Journal of Selected Areas in Mechatronics (JMTC)
Singaporean Journal of Scientific Research(SJSR)
Vol.6.No.6 2014 Pp. 260-275
available at:www.iaaet.org/sjsr
Paper Received :05-08-2014
Paper Accepted:23-08-2014
Paper Reviewed by: 1. Dr. P. Surya Prakash 2. Basu Reddy
Editor : Dr. Binod Kumar

INVESTIGATION ON R152A AS A SUBSTITUTE FOR R22 IN COMMERCIAL AIR CONDITIONING SYSTEM – A REVIEW

S.Vandaarkuzhali
Research Scholar
Dept. of Mechanical Engineering
Pondicherry Engineering College.
Pondicherry

Dr.R.Elansezhian
Associate Professor
Dept. of Mechanical Engineering
Pondicherry Engineering College.
Pondicherry

ABSTRACT

In recent years, Global Warming Potential (GWP) has turn out to be as important as Ozone Depletion Potential (ODP) when evaluating a probable refrigerant. Many automobile manufacturers and mobile A/C suppliers are exploring alternatives to today's R152a system because of concerns about its global warming potential. In the meantime, they are aggressively reducing R152a emissions by lowering the refrigerant charge and improving system refrigerant containment. The overall objective of this investigation is to evaluate R152a, hydrocarbon candidates and their potential as a replacement for R134a in mobile air conditioning systems. The performances of R152a in comparison with R22 are presented, from the theoretical as well as from an experimental point of view. The influence of R152a on compressor reliability has been also evaluated analyzing the bearing load and considering both the materials compatibility and the oil solubility; the lower operating temperature has a positive impact on compressor reliability. Some considerations of safety and why we are choosing R152a for our research are also presented.

Keywords: Global Warming Potential, Ozone Depletion Potential, R152a, hydrocarbon, Air Conditioning, refrigerant

1. INTRODUCTION

A leading international industry market research company in USA "The Freedonia Group", estimated that global demand for HVAC equipment is projected to rise 6.2 percent per year through 2014 to $93.2 billion and for fluoro chemicals will rise 2.7% yearly by volume through 2013.The cooling equipments growth will continue to outpace heating equipment gains through 2014, reflecting the lowest penetration rates of air conditioning equipment. Among the goods, room air conditioners will post the strongest gains worldwide. In India, annual report of Voltas limited company for the year 2009 stated that the trend in sales of room air conditioning system indicates a doubling of sales from 995,000 units in the year 2004-05 to 20.5 million units in the year 2007-08 (a growth of 27%) and according to a research carried out by Credit Rating Information Services of India Limited (CRISIL), the volume growth of air conditioners in the 5 years in India from the year 2003-04 to 2007-08 was 21 %. As the fossil fuel reserves are getting exhausted at a faster rate and considering the global warming also, it is an urgent need to improve the energy efficiency of vapour compression system based equipments.

The depletion of the ozone layer due to the release of chlorine from CFC and HCFC refrigerants has raised serious concerns about using them in vapor compression systems. Therefore, according to the amended version of the Montreal protocol, CFCs were phased out by January 1996, except for essential users, and HCFCs are to be phased out by 2020. Hence refrigerants or refrigerant blends with properties similar to CFCs and HCFCs and with zero ozone depletion potential (ODP) must be discovered to be used as replacements in existing systems. Two approaches are used to review the alternatives for R22. The first was to develop a substitute product with similar characteristics to R22. The refrigerant R134a has been accepted worldwide as the replacement with overall attributes best resembling R22. The second approach was to develop a substitute refrigerant, which would give the best performance when applied to the redesigned equipment, which traditionally uses R22. R410A is an azeotropic mixture of equal proportion by mass of HFC refrigerants R32 (CH2F2, difluoromethane) and R125 (HF2C-CF3, pentafluoroethane) with properties similar to those of R22. R410A has a higher volumetric cooling capacity compared to R22 and has better thermal exchange properties. This results in overall performance gains in terms of system efficiency, but some disadvantages are there. The higher density of the vapor in R152A permits higher system velocities, reduces pressure drop losses and allows smaller diameter tubing to be used. In turn a smaller unit can be developed using a smaller displacement compressor, less coil and less refrigerant while maintaining system efficiencies comparable to current day R22 equipment. Therefore, we have a low cost solution to meet specific equipment requirements.

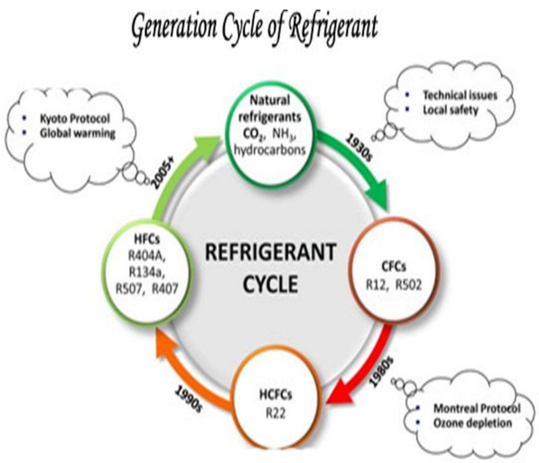

Figure 1: Diagram of Generation Cycle of Refrigerants

With the above objectives in mind a detailed literature survey has been carried out to assess the ongoing research in the area of alternative refrigerants for R22 and the possibility of adopting the nano fluids in the presence of Cu0, ZnO, Al2O3 in the range of 0.1% on the air conditioner to improve its performance and energy efficiency.

