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Ozone depletion and global warming: Case for the use of natural refrigerant – a review

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ABSTRACT

This paper presents natural refrigerants as the ideal, environmentally friendly refrigerants and the ultimate solution to the problems of ozone depletion and global warming. HFC refrigerants are currently the leading replacement for CFC and HCFC refrigerants in refrigeration and air-conditioning systems. However, they are equally foreign to nature like CFCs and HCFCs, consequently, strong basis for the need to embrace the use of natural refrigerants as replacement for the halocarbon refrigerants was provided. This paper also analyses potentials of various natural refrigerants and their areas of application in refrigeration and air-conditioning systems. Natural refrigerants especially hydrocarbons and their mixtures are miscible with both mineral oil used in R12 and poly-ol-ester oils used in R134a systems. Also, with exception of ammonia, they are fully compatible with all materials traditionally used in refrigeration systems. Finally, this paper has revealed that natural refrigerants are the most suitable long time alternatives in refrigeration and air-conditioning systems.

Contents

1. Introduction

Refrigeration technology plays an important role in modern life. It provides not only comfortable and healthy living environments but also regarded as necessities for surviving severe weather and preserving food. Especially, the preservation of food is vital to the stability and economic growth over the world. Conservation of food is achieved by slowing down biochemical processes to reduce the propagation of bacteria. This easily can be done by cooling or freezing and without extra preservatives.

Refrigeration technology gives the technical aids to cool food following the cold chain starting at production, transportation, finally storage, sale and storage at the consumer's home in a refrigerator without any interruption. Other uses include air-conditioning systems and industrial processes. Air-conditioning systems help to improve the comfort of human beings for private

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as well as for commercial purposes, to keep the health and increase the efficiency. However, accelerated technical development and economic growth throughout the world during the last century have produced severed environmental problems, forcing us to acknowledge that though these technological advances may contribute to human comfort, they also can threaten the environment through ozone depletion and global warming [1,2].

Ozone depletion and global warming are two major environmental concerns with serious implications for the future development of the refrigeration-based industries. The effects on the industry of the actions to reduce ozone depletion and global warming are now apparent. Ozone is a variant of oxygen, the ozone molecule having three atoms of oxygen. Ozone is a poisonous gas and if inhaled can cause death. Ozone layer surrounds the earth's stratosphere which is about 11 km above the earth surface. Life on the earth has been safe-guarded for thousands of years because of this life-protecting layer. It acts as shield to protect the earth against the harmful ultraviolet radiation from the sun [3].

Ozone layer efficiently screens all the harmful ultraviolet rays of the sun by absorbing most of the dangerous ultraviolet B (UV-B) radiation (Ultra-Violet A is allowed through while ultraviolet C is captured by oxygen). Since Ozone layer is a protector against harmful UV-B radiation, any damage to it could cause considerable harm to the environment and life on earth. Exposure to increased UV-B radiation can lead to incidents of eye damage (such as cataracts, deformation of eye lenses and presbyopia), cause skin cancer, reduce rates of plant growth, upset the balance of ecosystems, and accelerate the risk of disease [4].

Until the early 1970s nobody dreamt that human activity could threaten to deplete the ozone layer. Man is completely responsible for emissions of the most important ozone depleting and greenhouse gas halocarbons [4]. Halocarbons are a group of compounds which are mostly man-made gases consisting of both carbon and at least one of the halogens (fluorine, chlorine, iodine, and bromine). They are typically produced artificially for industrial purposes. They were first synthesised in 1928. Since then, they have come to be widely used for a variety of purposes such as propellants in aerosol cans, in the manufacture of soft and hard foams, in refrigeration and air conditioning, and as cleaning solvents [3]. The group includes chlorofluorocarbons (CFCs), hydro-chlorofluorocarbons (HCFCs) and hydro-fluorocarbons (HFCs).

CFCs and HCFCs have been used for years as refrigerants, solvents and blowing agents. The stable structure of these chemical enables them to attack the ozone layer. If these chemical escapes into the atmosphere, they drift up to the stratosphere and intense UV-C radiation breaks their chemical bonds, releasing chlorine, which stripe an atom from the ozone molecule, reducing it to oxygen molecule. Chlorine acts as a catalyst, which accomplishes this destruction without itself undergoing any permanent changes; therefore it can go on repeating the process.

