An Overview of Natural Refrigerants for Sustainable Growth in Refrigeration Sector

A.Lovelin Jerald
Assistant Professor (Sen.Scale),Department of Food Processing and Preservation Technology, Faculty of Engineering, Avinashilingam University, Coimbatore, Tamilnadu, India

Dr. D. Senthil Kumaran
Director, Adithya Institute of Technology, Coimbatore, Tamil nadu, India

Abstract - This article presents a review of various ecofriendly refrigerants in view of climate change which is one of the biggest environmental challenges at present. Most of the refrigeration and air conditioning equipment in India uses fluorocarbon refrigerants (CFC's) to facilitate the heat transfer process. Fluorocarbon refrigerants are synthetic chemicals which usually have a high global warming potential, and some still have the potential to cause damage to the ozone layer as well if released to the atmosphere. Gradually these CFC's were replaced by HCFC's which posses excellent thermodynamic and thermo physical properties but has high global warming potential (GWP) of 1300. Alternatives to these chemicals exist that can help to mitigate some of the environmental risks. They are often referred as 'natural' refrigerants because the substances also occur in nature; these alternatives include ammonia, carbon dioxide and hydrocarbons. These substances have been used as refrigerants for many years; however, they are now finding their way into applications where previously fluorocarbons were the preferred as the best option.

Key words: Refrigeration, climate change, CFC's, HCFC's, natural refrigerants, GWP

I. INTRODUCTION

In the mid 1970s, concerns about depletion of the ozone layer began to surface and the refrigerants responsible were CFCs like R-12 and R-22.These refrigerants were used widely in domestic, commercial and in Industrial applications [1].Natural refrigerants are naturally occurring, non-synthetic substances that can be used as cooling agents in refrigerators and air conditioners. These substances include hydrocarbons (propane, butane, and cyclopentane), CO2, ammonia, water and air [2]. These are sometimes referred to as `the Gentle Five', each with a different area of application. Natural refrigerants are ozone layer- and climate-friendly substances [3,4]. The lack of pure substances which are friendly to the environment stable, zero-ozone depleting refrigerants has been to blend the few available substances, sometimes with the addition of hydrocarbons [5]. Studies on curtailing the use of substances which contribute to global warming, conventional refrigerants are to be replaced by environment friendly working fluids. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are being substituted by hydrofluorocarbons (HFCs), hydrofluorooelifins (HFOs), and a variety of mixtures [6]

II. NEED OF NATURAL REFRIGERANTS:

In the 1970s, scientists discovered the dangerous impact Chlorofluorocarbons (CFCs) have in the Earth's atmosphere. CFCs were used as foam blowing agents, refrigerants and solvents. It was found that they destroy the ozone layer, so that aggressive UV-B radiation can reach directly the Earth's surface causing genetic damage in the cells of people, plants and animals. Therefore, in 1987, an international treaty was concluded at Montreal, Canada (the so called Montreal Protocol on Substances that Deplete the Ozone Layer), to prevent the ozone layer from further destruction and begin the phase-out of the use of CFCs and other Ozone Depleting Substances (ODS) like Hydrochlorofluorocarbons (HCFC's)[5,8].

Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) are fluorinated gases (F-gases) and are widely used in many commercial refrigeration applications, such as beverage coolers, vending machines, ice cream freezers, open deck coolers and freezers used in supermarkets. HCFCs are ozone depleters and will be phased out under the Montreal Protocol. In the refrigerant sector, two ozone-friendly replacement technologies are available: climate harmful fluorinated refrigerants (HFCs) and climate-friendly natural refrigerants. If HFCs will replace HCFCs, the climate benefits of the Montreal Protocol will be lost in a short period of time.

2.1. Ammonia, R-717

The main consideration with using R-717 is its safety, since it is "higher toxicity" and "lower flammability" corresponding to ISO 817 Group B2 classification. The B2 classification for R-717 means that it is effectively prohibited from use inside occupied

Spaces because of its toxicity (except for small absorption machines), but it can be accommodated in unoccupied spaces or outside. Thus R-717 can be used where indirect (or secondary) systems can be economically employed. In addition, consideration needs to be given to ventilation requirements and the consequences of a release of gas may cause danger for the public if inhaled in large quantities. In lesser quantities it is irritating to the eyes, nose and throat. Due to its chemical properties this refrigerant attacks copper and bronze in the presence of little moisture , pipelines and system components is not recommended with R-717, and therefore steel must be used which can often present a cost detriment for smaller capacity systems.This refrigerant is ideal in a wide range of applications, including: food freezing, industrial heat extraction, brewing, chilled storage, ice rinks, and commercial refrigeration [8]

2.2. Hydrocarbons (HC)

Hydrocarbons are environment friendly refrigerants due to their ozone depletion and negligible global warming Potential (GWP).R-600a (iso-butane), R-290 (propane), R-1270 (propylene), and mixtures thereof, have "lower toxicity" and "higher flammability", giving them a Group A3 classification in ISO 817. The latent heat of vaporization of hydrocarbon refrigerants is very high in comparison to CFC-12 making these refrigerants attractive because of its low charge requirements and circulation rates. This introduces stricter safety requirements, in terms of the quantities permitted in certain locations – specifically safety standards such as EN 378 tend to limit quantities to up to 1 – 2,5 kg within occupied spaces. Because of these charge size limitations for systems in occupied spaces, it is beneficial to design the system to maintain a small refrigerant charge (for a specific capacity), i.e., low specific charge in terms of kg/kW. However, it may not be practical to use this in circumstances where the refrigerant charge is above the permitted limits, as it may convert into an explosive when comes in contact with air at highly compressed state. Regarding the refrigerating system, using HCs is essentially identical to using R-22 [8, 9]. For example, the same compressor displacement, pipe sizes, heat exchanger dimensions and oil selection may be used (although as with any fluids whose thermo physical properties differ, opportunities for optimization should be exploited). The only significant difference in the design of equipment is the presence of elimination of ignition sources near the equipment, for example, switches, thermostats, etc., that are capable of producing a spark.

