Estimation of Refrigeration side Heat transfer coefficient of Zero Ozone Depletion Refrigerant R134a used in Mobile AC in comparison with R22 Refrigerant

Kasuba Sainath
Research scholar JNTUH & Asso. professor in MED
Sreyas Institute of Engineering and Technology
Nagole,Hyderabad.India500068.,

P.S.Ravi
Research scholar OU Hyderabad,

Rajan Saini
Student of MED,
Sreyas Institute of Engineering & Technology,
Nagole, Hyderabad.

Dr Suresh Akella
Principal & professor in MED
Sreyas Institute of Engineering and Technology
Nagole,Hyderabad.India500068.,

Abstract- This document presents a theoretical study, Design & Experimental results gives the performance of R134a refrigerant as alternative to ozone layer depleting R22 refrigerant. R134a refrigerant has no ozone layer depleting property and inconsequential global warming potential with respect to R22. As per the rules of Montreal and Kyoto protocol the world community has decided to reduce the production and consumption of HCFC-22 from the refrigeration and air conditioning industry completely by 2020. In R22, chlorine is the element which depletes the Ozone layer, with Ozone Depletion Potential 0.05 and Global Warming Potential 1700, which effects the environment

Keywords –ODP, GWP, Critical pressure, critical pressure, Enthalpy, C.O.P, condenser, *rotary* compressor, refrigerants , R22, R134a, capillary tube, thermal conductivity, heat transfer.

I. INTRODUCTION

The purpose of this study was to compare R22 and R134a refrigerants on the basis of their environmental affect and thermal properties. The objective of this study is to show how R22 can be replaced by R134a as this refrigerant has better coefficient of performance than R22. Relatively, this study was motivated by Montreal Protocol, an international agreement by many nations to reduce the production of ozone-depleting substances. Since then, there are many experiments carries forward and much discussion about alternative refrigerants.

This report discuss about the calculations of R134a and R22 refrigerants. It also shows the thermal properties of both the refrigerants. It also shows the p-h diagram and concluded by the overall properties of both the refrigerants.

II. AIR CONDITIONING SYSTEM

Before learning the operation of the air-conditioner system, we should know first about the significant components which they are applied in the refrigerant circulate system.

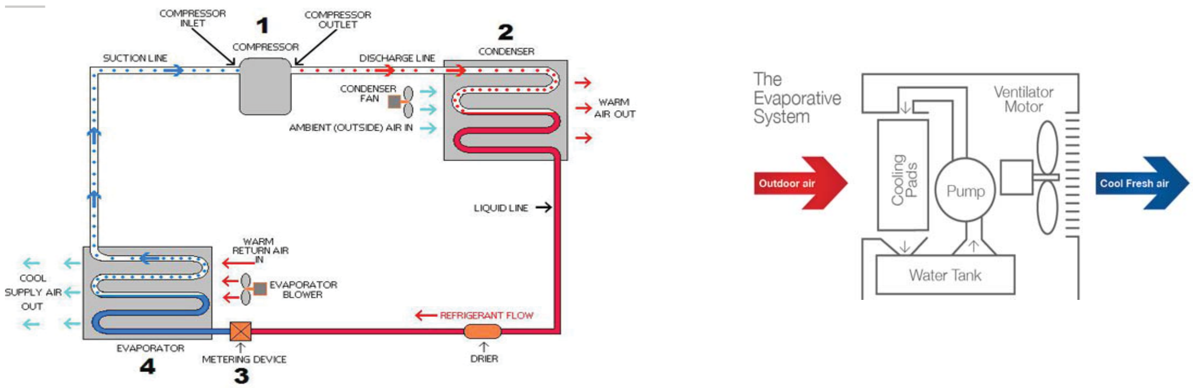


Fig1. Refrigerant flow of Air Conditioning System & Working of the Air Cooler

Compressor: It drives the refrigerant flow into each part of the air-conditioner so these caused the temperature and the air pressure in the refrigerant being high.
Condenser: It drains heat from the refrigerant.
Evaporator: It can absorb and transfer the heat in the building to the refrigerant.
Throttling Device: It reduces the air pressure and the temperature in the refrigerant. Generally, it can be used as Capillary tube or Expansion Valve.

The cooling system as mentioned above is Vapor-Compression Circulate system which it has the simply working regulation via driving the refrigerant flow along the system and this also passed continually throughout 4 major components as Refrigerant Circulate system. Besides, the followings are its working process.