2.LITERATURE SURVEY

Jung et al. [3] tested 14 refrigerant mixtures composed of R32, R125, R134a, R152a, R290 (propane), and R1270 (propylene) in a breadboard heat pump in an attempt to substitute R22 used in residential air-conditioners. Test results show that ternary mixtures composed of R32, R125, and R134a have a 4-5% higher coefficient of performance (COP) and cooling capacity than R22. On the other hand, ternary mixtures containing R125, R134a and R152a have both lower COPs and cooling capacities than R22. R32/R134a binary mixtures show a 7% increase in COP with an analogous cooling capacity to that R22 while R290/R134a azeotropic shows a 3-4% increases in both COP and cooling capacity. The compressor discharge temperatures of the tested mixtures are much lower than those of R22, indicating that these mixtures would offer better system reliability and longer lifetime than R22.

Devotta et al. [4] studied theoretically some selected fluids that have been assessed for their suitability as alternatives to R22 for air-conditioners. Among the refrigerants studied R134a, R290, R407C, R410A, and three blends of R32, R134a and R125. The replications indicate that R134a offers the highest COP, but its cooling capacity is the lowest and requires much larger compressors. The thermodynamic performances obtained with R290 are similar to that obtained with R22 and compressors require very little modifications. The authors concluded that R290 is a potential candidate on condition that the risk concerns are mitigated. For retrofitting, R407C seems to be the best candidate.

Devotta et al. [4] presented an experimental performance analysis of a window air-conditioner, retrofitted with R407C, as a substitute to R22. Experimental results showed that R407C had lower cooling capacity in the range 2.1-7.9% with respect to R22. The coefficient of performance for R407C was lower in the range 7.9-13.5%. The power consumption of the unit with R407C was higher in the range 6-7% than R22. The discharge pressures for R407C were higher in the range 11-13% than R22.

Devotta et al. [5, 6] presented an experimental performance study of a window air conditioner with propane (R290) as a drop-in substitute to R22. Experimental results showed that R290 had lower cooling capacities in the range 6.6-7.9% with respect to R22. The coefficient of performance for R290 was higher in the range 2.8-7.9%. The energy consumption of the air-conditioner was lower in the range 12.4-13.5% than R22. The discharge pressures for R290 were lower in the range 13.7-18.2% than R22.

Jabaraj et al. [7] conducted an experimental investigation in a window air conditioner retrofitted with refrigerant mixtures of R407C/R290/R600a without changing the mineral oil. It is observed that the mixtures demand lengthening of the condenser in order to maintain the discharge pressure within acceptable limits. This also results in better heat transfer at the condenser. Compared to R22, the refrigeration volume of the mixtures is 9.5% to 12.8% sophisticated than that of R22, while the COP is found to be 11.9 to 13.2% higher than that of R22.

Jabaraj et al. [8]studied the possibility by using the R407C/R290/R600a refrigerant mixture as a substitute for R22 in a window air conditioner and to progress an optimal composition for the mixture. The experiments for the mixtures comprising 10, 15, 20 and 25% R290/R600a blend (by weight) in R407C (referred as M10, M15, M20, and M25, respectively). Among the mixtures, the M20 is characterized by extreme refrigeration capacity. It is observed that the improvement in refrigeration capacity of M20 mixture is 9.54 to 12.76% higher than R22 at various condenser inlet air temperatures. It was noted that the discharge pressure of R22 is found to be lowest among these refrigerants. For M20, the discharge pressure is found to be 3.73 to 11.46% higher than that of R22. However, the pressure ratio for M20 was the lowest and was found to be 3.56 to 4.97% lower than that of R22. It was also observed that among the mixtures, the M20 is found to be having the lowest power consumption, which is 1.25 to 1.45% higher than that of R22. It was also noted that even though with mixtures, the power consumed by the compressor is higher than that of R22, the COP is also higher because of the higher mass flow rates and better transfer characteristics. Among all the mixtures, M20 has the maximum COP, which is 8.19 to 11.15% higher than that of R22. The lowest COP is obtained with M25. The compressor discharge temperatures obtained with the mixtures are less than that of R22 and it was the lowest for M20 with 12.07 to 14.09% reduction as compared to R22. M20 allows for the lowest per day energy consumption. Typically, it is 5.08 to 10.45% less than that of R22.

Park and Jung [9] studied the thermodynamic performance of two pure hydrocarbons and seven mixtures composed of propylene (R1270), propane (R290), R152a, and dimethylether (RE170) as substitute refrigerants for residential air-conditioning applications. The test results showed that:

(1) COPs got with these fluids are similar to or better than that of R22. 45% R1270/40% R290/15% RE170 mixture showed the highest COP, which is 5.7 % higher than that obtained with R22;

(2) Refrigeration capacities obtained with propane (R290)and 20%R1270/80% R290 mixture are lower than that of R22 by 11.5% and 6.6% respectively, while the other fluids showed a similar refrigeration capacity to that obtained with R22;

(3) The compressor discharge temperature of all fluids tested were lower than that of R22 by 11% to 17% and (4) the refrigerant charge for all refrigerants tested was reduced up to 55% as compared to R22 due to their lower density.

