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PERFORMANCE ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM OF WATER COOLER USING AN ECO FRIENDLY REFRIGERANT

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ABSTRACT

R134a (Hydrofluorocarbon refrigerant) is used in domestic refrigeration and other vapour compression system.R134a has zero ozone depletion potential (ODP) and excellent thermodynamic properties, but it has 1300 global warming potential (GWP) which is very high and consumes more power due to it high global warming potential. There is a need to find out the alternatives of R134a. In this study a new zeotropic mixture R407-x ((By weight ratio 88%R134a, 5%, R125, 7%R-32) is studied as a possible replacement of R134a in the vapour compression refrigeration system of water cooler. The performance analysis of new refrigerant mixture was done using property software (NIST REFPROP 6.01 SOFTWARE) .It has found to improve the COP of the system 5.28 to 5.666 and may prove to be a better refrigerant for use in the water cooler.

KEYWORDS: R134a, R407-x, ODP, GWP, COP, power.

INTRODUCTION

In India, more than 70% of the domestic refrigerator utilizes HFC 134a as refrigerant, due to its excellent thermodynamic and thermo physical properties. But, HFC 134a has a high global warming potential (GWP) of 1300.The HFC refrigerants are considered as one of the six target greenhouse gases under the Kyoto protocol of united nations framework convention on climate change (UNFCCC) In 1997 [1, 2]. The Kyoto protocol was approved by many nations called for the reduction in emission of greenhouse gas including HFC refrigerants. The presence of fluorine atoms in HFC134a is responsible for the major environmental impact (GWP) with serious implications for the future development of the refrigeration based industries. Usage of R134a consumes more power, up to 10-15% [3]. The COP of the system was also found to be 3% less than the system with R12 refrigerant [4]. Hydrocarbon refrigerants also have got the problem of flammability [5]. In the process of searching for new alternatives, since no single component refrigerant matches, hence refrigerant blends as the alternative was recommended, because by mixing two or more refrigerants a new working fluid with the desired characteristic can be developed.

LITERATURE REVIEW

1. ***R. Cabello et al [6]*** studied the influence of the evaporating pressure, condensing pressure and superheating degree of the vapour on the exegetic performance of a refrigeration plant using three different working fluids R134a, R407c, R22.

2. ***A.Baskaran&P.koshymathews [7],*** A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential. R600a have a slightly higher performance coefficient (COP) than R134a for the condensation temperature.

3. ***B.O. Bolaji et al [8]*** investigated experimentally the performances of three ozone friendly Hydrofluorocarbon (HFC) refrigerants R12, R152a and R134a. R152a refrigerant found as a drop in replacement for R134a in vapour compression system.

4. ***B.o. bolaji [9]*** discussed the process of selecting environmental-friendly refrigerants that have zero ozone depletion potential and low global warming potential. R23 and R32 from methane derivatives and R152a, R143a, R134a and R125 from ethane derivatives are the emerging refrigerants that are non toxic, have low flammability and

environmental-friendly. These refrigerants need theoretical and experimental analysis to investigate their performance in the system

5. ***Alka Bani Agrawal, R.K. Dave and Vipin Shrivastava[15]*** Replacing harmful refrigerant by comparing volumetric refrigeration capacity.

GENERATION OF REFRIGERANTS

1. The first generation (1830-1930) of refrigerants was based on the availability. These refrigerants were often highly toxic, flammable and some very highly reactive. Example Ethers, CO2, NH3, CCl4 etc.

2. The second generation (1930-1990) of refrigerants focused on reducing toxicity and flammability. Example: CFCs, HCFCs, HFCs, NH3, H2O etc.

3. The third generation (1990-2010) of refrigerants focused on protecting the ozone layer. Example HCFCs, HFCs, HCs, NH3, H2O, CO2 etc.

4. The fourth generation (from 2010 onwards) focused on refrigerants that do not contribute to global warming, ozone layer depletion, efficient, non flammable and non toxic with good stability. But the outlook for discovery or synthesis of these ideal refrigerants is extremely unlikely. Therefore, trade off among desired objectives is necessary to achieve the balanced solution.

