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Replacement of R22 in Vapour Compression Refrigeration Cycle with Mixture of Environment Friendly Refrigerant

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Abstract- In this paper, as a result discusses the opportunity of R-22 in vapor compression refrigeration device. R-22 has been changed by way of an aggregate of refrigerant R134a, R32, and R152a in a ratio of 0.3:0.3:0.4 in MIXTURE 1 and 0.1:0.4:0.5 in MIXTURE 2 and 0.4:0.3:0.3 in MIXTURE 3 by way of mass respectively .The overall performance evaluation in R-22 and the mixture refrigerants are made in terms of C.O.P, Variation of density with temp at consistent strain, Variation of enthalpy with temp at constant stress, Variation of entropy with temp at consistent pressure, Global warming ability, Molecular weight and Ozone depleting potential. It is observed that C.O.P of mix 1, mix 2 and mix 3 have larger than R22.

Temperature and pressure for the analysis has been has been taken from the ice plant working on vapour compression refrigeration cycle using R-22 as refrigerant.

KEYWORDS: R-22, R-134a, R-32, R-125a, Eco-Friendly Refrigerants.

I. INTRODUCTION

Refrigeration may be a method of moving heat from one location to a different. The work of warmth transport is historically driven by mechanical work, however may also be driven by heat, magnetism, electricity, laser, or alternative suggests that. Refrigeration have many or several applications including, and not only limited to: house hold refrigerators, industrial freezers, cryogenics, and air-con. Heat pumps could use the warmth output of the refrigeration method, and conjointly is also designed to be reversible, however are otherwise the same as refrigeration units.

Refrigeration has had an outsized impact on business, lifestyle, agriculture and settlement patterns. The thought of protective food dates back to the traditional Roman and Chinese empires. However, refrigeration technology has speedily evolved within the last century, from ice gathering to temperature-controlled rail cars. The introduction of cold rail cars contributed to the westward enlargement of the United States, permitting settlement in areas that weren't on main transport channels like rivers, harbors, or vale trails. Settlements were conjointly developing in sterilized elements of the country, crammed with new natural resources. These new settlement patterns sparked the building of enormous cities that is able to thrive in areas that were otherwise thought to be inhospitable, like Houston, Lone-Star State and metropolis, Nevada. Most of them countries around the world, their cities are totally dependent upon refrigeration in supermarkets, so as to get their food for daily consumption. The rise in food sources has led to a bigger concentration of agricultural sales coming back from a smaller share of existing farms. Farms nowadays have a way larger output per person as compared to the late 1800s. This has resulted in new food sources on the market to entire populations that have had an outsized impact on the nutrition of society.

II. LITERATURE SURVEY

In a paper conferred by Piotr A. Domanski, mentioned analytical analysis of iso-butane (R600a), fuel (R290), R134a, R22, R410A, and R32 in an exceedingly vapor compression system used for comfort cooling applications. The analysis of performance of R600a, R290, R134a, R22, R410A, and R32 in systems with optimized heat exchangers showed the COP for the studied refrigerant to be inside 13 the concerns, with R32 and R290 having the best COP. This analysis created an immensely totally different ranking of the compared fluids than that obtained from a theoretical cycle analysis supported thermo-dynamical properties alone. Within the system simulations, the air mass refrigerants overcame the thermo-dynamical disadvantage related to their low crucial temperature and had higher COPs than the depression R134a and

R600a. Though the conferred analysis methodology relies on simulations alone, they tend to expect it to supply a good indication of performance of various fluids on a relative basis. This approach is also followed with experimental effort if stronger credentials are desired. Still, such a COP ranking is simply a preliminary step in an exceedingly refrigerant choice method that ought to embody the life cycle climate performance for a given value needed to place air-conditioning instrumentality on the market.