Park et al. [10] Have carried out an experimental study of the thermodynamic performance of R432A used to replace R22 in residential air-conditioners and heat pumps. R432A is a near azeotropic mixture composed of 80% propylene (R1270) and 20% dimethylether (RE170). Test results showed that the coefficient of performance and capacity of R432A are 8.5 to 8.7% and 1.9 to 6.4% higher than those of R22 for air-conditioning and heat pumping conditions.

The compressor discharge temperature of R432A is 14.1 to 17.3% lower than that of R22 while the amount of charge for R432A is 50% lower than that R22 due to its density. The authors concluded that R432A is a good long term 'drop-in' environmentally friendly alternative refrigerant to replace R22 in domiciliary air-conditioners and heat pumps due its outstanding thermodynamic and environmental properties.

Chen [11] carried out a comparative study on four sets of comparable R410A and R22 split-type residential air conditioners. It was concluded that the adoption of R410A could be helpful for air conditioners to decrease their heat exchanger size or improve their operation efficiency for power saving. The improvement of the cooling capacity and that of the coefficient of performance are about 4% and 13.9%, respectively when the air conditioner conception is optimized.

Using the cycle-II, Pannock and Didion (1991) and Domanski and Didion (1993) studied the performance of nine R22 alternatives. Sagia (2001) developed an algorithm on the basis of heat and thermodynamics theory to define the blend with the most favourable composition, as an environmentally acceptable solution for R22 replacement. Corberan et al (2008) reviewed the standards followed for vapour compression refrigeration systems working with HC refrigerants and reported existing standards, maximum charge, room area limits and specific requirements.

Palm (2008) compared the properties and performance of hydrocarbons as refrigerants in small-size heat pump and refrigeration systems (< 20 kW cooling) and reported that usage of hydrocarbons will result in COPs equal to, or higher than, those of similar HFC systems. Also suggested that reduced the charge through indirect systems and compact heat exchangers, outdoor placing of the unit, hydrocarbon sensors and alarms and forced ventilation are the steps which may be applied to reduce the risks under normal operation.

Prapainop and Suen (2012a) have reviewed the effects of thermophysical properties and derived parameters of refrigerants on system performance and noted that to obtain a high COP, combinations of high values of latent heat, liquid thermal conductivity and vapour density and low values of liquid viscosities and molecular weight are required. Critical temperature and vapour specific heat are important properties when considering trade-offs between capacity and COP.

HFC mixtures are not miscible with mineral oil, which is used as a lubricant in CFC and HCFC systems. HFC mixtures require synthetic lubricant like polyolester. Hence, a major modification is required for HFC mixture to retrofit in HCFC systems.

Bivens (1996) conducted performance tests for HCFC-22, R407C and R410B in a split system heat pump to suggest alternative refrigerants for building air-conditioning and concluded that it is possible to exceed the energy efficiency of HCFC-22 with either R407C or R410B if appropriate equipment design changes are made. The future choice of these alternatives will be based on economics and difficulty of design changes for specific equipment. Mongey et al (1996) compared the performance of R407C and R22 in vapour compression based refrigeration system and reported that the performance of R407C approached that of R22 at higher evaporator temperature. Also the temperature glide of R407C, in the evaporator will change the composition and reduces evaporator capacity and COP.

Pande et.al (1996) tested three refrigerants, R32, R410A (R32 / R125, 50/50 wt %) and R410B (R32 / R125, 45/55 wt %) in a residential heat pump system and compared their performance with R22. It was found out that R32 yielded the best performance. R32 showed cooling seasonal performance 5 % better than R22 and heating seasonal performance 3 % to 4 % better than R22. R410A and R410B showed 2% to 3% better cooling seasonal performance and equivalent heating performance than those of R22.

Greco et.al (1997) analyzed the problem of HCFC-22 phase-out in refrigeration plant by comparing the performance of R22 and R407C in a water cooled vapor compression plant and reported that COP for R407C is 5 - 17% lower than that of R22 and compression ratio for R407C is 5-21% higher than that of R22. In order to provide the same cooling load, a plant working with R407C requires higher electric-power consumption and R407C is a good R22 substitute in all applications requiring high evaporation temperatures, such as air-conditioning plants.

Aprea et.al (1998) examined the problem of R22 substitution in terms of global warming effect in vapour compression refrigeration effect and reported that at higher condensation (over 50 °C) and the evaporation temperature (2- 10 °C), the Total Equivalent Warming Impact (TEWI) of R407C is even slightly lower than of R22 and its substitution for R22 is convenient from the point of view of the greenhouse effect.

Chin and Spatz (1999) conducted the tests in residential and light commercial equipment and noted that the performance of R410A is higher than R22 when ambient temperature is lower than 35 °C. Due to the compressor efficiency degradation, the performance of R410A is inferior to that of R22 at high ambient temperatures.

The performances of some new refrigerant mixtures like R32/125/152a, R125/290 and R32/125/290 have been theoretically and experimentally investigated by Yang Zhao et al (1999) under varying working conditions and they can be suitable replacements for R22. The evaporator temperature range considered is –35°C to 10°C and condenser temperature ranges from 30°C to 60°C. The performances of the R32/125/152a mixtures are close to that of R22 under all ranges of operating conditions.

