Improving Heat Transfer Efficiency for Condenser by Changing Tube and Fin Material in Window AC

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Abstract - The main objective is to develop and utilize the high efficient heat transfer of an AC condenser. In system involving heat transfer, A condenser is a device or unit used to condense a substance from its gases to its liquid state, typically by cooling it.

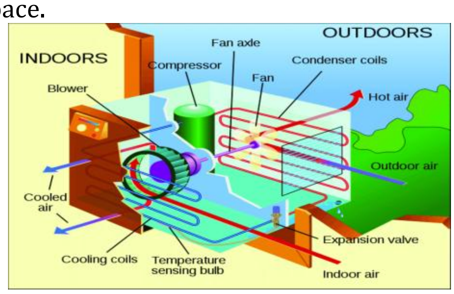
Latent heat is given up by the substance, and will transfer to the condenser coolant. The assessment is carried out on air-cooled finned tube condenser of a vapor compression cycle for air conditioning system. Heat transfer analysis will be carried out in condenser to evaluate the material and refrigerant. The material considered for tubes are copper and for fins are alluminium alloy.

Key Words: Heat Transfer, Condenser, Copper C11000, Condenser Tube, Coefficient of Performance, Air Conditioning System.

1. INTRODUCTION

An air conditioner is a home appliance, system, or mechanism designed to dehumidified and extract heat from an area. Its purpose, in a building or an automobile, is to provide comfort during either hot or cold weather. In the refrigeration cycle, a heat pump transfers heat from a lower-temperature heat source in to a higher temperature heat sink. Heat would naturally flow in the opposite direction.

In the refrigeration cycle there is a condenser which is located outside of the cooled compartment, where the refrigerant vapor is compressed and forced through the another heat exchange coil, condensing the refrigerant into liquid, thus rejecting the heat previously absorbed from cooled space.



An air conditioner (AC) in a room or a car works by collecting hot air from a given space, processing it to release cool air into the same space where the hot air had originally been collected. This processing is primarily done using five components:

- Evaporator
- Compressor
- Condenser
- Expansion valve
- Refrigerant

The warm air is drawn through a grille at the base of the indoor unit, which then flows over some pipes through which the refrigerant is flowing. The refrigerant liquid absorbs the heat and becomes a hot gas itself. This is how heat is removed from the air that falls on the evaporator coils.

This hot refrigerant gas is then passed on to the compressor where temperature of gas is increases then it travels to the third component condenser temperature of refrigerants is decrease. Then heat travel into the expansion valve where pressure of refrigerant is decrease and then it enters to the indoor unit evaporator again.

1.1 History:

In 1935, Otto Happel in co- operation meet with the engineer Dr. Kurt Lang, for start developing air cooled condenser for stationary steam turbines.

The earliest laboratory condenser, a “Gegenstrom Kuhelar” was invented in 1771 by the Swedish-Germen chemist Christian Weigel.

At mid 19th century Germen chemist Justeen Von Liebig would provide his own improvements on the preceding design of Weigel and Johann Freidrich and August Gottling with the device becoming known as the Liebig condenser.

1.2 Problem Statement:

Now a days the A.C. used the material for condenser tube is copper or alluminium, mostly the copper is used as a tube material but the copper used is having low thermal conductivity.

So, to increase the heat transfer rate the copper material must have higher thermal conductivity. To overcome this problem we have selected a copper material C11000 which is having highest thermal conductivity in the entire copper alloy. So, the heat transfer rate can be increase.

1.3 Objectives

- The main objective of the project is to change the material of condenser tube for better efficiency.
- To improve heat transfer rate of A.C. condenser by changing tube material and fin material.
- The copper material will be replaced by Copper alloy (C11000).
- The tube material will be replaced by Alluminium 1050.
- By the little more initial cost, we obtain very efficient refrigeration system with good C.O.P. than existed one.

2. WORK METHODOLOGY

- Fourier law of Conduction :

  "Fourier law states that the rate of heat transfer in conduction is proportional to the thermal conductivity of the wall. (K.W/m²)"
- The idea behind proposed system is to optimize the material of tube of condenser. So that heat transfer rate can increase.
- The material considered for tube of condenser is copper alloy C11000.

