAGE BOX

- We took a glass of water and inserted in the sheet metal box slot.
- We embedded the temperature sensors in the water and PCM.
- The procedure took 4 hours to complete.
- We also registered the temperature and time.
- We recorded the temperature v/s time values, and created a graph.

CHAPTER-6

RESULTS AND DISCUSSION

FREEZING IN PCM STORAGE BOX VS REFRIGERATOR

TEMPERATURE	TIME TAKEN	TIME TAKEN
REFRIGERATOR AND P.C.M STORAGE	**REFRIGERATOR**	**P.C.M STORAGE**
30°C	0 mins	0 mins
22 °C	10mins	3mins
14°C	17mins	8mins
8°C	26mins	14mins
4.2°C	31 mins	17mins
0°C	34mins	21mins

Table 6.1.1-freezing point differences

The aim of this study was to determine the influence of temperature on a model cold storage when phase change material was used.

PCM Melting Behaviour

- We determined the melting behaviour of PCM by running experiments and plotting graphs between temperature and time for two PCM, namely water and ethylene glycol.
- Since calculating the melting point, which is the steady temperature at which the phase transition occurs, is impractical, we used the average temperature of extreme temperatures on the phase transition profile.

Water freezing profile

- To analyze the freezing behavior of water, we plotted a graph between temperature and time (in minutes). We can see from the graph that the water, which was originally 28°C, is taking temperature from the PCM and starting to freeze.
- The curve shows a sinusoidal behavior up to 4.2 °C, which is the phase transformation of water to ice, and then it continues a normal pattern of falling temperature from 28 °C to 4.2 °C. After that, the curve varies, and the temperature drops even more. As a result, the melting point of ice is 0 degrees Celsius (approx.)

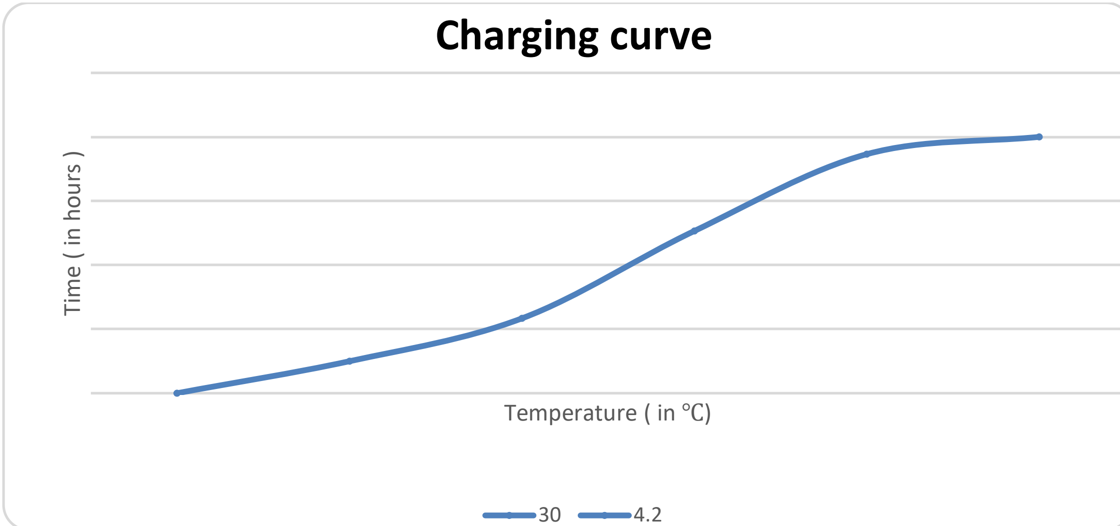
PCM CHARGE-DISCHARGE ANALYSIS

This experiment aims to determine the charging and discharging time of PCM, which is extremely useful for analysis.

CHARGE

- When the PCM reaches its maximum temperature of 30 ° C, it is completely discharged.
- To charge, we stored the PCM in the refrigerator.
- Also, we recorded the charging time after placing the PCM panels in the refrigerator.