In a paper conferred S. S Jadhav mentioned the analysis of R410a as an attainable substitute for R22 in vapour compression refrigeration cycle. R410A is refrigerant mix, with zero gas depletion potential (ODP). It has higher or the next meter cooling capability compared to R22 and has better thermal exchange properties. The COP of the system is 5 to 6 over R22. R410A operates at roughly 50 to 70 p.c higher pressure at a similar saturated temperatures than R22, so system should be redesigned. A specially designed "ZP" scroll mechanical device should be used for R410A otherwise shell rupture might occur. The evaporator capability and COP of the system with the small channel condenser were 3.4 and 13.1% higher, severally, than those of the system with the round-tube condenser. A small channel condenser resulted in an exceedingly 2.5°C lower compression temperature and attenuate the refrigerant pressure to 57 kPa, at a similar time it needed 9.2% lesser refrigerant charge. For a 7.0°C evaporator exit saturation temperature, R410A had a bigger capability by 10.7% than that of R22. The bigger density of the vapour in R410A permits higher system velocities, reduces pressure drop losses and permits smaller diameter tube to be used. Successively a smaller unit is developed employing a smaller displacement mechanical device, less coil and fewer refrigerant whereas maintaining system efficiencies similar to current day R22 instrumentality. So we've got an occasional value resolution to fulfill specific instrumentality needs.

In a paper mentioned by M. Ashok Chakravarthy, R22 is replaced by R-407C (mixture of R-32/125/134a), R-407A (mixture of R-32/125/134a) the current experimental work showed the subsequent findings:

• The call technique of R-22 by R-407C and R- 407A improved cooling capability up to (4.5%) and (7.5%) severally. This emphasizes a really vital purpose that the present evaporator circuit is incredibly appropriate for the current various refrigerants.

• R-407A exhibited lower power consumption than that full-fledged with R-22 tests by (2%). On the contrary, R-407C showed the next consumed power than that of R-22 by (9%).

• R-407C and R-407A showed a big increase in Energy potency Rate by (4%) and (7.5%) severally for the in operation conditions conferred here.

• R-407C exhibited decrease in mass rate than that full-fledged with R-22 tests by (5%). On the contrary, R-407A showed a rise in mass rate than that of R-22 by (6.5%).

• R-407C and R-407A showed a big increase in COP by (3.75%) and (7.2%) severally for the in operation conditions conferred here.

• The results confirmed that R-407C and R-407A are promising alternatives as a right away replacement; call of R-22 in RAC. Noting that the call technique could be a feature of the refrigeration unit. Therefore, the performance of a selected various varies from one application to a different.

III. EXPERIMENTAL SETUP

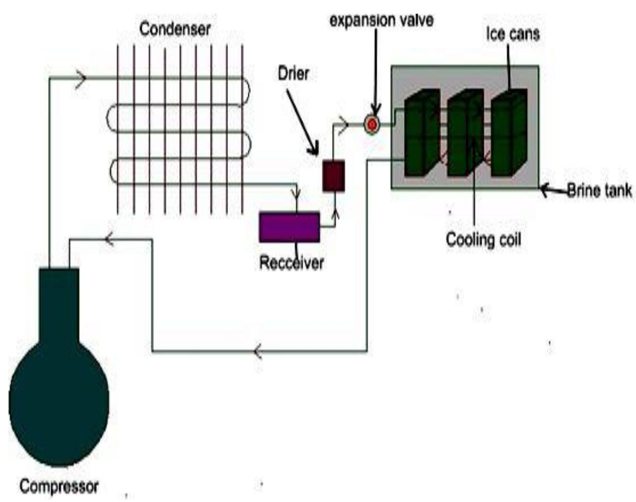

Figure 1 Block diagram of ice plant

COMPONENTS OF AN ICE PLANT:

1) **COMPRESSOR**
2) **CONDENSOR**
3) **RECEIVERS**
4) **FILTER DRIER**
5) **EXPANSION DEVICES**
6) **EVAPORATOR**
7) **CHILLING TANK**
8) **REFRIGERANT ACCUMULATOR**
9) **PRESSURE GAUGE**

