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**Natural Volatiles &
Essential Oils**

Evaluating COP and setting up LM35 temperature sensors for portable air conditioner

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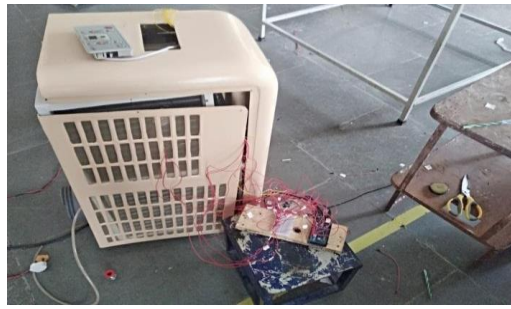
Abstract

The refrigerant has the capacity to work on very low temperatures which is very much flexible to change its physical state. The refrigerant that is being used is generally R22 in several air conditioning systems and also in portable Air conditioner manufactured at AKELLA systems, after Kyoto protocol on 11th December 1997 it came to a conclusion that the refrigerant R22 has to be banned till 2020 since it is very much polluting the ozone and one of the main reasons for depletion of this layer. The most feasible solution used for the refrigeration industry was R134a refrigerant. The refrigerant was tested in the system of portable air conditioners. The temperature was found out using an Arduino microcontroller and LM35 temperature sensors. Finally, the temperature was found out at all the points and recorded in a tabular column. Then the temperatures recorded at the systems are analyzed in software called cool pack and graph is plotted. The COP is found out and further steps are taken to improve the efficiency of the system.

Introduction

Temperature is the measurement that gives the reason whether the body is hot or cold. Usually, temperature is measured using the devices known as thermometer and even the other devices such as thermistors, thermocouples [1]. Thermistors are generally used for measuring a temperature in a defined way with a microcontroller. But the main problem faced over here is calibration. LM35 temperature outputs analog voltage signal as these work on the semiconductor principle which is a measure of index for temperature and how it is changing is judged accurately[2]. The output impedance or the voltage generated is directly proportional to the centigrade temperature [3]. Unlike the temperature sensors which are dependent on linear impedances as it should be adjusted by using stein heart equation [4]. The LM35 temperature sensors consist of three pins they are voltage analog and ground which are setup to the microcontroller at that particular positions [5]. The micro controller like Arduino has several analog pins and 5V pins attached to it also it can take up several digital connections. This microcontroller has an openly developed interface (opensource) and they can be easily programmed using some logics od coding [6]. Arduino is used by everyone as this is an economically trouble free and simple for students [6]. The Arduino 2560(mega) is generally used for accessing more analogue values. Nearly it can provide readings of 16 values[7]. The measurement of temperature for LM35 sensor is done by mapping the values of temperature with voltage. When a graph is plotted between temperature and voltage then it would be a straight line. PLX daq is a software developed by parallax.inc that reads the temperature in to excel. This software is special kind for Arduino which is helpful in acquiring and recording the data from microcontroller[8]. The acquired data is utilised for further calculations and plotting the points in the cycle of refrigeration. The principle of refrigeration follows the second law of thermodynamics where the work is done on the fluid with the help of a compressor and expanded with an expansion device like a capillary tube to provide cooling effect[9]. Finding the temperature will be an initiation to calculate the coefficient of performance (COP). The COP can be measured by using a graph plotting software called cool pack [10]. R22 the working fluid was being used as a refrigerant since 1930 and in the succession years it came to a conclusion that the ozone depletion is happening because of the CFC's that are present in this refrigerant [11]. Later it came to a

conclusion that this refrigerant should be banned and not used completely from 2021 onwards in Montreal protocol [12]. Then R134a with optimum reduction of "Ozone Depletion Property" was introduced with a minimum GWP in 1980's [13].

Basic Setup Procedure Temperature Sensor Fabrication and Setup

Temperature Sensor

The area at which heat transfer takes place in a portable air conditioner is where the sensors are placed and temperature is to be determined. As

temperature in certain areas keep varying, Lm35 resistance keeps changing and the resistance change varies the temperature indication in output.