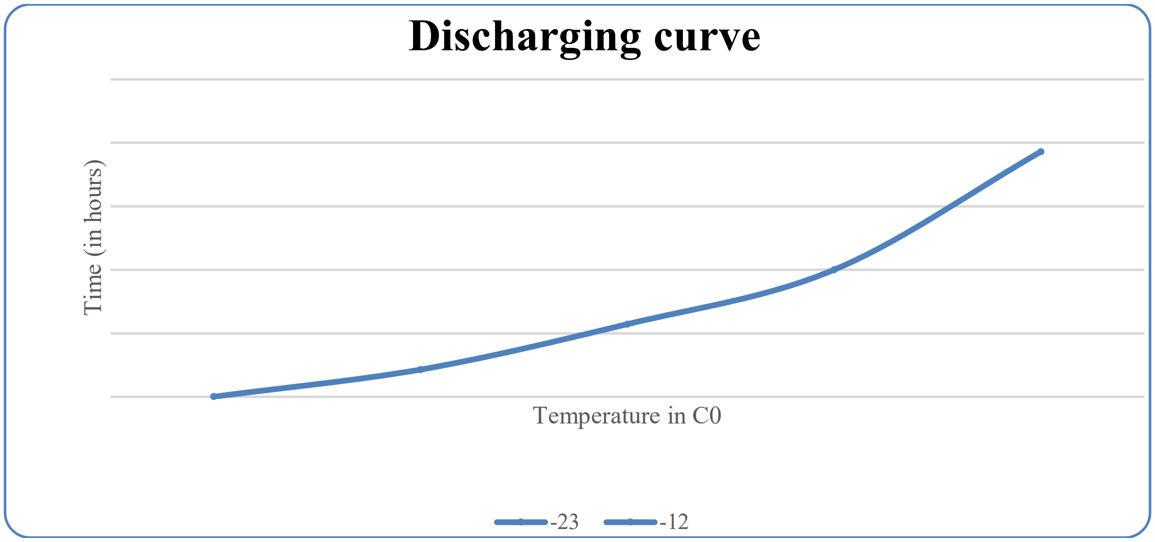
TEMPERATURE	TIME(IN HOURS)
30°C	0
4.2°C	2
0°C	3.5
°-14C	7
-20°C	10
-23°C	12



DISCHARGE

- Now, we stored the PCM in a storage container.
- Since its completely charged, the PCM has reached its minimum temperature of -23C.
- We then extensively used the PCM in phase-change processes.
- We recorded and tabulated the discharge time and values.

TEMPERATURE	TIME(IN HOURS)
-23°C	0
-12°C	1.5
0°C	4
12°C	7
30°C	13.5



6.3 OBSERVATION

We gathered readings for 4 different PCMs and performed calculations and according to that, based upon performance and cost, the best one was chosen, which is TN 24.

- Charging time for TN 24= 3 hours
- Initial temperature =30^0 C
- Discharging time =16hours

Table 6.4 -DIFFERENCES BETWEEN PCM AND REFRIGERATOR

PCM STORAGE BOX	REFRIGERATOR
It does not need a power source to work.	Continuously requires a power supply to operate
It is portable and can be carried all over the place.	It cannot be moved due to its weight and lack of power backup, since it needs a constant power source to operate.
more efficient than a fridge	Less effective
A wireless refrigerator.	Wired variant
Portable and rechargeable	It cannot work without a power source.
Energy intake is minimal.	Excessive energy/power consumption
Because of its structure, it can withstand fewer repairs.	After extended use, there are further maintenance issues.
There is no need for a power supply.	Power outages may be a problem.
Less expensive	The price is significantly higher than the PCM-based price.

PCM STORAGE BOX	REFRIGERATOR
The rate of cooling is less than or equal to the refrigerator's rate of cooling.	Increased cooling pace
Temperatures can not be manually changed.	Temperature control
When compared to a refrigerator, it takes up less room.	More storage room than PCM storage
The temperature scale is the only choice (30C to -23C)	The temperature limit is greater than that of PCM.
Options are few.	More alternatives

Table6.5-DIFFERENCES BETWEEN PCM AND REFRIGERATED TRUCK

PCM STORAGE	REFRIGERATED TRUCK
It's less costly and easier to use.	Independent refrigeration systems are more costly and need more maintenance than non-independent refrigeration units.
Perishables, especially fruits and vegetables, benefit from cold storage the most.	Refrigerated shipments can be more difficult, complex, and costly to obtain.
There is less difficulty and maintenance needed.	The power system is more difficult in terms of servicing and maintenance, the refrigeration unit is more complex than the PCM Storage unit, and the independent refrigeration unit is more physically challenging and costly.