Table 1 Components specification

Components	**Specifications**
Compressor	Specifications of the compressor used in project are given below: Application with R-22 ➢ Type -Hermetically sealed compressor ➢ Electrical circuit-CSIR Operating voltage- 1ph, 180- 260V AC ➢ Relay- KARP3141 OR MTRP3141 ➢ Start capacitor- 40-60 microF,@275V A Capacity- 240BTU
Condenser	Single role forced air cool Condenser with fan.
Filter drier	Working pressure = 500psig (34.01bar) For use with CFC, HCFC, HFC, R-134a, R12, R22, R40, R401a, R402a, R404a, R407a, R502a, R502a Refrigerants
Expansion device	Type- capillary tube Diameter of capillary tube is 1.0 mm. Length of capillary tube is 2.5m.
Evaporator coil	Specifications of the evaporator used in project are given below: Diameter of copper coil is 0.6mm. Length of copper coil is 7500mm.
Chilling tank	dimensions of tank – length=600mm, width=450mm, height=300mm Insulation is done with the help of wood and thermo-col. The thickness of wood and thermo-col are 10mm and 24.5mm
Energy meter	Static watt hour meter 3 Phase 4 wire energy meter Rating- 10-40 Amp, 240V, 50Hz

IV. PERFORMANCE COMPARISION OF R22 WITH ALTERNATE REFRIGERANT

R22 has non zero ODP hence it needs to be phased out. The basis of replacement is to analyze the performance of existing plant working on R22 and comparing it with eco-friendly refrigerant which can be possible replacement of R22.

Pressure and temperature reading for the calculation is taken from an ice candy plant working on vapour compression refrigeration cycle using R-22 as refrigerant. Theoretical C.O.P is calculated by using pressure – enthalpy chart at given pressure and temperature condition. Actual C.O.P is calculated as the ratio of desired effect and work supplied.

Table 2 pressure and temperature reading of ice candy plant

P1	P2	T1	T2	T3	T4
2 bar	12 bar	5 (°C)	85 (°C)	30	-26 (°C)

P1= Inlet Pressure of Compressor (Bar)
P2= Exit Pressure of Compressor (Bar)
T1= Inlet Temp of Compressor (°C)
T2 = Exit Temp of Compressor (°C)
T3= Condenser Exit Temp (°C)
T4 = Temp (°C) After Expansion

R22

h 1 = 414 kJ/kg, at temp 5 °C and 2 bar pressure
h 2 = 460 kJ/kg, at temp 85 °C and 12 bar pressure
h 3 =236.6 kJ/kg, at temp 30 °C and12 bar pressure
h 4 = 171 kJ/kg, at temp -26 °C and 2 bar pressure

C.O.P = ref effect / w_{input} = (h1-h4)/(h2-h1) =5.28

R22 (chlo fluoro methane) has O.D.P of 0.05 and G.W.P of 1700 .Due to its non-zero O.D.P value and high global warming potential, it has to be phased out from vapour compression cycle. The possible replacement of R22 must have non zero O.D.P and lower global warming potential as compared to R22. Table 5.2 shows some hydro fluorocarbon which can be possible replacement of R22 in vapour compression cycle. Based on chemical properties like flammability, toxicity environmental properties like G.W.P. R134a, R32 and R152a mixture in certain proportion may be a possible replacement of R22.

Table-3 Hydro fluorocarbons Refrigerant Properties

Refrigerants	O.D.P	G.W.P	Chemical properties
R23	0	14800	Slightly flammable
R32	0	650	Slightly flammable
R125	0	3400	Not flammable
R134a	0	1300	Non-Flammable and non toxic
R143	0	4300	Slightly flammable
R152a	0	120	Slightly flammable
R218	0	8830	Non flammable
R245a	0	1030	Flammable

Tables 5, 6 and 7 shows mixture of **R134a, R32 and R152a** in specific proportion, their enthalpy at working pressure and temperature obtained experimentally from an ice candy plant working at vapour compression cycle. Also their molecular weight and GWP are compared .molecular weight of refrigerant can be considered as thermodynamic property. Higher the molecular weight lower will be the specific volume and hence lesser quantity of refrigerant is required to obtain desired refrigeration effect.