It has been discovered that one chlorine atom can destroy 100,000 ozone molecules. The higher the chlorine content of a compound, the longer will be its impact with the ozone layer. CFCs have more chlorine content than HCFC, therefore CFCs have higher potential for ozone depletion. The efficacy of ozone destruction is often measured by a comparative unit termed Ozone depletion potential (ODP), which is based upon the ODP of trichloro-fluoro-methane (CFC-11) being assigned a value of unity. It is estimated that CFCs contribute nearly 70% of man-made ozone depleting chemicals in the atmosphere [5]. The inventors of these refrigerants could not have visualised the ravaging effects of the refrigerants on the ozone layer. They intentionally pursued refrigerants with the exceptional stability that was imposed as one of the necessary requirements of the ideal refrigerant they were called upon to invent [6].

The second major environmental concern is climatic changes or global warming. This did not become a major area of attention until after the responses to ozone depletion had been initiated. Concerns on this issue are now beginning to complicate the handling of ozone depletion. In a green house, glass allows sunlight in but prevents some infrared radiation from escaping. The gasses in the earth's atmosphere, which exert a similar effect, are called "greenhouse gasses". Some of these greenhouse gasses include CFCs, HCFCs, CO_2, methane (CH_4) and nitrous oxide (N_2O). Different gasses absorb and trap varying amounts of infrared. They also persist in the atmosphere for different time period and also influence atmospheric chemistry in different ways.

Global warming arises because of the greenhouse effect. According to Ko et al. [7,8], the frequency distribution of the radiation coming from the sun closely approximates that from a black body at a temperature of about 5800 K, the spectrum wavelengths range from less than 1 nm to hundreds of metres, the peak in the spectrum is in the visible region at about 500 nm. When solar radiation ($1360\ \mathrm{W\,m^{-2}}$) arrives at the earth, about 30% is reflected back into space and most of the remainder passes through the atmosphere to the ground. This heats up the earth, which then behaves approximately as a black body, radiating energy with a spectral peak in the infrared. This infrared radiation cannot pass through the atmosphere because of absorption by water vapour, and other infrared absorbers. As a consequence, heat energy is trapped and the temperature at the surface of the earth is higher than it would be without the insulating blanket of the atmosphere.

Global warming is a good thing in itself and allows life to exist in all its variety [9]. The concern is that man's activities are increasing the concentration of greenhouse gases in the atmosphere, causing the amount of absorbed infrared radiation to increase, and leading to increased atmospheric temperatures and consequent long-term climate changes.

The amount of radiant energy that the refrigerants absorb is measured by an index called Global Warming Potential (GWP). GWP is the amount of infrared radiation that the gas can absorb, relative to carbon dioxide (with an assigned GWP of 1), integrated over a period of 100 years. A more appropriate measure of a refrigerant contribution to global warming is based on a concept called Total Equivalent Warming Impact (TEWI).

Hwang et al. [1] described two types of global warming effects. The first is the direct global-warming potential that is due to the emission of refrigerants and other pollutants. The second type is an indirect global-warming potential, which results from the emission of carbon dioxide due to the consumption of energy obtained from the combustion of fossil fuels (oil, natural gas, and coal). The combined effects of the two global warming potentials is known as TEWI.

The discovery of the two major environmental problems, discussed above, has resulted in a series of international treaties demanding a gradual phase out of halogenated fluids. The CFCs have been phased out in developed countries since 1996, and 2010 in developing countries. Initial alternative to CFCs included some hydro-chlorofluorocarbons (HCFCs), but they will also be phased out internationally by year 2020 and 2030 in developed and developing nations, respectively, because their ozone depletion potentials (ODPs) and global warming potentials (GWPs) are in relative high levels though less than those of CFCs [5,10,11].

Hydro-fluorocarbon (HFC) refrigerants have been found as the leading replacement for CFC and HCFC refrigerants in refrigeration and air-conditioning systems. However, international concern over relatively high global warming potential of HFC refrigerants has caused some European countries to abandon them as CFCs and HCFCs replacements. Hydrocarbons are the refrigerants favoured in many European countries [12]. It has