Calibration of lm35

Semiconductor sensor(lm35) is calibrated with thermometer. To the system all the probes are fitted and the system is run for a time period and temperatures shown by the LM35 temperature sensors are taken in the computer and using mercury thermometer temperatures of area at which probes are placed is recorded. Variations of the LM35 sensor with that of the thermometer is observed by plotting a graph between the scientific value and known instrument(thermometer) value. The variation is observed, error and error percentage can be determined by calculations.

Figure.1 calibration graph between thermometer and LM35 sensor

The above graph depicts the deviation of lm35 with that of thermometer and can be inferred that there is slight variation of lm35 with that of instrument value. This slight deviation can be neglected and thus the sensor is calibrated.

Setup of Sensor

Microcontroller, namely Arduino, is used for functioning of sensors. C Program language is used for programming Arduino in order to get the data from the system. The output data can be seen in the serial monitor in computer or laptop; however, the data viewed is not recorded as it is temporary. To avoid this problem software namely Plx-daq is used where the data is automatically recorded in the excel sheet by the computer itself.

The circuit for the sensor is designed using the application like Circuito.io.The wiring for the sensor is done as per the circuit using single core wire. The wire is soldered to the terminals of the sensor and heat shrink is placed to each of the terminals to avoid the grounding of the sensor.

Figure 3. Connection layout with Arduino to temperature sensors
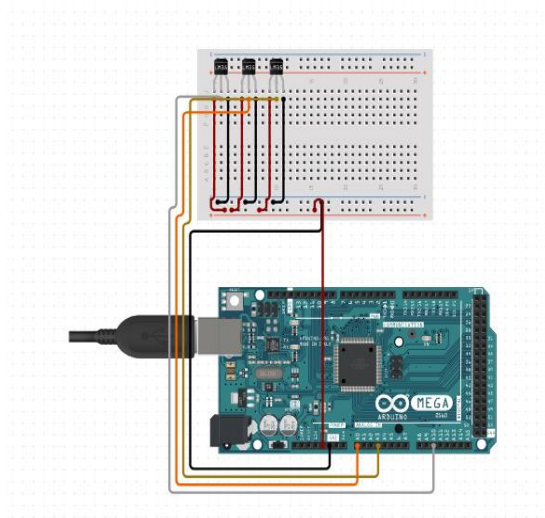
Setup of temperature across the portable air conditioner and assembling processes

Assembling of portable AC

Step 1: Selection of material

In this step suitable tonnage of compressor is selected as per the requirement and in this AC, we selected 1ton compressor. Moreover, both the condenser and evaporator are selected and here we used 3row fin type evaporator and 4 row fin type condensers.

Copper tubes of required diameters are used for the joining of condenser, compressor and evaporator. Frame made of fibre, blower casing and blower made of plastic are selected.

Step 2: Making of Expansion valve

A copper tube of 1/8" inch and required length (say 50mm) is selected. The copper tube is coiled to form a capillary tube. Capillary is a tube with small internal diameter and could be coiled for part of its length. It is installed to the suction line. A strainer is fitted before the tube to remove dirt or moisture from the refrigerant.

Step 3: Fitting of parts on the frame

Parts like Compressor, Condenser, Evaporator are placed on the frame. These parts are connected by copper tubes with the help brazing process. Compressor-out is connected to the condenser-in known as discharge line. Condenser-out is connected to the strainer which is further connected to the capillary tube-in (expansion device) known as liquid line. Capillary tube out is connected to the evaporator-in. Evaporator-out is connected to the compressor-in known as suction line.

Step 4: Leak Test

After connection of the parts with copper tubes the tubes are filled with nitrogen gas. By soap and bubble methodology, soap solution froth is applied on the joints of the tubes. If there are any leaks the froth gives us bubbles, if not there is no leak. All the flare nuts are tightened to avoid leak of gas and is approved if the pressure of nitrogen in tubes remains constant for a long time.