Yajima et.al (2000) selected the low GWP refrigerant R32 as an alternative to R410A based on the concept that the higher the non flammability of refrigerant is, the larger its GWP and the lower its energy efficiency and tested its performance and TEWI in a 16 kW prototype with a variable speed compressor. Test analysis showed that COP of R32 was higher than that of R410A not only under the rated capacity condition, but also under the capacity reduction by compressor speed control. The analysis also shows that its heating COP at a low ambient temperature and its cooling COP under the overload condition are superior and the refrigerant charge can be reduced by the adoption of smaller diameter heat transfer tubes for heat exchangers. In the Tokyo area, its TEWI dropped by 18% in comparison with that of R410A and a direct impact portion of R32 decreased to 7% of the total impact. Also stated that since R32 has a potential to economically satisfy the requirements of safety and environmental protection simultaneously, R32 is likely to become the major refrigerant for the future air conditioning equipment.

Dongsoo et.al (2000) reported that R407C, a non azeotropic refrigerant mixture is having gliding temperature difference of roughly 6°C. Its vapor pressure is similar to that of R22 and hence it is expected that R407C may be used in existing equipment without major changes. At present it seems that instead of R407C, R410A can be adopted in new systems. Due to high pressure, the compressor needs to be reshaped completely and also the heat exchangers need to be optimized to accommodate lower volumetric flow rates associated with the use of R410A. HFC407C is a close match to HCFC22 in existing equipment with respect to energy efficiency and other performance parameters such as compressor discharge temperature and pressure.

Henderson et.al (2001) compared the performances of a domestic and commercial heat pumps working with R22 and its alternatives R410A and R290 and suggested that R410A is a good substitute compared to R290 to replace R22 in domestic and commercial heat pump due to increase in performance and comparable global warming potential.

Han et.al (2007) investigated with a ternary HFC mixture composed of R32/R125/R161 as an alternative to R407C and reported that the pressure ratio and power consumption are found to be lower than R407C and the above mixture has the high refrigeration capacity and COP compared to R407C.The slightly higher discharge temperature of the mixture than R407C might affect the life of the compressor.

Wu et.al (2009) experimentally studied the performance and flammability of a new refrigerant mixture (composed of R152a/R125/R32 in the ratio of 48:18:34 by mass respectively) in a R22 based domestic air conditioner and concluded that COP of the mixture was slightly lower than that of R22.The variation of COP and gliding temperature under leakage conditions (leaking ratio between 0 and 20%) was reported to be very low. The flammability test of refrigerant mixture reported that it could safely use in domestic air conditioners.

Bolaji et al (2011) selected three ozone friendly Hydro fluorocarbon (HFC) refrigerants (R32, R134a and R152a) tested in a vapor compression refrigeration system and compared the performance. The results obtained showed that R32 yielded undesirable characteristics, such as high pressure and low COP. Comparison among the selected refrigerants confirmed that R152a has a higher COP than those of R134a and R32 by 2.5% and 14.7% respectively.

Taira et.al (2011) tested room air conditioner with R32 as an alternative to R410A based on Japanese Industrial Standards, JIS-C 9612 Standard and confirmed that the recital of R32 is higher than R410A due to its pressure drop and heat exchange characteristic in evaporator and condenser and also the charge amount of R32 is lesser than R410A.

Tu et.al (2011) compared the performance using R32 and R410A in a thermodynamic model and conducted experiments at different operating conditions in a 3.2 kW residential heat pump unit. Experimental results showed that R32 outperformed R410A by 8 % and 3 % in cooling and heating capacities, respectively, and by 3 % and 2 % in cooling and heating COPs, respectively.

Pham and Rajendran(2012) conducted various drop in system tests with different heat exchangers and scroll compressors by using R32, R410A and Hydro Fluoro Olefins (HFO) blends such as R1234yf and R1234ze and compared the system performance theoretically and experimentally on basis of

Life Cycle Climate Performance (LCCP), system economics, compressor discharge temperature and A2L refrigerants (refrigerants with flame velocity below 10 cm/s were recently classified as "2L" by ASHRAE 34) flammability safety aspects. They suggested that the performance of R32 can be improved by finding new compatible lubricating oil and optimizing the compressor and system towards achieving its theoretical potential as well as mitigating its higher compressor discharge temperature.

3. SELECTION CRITERIA OF THE REFRIGERANTS AS ALTERNATIVES TO R22

It can be observed that only few pure and many mixed refrigerants have been considered so far as alternatives to R22. The refrigerant selection supposes to consider several criteria among them we can distinguish: (1) the thermodynamic criteria, (2) the safety criteria, (3) the action on the environment criteria, (4) the technical criteria, and (5) the economic criteria which constitutes the heart of the technical problems.

3.1 Thermodynamic Criteria

- Critical temperature: The temperature of condensation, Tk, must always be lower than the critical temperature. Hence, if the critical temperature is low, the efficiency of the refrigerated system decreases.
- The pressures of the refrigeration cycle: The pressure limits of the refrigeration cycle are so well defined by the manufacturer and we necessarily have to stay in these limits. To keep a good efficiency for the compressor, the compression ratio, $\delta = Pk/Po$, also has to remain limited. The important values of the compression ratios, besides that they are generally the cause of excessive heating of the fluid, entrains a decrease of the volumetric compressor efficiency and an increase of its energy consumption.
- Heating of vapors during the compression: According to the nature of the refrigerant, the overheating of vapors can, during the compression, undergo different variations. In case of a strong increase of the vapor overheating, the discharge temperature becomes quickly intolerable. With certain fluids, it is necessary to limit the compression ratio and admit vapors in the compressor in the lowest conceivable temperatures.
- Sliding of temperature during condensation and evaporation: The temperature of a pure fluid or an azeotropic mixture does not vary during the evaporation or condensation. On the other hand, zeotropic mixtures see their temperature evolving during these changes of state. According to the composition of these zeotropic mixtures, this sliding of temperature can be enough reduced (of the order of 1 K or less). For other mixtures, this sliding is much more important and can reach about 10 K. Hence, we have to take into account this temperature variation of the refrigerant in heat exchangers, in particular for the regulation of the evaporator supply.
- Volumetric refrigeration capacity: This important parameter is defined by the cooling capacity produced by unit of volume of fluid slurped up by the compressor. If the volumetric refrigeration capacity is high, then the volume flow rate sucked up by the compressor is low. Hence, smaller compressor can be used. This

parameter varies with the conditions of the refrigerated cycle and the nature of the refrigerant.