THEORY OF REFRIGERATION (WATER COOLER)

Water cooler with water condenser is device which absorbs heat form refrigerated space to a temperature of 3 to 4^{o}c and water to be cool down .This cycle based on vapour compression refrigeration cycle has four main process are as

Compression: The low pressure vapour is drawn from the evaporator during the suction stroke of the compressor. During compression stroke the pressure and temperature increase until vapour temperature is greater than the temperature of condenser cooling medium.

Condensation: When the high pressure refrigerant vapour enters the condenser heat flows from the condenser to cooling medium .Thus allowing the vaporized refrigerant to return to a liquid state.

Expansion: After condenser the liquid refrigerant is stored in the liquid receiver until needed. From the receiver it passes through an expansion valve where the pressure is reduced.

Vaporization: The low pressure refrigerant vapour after expansion in the expansion valve enters the evaporator or refrigerated space where a considerable amount of heat is absorbed by it and refrigeration is furnished.

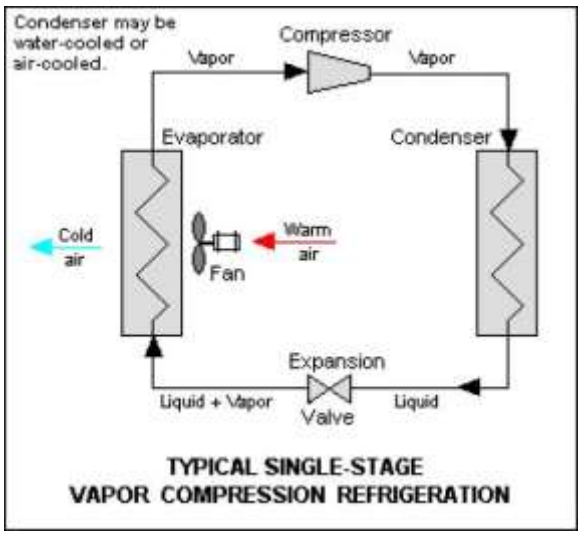


Figure: 01 VCRS cycle

Figure: 02Water Cooler

MONTREAL PROTOCOL

Montreal protocol on substances that deplete the ozone layer in the stratosphere was designed to gradually decrease the production and consumption rate of chemicals or refrigerant (chlorofluorocarbons, halons, carbon tetrachloride, and methyl chloroform). Scientific theory suggests that, once emitted to the atmosphere, these compounds could significantly deplete the stratospheric ozone layer that shields the planet from damaging UV- B radiation. The United Nations Environment Program (UNEP) has prepared a Montreal protocol.

The original Montreal protocol was agreed on 16 September 1987 and entered into on 1 January 1989. The Montreal protocol made an important adjustment that enables the parties to the protocol to respond quickly to new scientific information and decrease the rate of required on chemical or refrigerant already covered by the protocol. These adjustments are automatically applied to all the countries which are under this protocol. The Montreal protocol has been adjusted six times manually, the second, fourth, seventh, ninth, Eleventh and Nineteenth meetings of the parties to the Montreal protocol adopted. [10]

India had prepared a detailed Country Program (CP) in 1993 for the phase-out of ODSs in accordance with its National Industrial Development Strategy by accessing funds from the financial mechanism of the Montreal Protocol. The CP was updated in 2006. India has proactively phased out the production and consumption of CFCs except the use in Metered Dose Inhalers (MDIs) used for treatment of Asthma and Chronic Obstructive Pulmonary Disease (COPD) ailments from 1st August, 2008. Subsequently, the use of CFCs in MDIs has been phased out from December, 2012. India has also completely phased out production and consumption of CTC and headlines as of 1st January, 2010. [11]

KYOTO PROTOCOL

The Kyoto protocol is an international agreement linked to the United Nations framework convention on climate change, which commits its parties by setting internationally binding emission reduction targets.
The developed countries are mainly responsible for the current high level of greenhouse gas emission in the atmosphere.

The Kyoto protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005.On 21 December 2012, the amendment was circulated by the secretary general of the United Nations acting in his capacity as depositary for all parties to the Kyoto protocol.

During the first commitment period 37 industrialized countries and the European community committed to reduce greenhouse gas emissions to an average of five percent against 1990 levels. During the second commitment period, the parties committed to reduce greenhouse gas emissions by at least 18% below 1990 levels in the eight year period from 2013 to 2020. [12]

REFRIGERANT

Refrigerant are those working media or heat carries which directly take part in the refrigeration system and cool the substance by absorption of latent heat. There is different type of refrigerants but here about hydrofluocabons.

