TAYLOR'S UNIVERSITY
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SCHOOL OF ENGINEERING

BACHELOR OF ENGINEERING (HONOURS) MECHANICAL ENGINEERING

ASSIGNMENT PROJECT REPORT MARKING RUBRIC
ENG61603 ELECTRONICS AND MICROPROCESSOR

Area	Actual Mark
Abstract, Introduction, Figures, and Diagrams (5)	
Materials and Method (5)	
General Results and Conclusion (15)	
Discussion, English and References/ Appendix (5)	
Total (30)	

Title of Project:	**PCM Heat Exchanger**
Lecturer:	**Dr. Taghi Hajibergy**
Due Date: 29/11/2019	**Submitted Date:29/11/2019**

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MARKS BREAKDOWN ASSIGNMENT/PROJECT ENG61603 ELECTRONICS AND MICROPROCESSOR

Area	Actual Marks	Scoring Band	Criteria
Abstract, Introduction, Figures, and Diagrams		3-5	Abstract provides a concise summary of the entire report and presents upfront the major conclusion derived from the experimental/simulation investigations. Introduction shows clear objective of the experiment and provide with all the necessary background, the scientific theory behind the experiment/simulations and basic background needed to understand the experiments/simulations. Clear and completely labeled figures/diagrams of the experiment/simulation setup.
		0-2	Abstract not providing a concise summary of the entire report. Introduction states no background, scientific theory and basic background of the experiments. Figures/Diagrams and labeling of the experiment/simulation layout setup are not correct and/or unclear.
Materials and Method		3-5	Detailing of materials for experimental/simulation setup and clear explanation of the procedure needed to calibrate /set the measurements are clearly described.
		0-2	List of materials for experimental set up and procedure are not clearly described. Materials and method are copy and paste from laboratory manual.
General Results and Conclusion		11-15	All the parts of the project work according to the project agreement and complete data collection and presentation using tables/figures/ graphs with appropriate labels. Discussion of the results with prudent judgment. Have comparison of the measured results with theoretical values and citation from the peer-reviewed references.
		6-10	Some of the parts of the project works according to the project agreement and discussion shows little understanding of what the experiment/simulation is all about.
		0-5	Only few parts of the project work according to the project agreement and only restatement of the results without commenting on the expected key points. Incorrect judgment/arguments were used.
Discussion, English and References/ Appendix		3-5	State whether the aim of the experiment has been achieved or not, summarised the key features of the methods used, and summarised the most important results. Complete references to any book, articles and websites indicating in-text citations report with correct referencing format are in place.
		0-2	No sensible conclusion. Incomplete references and were presented in wrong format. No evidence, attachments, appendices are attached. Online referencing was used.
Sum			
Total mark deducted		0-1	For each day delay the total Mark will be reduced 10%. One day late the total mark X 0.9, two days late total mark X 0.8 …etc
Actual Mark			

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Signature of Lecturer

Date: ____________

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1.0 Abstract

During the early stages, the project was divided into two sections which is the PCM tank and also the electric circuit. We were required to source for manufacturers which are able to manufacture a tank according to our copper coil. This process took slightly longer than expected due to several reasons. This is because we were required to modify the initial dimensions and also refabricate the copper pipe twice. However, after much consideration which will be explained below, metal has been chosen as our tank material. The tank took around 2 weeks to be done.

As for the electric circuit, it was mainly used to control the pathway of refrigerant during heating and defrost mode. The circuit consisted of an arduino and solenoid valve which was provided by Daikin. We were able to apply the application of relay switch in our project as it helps to switch between cycles.

After the tank and electric circuit was done, testing took place at Daikin Sg. Buloh. The testing was done over the course of 3 days. Before we went over to Daikin, the mock up process was already done to integrate our tank with the existing heat pump system in the test room. After the mock up, we were able to connect our electric circuit which controls the cycle which switches two sets of solenoid valve between two cycles. After setting up, the whole system was allowed to run without PCM with two conditions to ensure that everything is running smoothly. The whole system only managed to be tested with only one standard condition with the addition of PCM due to several difficulties encountered during the testing and also insufficient of time. Nevertheless, the results obtained were sufficient to meet our objective, which was to reduce the time taken for defrost. The graphs obtained was able to show the time taken for the cycle to switch between defrost and heating.tr

2.0 Introduction

Heat pump is a common product in 4 four season countries. Heat pump has the reversed cycle of a normal air-conditioning unit, which means that the heat pump is providing warm or hot air indoor and cold air is discharged outdoors. Due to humidity and low temperature outdoor, frost is formed on the outdoor coil. The frost formed on the outdoor coil affected the overall heating performance of the heat pump which results the end-user to feel uncomfort due to instability of the warm or hot air was discharged indoors. To overcome this issue, the heat pump was designed to have a defrost cycle which was meant to reverse the heat pump cycle to normal air-conditioning cycle. During the heat pump is running the defrost cycle, heat is stop providing indoor as the heat was used to defrost the outdoor coil which leads to the end-user to feel uncomfortable. Some heat pumps were implemented with a heater which consumes electricity to defrost. The aim of the project is to resolve the problems above by implementing a Phase-Change-Materials Heat-Exchanger (PCM-HE) to shorten the defrost cycle and enhance the overall heating performance in a green way. This is because PCM-HE does not require any fuel or additional energy to defrost. The concept of the PCM-HE is to allow the heat transfer to take place in between the PCM and the refrigerant. The Phase-Change-Materials (PCM) is the main component for the Heat-Exchanger and the PCM that used in the project has a low melting point and high heat capacity. As the PCM would trap and store heat from the refrigerant in the heat pump during the heating cycle, the heat would be released by heat transfer to the refrigerant from the PCM during the defrost cycle. By doing so, it could enhance the overall heating performance and shorten the defrost time ideally.