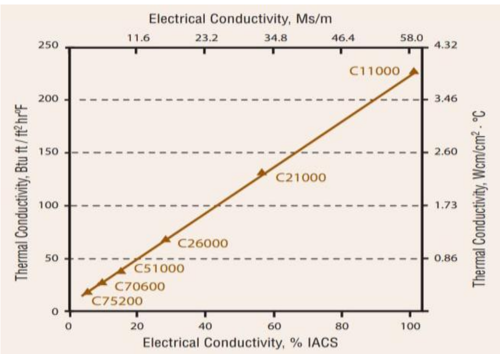


Fig. Thermal Conductivity Graph of Copper Alloys
(Ref: https://copperalliance.org.uk)

- The tube will have a circular wall.
- Fourier's law has state that, the rate of conduction heat transfer is proportional to the thermal conductivity of the wall (K.W/m²) that means surface area (A) m² is the increase of the wall thickness (L) in meters and the temperature difference between the inside wall.

- Copper and Alluminium is proven time and time again to all the criteria mentioned with excellent thermal conductivity.
- **There are more than 400 copper alloys, each with a unique combination of properties to suit many applications, high quality requirements, manufacturing process and environments.**

Metals Thermal Properties			
Material	Conductivity W/m-C	Density kg/m^3	Specific Heat J/kg-°C
Aluminum, 2024, Temper-T351	143.0	2.8×10^3	795.0
Aluminum, 2024, Temper-T4	121.0	2.8×10^3	795.0
Aluminum, 5052, Temper-H32	138.0	2.68×10^3	963.0
Aluminum, 5052, Temper-O	144.0	2.69×10^3	963.0
Aluminum, 6061, Temper-O	180.0	2.71×10^3	1.256×10^3
Aluminum, 6061, Temper-T4	154.0	2.71×10^3	1.256×10^3
Aluminum, 6061, Temper-T6	167.0	2.71×10^3	1.256×10^3
Aluminum, 7075, Temper-T6	130.0	2.8×10^3	1.047×10^3
Aluminum, A356, Temper-T6	128.0	2.76×10^3	900.0
Aluminum, Pure	220.0	2.707×10^3	896.0
Beryllium, Pure	175.0	1.85×10^3	1.885×10^3
Brass, Red, 85%Cu-15%Zn	151.0	8.8×10^3	380.0
Brass, Yellow, 65%Cu-35%Zn	119.0	8.8×10^3	380.0
Copper, Alloy, 11000	388.0	8.933×10^3	385.0
Copper, Aluminum bronze, 95%Cu-5%Al	83.0	8.666×10^3	410.0
Copper, Brass, 70%Cu-30%Zn	111.0	8.522×10^3	385.0
Copper, Bronze, 75%Cu-25%Sn	26.0	8.666×10^3	343.0
Copper, Constantan, 60%Cu-40%Ni	22.7	8.922×10^3	410.0
Copper, Drawn Wire	287.0	8.8×10^3	376.0
Copper, German silver, 62%Cu-15%Ni-22%Zn	24.9	8.618×10^3	394.0
Copper, Pure	386.0	8.954×10^3	380.0

Table 1: Thermal Conductivity List of Various Materials
(Ref: https://copperalliance.org.uk)

3. MEASUREMENT AND SPECIFICATION

3.1 Specification of Window AC

We bought one 1.5 window AC of ONIDA company for our experiment purpose. The following specification of AC is given below:

- Capacity: 1.5 Ton (4500 Kcal/hr)
- Compressor: Rotary Type
- Dimension: 660×780×435 mm
- Refrigerant Used: R-22
- Gas Charging Capacity: 0.88 Kg.
- Weight: 67 KG
- Power Supply: 230 Volts, 50 Hz.

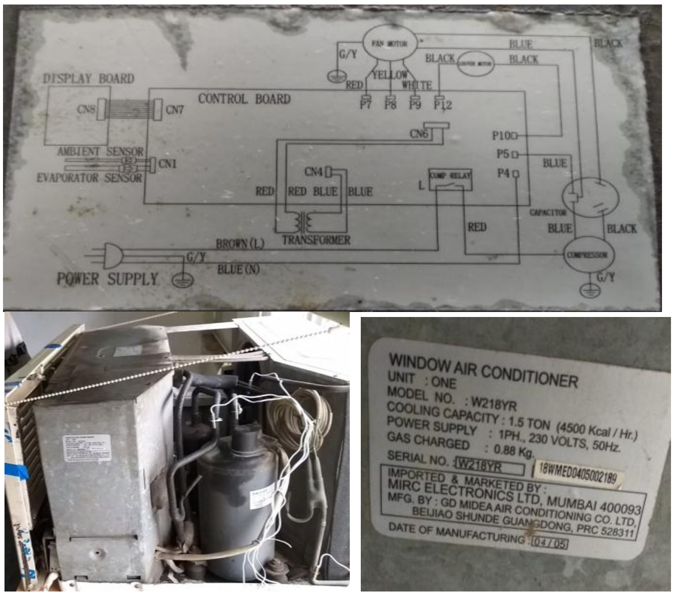


Fig.: Specification of Window AC

3.2 Measurement of Compressor Pressure:

We measure the pressure of compressor by using two pressure gauges. Two different pressures has been measured in compressor like,