1. Firstly, the compressor will absorb and charge the refrigerant for enhancing its pressure and temperature and also move it forward to the evaporator later.
2. Then, the refrigerant will be flown throughout the evaporator by using the fan drain the heat out. So it caused the refrigerant's temperature in the evaporator which it is emanating being low. Next, this will be flushed to Throttling Device hereafter.
3. Next, the pressure and temperature in the refrigerant that flown through Throttling Device will be quite low. After that, it will be flushed into the cooling coil
4. Later, the refrigerant will be circulated around the cooling coil which it used the fan to absorb heating in that room so it caused the room's temperature getting low and the refrigerant's temperature of emanating cooling coil getting high (stable pressure). Lastly, this refrigerant will be transferred back to the compressor for operating over circulated system continually

III. Design Of A Mobile Air Conditioner

Design of a mobile air conditioner is done using AutoCAD 3D. The parts of air conditioner are compressor, condenser, evaporator, capillary tube and cooler fan.

S. No	Description	Specification
1	Model	pH170G1C-3DZDU2
2	Display. (cm3/rev)	16.8
3	Capacity (W)	3420
4	Capacity (BTU/h)	11670
5	Power (W)	1085
6	COP (W/W)	3.15
7	Capacitor(F/V)	35/370

Fig2. 3D Design Of Air Conditioner Toshiba / GMCC R22 1 -60Hz-208/230V air conditioner rotary compressor

Tube and fin Condenser:

It consists of a copper coil located in a steel rectangular shell, alternatively placed, bent in U shape and brazed. Water is circulated through the coil, and refrigerant vapors are discharged from the compressor, heat exchange takes place between the water and the refrigerant, with same pressure temperature drops on copper tubes.

Though it's economical, this type of condensers maintenance is difficult and also if any leakage occurs entire unit is to be replaced.

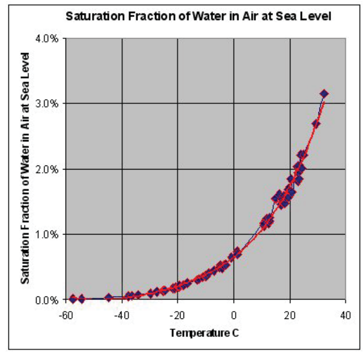


Fig3. Condenser attached behind the cooler; Relationship To Human Control

Dew point		Human perception[2]	Relative humidity at 32 °C (90 °F)
Over 26 °C	Over 80 °F	Severely high. Even deadly for Bronchitis	65% and higher
24–26 °C	75–80 °F	Extremely uncomfortable, fairly oppressive	62%
21–24 °C	70–74 °F	Very humid, quite uneasy	52–60%
18–21 °C	65–69 °F	Somewhat uneasy for most people at upper edge	44–52%
16–18 °C	60–64 °F	OK for most, but all the humidity at upper edge	37–46%
13–16 °C	55–59 °F	Comfortable	38–41%
10–12 °C	50–54 °F	Very comfortable	31–37%
Under 10 °C	Under 50 °F	A bit dry for some	30% and lower

Fig 4. Relationship to Human Control

IV. CALCULATIONS OF R134A REFRIGERANT

Design parameters:

- Capacity of air conditioner $1\frac{1}{2}$ + R = 1.5*210 KJ/min = 1.5 * 210 * $\frac{1000}{60}$ J/sec = 5250 W
- Roll bond tube outside diameter $d_o = \frac{1}{2}$' = 12.7mm
- Thickness of tube = 2.108mm
- Inside diameter of tube $d_i = d_o - 2t$ = 8.484mm
- $T_{condenser} = 50^0$c $T_{evap} = 5^0$c
- P_{cond} = 13.77 bar $P_{evap} =$ 3.49705 bar = 3.49705 bar