In this project, our main objective is to implement and operate a phase change material (PCM) heat exchanger to be integrated into an existing heat pump as proposed by Daikin Malaysia. PCM was chosen as a potential replacement or improvement method for heat pumps in cold regions. In cold countries or during winter such as in Canada and the United Kingdom, or during winter in Japan and Korea, heat pumps are a common necessity. In extremely cold conditions, heat pumps are used as a method to extract heat from a region of lower temperature to a region of higher temperature and is the reverse of air conditioners. In the process of extracting heat, the outer coils on the outdoor unit experiences extremely low temperatures, and the water that condenses on the coils freeze and forms icicles and frost. The frost in turn hinders heat transfer, causing the heat pump efficiency to drop drastically.

For current heat pumps available in Daikin, supplementary heating methods are not available. when frost forms the heat pump switches into reverse cycle, one that is like an air conditioner cycle, and draws heat from the indoors to melt the frost formed on the outer coils.

The downside to this method is that the customers experience major discomfort when the reverse cycle runs, as the heat pump is no longer providing heat, and is drawing heat from an already cold indoor environment. Currently, Daikin does not have any heat pump that utilizes phase change materials (PCM) to melt frost that forms on the outer coils during winter and is planning to research into using PCM as a method of heat storage to improve the defrost cycle. Hence, our group was given the task to generate ideas and come out with the prototype.

Figure 1: Team FaiDitLah comprising of (from the left) Zhi Heng, Alwyn Yip, Jian Hua, Jia Hao and Jason Chong.

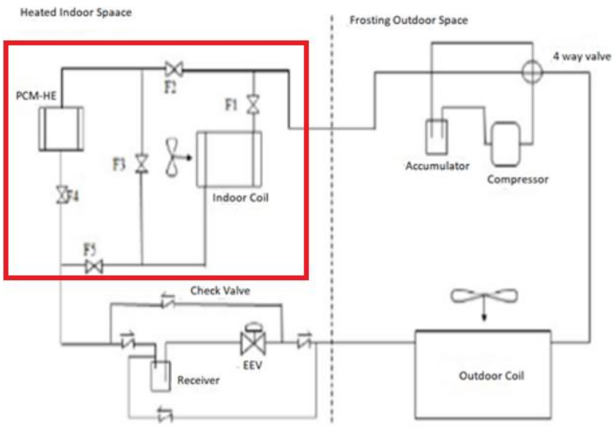

Figure 2: Circuit diagram of the whole system

3.0 Objective

- To design a phase change material (PCM) heat exchanger for reduction in defrost time of heat pump.
- To integrate the phase change material(PCM) heat exchanger into the heat pump system.
- To improve the heating efficiency of the heat pump unit under various ambient conditions with the phase change material (PCM).

4.0 Figures and Diagram

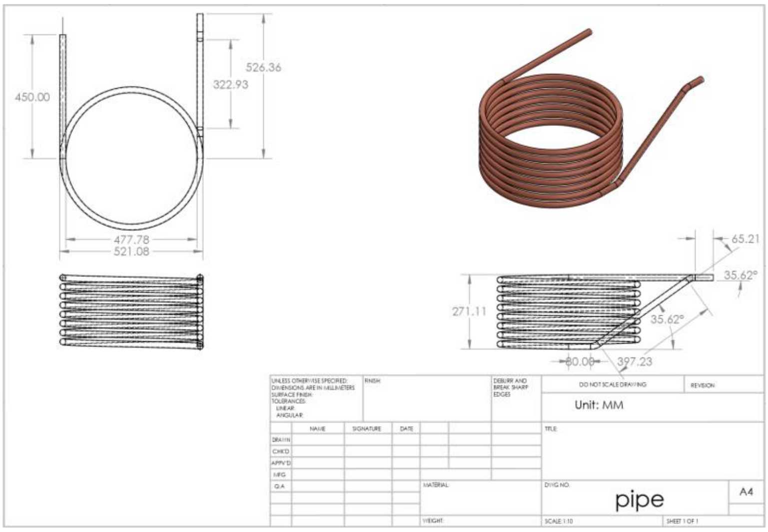

Figure 3: Schematic diagram of the copper pipe coil

Figure 4: First(left) and Second(right) fabrication of copper pipe coil

Figure 5: Support for copper pipe coil.