- Pressure at compressor suction
- Pressure at compressor discharge

3.3 Specification of Condenser Tubes and Fins:

- No. of tubes in condenser = 32
- Tube Thickness = 1mm
- Tube Outer Diameter = 9.7mm
- Tube Inner Diameter = 7.7mm
- Tube Length = 558mm
- Tube Gap = 15.7mm
- Fins Gap = 1.5mm
- Fin Types = Straight (Alluminium)

4. CALCULATIONS

We have done calculations of performances of condensers by taking reference of Refrigeration and Air Conditioning (RAC) lab manual.

The comparison of the performance of both condensers is measured in by means of C.O.P. (Coefficient of Performance).

- **Coefficient of Performance (C.O.P.):**

The Coefficient of Performance of (C.O.P.) of a refrigerating cycle is defined as the ratio between net refrigeration (Output) and compressor work (Input).

$$COP = \frac{RE}{CW}$$

$$RE = H_1 - H_4$$

$$CW = H_2 - H_1$$

$$COP = \frac{H1 - H4}{H2 - H1}$$

- **Procedure OF Taking Reading:**

1. Switch oned the main supply.
2. Switch oned the compressor.
3. Waited for 2-3 minute for switch 'ONED' the compressor.
4. After 15 minutes noted down the reading of temperature sensors.
5. Noted down the reading of pressure gauges.
6. Repeated steps 4 to 5 after every 15 minutes till the temperature of outlet of air come constant.

4.1 Performance Analysis of Previous Condenser:

- We have taken these reading with previous condenser which was already installed.
- We have taken 3 different readings at 3 different temperatures (16°C, 22°C and 31°C) in time interval of 15 minutes.
- **Observation Table:**

Sr. No.	P_1 (Kg/cm^2)	P_2 (Kg/cm^2)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
1	3	17.3	27.5	58.7	38.9	10.3	20.4
2	3	17.5	21.9	58.9	39.0	9.4	30.1
3	3	18.5	22.3	61.1	39.8	8.8	20.3

Table: Observation Table

- P_1 = Pressure at compressor suction.
- P_2 = Pressure at compressor discharge.
- T_1 = Temperature at compressor suction.

- T_2 = Temperature at compressor discharge.
- T_3 = Temperature at condenser outlet.
- T_4 = Temperature at evaporator inlet.
- T_5 = Temperature of air at inlet of duct.

➢ **Average of All Parameters:**

1. Average of P_1 = 3 kg/cm^2
2. Average of P_2 = 17.76 kg/cm^2
3. Average of T_1 = 23.73 °C
4. Average of T_2 = 59.56 °C
5. Average of T_3 = 39.9 °C
6. Average of T_4 = 9.5 °C
7. Average of T_5 = 23.6 °C

Now,

➢ **Coefficient of Performance (C.O.P.):**

- H_1 = Enthalpy of refrigeration effects at compressor inlet
- H_2 = Enthalpy of compressor work at compressor outlet
- H_3 = Enthalpy of sub cooling at the outlet of condenser
- H_4 = Enthalpy of refrigerant inlet of evaporator

➢ $\mathbf{H_1} = \{(0.011*T_1)-1.98\} * P_1 + (0.652*T_1) + 415.723$

$= (-5.15691) + 15.7196 + 415.723$

$\mathbf{H_1 = 426.038\ KJ/Kg}$

➢ $\mathbf{H_2} = \{(0.011*T_2)-1.92\} * P_2 + (0.652*T_2) + 415.723$

$= (-22.46355) + 38.833 + 415.723$

$\mathbf{H_2 = 536.81\ KJ/Kg}$

➢ $\mathbf{H_4} = (1.228*T_3) + 199.93$

$\mathbf{H_4 = 248.80\ KJ/Kg}$

➢ $\mathbf{H_3 = H_4 = 248.80\ KJ/Kg}$

➢ $$\text{C.O.P.} = \frac{\text{Refrigeration Effect}}{\text{Compressor Work}}$$

$$= \frac{H1-H4}{H2-H1} = \frac{426.038-248.80}{536.81-426.038}$$

C.O.P. = 1.60

4.2 Performance Analysis of New Condenser:

➢ We have taken these reading with new installed condenser which was modified by us.