Basic Cycle Calculations

1.Assumptions

- There is no liquid sub cooling
- Vapour super heat at evaporator is ok

2.Mass flow rate Calculations

From Ref prop, h_1=401.57 KJ/kg = 401.57*10^3 J/kg $h_3 = h_4$ = 271.59 KJ/kg = 271.59*10^3 J/kg

m (h_1-h_4) = 5250W m(401.57-271.59)*10^3 = 5250 m = 0.0404 Kg/sec

- Finding quality of refrigerant at entry of roll band evaporator

For Isenthalpic flow $h_3=h_4$ $h_3 = (h_f + xh_{fg})_4$

$h_{32} = h_{f3}$ =271.59 KJ/kg h_{f4}= 206.725 KJ/kg $(h_{fg})_4$= 195.98 KJ/kg

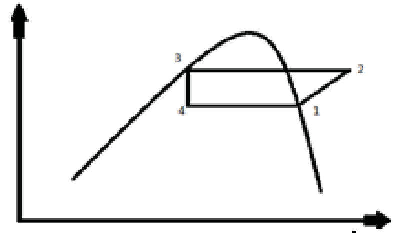
271.59= 206.725+ x(195.98) x=0.331 therefore, quantity of refrigerant, x_4= 0.331

- Porkel, Qumstan, Spilter condition for F134a (ASHRAE)

$$\frac{h_i D}{K} = C_1 \left[\left(\frac{GD}{\mu_L}\right)^2 \left(\frac{J \Delta x h_{fg}}{Lg}\right)\right]^n$$

Where, h= internal (Refrigerant side heat transfer coefficient)

D= internal diameter of tube
K= thermal conductivity refrigerant
C_1= constant = $9*10^{-4}$ if $x \le 0.9$ $=8.2*10^{-3}$ if $x \ge 1.0$, x is quantity refrigerant leaving roll bond evaporator
n= constant= 0.5 if $x<0.9$ = 0.4 if $x \ge 1.0$
μ_L= viscosity of refrigerant R134a at 5°C
J= Joule coefficient= 1 for SI unit



Pressure (p) vs Enthalpy(h)

$\Delta x h_{fg} = (1 - 0.331)(195.98) = 131.11$ KJ/kg
$K_l = 91.46*10^{-3}$ W/mK (from Ref Prop)
G= mass velocity of refrigerant = m/A
$A= \frac{\pi}{4}(d_1)^2 = \frac{\pi}{4}(8.484*10^{-3})^2 = 5.653*10^{-5}\ m^2$
$G= \frac{0.0404}{5.653*10^{-5}} = 714.64\ Kg/Sm^2$
G_c= 1
Total length of roll band evaporator tube= 80m

If 8 parels are used length of evaporator tube in each parel will be $\frac{80}{8}$= 10m, number of parel= 10, length of parel= 1m

If 8 parels are kept parallel for each other, the length of tube per parel will be 8*1= 8m.
$\mu_L = 249.9*10^{-6}$ pas (From Ref Prop)
$\frac{h(8.484*10^{-3})}{91.46*10^{-3}} = 8.2*10^{-3}[\{\frac{714.64*8.484*10^{-3}}{249.9*10^{-6}}\}^2 * [\frac{1*131.11*10^3*1}{8*9.81}]]^{0.4}$ h= 5540.29 W/m^2K

Therefore, Inside HT coefficient for R134a is 5540.29 W/m^2K

V. CALCULATIONS OF R22 REFRIGERANT

Design parameters:

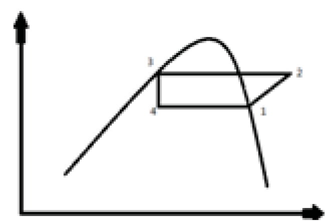
- Capacity of air conditioner $1\frac{1}{2}$ + R = 1.5*210 KJ/min = 1.5 * 210 * $\frac{1000}{60}$ J/sec = 5250 W
- Roll bond tube outside diameter $d_o = \frac{1}{2}$= 12.7mm
- Thickness of tube = 2.108mm
- Inside diameter of tube $d_i=d_o-2t$ = 8.484mm
- $T_{condenser}= 50^0c$ $T_{evap}=5^0c$

Basic Cycle Calculations

1.Assumptions

- There is no liquid sub cooling
- Vapour super heat at evaporator is ok

2.Mass flow rate calculations



Pressure (p) vs Enthalpy(h)

From REFPROP, For Refrigerant R-22 properties, enthalpies at state1 and state 4 are 407.45 kJ/kg and 262.27 kJ/kg respectively.
The mass flow rate is calculated from the relation m (h1-h4) = heat load.
The estimated mass flow rate of refrigerant is m = 0.03616 kg s-1
The heat transfer coefficient so calculated for R-22 is 1244.38W/m2K