3.2 Safety Criteria

The major disadvantage of hydrocarbons is their flammability. Some national safety codes still permit the use of flammable refrigerants. The minimization of risks associated with the use of flammable refrigerant can be accomplished either by means of adding safety features or by mixing the flammable refrigerant with other non-flammable refrigerants to obtain a non-flammable mixture. If safety measures are taken to prevent refrigerant leakage from the system, then a flammable refrigerant system could be as safe as any normal system.

3.3 Environmental Criteria

The environmental impacts of the fluids are characterized by their Ozone Depleting Potential (ODP) relative to R11, Global Warming Potential (GWP) relative to carbon dioxide, Total Equivalent Warming Impact (TEWI), Life Cycle Climate Performance (LCCP), and atmospheric lifetimes. While the decision to phase out R22 is based on its potential to deplete stratospheric ozone, consideration of alternatives also must consider additional environmental data.

- The Ozone Depleting Potential (ODP) is a normalized indicator of the ability of refrigerants (and other chemicals) to destroy stratospheric ozone molecules.
- The Global Warming Potential (GWP) is a normalized indicator of the potency to warm the planet by action as greenhouse gas (GHG). These days, greenhouse warming has become one of the most important issues and Kyoto protocol was proposed to resolve this issue, and classified HFCs as greenhouse gases. R134a (GWP = 1300) will be banned in mobile air-conditioners of new vehicles from 2011 (HFC who's GWP is more than 150 will be banned).
- Total Equivalent Warming Impact (TEWI) is besides GWP measure used to express contributions to global warming. It is defined as the sum of the direct (chemical emissions) and indirect (energy use) emissions of greenhouse gases:

TEWI = GWP (direct effects due to refrigerant leaks) + GWP (indirect effects due to A/C operation)

(1) The direct and indirect impacts are determined by: Direct effects = Refrigerant charge × (Annual loss rate × lifetime + End-of-Life loss) × GWP

(2) Indirect effects = Annual power consumption × Lifetime × Country-specific CO2 emission factor

(3)TEWI results have indicated that the direct GWP of the refrigerant is less important than 10% of the total TEWI for these products depending on what assumptions are used for the analysis, and that the direct GWP of the refrigerant is less important than the overall efficiency of the unitary system. This indicates that any refrigerant blend proposed as an alternative for R22 must provide good cycle efficiency in addition to a low or moderate GWP.

- Life Cycle Climate Performance (LCCP): The use of Life Cycle Climate Performance (LCCP) assessment is becoming a preferred alternative to the Total Equivalent Warming Impact (TEWI) calculation because it includes consideration of the equivalent warming impact of the refrigerant during production as well as during use. The warming impacts associated with the manufacture of any fluorocarbons must be accounted for. Two basic categories of manufacturing related warming impact have been identified:

(1) the indirect warming impact associated with the energy consumed (electric energy and various fuels burned on site) to manufacture both the fluorocarbon and the raw materials used to make the fluorocarbon (the so-called "embodied energy" or "embedded energy") and

(2) the direct warming impact of any byproduct greenhouse gases that are emitted by the manufacturing process (the so-called "fugitive" emissions).

LCCP = TEWI + embedded energy (Indirect) [(chemical production of refrigerant & transport) +
(manufacturing A/C components & their assembly) + (end-of-life)]+fugitive emissions (direct) [(atmospheric reaction products of refrigerant) + (end-of-life) + (manufacturing leakage)]

(4)Hence, it is an indicator that includes the direct contribution of greenhouse gases used as refrigerants in the systems and the indirect contribution of the carbon dioxide emissions resulting both from the energy required to run the systems over their lifetime and producing the refrigerant.

-The atmospheric lifetime is defined as the time after which the concentration of an emitted chemical substance has decreased approximately by 64%. It is an indication of the average persistence of refrigerant released into the atmosphere until it decomposes, reacts with other chemicals, or is otherwise removed. Long atmospheric lifetime implies the potential for slow recovery from environmental problems, both those already known and additional concerns that may be identified in the future. Hence, short atmospheric lifetime is desirable. The atmospheric lifetime impacts both the ODP and GWP.

3.4 Technical Criteria

- Metal compatibility with refrigerants: The refrigerant obviously has to remain passive towards
metals with which it is in contact with the refrigerated circuit. Except the ammonia, which reacts with the copper, all other refrigerants, former and new, accept all the current metals.