PCM STORAGE	REFRIGERATED TRUCK
It is not reliant on a power supply.	It is overly reliant on the truck's power supply. As the refrigerated truck engine fails, the refrigeration unit loses power, and the refrigeration fails to function.
It has no impact on the temperature inside the vehicle.	Due to the extremely significant lack of cool air in the vehicle's body, the temperature inside the truck rises.
Since the climate control system does not rely on a power supply, there is no risk of problems developing, maintaining the load security.	If something goes wrong with the temperature control system of the truck, the whole cargo will be damaged, costing the business a lot of money. Many carriers do not protect perishables and temperature-sensitive goods in their freight insurance plans due to their condition and if they do, their liability is often limited.
It's easy to reposition.	Repositioning is very difficult. There are instances like this.
When exposed to severe conditions, this storage device has a lower risk of leaking.	Some issues can lead these units to function inefficiently. Leaks are a common issue in trucks, ships, and train cars that are continually exposed to the elements and extreme conditions.
Since PCM storage does not need a power source, it will never stop cooling.	When the truck fails (engine failure), the refrigerator fails to cool, and the cargo inside the vehicle is easily destroyed.
There's no risk of a performance issue.	It raises concerns about performance.
Low-cost expenses	Expensive prices
It does not affect the battery.	If the battery truck is continuously used for an extended time, it may need to be replaced.

6.6 BILL OF MATERIALS

SL.NO	NAME OF THE MATERIAL	QUANTITY	PRICE	TOTAL
1	Phase change materials	4	Rs.1500	Rs.6000
2	Wooden box	1	Rs.1000	Rs.1000
3	Sheet metal box	1	Rs.1200	Rs.1200

SL.NO	**NAME OF THE MATERIAL**	**QUANTITY**	**PRICE**	**TOTAL**
4	Styrofoam	4	Rs.50	Rs.200
5	Thermocoal	1	Rs.40	Rs.40
6	Temperature Sensor/ Thermocouple	6	Rs.150	Rs.900
7	Temperature Reader	3	Rs.500	Rs.1500
8	Batteries	4	Rs.30	Rs.120
9	Battery clip connector	10	Rs.25	Rs.250
10	**Labour charges**	——	Rs.1500	Rs.1500
	TOTAL	——	——	Rs.12710

Table-6.5.1-Bill of materials

CHAPTER-7

MERITS AND DEMERITS

MERITS

- It does not necessitate the use of a power source.
- Portable, lightweight, and convenient to transport
- In comparison to a refrigerator, it is more effective.
- The battery can be charged.
- More value at a lower cost.
- Energy consumption is lowered.
- Cold storage helps perishables the most, especially fruits and vegetables.
- There is less complexity and maintenance needed.
- Less costly and easier to manage

DEMERITS

- Limited Options
- When compared to a fridge, it takes up less room.
- Temperatures cannot be changed manually.
- It's a bit difficult to charge PCM.

CHAPTER-8
CONCLUSION

- We investigated the temperature differential in cold storage as well as a domestic refrigerator, with and without PCM integration.
- The benefit of incorporating PCM into cold storage is obvious. We found that using PCM in the refrigerator reduced the air temperature by 1-4 ° C, relative to not using PCM.
- The temperature drop was greater in the storage system than in the refrigerator without PCM, indicating that the greatest difference in temperature drop with and without PCM integration was found with a one-hour time limit.

- The PCM kept the temperature below -4.5°C for less than 20 minutes without using any power, while a refrigerator with a power source needed more than 38 minutes to keep the temperature under -4.5°C.
- Within a two-hour interval, we observed the most significant difference in temperature fall with and without PCM incorporation (refrigerator). As PCM was fully discharged, we measured the temperature increase and compared it with the temperature of the refrigerator that was not powered (considering power failure).
- As the time of the power outage reduces, this variation decreases. The temperature in the refrigerator without power increased faster than in the PCM storage box.
- When PCM can consume energy at higher speeds, more fuel can be saved. As a result, the PCM storage box is far less expensive than a refrigerator.

CHAPTER-9
FUTURE SCOPE

- This PCM technology is still being researched and has a long way to go.
- Improving PCM would necessitate a significant amount of testing.
- The PCM charging method is a little more difficult than normal, and it can take longer to charge.
- There are even more ways to charge the PCM that are yet to be explored.
- In the future, PCM storage has a huge amount of potential to become the strongest mode of refrigeration transport.
- Even a slight research will enable to add a lot of functionality to the PCM storage.
- There's a possibility that PCM Storage will get far more energy efficient.

CHAPTER-10
REFERENCES

- Evaluation on performance of a phase change material based cold storage house - Changjiang Wang, Zitao He, Hailong Li, Ronald Wennerstern, Qie Sun
- Evaluation on performance of cold storage box enveloped with phase change Materials - A H Dongoran and A Setiawan
- PCM storage system with integrated active heat pipe - R. Yogev, A. Kribus
- Energy and Exergy Analysis of a Multi-PCM Solar Storage System - Wisam H. Mousa, Fawziea M. Hussein, Johain J. Faraj