- Dittus Boelter equation: The heat transfer coefficient so calculated for R-22 is 1236.46 W/m2K
  Nusselt's number Nu = 0.023 Re0.8 Pr0.4 Nusselt's number is given by Nu = (h d)/k
- Correlation from heat transfer data book: The heat transfer coefficient so calculated for R-22 is 1299.31 W/m2K
  Nusselt's number Nu = 0.026 Re0.8 Pr(1/3)
- Gnielinski equation: The heat transfer coefficient so calculated for R-22 is 1175.25W/m2K
  Nud = { (f/8) x (Re – 1000) Pr }/{ 1 + 12.7 (f/8) 0.5 (Pr2/3) friction factor, f = (0.79 ln Re – 1.164) -2

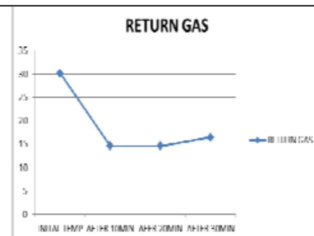
VI. RESULTS & CONCLUSION

In the present work we have identified there are 11 critical areas where all these conditions play a vital role in the present specified application, from the cooling effect of modified air cooler. The 11 critical thermocouples results identified are as shown below

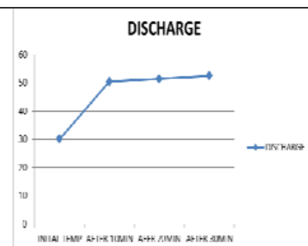
S.no		Inital temp	After 10min	Afer 20min	After 30min
1	Return gas	30.2	14.6	14.6	16.5
2	Discharge	30.1	50.4	51.3	52.4
3	Condensor out	28.9	36.3	37.5	38.3
4	Compressor top	32.8	51.3	52.2	53.1
5	Compressor middle	32.9	52.5	53.9	55
6	Capillary in	29.6	17.3	17.8	18.4
7	In b/w evaporator	29.0	17.7	17.9	18.1
8	Evaporator out	28.9	16.7	17.1	17.8
9	Ambient	28.8	32.3	32.7	34.1
10	Wet-bulb temperture	30	30	31	32
11	Dry-bulb temerature	32	32	35	35

The following results are explained in detail with the results obtained by the thermo couples as follows below

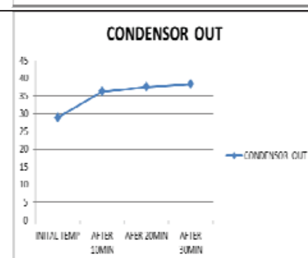
Graph 1 shows the return gas temperature from compressor that are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of the gas from the compressor, at initial condition the temp is 30.2,after 10 minutes the temp is 14.6,after 20 minutes the temp is 14.6 and after 30 minutes the temp is 16.5



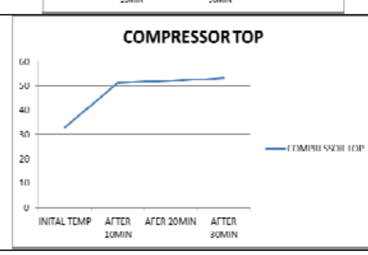
Graph 2 shows the discharge temperature of refrigerant that are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of the discharge temperature of refrigerant, at initial condition the temp is 30.1,after 10 minutes the temp is 50.4,after 20 minutes the temp is 51.3 and after 30 minutes the temp is 52.4.

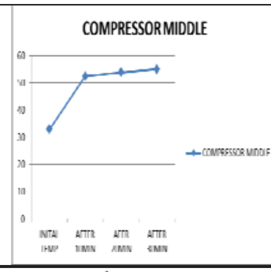
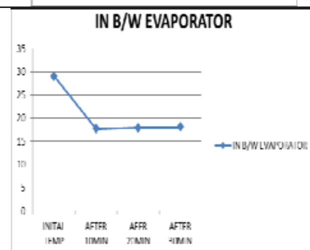
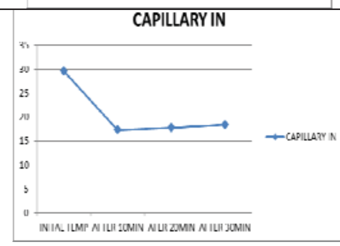
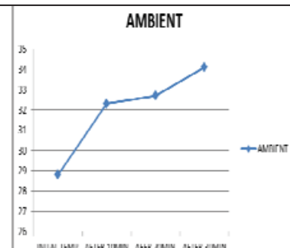
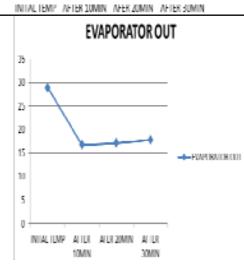


Graph 3 shows the temperatures of the condenser out are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of the condenser out is, at initial condition the temp is 28.9,after 10 minutes the temp is 36.3,after 20 minutes the temp is 37.5 and after 30 minutes the temp is 38.3.



