# Phase Change Material(PCM)-Heat Exchanger

Teoh Zhi Heng, Hong Jian Hua, Chong Jia Joon, Yip Winn Sheng Alwyn, Tan Jia Hao
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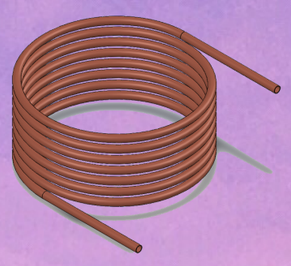
## INTRODUCTION

In countries with winter, heat pumps are commonly used for thermal heating and cooling purposes. During harsh winters, the heat-exchanger which is located outdoor freezes, which affects the heating performance of a heat pump. The heat pump will then switch to the defrost cycle to melt the frost formed on the outdoor heat-exchanger, halting the heat production temporarily. To overcome this using an environmentally friendly method, a PCM heat-exchanger is used, which acts as a heat storage during heating cycle, and then discharges heat stored for defrosting. By doing so, the defrosting time can be reduced, shortening the defrost time, and the overall efficiency of the heat pump can be improved.

## PROBLEM STATEMENT

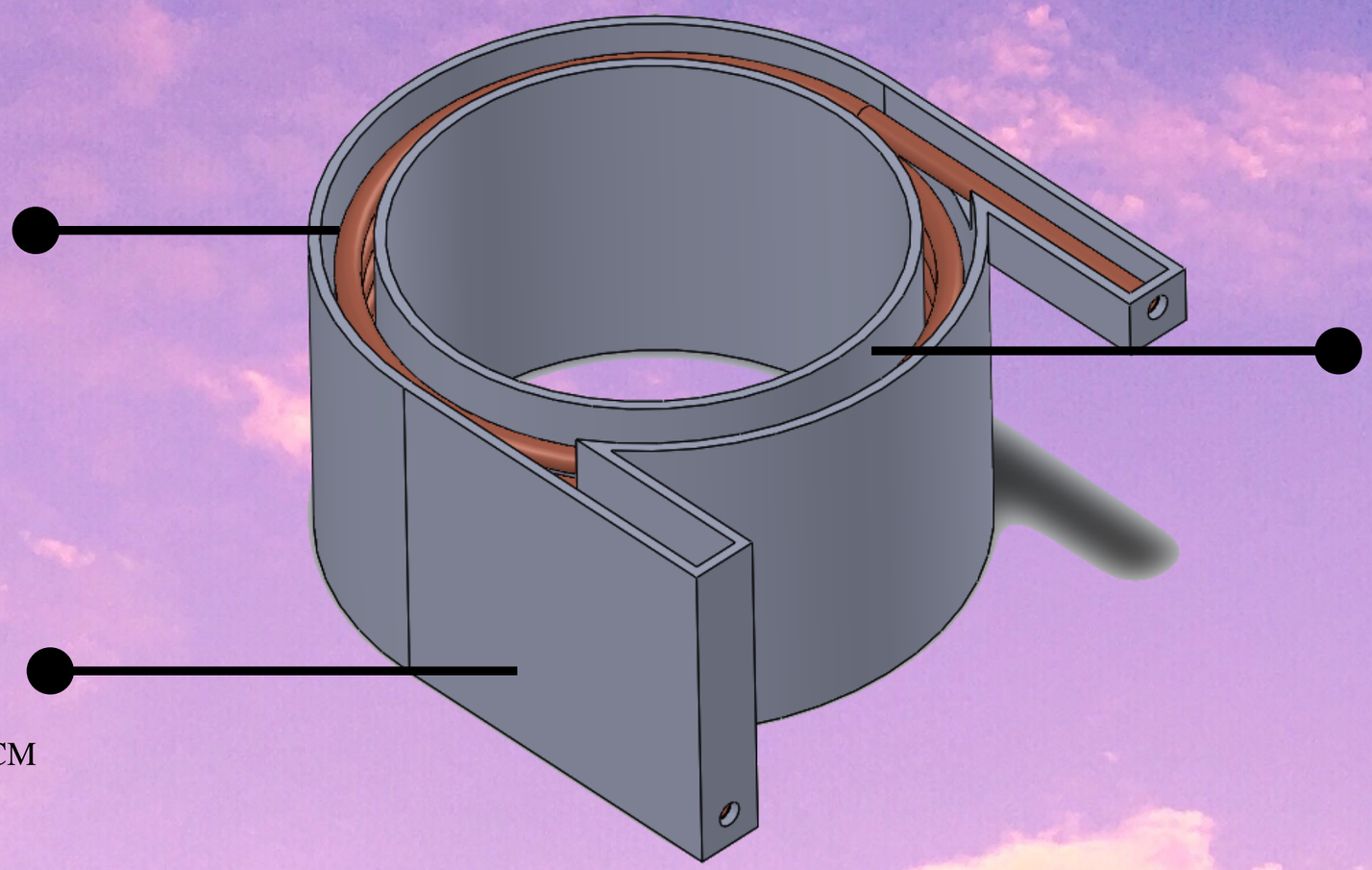
How to reduce defrosting time of frost which is formed on a heat pump during extreme winter conditions ?