- Elastomers, plastics and insulating resin compatibility with refrigerants: These materials enter the constitution of seals, the drying granules in the dryers, elements of the electrical insulation, etc. We have to consider the action of the refrigerant of these substances, but more generally, the action of the couple refrigerant/lubricant. The physical and chemical actions of the refrigerant, essentially when it is in liquid phase, or of the mixtures refrigerant/oil could happen by inflation or shrinkage of the plastic or the elastomer, softening or hardening, dissolution of a constituent of the material, degradation of its mechanical properties, and the diffusion of the refrigerant through the material which does not insure any more the waterproofness, etc.

-Oil and lubricants: This action takes on three essential aspects: (1) a physical aspect, concerning the conditions of miscibility of the considered refrigerant and the lubricant; (2) a chemical aspect, concerning the mutual actions of the refrigerant on the lubricant; and (3) a mechanical aspect, concerning the capacity of the lubricant to insure the deliberate lubrication of a couple of metals in relative movement, in the presence of the considered refrigerant and in conditions of use. The miscibility of the refrigerant with the oil can be total, very weak, and dependent on the temperature and on the composition of the mixture. For example, with R407C, Polyolester (POE) oil must be used instead of mineral oil. This POE oil is highly hygroscopic leading to several service issues. It is also expensive and it causes irritation if it comes in contact with the skin. If R407C could be made to work with mineral oil, the above service issues could be alleviated. It is possible to mix suitable hydrocarbon refrigerants with HFCs to solve the miscibility issues with mineral oil.

Preliminary investigations proved that the addition of hydrocarbon blend with R407C could solve the immiscibility issue with mineral oil and also improve the system performance. The only drawback of HC is its flammability, but a reduction in flammability can be achieved by mixing HC and HFCs. Behavior in the presence of water: If the presence of water is relatively well tolerated by the ammonia (big affinity for the water), it can raise numerous problems with most of the refrigerants. Among these problems, we can distinguish: (1) formation of hydrates by association of a molecule of refrigerant with several water molecules. The hydrates, which have thermodynamic properties different from those of the refrigerant, can become solid at low-temperature and seal the capillaries; (2) chemical destruction of the refrigerant molecules by hydrolysis; and (3) reaction with the copper.

-Thermal stability of the molecule: The molecule of refrigerant (or the molecules of the components of a refrigerant mixture) must be able to support, without decomposing, the action of the temperature.

-Electrical conductivity: The electric conductivity of the refrigerant, in particular its liquid phase, plays an evident role in the technique of the hermetic groups, it also has its importance in the problems of corrosion.

-The efficiency of the thermal exchanges of the condenser and the evaporator: The efficiency of the thermal exchanges depends on various thermophysical properties of the refrigerant such as the thermal conductivity, the density, the viscosity, the specific heat capacity, the surface tension, and the latent heat.

-Leaks: Openings of very small sizes are filled with corks of oil maintained in place by capillary strengths. The durability of these corks depends directly on the surface tension of the oil in the presence of the refrigerant. When the oil absorbs the refrigerant, its superficial tension decreases and corks of oil are chased and leaks appear.

-Detection and localization of the leaks: To improve the waterproofs of a refrigerating plant, it is better to confine the refrigerant. If there are leaks, it is necessary to detect their presence. This operation, easy when the refrigerant is very nice-smelling (as the ammonia), turns out delicate when the fluid is practically odorless (case of all other refrigerants). If we detected leaks, it is then necessary to localize them. Certain practitioners use soapy solutions which, spread on the distrustful zones, form bubbles in the locations where leaks appear. Other methods to be used depending on the refrigerant. Indeed, halogenous refrigerants are detected by means of devices equipped with snifflers, which drive the molecules of these fluids on a deep surface, decompose them, and release halogens of the compound. It is the presence of these atoms of halogen which acts on the sensitive element of the detector. With chlorinated refrigerants CFC and HCFC, it is the chlorine, easily released, that we detect. With HFC, it is necessary to release the fluorine of the molecule, which is much more difficult. Certain detectors are so incapable to reveal the leaks of these new refrigerants.

3.5 Economic Criteria

-Prices of the refrigerant and the associated lubricants: It is a considerably fluctuating criterion. For a long time, its impact on the choice of the fluid was considered as minor. However, today it is considered as an important criterion. It is usual to report the price of the refrigerant in the unit of mass while the price referred to the unit volume is much more significant. The rise of the price of refrigerants incites to the research, on one hand, for a reduced load of refrigerant in machines and, on the other hand, for a better seclusion. The prize of lubricants associated to refrigerants also is to be considered. Polyoester oils (POE), imposed by the use of HFC refrigerants and their mixtures are more expensive than mineral oils used with former refrigerants. Besides, the choice of the refrigerant influences directly those of the compressor and heat exchangers. To give refrigeration power and pressure drop, the nominal diameter of the liquid and vapor lines, thus their prices, as well as those of the accessories (stop valves, regulating valves, filters, etc.) depend directly on the choice of the refrigerant.

- **Availability of the refrigerant:** It must be sufficient to cover immediately the needs. Indeed, the refrigerated service cannot be interrupted for a long time. The refrigerant thus has to be a widely produced fluid and internationally distributed. The follow-up of the manufacturing and the distribution of the classic refrigerants have never raised serious problems. Users were assured to find the refrigerant during the life of the installations.

4. CONCLUSION

Background and Objectives of the Present Work To avoid the global warming and ozone depletion, environment friendly alternative refrigerants should be used in HVAC equipment and also new system design or method should be implemented to save the energy and improve the performance of the system. Hence, based on refrigerant property details given in the refrigerants R152A are considered as a suitable alternative for R22 for room air conditioner. To improve the performance of the system and save the energy, add the Nano fluids in the presence of CuO, ZnO, Al_2O_3 in the range of 0.1% on the air conditioner to improve its performance and energy efficiency. Keeping the above aspects in mind it has been decided to carry out the present research work.