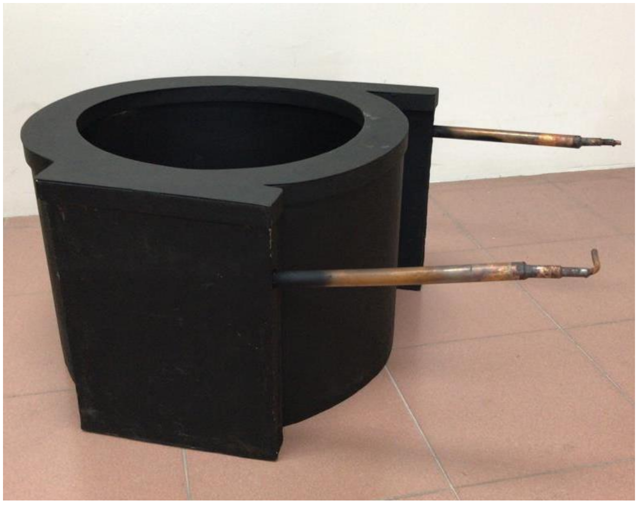

Figure 6: PCM Heat-Exchanger Tank

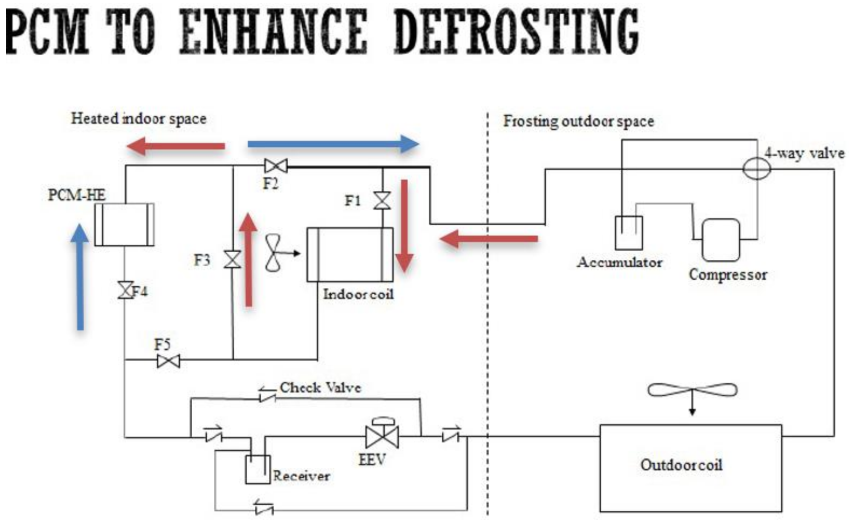

Figure 7: Pathway of the refrigerant

Figure 8: Connection of the solenoid valve

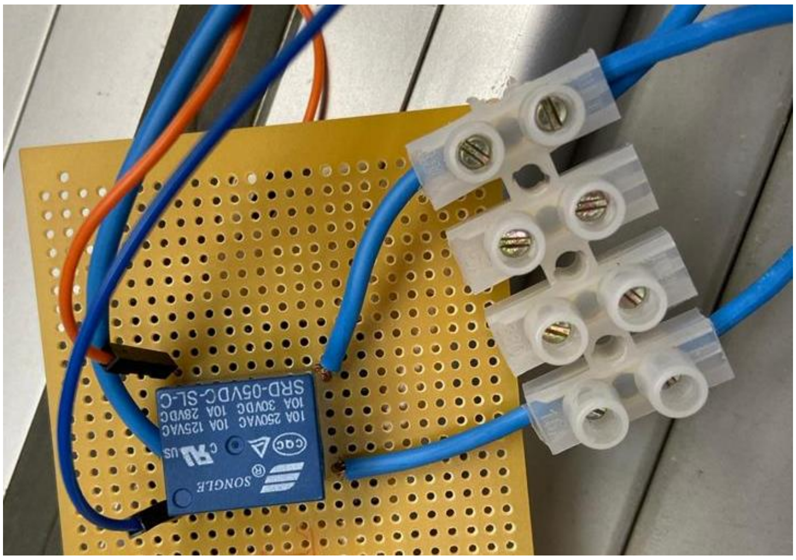

Figure 9: Connection for the relay and the valve

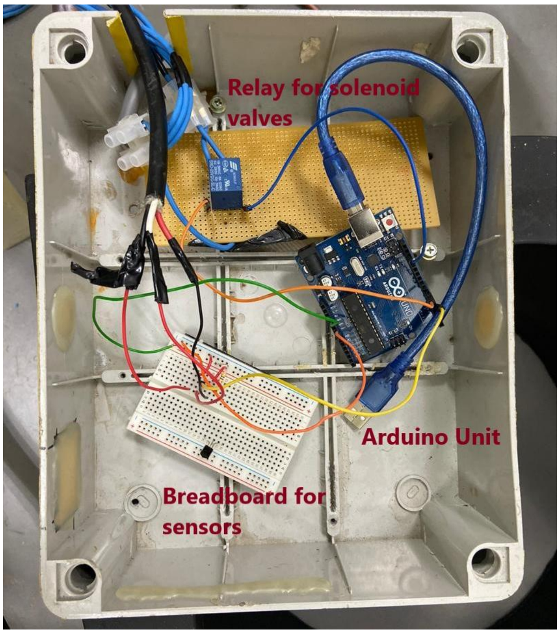

Figure 10: Container for control system

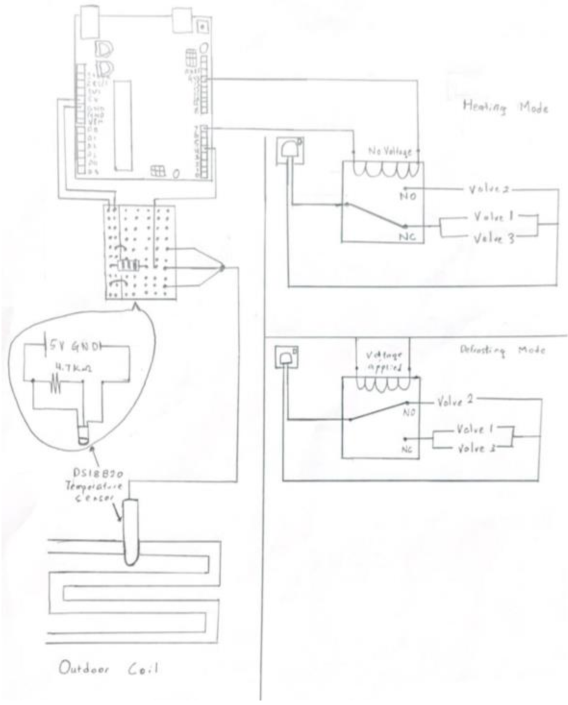

Figure 11: Circuit diagram of the control system

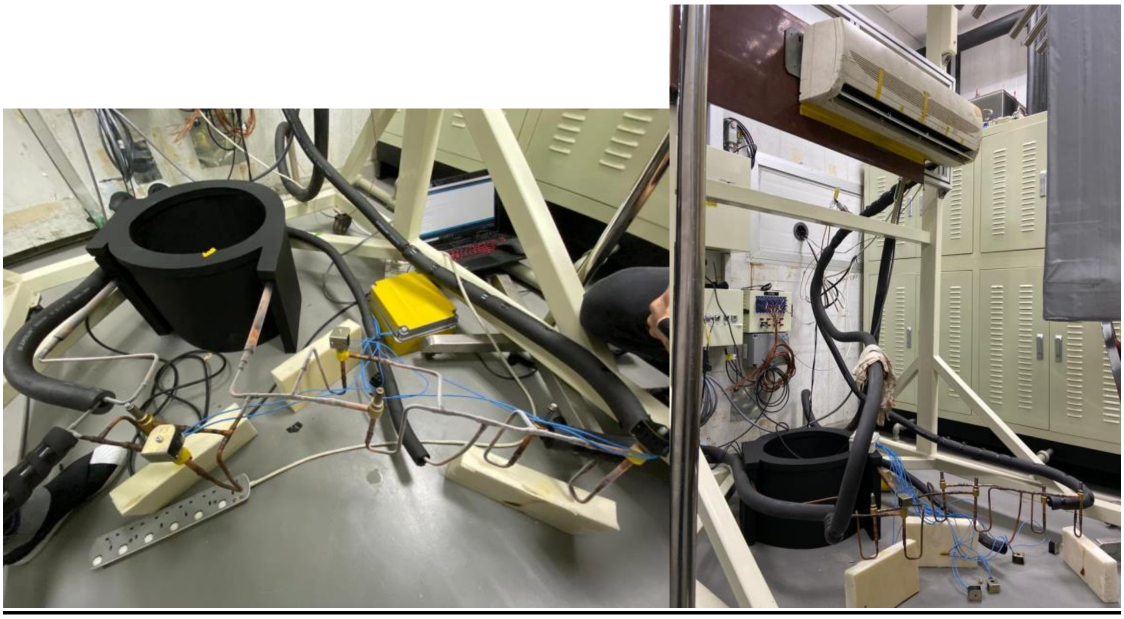

Figure 12: PCM Heat-Exchanger whole system

5.0 Materials and Methods

5.1 Materials

<u>Bill of Materials</u>

The materials used for the project were separated into two categories. Daikin Malaysia sponsored three items for the project while the rest were either purchased from reliable vendors or obtained from the electrical lab at Taylor's University.

Table 1: Bill of material for sponsored items

Materials	Unit	Total Cost (RM)	Vendor
Air conditioner	1	1200.00	Daikin Malaysia
PCM (SP31)	1	300.00	Daikin Malaysia
Solenoid valve and coil	6	210.00	Daikin Malaysia
Total	8	1710.00	Sponsored by Daikin Malaysia

Table 2: Bill of material for purchased items

Materials	Unit	Total Cost (RM)	Vendor
PCM tank	1	1900	Rajini Welding Works
PYE rust converter	1	15.3	Shopee
Temperature sensor DS18B20	1	9.3	Robotedu
Relay 5V	1	-	School Lab

Arduino Uno	1	-	School Lab
Breadboard/ PCB board	2	-	School Lab
3 Pin plug type G	1	-	School Lab
3D printed support	36	-	Printed in School Lab
Total	44	1924.60	-

Overall the grand total cost of this whole project including the sponsored item by Daikin Malaysia will be a grand total of RM 3,634.60.