Step 5: Attachment of blowers and Electrical wiring

The blower casings and blowers are attached to the evaporator and condenser in opposite direction. The cool air is circulated by the blower attached to the evaporator on top of frame whereas the hot air is exhausted by the blower attached to the condenser at bottom of frame.

Electrical wiring is done by giving wiring and capacitor connection to the compressor and controller board.

Step 6: Gas charge

The nitrogen in tubes is released into atmosphere and tubes are vacuumed with the help of   vacuum pump. Now the refrigerant R134a is filled in the tubes up to certain suction and discharge pressures.

Step7: Final assembly and Trial run

Finally, the body is closed with front and back frames, hose pipe is attached to the exhaust side and controller is attached on top of the body. The portable AC undergoes trial run and is observed whether the suction and discharge pressures are within range and cooling effect is observed.

Schematic representation of temperature measuring areas

The below is a schematic representation of a portable air conditioner where temperatures of the air conditioner are measured using lm35 sensors during its testing.

1. T1, T2,T3 are the temperatures measured near the compressor. T1 is suction temperature where suction line is the line from evaporator out to compressor in. The refrigerant is sucked by the compressor to increase the pressure. T2 is the discharge temperature where the discharge line is from the compressor out to the condenser. The pressurized refrigerant is discharged by the compressor in this line. T3 is the liquid line where the line is from the condenser out to the expansion valve.

2. T4 is the temperature measured in the condenser to determine the heat transfer.

3. T5 is the temperature of the hot air from the condenser blower.

4. T6 is the temperature of the refrigerant on the coils of the capillary tube.

5. T7, T8, T9 are the temperatures measured in the evaporator. T7 is the evaporator inlet temperature, T8 is the temperature of gas in the middle/ coils of the evaporator, T9 is the evaporator out temperature.

6. T10 is the temperature of cool air out from the air conditioner from the evaporator blower.

7. T11 is the temperature of atmospheric air entering the fins of the evaporator.

8. T12 is the ambient air temperature.

Figure 5. Arrangement of sensors
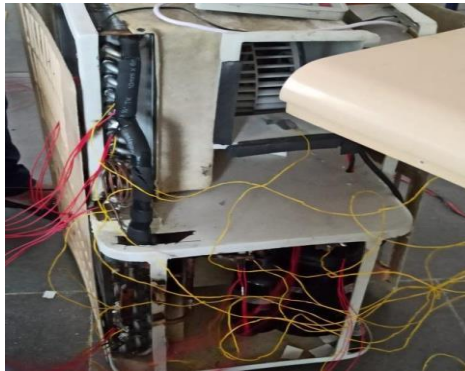
Figure 6. placing of LM35 sensors
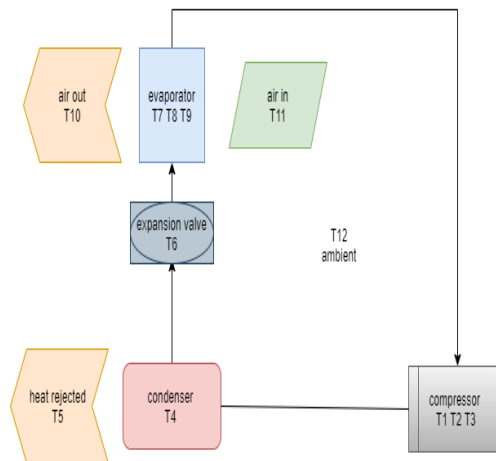
Plotting of the thermodynamic cycle in cool pack software

Physical relation of thermodynamic cycle

The VCRS (vapour compression refrigeration cycle) proceeds in four processes i.e., adiabatic compression, heat rejection at constant temperature, isenthalpic expansion and constant temperature heat absorption.

The processes involved are:

VCRS has the basic working progresses on four systems and these are the following working processes:

Step 1: The compressor absorbs a charge from the suction side to outlet (the fluid coming from the evaporator to condenser) or drains out.

Step 2: The refrigerant will be flown through the evaporator causing a cooling effect through a throttling device

Step 3: The pressure and temperature will increase because of the heat exchanged from the system these phenomena will be happening in the compressor.