Table – 4 Refrigerant Properties

Refrigerants	Mol. Wt	Critical temp (°C)	Boiling point temp (°C)	Temp range (°C)
R22	86.5	96.15	-40.81	-157.4 to 276.9
R134a	102	101.06	-26.07	-103.3 to 180
R32	52.02	78.11	-51.65	-136.8 to 161.9
R152a	66.05	113.26	-24.02	-118.6 to 226.9

Table -5 Mixture Composition Keeping R152a Constant

R134a (by mass)	R32 (by mass)	R152a (by mass)	h1 (kJ/kg)	h2 (kJ/kg)	h3 (kJ/kg)	h4 (kJ/kg)	Ref Eff (h1-h4) (kJ/kg)	C.O.P (h1-h4)/(h1-h2)	Mol Wt	GWP

0.4	0.2	0.4	475.5	538.9	248.7	160.4	315.1	4.97	97.6	698
0.3	0.3	0.4	488.7	552.1	250	159.4	329.2	5.19	72.6	633
0.2	0.4	0.4	502.1	565.3	322.3	184.8	317.3	5.02	67.6	568
0.1	0.5	0.4	515.6	578.7	439.2	286.6	229	3.62	62.6	503

Table – 6 Mixture Composition Keeping R32 Constant

R134a (by mass)	R32 (by mass)	R152a (by mass)	h1 (kJ/kg)	h2 (kJ/kg)	h3 (kJ/kg)	h4 (kJ/kg)	Ref eff (h1-h4) (kJ/kg)	C.O.P (h1-h4)/(h1-h2)	Mol Wt	GWP
0.4	0.4	0.2	479.9	541.1	381	234.6	245.3	4	74.8	828
0.3	0.4	0.3	491	553.2	350.3	209.3	282	4.54	71.2	686
0.2	0.4	0.4	502.1	565.3	322.3	184.8	318	5.04	67.6	568
0.1	0.4	0.5	513.1	577.4	296	160.8	352.3	5.47	64	450

Table-7 Mixture Composition Keeping R134a Constant

R134a (by mass)	R32 (by mass)	R152a (by mass)	h1 (kJ/kg)	h2 (kJ/kg)	h3 (kJ/kg)	h4 (kJ/kg)	Ref Eff (h1-h4) (kJ/kg)	C.O.P (h1-h4)/(h1-h2)	Mol Wt	GWP
0.4	0.1	0.5	470.6	538.6	250.6	192.2	278.4	4.09	79	645
0.4	0.2	0.4	475.5	538.9	248.7	160.4	315.1	4.92	77.6	698
0.4	0.3	0.3	477.6	540	248.9	160.3	318	5.1	76.2	751
0.4	0.4	0.2	479.9	541.1	381	234.6	246	3.96	74.8	804

Table- 8 Composition Of Refrigerant In Mix 1 ,Mix 2 and Mix 3 In Ratio Of Mass

Ref	R134a (by mass)	R32 (by mass)	R152a (by mass)
M 1	0.3	0.3	0.4
M 2	0.1	0.4	0.5
M 3	0.4	0.3	0.3

From above tables based on suitable properties like molecular weight and global warming potential three refrigerant compositions one from each table is taken as possible replacement shown in table 8 and named as M 1, M 2 and M 3.

The selection for M 1 from table 5 is based on comparison of refrigerants based on their global warming change with their molecular weight change with varying composition. Similarly M 2 is also selected from table 6 on the same basis. Now M 3 is selected from table 7 since it has highest C.O.P and lowest global warming potential. Their properties are compared over a range of temperature. The performance is analyzed on the basis of enthalpy, density, entropy, mol wt and global warming potential. A comparision of R-22 refrigitent with M 1, M2 and M 3 is shown below

a) Variation of density with temp keeping pressure constant

When desity is high sp.volume will be low ,which means that for a given mass storage the required size of compressor will be small .A graph is plotted between density and temperature ,showing variation of density with temperature for R22 ,M 1, M 2 and M 3.Data for graph is taken from REFPROP at given pressure and temperature. It is clear from graph that size of the compressor for M1, M 2 and M 3 is larger as compared to R22.