Part Identification

1.0 PCM Heat-Exchanger Tank

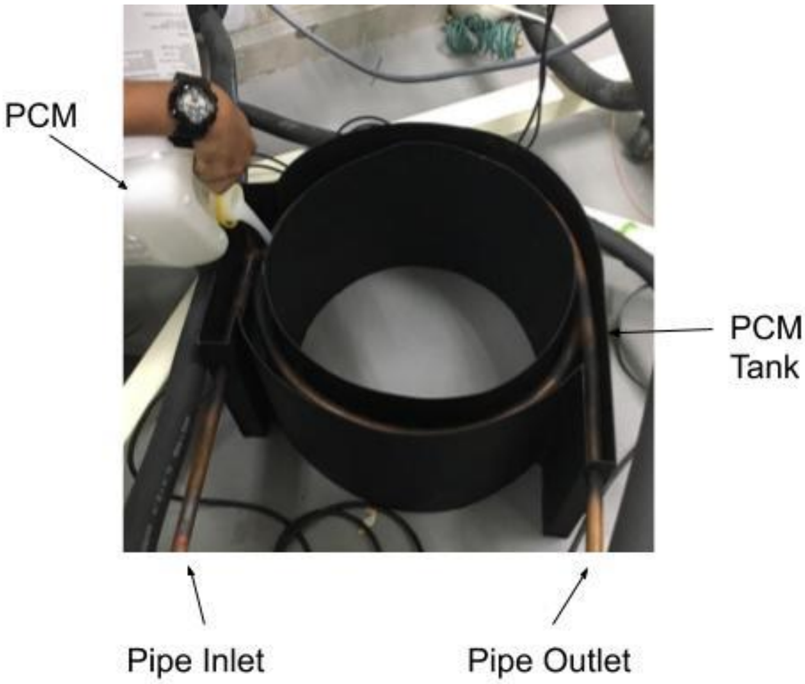

Figure 13: PCM Heat-Exchanger tank

2.0 Electrical Circuitry

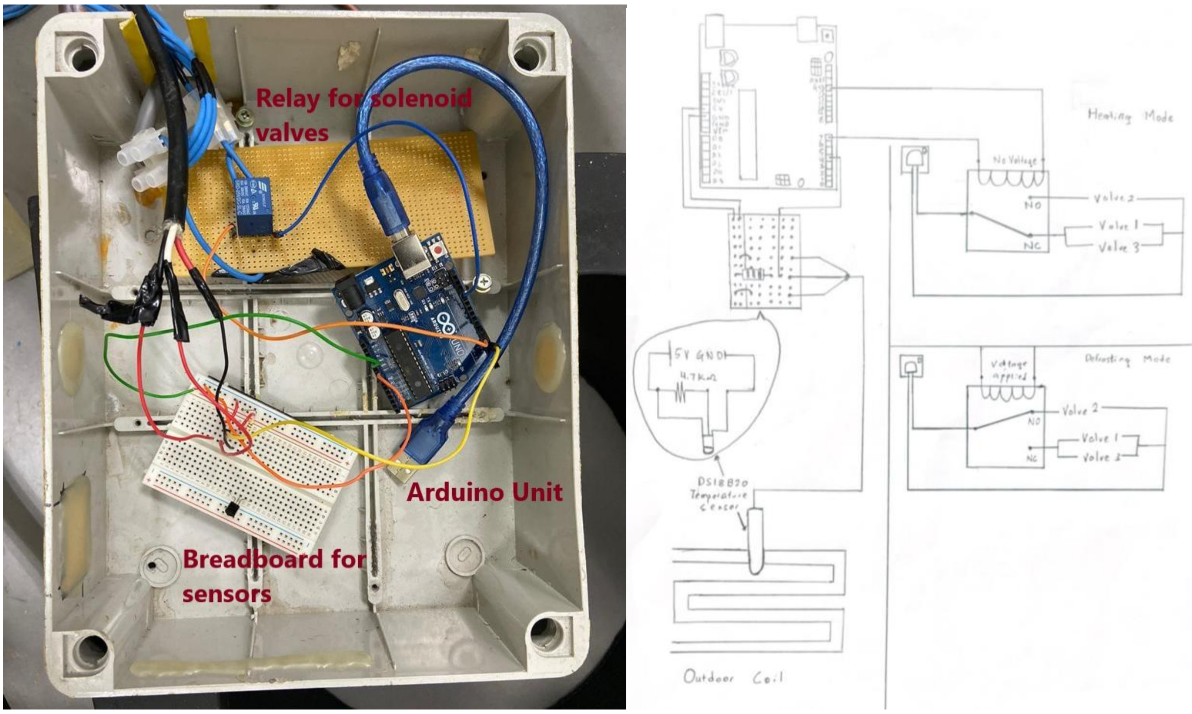

Figure 14: Electrical Circuitry

3.0 Heat Pump, Controller & Compressor Unit

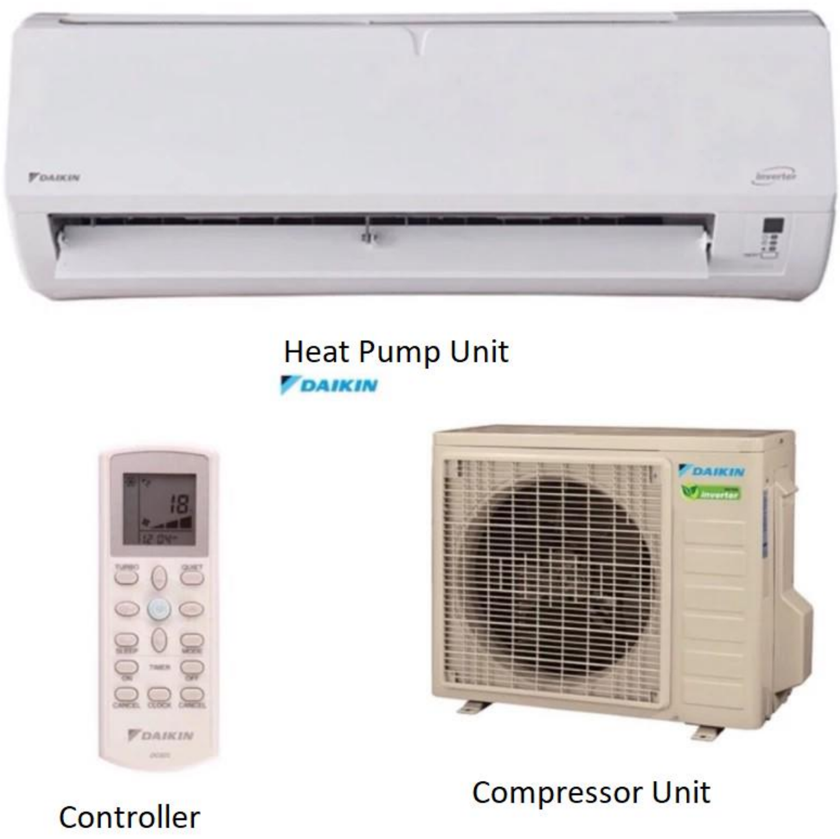

Figure 15: Heat pump, controller and compressor unit

<u>Specifications</u>

Heat Pump Unit Horsepower	: 1, 1.5, or 2 Horsepower unit.
Compressor Unit	: Horsepower according to heat pump unit.
Control Board	: Arduino Uno.
Relay Model	: SRD-05VDC-SL-C DC 5V.
Temperature sensor	: Waterproof DS18b20 Temperature Sensor Probe.
Solenoid Valve	: Sanhua FDF-A02080-008-RK.
Plug	: 3 Pin plug type G
PCM Tank Capacity	: 10 Litres.
PCM Tank Copper Pipe	: 7/8” Copper pipe for standard HVAC.
PCM Used	: Rubitherm SP-31.

5.2 Methods

Testing

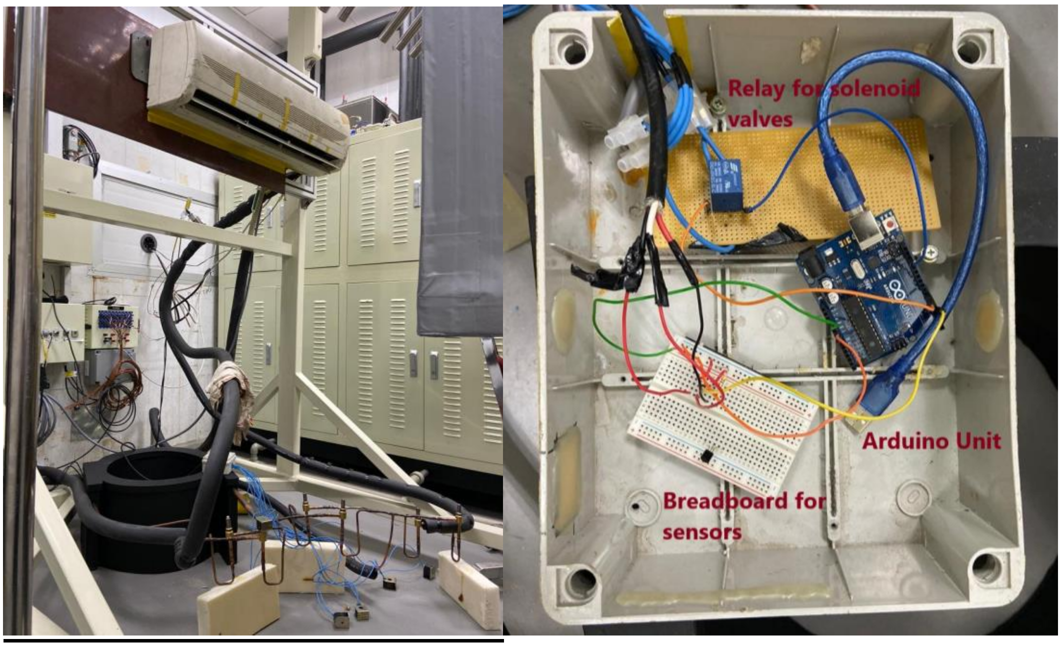

Figure 16: Complete set up of prototype

1. The prototype was brought to testing lab at Daikin Malaysia and mock up with the help of the personnel.
2. All pipe connections were checked to ensure all connections were connected properly.
3. All electrical components were placed in a junction box to prevent any short circuit.
4. The temperature sensor was attached to the coil of the outdoor unit
5. A test run was done to ensure the entire prototype was functioning accordingly and no leakage occurs.
6. All results obtained were tabulated.
7. PCM was melted and filled into the PCM tank.
8. The prototype was set to run at the given testing condition.
9. All results obtained were tabulated

Caution

1. Please consult a certified professional to install a standard heat pump unit, and for the modification of heat pump unit piping for installation of the PCM heat exchanger.
2. Do not attempt to install, weld, or make any piping modification without the consultation of a professional.
3. Do not continue using the PCM Heat exchanger if there are any leaks or abnormalities during operation.
4. If there are any leaks or abnormalities, please contact your manufacturer or professional engineer.
5. Before first time usage, ensure all required tests have been done to ensure the heat pump is able to run smoothly.
6. After test runs are done, add PCM into the PCM Tank.