Frost formed on heat pump



**Spiral coil**

- Made from copper
- Length : 12.6 m
- ID : 19 mm
- OD : 22.225 mm



**Storage Tank**

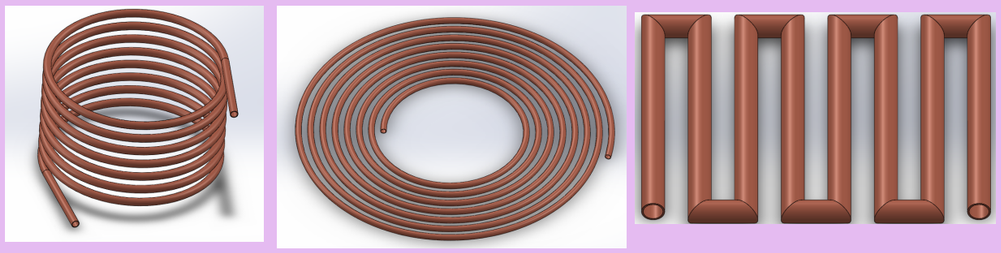
- Made from ABS
- Not corrosive to PCM

SP-31

**Phase Change Material (PCM)**

- Reliable and sustainable.
- Produced by RUBITHERM Germany.
- Inorganic components with low flammability.
- Melting area of 31-33 degree Celsius
- Heat storage capacity of 210 kJ/kg.
- Specific heat capacity of 2 kJ/kg.K
- Corrosive to metal