Hydrofluocabons (HFCs) provide an alternative to fully hydrogenated CFC refrigerants. They contain no chlorine atom and zero ODP. [13, 14]

R-134a is a commercially available hydrofluocabons (HFC) refrigerant for use as a long term replacement of CFC-12 systems. 1, 1, 1, 2-tetra- fluoroethane CH2FCF3 R134a is a single hydrofluocabons compound. Content no chlorine atom so no ozone depletion potential and global warming potential is 1300.

zeotropic refrigerant is the group of mixture of different substances. These substances can be separated into components by normal distillation. The separation factor zeotropic mixture can never be 1 but very close to 1. Making a separation by distillation is very difficult. Here use a zeotropic mixture of R134a, R125andR32 (low GWP refrigerant) and consist a group of R407. R407c is a non-ozone depleting blend of three HFC refrigerants (R32, R125, and R134a) and was designed to match as closely as possible replacement of R134a.

PERFORMANCE AND ANALYSIS

First of all charge Vapour Compression Refrigeration System (VCRS) of water cooler with R134a refrigerant and run the water cooler after 3hour when the steady state has come take an experimental reading of R134a given below in the table:

Table: 01 operating condition

Suction pressure P_1	1.9 BAR
Discharge pressure P_2	18.4 BAR
Compressor inlet temperature T_1	28.5 ^{O}C
Compressor outlet temperature T_2	90 ^{O}C
Condenser temperature T_3	36.4 ^{O}C
Evaporator temperature T_4	3.2 ^{O}C

Nomenclature

h_1 =Specific Enthalpy at the inlet of compressor.
h_2=Specific Enthalpy at the outlet of compressor.
h_{f3} =Specific Enthalpy at the outlet of condenser.
V_{g1}=Specific volume of vapour refrigerant at compressor inlet.
COP =Coefficient of performance.

FOR R134a

Take the thermodynamic refrigerant property at all point of VCRS cycle of water cooler by P-H refrigerant chart on operating condition.

Table: 02 Thermo physical property of R134a

Sr. No.	condition	Pressure (bar) P	Temp.(^{o}c) T	Enthalpy (kj/kg)
1.	COMPRESSOR INLET	1.9	28.5 ^{O}C	435
2.	COMPRESSOR OUTLET	18.4	90 ^{O}C	470
3.	EXPANSION INLET	18.4	36.4 ^{O}C	250

h_1 =435 KJ/Kg

h_2 =470 KJ/Kg

h_{f3} =250 KJ/Kg

ACTUAL COP= $(h_1-h_{f3})/ (h_2-h_1)$

ACTUAL COP = (435-250)/ (470-435)

ACTUAL COP =5.28

Compressor work input(KJ/Kg)= (h_2-h_1)

Compressor work input(KJ/Kg)= 470-435 Compressor work input(KJ/Kg)=35

Now find out the volumetric refrigerant capacity of the compressor for R134a refrigerant.

V_{g1}=0.02784 m^3/Kg

Refrigerating effect =h_1-h_{f3}
Refrigerating effect=435-250

Refrigerating effect=185 KJ/Kg

Volumetric refrigerant capacity (v.r.c.)=V_{g1}/ Refrigerating effect

Volumetric refrigerant capacity (v.r.c.) =0.02784/185

Volumetric refrigerant capacity (v.r.c.) =6643 KJ/m^3

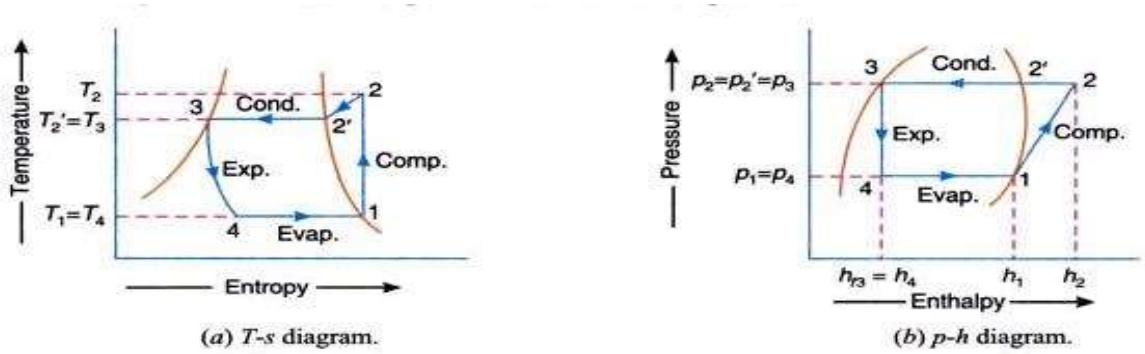
When the refrigerant has replaced with possible alternative new refrigerant, the volumetric refrigerant capacity of the new refrigerant should be equal to or very near to replace refrigerant. R407c is a non-ozone depleting blend of three HFC refrigerants (R32, R125, and R134a) and was designed to match thermodynamic refrigerant property and possible replacement of R134a.