7. For PCM Rubitherm SP-31, allow PCM to liquify properly for an hour before filling into the PCM Tank.
8. Properly ensure that the electrical circuitry is covered in a power box after installation, and kept or placed at a safe location.
9. The PCM Tank is meant for enhancing the efficiency of the heat pump unit, do not attempt to use it for other purposes.
10. PCM in the tank is non-toxic, but keep children away to prevent unwanted exposure or ingestion.

Cleaning and maintenance of the PCM Tank and Heat Pump

1. For the heat pump unit, follow standard heat pump cleaning and maintenance procedure provided by heat pump manufacturer.
2. For cleaning and maintenance of PCM Tank, open the cover of the PCM tank and drain existing PCM. Then, use water to fill the tank and wait for an hour. Finally, drain the water and allow the PCM Tank to dry before adding new PCM, and closing the cover.
3. Only use water and no cleaning agents such as detergents or dishwashing liquids to prevent rusting or the wearing of the anti-rust coating inside.
4. Ensure that the PCM Tank cover is properly closed to prevent contaminants from entering the tank.
5. Ensure that the heat pump is off during maintenance and cleaning process.
6. In case of faults in the circuitry, contact a professional for maintenance or repairs. Ensure that the power box is connected to a power source afterwards.

Usage Instructions

1. On first use, turn on your heat pump power supply, and switch on the heat pump using your controller.
2. Next, turn on the power supply for the PCM heat exchanger.
3. The heat exchanger will work automatically when frost forms on the outer coils.

6.0 Results and Discussion

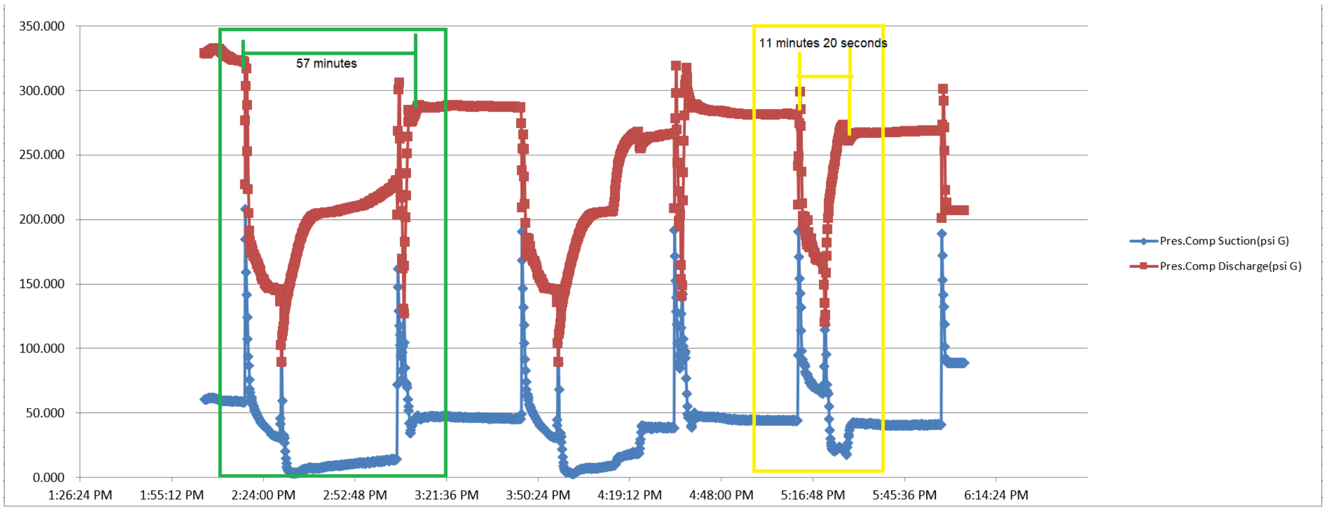

Figure 17: Pressure against time graph

The graph above was generated by the computer software in DAIKIN test room. The team was proposed to run testing under 5 different conditions of outdoor Dry-Bulb temperature which were 5°C, 0°C, -5°C, -10°C and -15°C. Due to the heat-pump unit was broke down and insufficient of time, the team could run the testing with one standard condition which was Dry-Bulb temperature 7°C. The graph was generated according to the testing results from the prototype at the standard condition. The green area indicated the time taken to defrost the frost that formed on the outdoor coil and it took 57 minutes to complete the defrost cycle without PCM. Whereas the yellow area indicated the time taken to defrost the frost that formed on the outdoor coil and it took 11 minutes and 20 seconds to complete the defrost cycle with PCM. On top of it, the copper coil and the tank weren't fabricated nicely and according to the desired dimensions, therefore, the required actual volume was greater than the desired volume. So, this prototype did not fill fully with PCM. Based on the result graph, it shows that the time was shortened by roughly 80% of time to defrost the frost that formed on the outdoor coil when the unit was added with PCM.