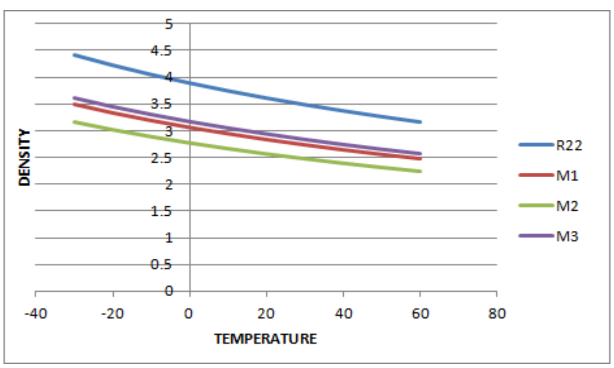

Figure 2 Density Vs Temperature at Constant Pressure

b) Variation of enthalpy with temp keeping pressure constant

Enthalpy of refrigerant is a good representation of heat extracting capacity. Higher the enthalpy greater the amount of heat a particular refrigerant can extract. Data for graph is taken from REFPROP at given pressure and temperature reading. Enthalpy versus temperature graph is plotted for R22, M 1, M 2 and M 3 which shows that heat extracting capacity of M 1, M 2 and M 3 is better than R22 .M2 has comparatively more enthalpy than M1 and M3.

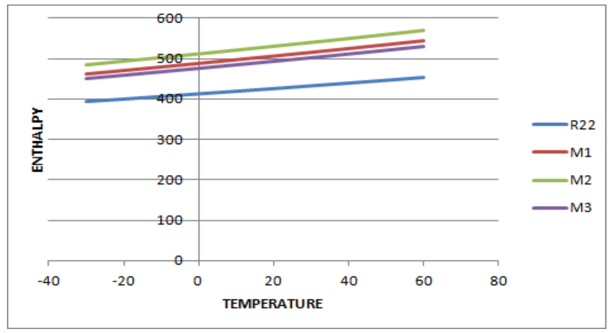

Figure 3 Enthalpy Vs Temperature At Constant Pressure

c) Variation of entropy with temperature keeping pressure constant

Entropy is measure of unstability of system . Data for graph is taken from REFPROP at given pressure and temperature reading. Entropy vs temperature graph is plotted for R22 M 1, M 2and M 3, which shows that entropy of M 1, M 2 and M 3 is greater as compared to R22 . Hence there will be slight rise in entropy when replacing R22 with M1 ,M 2 and M 3.

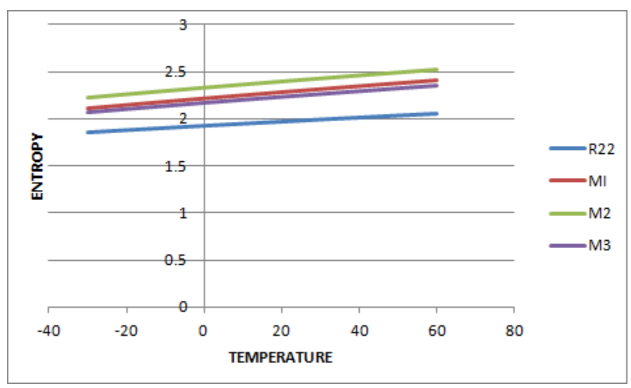

Figure 4 Entropy Vs Temperature At Constant Pressure

d) Global warming potential comparision

GWP is a relative measure of how much heat a greenhouse traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. A column graph is plotted showing the comparison of global warming potential of R 22, M 1, M 2 and M 3. It can be seen from the graph that global warming potential of R22 is very high as compared to M 1,M 2 AND M 3. Hence all replacement M 1, M 2 and M 3 has lower global warming potential as compared to R22. Out of three replacement Mix 2 is better replacement it has gwp of 450 only.

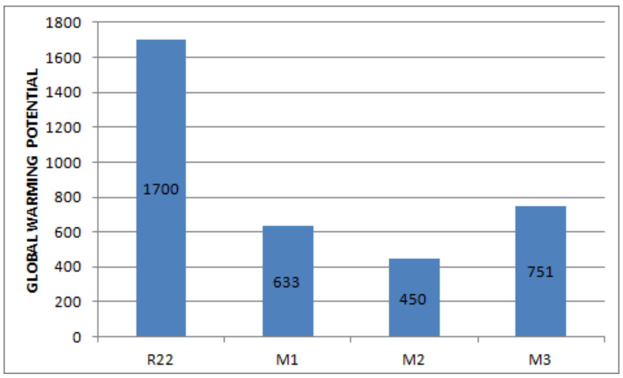

Figure 5 Global Warming Potential

e) Molecular Weight

Latent heat of vaporization and specific heat depends on molecular weight. Latent heat of vaporization will be high for refrigerant having lower molecular weight. Also higher the molecular weight lower will be specific volume hence lesser quantity of refrigerant is required to obtain the desired refrigeration effect. This is an advantage. A column graph is plotted to give a comparison between molecular weight of R22, M 1, M 2 and M3.Molecular weight of R22 is 86 which is higher than M 1, M 2 and M 3. M2 has minimum molecular weight.