## DESIGN



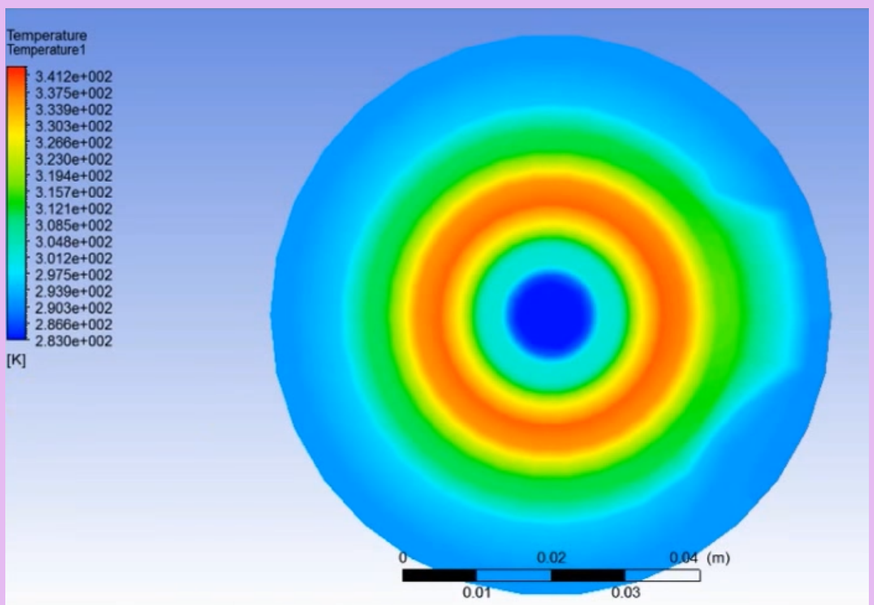
Initial Design of Coil

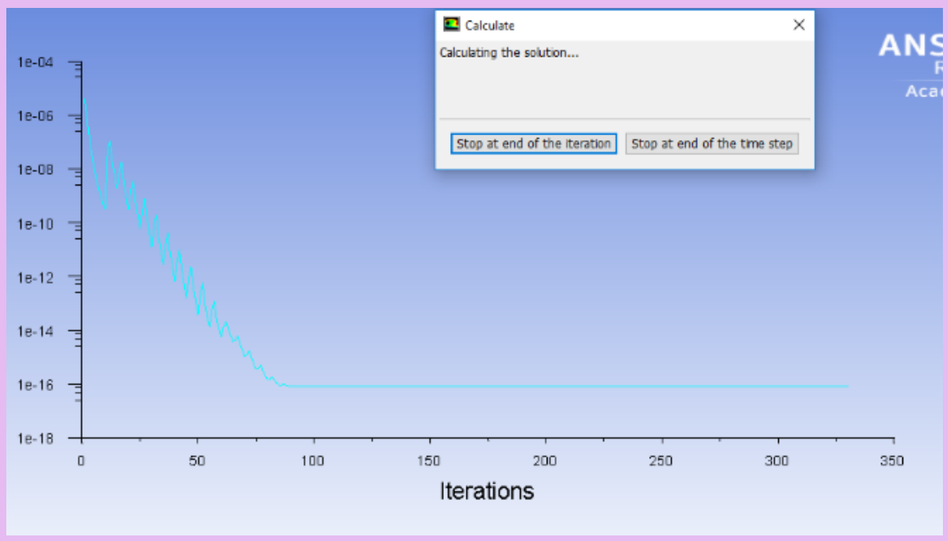
## LIMITATIONS

1. The dimension of the pipe is fixed to 7/8" diameter and 12.6 m long.
2. The space between the pipe and any boundary needs to be at least half of the outer diameter to maximize heat exchange between the copper pipe to the PCM.
3. The size of the PCM heat exchanger tank is limited as the tank needs to have a reasonable size and weight to carry and store.
4. The material of the tank cannot be made from metal.
5. The pipe cannot bend 90 degrees due to the pressure drop and it is unable to manufacture.

## ANALYSIS DATA

| | | | | |
|---|---|---|---|---|
| **If refrigerant is turbulent flow** | | | | |
| Qref= | m dot. Cp. dT | eq 1 | | |
| | | | | |
| Take Cp of liquid ref as | | 1.7 | kJ/kg.K | |
| Q ref = | 510 | kJ/hr | | |
| Q ref = | 0.142 | kW | | |
| | 141.6666( | W | | |
| q"ref = | href.(Tref-Tm) | eq 2 | | |
| | | | | |
| Nu= | 0.023*Re^0.8*Pr^0.4 | | | |
| μ = | 0.000107 | Pa.s | | |
| p= | 1100 | kg/m3 | | |
| dh=di | 0.019 | m | 19 | mm |
| v = | m dot / pA | | | |
| | 0.053417! | m/s | k= | 0.093 W/m.K |
| Re= | 10433.90! | | | |
| Pr= | 0.001955! | | | |
| Nu = | 3.11 | | | |
| href= | 15.23 | W/m2.K | | |
| q" ref | 106.6233! | W/m2 | | |
| | | | | |
| Ao = | 0.752635! | m2 | | |
| L = | 12.60 | m | | |




## RESULTS AND RECOMMENDATIONS

| Attributes | Sub-Attributes | Weightage | Spiral PCM-HE | Circular PCM-HE | Rectangular PCM-HE |
|---|---|---|---|---|---|
| Productivity | Defrost Time | 13 | 9 | 9 | 9 |
| | Heat storing Time | 12 | 9 | 9 | 9 |
| | Precision | 11 | 9 | 9 | 9 |
| Cost | Material Cost (higher better) | 10 | 7 | 8 | 5 |
| | Manufacturing Cost | 9 | 7 | 7 | 7 |
| | Maintenance Cost | 8 | 6 | 6 | 6 |
| Reliability | Ease of Maintenance | 7 | 5 | 5 | 5 |
| | Leakage | 6 | 1 | 1 | 1 |
| | Lifespan | 5 | 9 | 9 | 9 |
| | Ease of Assembly | 4 | 6 | 6 | 6 |
| Safety | Leakage of PCM | 3 | 1 | 1 | 1 |
| Sizing | Space saver | 2 | 5 | 8 | 7 |
| Environmental Impact | Lesser usage of material | 1 | 5 | 7 | 6 |
| | | **TOTAL** | 634 | 651 | 618 |

### Why use PCM Heat-Exchanger ?

- **Technologically feasible**
- **Economically viable**
- **Environmentally friendly**
- **Socially acceptable**