REFERENCE

[1] United Nations Environmental Program, Montréal protocol on substances that deplete the ozone layer, Final act, New York, 1987.
[2] Air-conditioning and Refrigeration Institute, R22 and R502 Alternative Refrigerants Evaluation Program, Arlington, VA, 1992-1997.
[3] D. Jung, Y. Song, B. Park, Performance des mélanges de frigorigènes utilisés pour remplacer le HCFC22, Int. J. Refrigeration 23 (2000) 466-474.
[4] S. Devotta, A.V. Waghmare, N.N. Sawant, B.M. Domkundwar, Alternatives to HCFC-22 for air conditioners, Applied Thermal Engineering 21 (2001) 703-715.
[5] S. Devotta, A.S. Padalkar, N.K. Sane, Performance assessment of HCFC-22 window air conditioner retrofitted with R-407C, Applied Thermal Engineering 25 (2005) 2937-2949.
[6] S. Devotta, A.S. Padalkar, N.K. Sane, Performance assessment of HC-290 as a drop-in substitute to HCFC-22 in a window air conditioner, Int. J. Refrigeration 28 (2005) 594-604.
[7] D.B. Jabaraj, P. Avinash, D. Mohan Lal, S. Renganarayan, Experimental investigation of HFC407C/HC290/HC600a mixture in a window air conditioner, Energy Conversion and Management 47 (2006) 2578-2590.
[8] D.B. Jabaraj, A. Narendran, D. Mohan Lal, S. Renganarayanan, Evolving an

optimal composition of HFC407C/HC290/HC600a mixture as an alternative to HCFC22 in window air conditioners, Int. J. Thermal Sciences 46 (2007) 276-283.

[9] K.J. Park, D. Jung, Thermodynamic performance of HCFC22 alternative refrigerants for residual air-conditioning applications, Energy and Building 39 (2007) 675-680.

[10] K.J. Park, T. Seo, D. Jung, Performance of alternative refrigerants for residual air-conditioning applications, Applied Energy 84 (2007) 985-991.

[11] W. Chen, A comparative study on the performance and environmental characteristics of R410A and R22 residential air conditioners, Applied Thermal Engineering 28 (2008) 1-7.

[12] K.J. Park, Y.B. Shim, D.Jung, Experimental performance of R432A to replace R22 in residual air-conditioners and heat pumps, Applied Thermal Engineering 29 (2009) 597-600.

[13] J. Chen, J. Yu, Performance of a new refrigerant cycle using refrigerant mixture R32/R134a for residential air-conditioner applications, Energy and Building 40 (2008) 2022-2027.

[14] P.A. Domanski, J. Chi, CYCLE_D : NIST Vapor Compression Cycle Design Program, Version 3, U.S. Department of Commerce, Technology Administration, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, MD 20899, April 2003, p. 43.

[15] United Nations, Greenhouse Gas Calculator 1.0, April 2009, p. 55.

[16] A.D. Little, Global comparative analysis of HFC and alternative technologies for refrigeration, air conditioning, foam, solvent, aerosol propellant, and fire protection applications, Final Report for the Alliance for Responsible Atmospheric Policy, March 21, 2002, Reference 75966, p. 150.

[17] Palm, B., 2008. Hydrocarbons as refrigerants in small heat pump and refrigeration systems – a review. Int. J. Refrigeration 31,552–563.

[18] Corberan, J.M., Segurado, J., Colbourne, D., Gonzalvez, J., 2008. Review of standards for the use of hydrocarbon refrigerants in a/c, heat pump and refrigeration equipment. Int. J.Refrigeration 31, 748–756.

[19] Domanski, P.A., Yashar, D., 2006. Comparable performance evaluation of HC and HFC refrigerants in an optimized system. In: Proceedings of the Seventh IIR-Gustav Lorentzen Conference on Natural Working Fluids at Trondheim, Norway, May 29–31.

[20] Colbourne, D., 2000. An overview of hydrocarbons as replacement refrigerants in commercial refrigeration and air conditioning. Refrigeration Northern Ireland Centre for Energy Research and Technology.

[21] Colbourne, D., Suen, K.O., 2000. Assessment of performance of hydrocarbon refrigerants. In: Proceedings of the Fourth IIRGustav Lorentzen Recovery of Engine Waste Heat for Reutilization in Air Conditioning System in an Automobile: An Investigation Conference on Natural Working Fluids, Purdue, USA.

[22] Colbourne, D., Ritter, T.J., 2000. Compatibility of Non-Metallic Materials with Hydrocarbon Refrigerant and Lubricant Mixtures. IIF-IIR- Commission B1, B2, E1 and E2 – Purdue University, USA.

[23] Maclaine-Cross, I.L., Leonardi, E., 1996. Comparative performance of hydrocarbon refrigerants. In: I.I.F. – I.I.R. – Commissions E2, E1, B1, B2, Melbourne, Australia.