Step 4: The heat exchanged from the system is passed through the condenser and heat is rejected to the surroundings from the system

The whole representation is shown in the below figure

Figure 7. VCRS cycle in P-h diagram
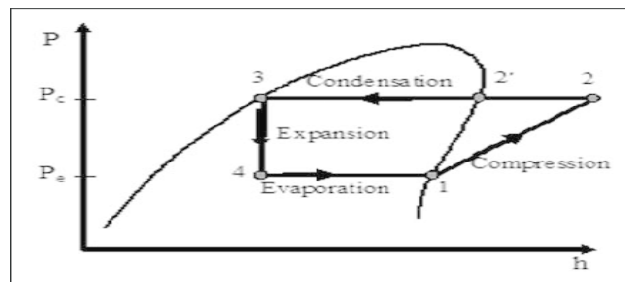
Using the cool pack software

The condensing and evaporating temperatures are given as input and the whole cycle is calculated by the software the parameters like enthalpy are being generated by applying the two parameters. The temperatures obtained during the testing process are given as input in the software. The Cool Pack uses the temperature values and plots the graph between pressure and enthalpy. Below is the obtained graph by recorded temperature values and can be compared with the ideal process graph.

To find the COP of the system refrigerating effect and work by the compressor must be determined from the above graph. It can be inferred from the graph that the bottom horizontal line is the refrigerating effect given by the evaporator and the inclination line to the right is the work done by the compressor. By dividing the refrigerating effect with work done we can find the COP of mobile air conditioner.

Observations are recorded in the table and the control points in the graph of the pH diagram the input temperature recorded by the sensor for condenser and evaporator is 17.2 and 63.3^{0}CThe above is the plot of the P-h graph that is plotted with the above temperatures taken into consideration. The graph below are the parameters such as specific enthalpy specific entropy and specific volume and pressures.

Figure 8. P-H diagram of the processes in portable air conditioner
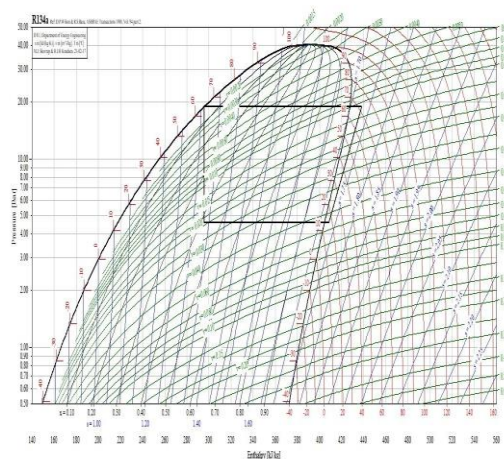
Calculations

Table values obtained from calculations

S.no	Temperature (°C)	Pressure (bar)	Specific enthalpy (kJ/kg)	Specific volume (m*3/kg)	Specific entropy (kJ/kg-K)
1	17.2	4.580	408.70	0.0456	1.730
2	73.113	18.847	439.17	0.0184	1.733
3	63.399	18.847	293.35	Subcooled region	1.302
4	13.109	4.580	293.01	0.0297	1.326(dryness fraction 0.403)

The temperature readings are recorded in the tabular form considering the extreme right corner point of the graph plotted the other parameters like enthalpy entropy and specific volume are noted down and COP is calculated manually and by the software. All the parameters are discussed in the results and conclusions below.

Conclusions

The LM35 calibration test has been passed successfully and graph was plotted which gave a minute deviation with a standard thermometer (refer fig.1).

All the thermodynamic processes were suited well with the plot of P-H diagram. It gave the below results

Te [°C]   =   13.10°C

Tc [°C]   =   65.40°C

DT subcooling [K]   =   2.00K

DT superheat [K]   =   4.10K

Calculated:

Qe [kJ/kg]   =   115.631 kJ/kg

Qc [kJ/kg]   =   145.439 kJ/kg

W [kJ/kg]   =   29.808 kJ/kg

COP [-]   =   3.88

Pressure ratio [-]   =   4.152

The above parameters were calculated from the software and the COP was found to be 3.8.

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