Graph 4 shows the temperature of the compressor top are measured at four conditions 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of the compressor top is, at initial condition the temp is 32.8,after 10 minutes the temp is 51.3,after 20 minutes the temp is 52.2 and after 30 minutes the temp is 53.1.

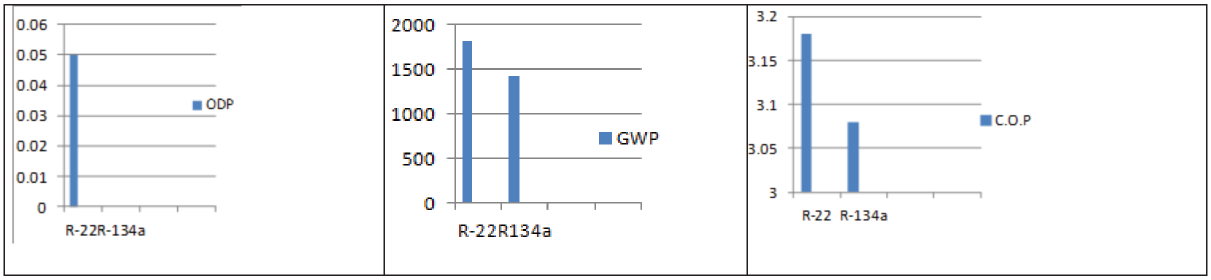


Graph 5 shows the temperature of the compreesor middle are measured at four conditions 1. Initial temp 2. After 10 mints 3. After 20 mints 4. After 30 mints.The initial temperature of thecompressor middle, at initial condition the temp is 2.9,after 10 mints the temp is 52.5,after 20 mints the temp is 53.9 and after 30 mints the temp is 55.	
Graph 6 shows the temperature in between evaporator are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of in between evaporator, at initial condition the temp is 29.0,after 10 minutes the temp is 17.7,after 20 minutes the temp is 17.9 and after 30 minutes the temp is 18.1.	
Graph 7 shows the temperature of capillary in are measured at four stages1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of the capilary in is , at initial condition the temp is 29.6,after 10 minutes the temp is 17.3,after 20 minutes the temp is 17.8 and after 30 minutes the temp is 18.4.	
Graph 8 shows the temperature of ambient are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of ambient, at initial condition the temp is 28.8,after 10 minutes the temp is 32.3,after 20 minutes the temp is 32.7 and after 30 minutes the temp is 34.1.	
Graph 9 shows the temperature of evaporator out are measured at four stages 1. Initial temp 2. After 10 minutes 3. After 20 minutes 4. After 30 minutes.The initial temperature of evaporator out is, at initial condition the temp is 28.9,after 10 minutes the temp is 16.7,after 20 minutes the temp is 17.1 and after 30 minutes the temp is 17.8.	

Ozone Layer Depletion Concerns

Montreal Protocol an international conference held in Montreal in September 1987, both developed and developing countries decided to control the production of Ozone Depletion Substance (ODS). As CFCs and HFCs are mainly effecting the ozone layer and depleting them from earth's atmosphere.

Kyoto Protocol concentrated on the Global Warming impacts, this protocol was noticed by the third conference of United Nations framework convention on climate change (UNFCCC) held in December 1997 at Kyoto. Due to high amount of production and consumption of HFCs and CFCs the earth's temperature is increasing and it is predicted that average global rise in temperature from 1.4^0C to 5.8^0 C



III. CONCLUSION

The main drawback of R-22 is that it has more Ozone layer Depletion and more Global Warming Potential than R134a. And the theoretical properties of R134a are more reliable and Coefficient of Performance is more than R134a.Bssed on the Montreal & Kyoto ,Reliability, Economical wise R134a is best alternative substitute of R22

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