For R407-x

The iteration has to be performed on different ratio of R407c.Here we use mixture ratio of R407 (By weight ratio 88%R134a, 5%, R125, 7%R-32 For 1Kg) and compares the operating condition of water cooler using R134a by property software (NIST REFPROP 6.01 SOFTWARE).Take a thermodynamic refrigerant property of R407-x at different point of VCRS cycle of water cooler by P-H refrigerant chart drawn by property software (NIST REFPROP 6.01 SOFTWARE).

Table: 03 Thermo physical property of R407-x

Sr. No.	Pressure (bar) P	Temp.(^oc) T	Enthalpy (kj/kg)	Quality
1.	1.9	28.5 ^OC	425	SUPERHEATED
2.	18.4	90 ^OC	455	SUPERHEATED
3.	18.4	36.4 ^OC	255	SUBCOOLED



(*a*) *T-s* diagram. (*b*) *p-h* diagram.

h_1 =425 KJ/Kg

h_2 =455KJ/Kg

h_{f3} =255 KJ/Kg

V_{g1}=0.0260824 m^3/Kg

Refrigerating effect =h_1-h_{f3}
Refrigerating effect=425-255

Refrigerating effect=170 KJ/Kg

Volumetric refrigerant capacity (v.r.c.)=V_{g1}/ Refrigerating effect

Volumetric refrigerant capacity (v.r.c.) =0.0260824 /170

Volumetric refrigerant capacity (v.r.c.) =6517.8 KJ/m^3

Obtain Volumetric refrigerant capacity which is very near to R134a (6643 KJ/m^3) is 6517.8 KJ/m^3 .This mixture is to be used in water cooler and mixture ratio of R407 is"88%R134a, 5%, R125, 7%R-32 "in their weight per Kg and named this new mixture is R407-x.

Compressor work input(KJ/Kg)= (h_2-h_1)

Compressor work input(KJ/Kg)= 455-425 Compressor work input(KJ/Kg)=30

ACTUAL COP= (h_1-h_{f3})/ (h_2-h_1)

ACTUAL COP = (425-255)/ (455-425)

ACTUAL COP =5.666

RESULT AND DISCUSSION

A comparative performance analysis was performed on R134a and R407-x obtain the following points:
1.The R407-x consume less power in the compressor which ensure that this is energy saving refrigerant. .
2. The irreversibility is less present in R407-x because R134a consume more power input.
3. The COP of the water cooler has improved 5.28 to 5.66 which ensure better performance.
4. The specific volume of the R407-x refrigerant is less than R134a which means that the size of the compressor has reduced.
5. GWP is reduces as compared to power consumption.
6. Ozone depleting potential of mixture is zero, since it does not contain any ozone depleting element like chlorine.

Table: 04 Compressions of R134a and R407-x

Compression	*R134a*	*R407-x*
ODP	0	0
Cop	5.28	5.666
Compressor work input(KJ/Kg)	35	30
Volumetric refrigerant capacity (KJ/m^3)	6643	6517.8
Miscibility with oil	same	same
specific volume(m^3/Kg)	0.02784	0.0260824
irreversibility	more	less

CONCLUSION

In this study, VCRS of water cooler is used for the performance analysis of alternative new refrigerants substitute for R134a. Considering the comparison of performance coefficients (COP) has increased and also compressor work input decreases.

The result proved that R407-x is the best environment-friendly, energy efficient and promising 'drop-in' substitute (without modification in the existing refrigeration system) for R134a in VCRS of water cooler.

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