➢ We have taken 3 different readings at 3 different temperatures (16°C, 22°C and 31°C) in time interval of 15 minutes.

➢ **Observation Table:**

Sr. No.	P_1 (Kg/cm^2)	P_2 (Kg/cm^2)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
1	4.64	17.486	16.1	45.8	33.6	8.5	26.9
2	4.78	17.576	17.7	47.5	35.9	9.2	28.3
3	4.85	17.717	18.3	44.8	34.9	8.6	28.6

Table: Observation Table

- P_1 = Pressure at compressor suction.
- P_2 = Pressure at compressor discharge.
- T_1 = Temperature at compressor suction.
- T_2 = Temperature at compressor discharge.
- T_3 = Temperature at condenser outlet.
- T_4 = Temperature at evaporator inlet.
- T_5 = Temperature of air at inlet of duct.

➢ **Average of All Parameters:**

1. Average of P_1 = 4.45 kg/cm^2
2. Average of P_2 = 17.593 kg/cm^2
3. Average of T_1 = 17.36 °C
4. Average of T_2 = 46.033 °C
5. Average of T_3 = 34.8 °C
6. Average of T_4 = 8.76 °C
7. Average of T_5 = 27.93 °C

Now,

➢ **Coefficient of Performance (C.O.P.):**

- H_1 = Enthalpy of refrigeration effects at compressor inlet
- H_2 = Enthalpy of compressor work at compressor outlet
- H_3 = Enthalpy of sub cooling at the outlet of condenser
- H_4 = Enthalpy of refrigerant inlet of evaporator

➢ $\mathbf{H_1} = \{(0.011*T_1)-1.98\} * P_1 + (0.652*T_1) + 415.723$

$= (-8497) + 11.31872 + 415.723$

$\mathbf{H_1 = 418.543\ KJ/Kg}$

- $H_2 = \{(0.011*T_2)–1.92\} * P_2 + (0.652*T_2) + 415.723$

  $= (-24.8701) + 30.135 + 415.723$

  H_2 = 500.953 KJ/Kg

- $H_4 = (1.228*T_3) + 199.93$

  H_4 = 242.66 KJ/Kg

- **$H_3 = H_4$ = 242.66 KJ/Kg**

- $$\text{C.O.P.} = \frac{\text{Refrigeration Effect}}{\text{Compressor Work}}$$

$$= \frac{H1-H4}{H2-H1} = \frac{418.543 - 242.66}{500.953 - 418.543}$$

C.O.P. = 2.13

5. RESULT

We achieved Coefficient of Performance (C.O.P.) of previous installed condenser is C.O.P. **= 1.6.** And after changing new modified condenser which is made of 'COPPER C1100' material we achieved C.O.P. = **2.13.**

6. CONCLUSIONS

We executed the experiment on Window Air Conditioner with old condenser which is already installed. After accession of new condenser contrived of copper C11000 in the existed window air conditioner, we perform the experiment by measuring the entire criterion with the interruption of 15 minutes. We found that A.C with newly installed condenser cools the room in less time as compared to the previous one. After performing the experiment we come up with higher C.O.P as compared to the A.C with old condenser. So, we gratified with the statement of Fourier Law of Conduction "The rate of heat transfer in conduction is proportional to the thermal conductivity of the material ($K.W/m^2$)" given by Joseph Fourier in 1822.

7. FUTURE SCOPE

- In future we can change the material of condenser tube by alluminium alloy; fin material can also be changed.
- We can increase the rate of heat transfer by changing the shape of condenser tube and fin and also by arranging it in different form or way.
- By using different refrigerant and choosing the perfect refrigerant heat transfer rate can be increased.

8. APPLICATIONS

- We can use copper C11000 material tube condenser in every refrigeration system like in Refrigerators, Air Conditioners, Water Chillers and many more area.
- Generally we can use this materials condenser refrigeration system at warm place like gulf countries where the surrounding outdoor temperature is very high.
- And we can use it at many places like where the cooling is required.

Fig.: Applications

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