Furthermore, our prototype is an additional part that was attached into the existing heat-pump unit as mentioned earlier. The heat-pump unit has its own complete system and one of the challenges for the project is to make sure our prototype is synchronise to the system of the existing heat-pump unit. The main component must be synchronise with the heat pump unit would be the solenoid valve used in the project. As the solenoid valve must be switched on or off automatically and synchronise with the heat pump unit at the same time, otherwise the project will be failed and the heat pump unit couldn't be run. This is because the heat pump unit has two cycles to run. When the cycle changed, the refrigerant in the heat pump would flow reversely. For our prototype, the team must generate two different paths for the refrigerant to flow when the cycle changed. The result graph shown above was generated by the heat pump unit with attached of our prototype. Hence, it proved that our project is succeed as the heat pump unit could run and generate the results.

7.0 Conclusion and Recommendations

The first recommendation for improvement that can be made is the improvement to the tank, in terms of overall design, type of material, ease of maintenance, and future easing of manufacture. In terms of overall design, the PCM tank has myriads of room for improvement. The shape of the PCM tank can be redesigned to be more easily moulded, and a drainage pipe with a cap can be added to allow easy maintenance, and built in brackets can be added to hold the copper pipe in place. The PCM tank,is current using steel as material, and it can be changed into plastic to decrease the overall weight of the PCM tank, as well as prevent the possibility of rusting. Currently, the main reason why the PCM tank cannot be manufactured using plastics is because of the size of our design that do not allow 3D printing. In the future, further research can be done by using newly designed models, and research into rapid prototyping is recommended to produce a future prototype in plastics instead of steel. As for taking the product into mass production, injection moulding can be considered as the PCM tank has a fixed design with a complicated shape.

Another possible improvement is to improve the coil copper pipe used in the PCM tank. Currently, due to the thickness of the pipe used, there was difficulty in bending the pipes into the desired shape according to our design. The use of a spiral bender that is currently in the industry would solve this problem, and allow the pipes to be bent into the exact required dimensions. Also, it is possible to change the design of the piping into an entirely new design to replace the current spiral coil design. This would require additional research, and hopefully it will result in a more compact and efficient design in the future, such as a spherical shape or a flat plate shape.

An improvement to the circuitry is also possible, by simply replacing the Arduino Uno unit used with a specialized Programmable Logic Controller (PLC) unit. PLC units are desirable because they are more reliable, responsive, and accurate compared to Arduino units in terms of long term usage, and also they are able to handle a high voltage of 240V from household sockets. The ability to handle 240V from sockets also removes the need of using a relay, as arduino units cannot handle high voltages. This allows for the PLC unit to directly control individual solenoid valves, unlike Arduino units that can only control two predetermined sets of valves. This makes PLC units a pre-programmable, easy maintenance, flexible and cost effective control system.

Replacement of the currently used PCM into a better one is also a means of improvement. From the specs sheet and information provided by Rubitherm, the manufacturer company of the PCM SP-31, it can be seen that the thermal conductivity and thermal storage capacity of the SP-31 is somewhat low when compared to other PCMs available in the market. Also, PCM can be designed as it is a man made material. The design or discovery of a PCM with higher thermal storage capacity and thermal conductivity would improve the efficiency of the PCM heat exchanger. Also, the switch to a non-corrosive PCM would widen the range of materials available for use of manufacture of PCM Tank. Also, if the improved PCM is more easily available than the current SP-31, it would be desirable.

As the PCM tank is a heat storage, heat loss is a factor that needs to be considered. The heat loss from the PCM tank can be reduced by applying insulation, such as using a layer of insulation foam on the outside of the tank. Reducing heat loss would increase the total heat transferred to the refrigerant during defrost cycle, and contributes to the increment of efficiency of the heat pump.

In conclusion, the team was able to achieve all the required deliverables of the project, and obtain test results during testing at the Daikin Test Lab. Results obtained shows that the implementation of PCM heat exchanger improves the defrost time, and thus successfully shows that integration of PCM heat exchanger is beneficial, but requires more research and optimization. Also,the PCM heat exchanger benefits society and solve multiple issues, and more research should be done as a step forward into a future with eco-friendly technology such as PCM.

8.0 References

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9.0 Appendix

```
#include <OneWire.h>
#include <DallasTemperature.h>
int Relay = 7;
// Data wire is connected to the Arduino digital pin 4
#define ONE_WIRE_BUS 4
// Setup a oneWire instance to communicate with any OneWire devices
OneWire oneWire(ONE_WIRE_BUS);
// Pass our oneWire reference to Dallas Temperature sensor
DallasTemperature sensors(&oneWire);
unsigned long counter = 0;

void setup(void)
{
  // Start serial communication for debugging purposes
  Serial.begin(9600);
  // Start up the library
  sensors.begin();
  pinMode(Relay, OUTPUT);
}

void loop(void){
  // Call sensors.requestTemperatures() to issue a global temperature and Requests to all devices on
the bus
  sensors.requestTemperatures();
  Serial.print("Celsius temperature: ");
  // Why "byIndex"? You can have more than one IC on the same bus. 0 refers to the first IC on the
wire
  Serial.print(sensors.getTempCByIndex(0));
  Serial.print(" - Fahrenheit temperature: ");
  Serial.println(sensors.getTempFByIndex(0));
  delay(1000);

  if (sensors.getTempCByIndex(0) > 5){
    counter++;
  }
  else if (sensors.getTempCByIndex(0) < 0){
    counter = 0;
  }

  if(counter > 75){
    digitalWrite(Relay,LOW);
  }else{
    digitalWrite(Relay,HIGH);
  }

}
```