2.3. Carbon dioxide(R-744)

In terms of its fundamental safety properties, R-744 has "lower toxicity" and "no flammability", giving it a Group A1 classification in ISO 817. it is non toxic, on irritating and non flammable. This means that its use is permitted in almost any situation, without restriction of refrigerant charge sizes. Due to its high operating pressures, the compressor of carbondioxide is very small even for a comparatively large refrigerating capacity may does introduce some technical problems. Specifically, there is an increase in the pressure rating of components and assemblies by a factor of 5 – 10 times above that of conventional refrigerants [8,9] .As a result, the choice of materials, component thickness, jointing methods and mechanical operation of certain components (such as compressors) are affected. With the advancement of technology, the industry have managed to overcome most of these issues for a wide variety of equipment sectors, although the cost implications of handling these high-pressure problems though the cost is very high and sometimes prohibitive for larger volumes. Another feature of R-744 is that, the extremely low boiling point of this refrigerant requires a slight variation of the conventional vapour compression cycle to be incorporated into the RAC equipment.Excellent thermodynamic properties and low energy-use make it suitable for a range of applications, including-industrial heat extraction, chilled warehousing, shipping vessels, commercial refrigeration, and mobile air conditioning .

III. ENVIRONMENTAL CHALLENGES OF REFRIGERANTS:

The awareness to protect the environment from the harmful effects of CFCs has motivated the industry globally to switch over from CFCs to zero ODP, alternate refrigerants like HFC 134a and hydrocarbon [11]. The Montreal Protocol and the Kyoto Protocol are two global environmental agreements with a common objective to protect earth's atmosphere from the adverse effects of human actions. The Kyoto Protocol is the first internationally binding agreement to cut greenhouse gas emissions. The main focus is carbon dioxide (CO2) emissions from the burning of fossil fuels such as oil, gas and coal. The Montreal Protocol marked tremendous progress through intermediate and innovative iniative to reduce or if possible phase out the use of substances with high ozone depletion potential in the industrial arena towards alternative substances and processes without any negative impact on the ozone layer [11,12]

Gas	Lifetime (years)	20 year	100 year	500 year
co2		1	1	1
CFC -11	45	6730	4750	1620
CFC -12	100 11	11000	10900	5200
HCFC-141b	9.3	2250	725	220
HFC-134a	14	3830	1430	435
Cyclopentane	weeks	<3*	<3*	<3*
Isobutane	weeks	<3*	<3*	<3*
Propane	months	<3*	<3*	<3*

Table .1 Comparision of the GWP of CFCs and HCFCs to natural(CO2 and hydrocarbon) technology.

IV. CONCLUSIONS

Alternative refrigerants find great difficulty in being accepted by the commercial refrigerating and air conditioning sector. The halocarbon refrigerants tend to dominate the market, especially when used in sealed systems. The application of hydrocarbon refrigerants in fully sealed systems will continue to expand in a rapid rate but may stammer due to its chemical characteristics and the fear of possible hazards of explosion. But still hydrocarbon refrigerants tend to more be efficient and act as a good alternator for domestic and commercial refrigeration system with proper safety measures. In spite of the toxic nature of ammonia, its use continues in larger industrial systems and for larger air conditioning systems. Carbon dioxide being the oldest gas has returned to the field of refrigeration and its use is increasing rapidly. It is non toxic and non corrosive, can be easily handled and have an advantage over water ice of lower temperature in the absence of objectionable liquid and smaller space requirement for a required cooling capacity.

REFERENCES

[1] J. M. Calm ,"The Next Generation of Refrigerants – Historical Review, Considerations ,and Outlook," International Journal of Refrigeration, 2008(7):1123-1133, 2008

[2] Dr .S F Pearson," New, natural and alternative refrigerants", Star Refrigeration Limited.

[3] Volkmar Hasse,"Natural Refrigerants", Federal Ministry for Economic Cooperation and Development (BMZ) .

[4] Philip CH Yu,"Refrigeration Selection for Sustainable Future", ASHRAE Journal, 2007-2008

[5] Dr S. Forbes Pearson," Challenges and Solutions for Next-Generation Air Conditioning and Refrigeration Technology ", Star Refrigeration Ltd, Glasgow, Scotland, G46 8JW, UK

[6] G Venkatarathnam and S Srinivasa ,"Refrigerants for Vapour Compression Refrigeration Systems" *,Resonance 2012*,pp139-169

[7] Dr.R.S.Agarwal &R.S.Iyer ,"Practical consideration when switching over to HFC-134a and HC from CFC-12,Air conditioning and Refrigeration Journal,2004

[8] Piotr.A.Domanski, "Evolution of refrigerant Application", International congress on Refrigeration.

[9] Arora, C.P., 2000. "Refrigeration and Air Conditioning, 3E edition. Tata McGraw Hill publishing company limited, New Delhi.

[10] Roy J Dossat, 2001,'Principles of refrigeration"5E , Prentice Hall India Publication, New Delhi

[11] Tao Zhu, Life Cycle Assessment in Designing Greener Semiconductor, University Of Arizona, February 2004

[12] Agrawal R S (2001) "Montreal protocol on refrigeration and air conditioning industry", Proceedings of International conference on emerging technologies in air-conditioning and refrigeration, New Delhi, India, Sept 26-28, pp13-25