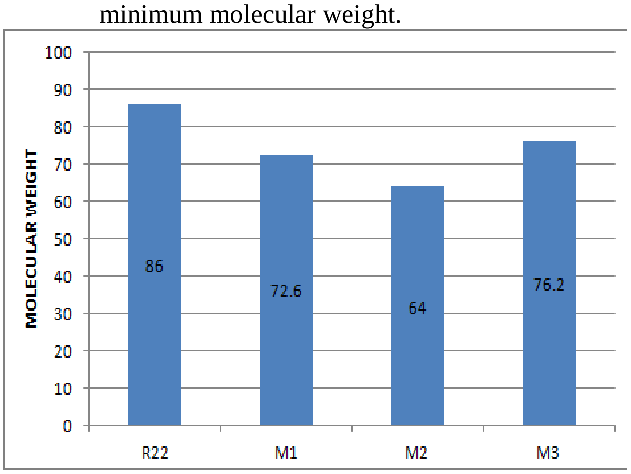

Figure 6 Molecular Weight

f) Ozone Depleting Potential

Ozone depleting potential (ODP) of a chemical compound is the relative amount of degradation to the ozone layer it can cause, with tri chloro fluoro methane (R-11 or CFC-11) being fixed at an ODP of 1.0. R22 has ODP of 0.05 and it has to phase out from vapour compression refrigeration system. R22 is replaced with mixture of refrigerants whose ODP is zero.

V. RESULT AND DISCUSSION

Table- 9 Result comparision of R22 with M 1, M 2 and M 3

REFRIGERENT	R22	M 1	M 2	M 3
C.O.P	5.28	5.2	5.47	5.1
Molecular weight	86	72.6	64	76.2
Global warming potential	1700	633	450	751
Ozone depleting potential	0.05	0	0	0

1) C.O.P of M 2, is greater than C.O.P of R22, but C.O.P of M 2 and M 3 is little less than that of R22 hence M 2 will ensure better performance. C.O.P is ratio of heat extracted from cold body and work supplied, hence higher C.O.P represent higher heat extraction rate at a given work supplied.
2) Enthalpy of the M 1, M 2 and M 3 is greater than that of R22, which ensure better heat transfer. It is clear from graph that M 2 has highest enthalpy. Higher enthalpy represents that heat extracting capacity of refrigerant is good which increases the refrigeration effect of the vopour compression cycle.
3) Density of M 1, M 2 and M 3 is lower than R22, which means specific volume is high, which further signifies that large size of compressor is required. Hence the size of compressor will be minimum for R22.

4) Entropy of the M 1, M 2 and M 3 is greater than that of R22 .Higher the entropy greater will be the dis-order ness of the system.
5) Global Warming Potential of M 1, M 2 and M 3 is lower than that of R22. Since M 1, M 2 and M 3 have comparatively low GWP as compared to R22 it can be widely used in vapour compression cycle and will cause less harm to the environment as compared to R22.
6) Ozone Depleting Potential of mixture is zero, since it does not contain any ozone depleting element like chlorine. Non-zero value of ODP of R22 is the major reason of its replacement from vapour compression cycle. Depletion of ozone has several bad effects on environment like melting of glacier, rise in sea water level, harm full skin disease, destruction of eco system etc.
7) Molecular weight of M 1, M 2 and M 3 is less than that of R22. Molecular weight of M 2 is minimum.

VI. CONCLUSION

M 1, M 2 and M 3 can be possible replacement of R22. Out of these three refrigerant, C.O.P **M 2** is higher than R22, also it has zero ozone depleting potential and low global warming potential as compared R22 which makes it an environment friendly refrigerant.

It is miscible with organic refrigerant and also chemically stable. These all properties make M 1, M 2 and M 3 as a possible replacement of R 22 in vapour compression refrigeration system. From table 8 it can be concluded that out of M 1, M 2 and M 3, M 2 is better replacement of R22.

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