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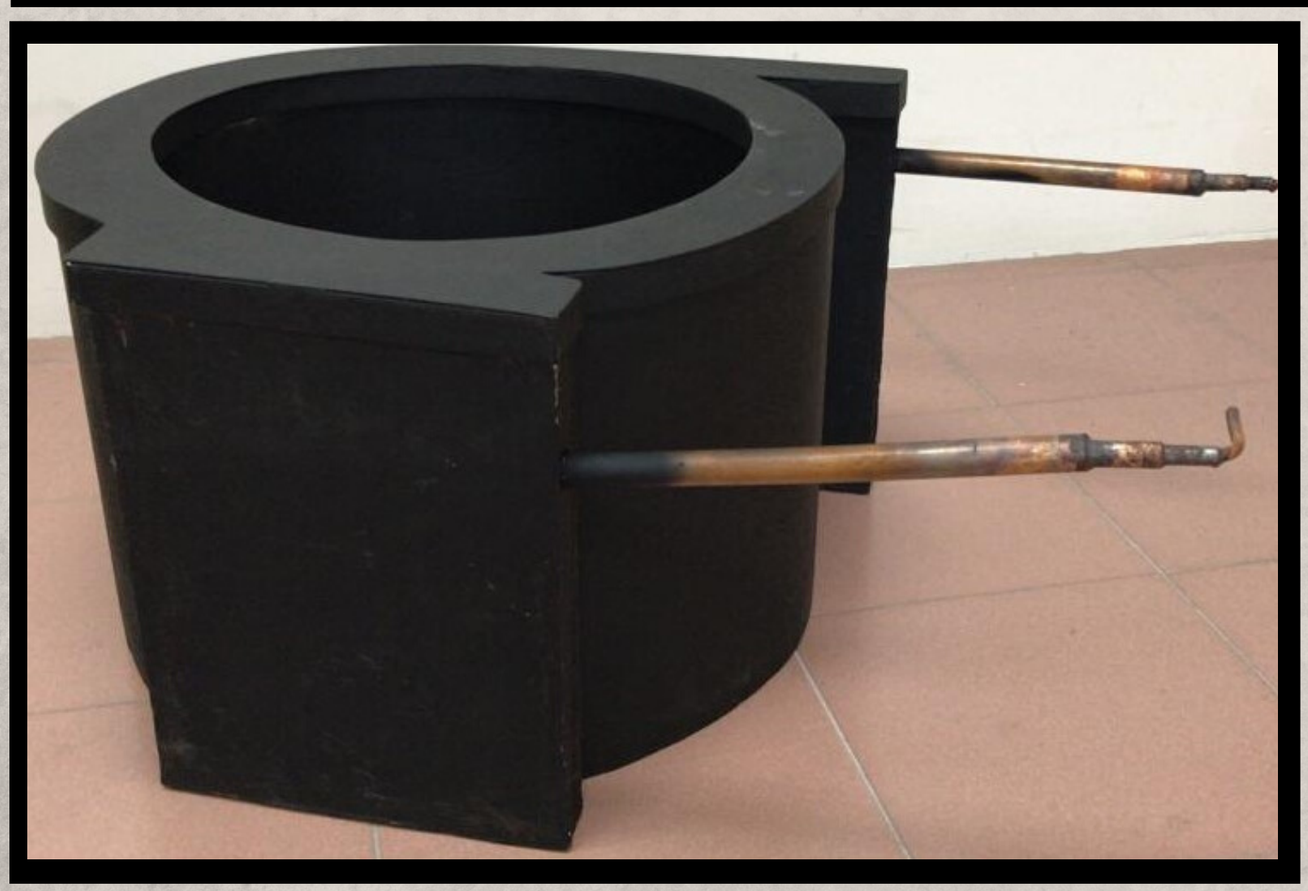

## MATERIALS USED

1. PCM (SP31)
2. Arduino Uno
3. 5V Relay
4. Solenoid Valve (SANHUA-FDF8A08)
5. Copper Pipe ( 7/8 inch OD)
6. Steel Tank
7. Temperature Sensor (DS18B20)

## PROJECT IMPACT

1. SOCIETY: Reduction of CO2 emissions by reducing fuel consumption.
2. HEALTH: Non-toxic PCM is used, and it imposes no health issues.
3. SAFETY: PCM Tank is built so that no leaks occur, PCM used has low flammability.
4. LEGAL: Does not violate any existing laws, patents, or copyrights.
5. ECONOMY: Reduces cost of energy, Increases efficiency of heat pumps
6. CULTURE: Encourages energy saving, and helps reduce dependency on non-renewable energies.

## RECOMMENDATION FOR IMPROVEMENT

1. **Improvements to the tank and piping design.**
2. **Replace Arduino with PLC.**
3. **Replace current PCM SP-31.**