[24] Ghodbane, M., 1999. An investigation of R152a and hydrocarbon refrigerants in mobile air conditioning. In: International Congress and Exposition, SAE Paper 1999-01-0874, Warrendale, PA.
[25] Razmovski, V., 1994. Safety of hydrocarbon refrigerants for car air conditioning systems. B.E. thesis, School of Mechanical and Manufacturing Engineering, UNSW, Sydney.
[26] Rajasekariah, C., 1995. Safety of hydrocarbon refrigerant safety in automobiles. B.E. thesis, School of Mechanical and Manufacturing Engineering, UNSW, Sydney.
[27] M. Suzuki, Apphcation of adsorption cooling systems to automobiles. Heat Recovery Systems & CHP 13, 335- 340 (1993).
[28] ASHRAE, 2008. ASHRAE Handbook, HVAC Systems and Equipment. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.
[29] ASHRAE, 2004. ANSI/ASHRAE Standard 34, Designation and Safety Classifications of Refrigerants. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.
[30] Granryd, E., 2001. Hydrocarbons as refrigerants – an overview Int. J. Refrigeration 24, 15–2
[31] Dieckmann, J.T., Bentley, J., Varone, A., 1991. Non- Inert Refrigerant Study for Automotive Applications. p. 75. DIN, 2004.
[32] Colbourne, D., Suen, K.O., 2004. Appraising the flammability hazards of hydrocarbon refrigerants using quantitative risk assessment model, part II, model evaluation and analysis. Int. J. Refrigeration 27, 784–793.
[33] Gigiel, A., 2004. Safety testing of domestic refrigerators using flammable refrigerants. Int. J. Refrigeration 27, 621–628.
[34] Pearson, A., 2005. Carbon dioxide – new uses for an old refrigerant. Int. J. Refrigeration 28, 1140– 1148.
[35] Devotta, S., Sawant, N.N., 2000. Life testing of hermetic compressor with various hydrocarbon grades and other alternatives to CFC-12. In: Proceedings of the Fourth IIRGustav Lorentzen Conference of Natural Working Fluids, Purdue, USA, pp. 245–249.
[36] Pellec, C.L., Marvillet, C., Clodic, D., 1996. Experimental study of flat heat exchangers in ammonia refrigeration unit. In: Proceedings of the IIR Conference on Applications for Natural Refrigerants, Aarhus, Denmark, pp. 785–794.
[37] Setaro, T., Boccardi, G., Corberan, J.M., Urchueguia, J., Gonzalvez, J., 2000. Comparative study of evaporation and condensation of propane and R22 in a brazed plate heat exchanger and a tube and fins coil. In: Proceedings of the Fourth IIR Gustav Lorentzen Conference of Natural Working Fluids, Purdue, USA, pp. 233–238.
[38] Hrnjak, P.S., Hoehne, M.R., 2004. Charge minimization in systems and components using hydrocarbons as a refrigerant. ACRC TR-224.
[39] Fernando, P., Palm, B., Ameel, T., Lundqvist, P., Granryd, E., 2004. Propane heat pump with low refrigerant charge: design and laboratory tests. Int. J. Refrigeration 27, 761–773.
[40] Fernando, P., Palm, B., Ameel, T., Lundqvist, P., Granryd, E., 2008a. A minichannel aluminum tube heat exchanger – part I: evaluation of single-phase heat transfer coefficients by the Wilson plot method. Int. J. Refrigeration 31, 669–680.
[41] Kruse, H., 2000. Refrigerant use in Europe. ASHRAE J. 42, 16–25. Likes, P., 1996. Secondary refrigerant systems for supermarket equipment. In: International Conference on Ozone Protection

Technologies, October 21–23, Washington, D.C pp. 158–164.
[42] Kauffeld, M., 2008. Trends and perspectives in supermarket refrigeration. In: International Technical Meeting on HCFC Phase-out, 5–6 April, Montreal, Canada.
[43] Delventura, R., Evans, C.L., Richter, I., 2008. Secondary loop systems for the supermarket industry. http://www. thecoldstandard.com/bohnwhitepaper/ (accessed 14.11.2008).
[44] Kazachki, G., Hinde, D., 2006. Secondary coolant systems for supermarkets. ASHRAE J., 34–46. September.
[45] Wang, M.J., Goldstein, V., 1996. A novel ice slurry generation system and its application. In: Proceedings of the IIR Conference on Applications for Natural Refrigerants, Aarhus, Denmark, pp. 543–551.
[46] Wang, M., Inoue, J.Y., Goldstein, V., 1999. Ice thermal storage in modern building. In: Proceedings of the 20th International Congress of Refrigeration, 19–24 September, Sydney, Australia.
[47] Choi, D.K., Domanski, P.A., Didion, D.A., 1996. Evaluation of flammable refrigerants for use in a water-to-water residential heat pump. In: Proceedings of the IIR Conference on Applications for Natural Refrigerants, Aarhus, Denmark, pp 467– 476.
[48] Chang, Y.S.,Kim, M.S., Ro, S.T., 1996. Performance and heat transfer of hydrocarbon refrigerants and their mixtures in a heat pump system. In: Proceedings of the IIR Conference on Applications for Natural Refrigerants, Aarhus, Denmark, pp. 477– 486.
[49] Payne, W.V., Domanski, P.A., Muller, J., 1998. A study of a water to- water heat pump using flammable refrigerants. In: Proceedings of the IIRGustav Lorentzen Conference on in Natural Working Fluids, 2-5 June, Oslo, Norway, pp. 658–667.
[50] Jiangzhou S, Wang RZ, Lu YZ, Xu YX, Wu JY, Li ZH. Locomotive driver cabin adsorption air-conditioner. Renew Energy 2003;28:1659–70.