A Review on New Generation Refrigerants

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ABSTRACT: A growing issue in today's time environment is the effect of different refrigerants on Ozone Layer depletion and increase of global warming. The main reason responsible for this impact on environment is Chlorine with halogenated hydrocarbons, known as CFCs which are used as refrigerants in refrigerators and air conditioners in every household, industrial or commercial application. This paper, is talking about various refrigerant manufactured to overcome various other issues like flammability and toxicity of refrigerants generation after generation. By studying physical, chemical, environmental as well as safety properties for various refrigerant. With the advancement in the sector of refrigeration and air conditioners, we would get to know that now the research is selecting or producing a best choice refrigerant that is environment friendly with the replacement of older refrigerants. Moreover, it is found that the new generation refrigerants shall be manufactured based on '0' Ozone Depletion Potential and low Global Warming Potential to become both environmentally safe and eco-friendly.

KEYWORDS: Environment friendly, Flammable, Global Warming Potential, Ozone Depletion Potential, Refrigeration System, Refrigerants, Toxic.

1. INTRODUCTION

The process of refrigeration started long time ago. It is a procedure to remove hotness from a closed surrounding in order to enable low temperature from the outer environment. Evaporative cooling was carried out in India and Egypt. Refrigeration is widely used in various application not limiting to household refrigerators, in industrial application, air conditioners, etc.

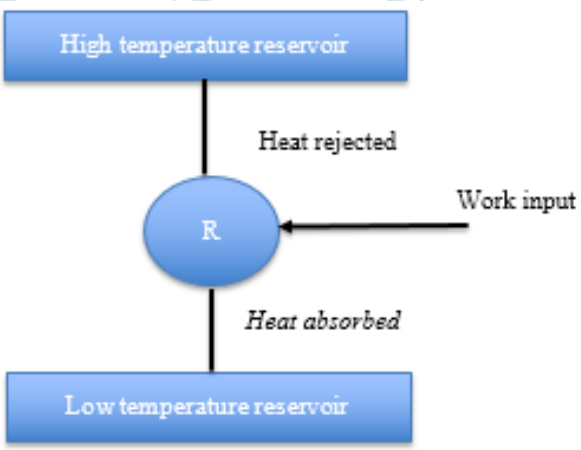

Figure 1: Represents the heat transfer mechanism of a refrigeration system

This system represents heat is being transferred from a low temperature reservoir to a high temperature reservoir (Figure 1).

1.1. Refrigerant:

Refrigerant is a chemical component mainly found in gaseous or fluid state used in refrigerators, air conditioners, freezers etc. Without refrigerants, there would be no further freezing technology related inventions happening. Moreover, it is used to absorb heat from the items present in closed refrigerator space or room i.e. to be cooled (in the example of ACs) and toss out the heat into the outer surrounding, producing the cooling effects. A Refrigerant encounter phase changes starting from liquid state to gaseous state while absorbing the heat and again back to liquid state, when the refrigerator compressor compresses refrigerant [1]–[4].

1.2. Desirable properties for an ideal refrigerant:

1.2.1. Physical Properties:

- Freezing point*:* Refrigerants must have low freezing point that it must freeze during the application process.
- Condense pressure: The more less value of condense pressure is there, the least power will be required for compression. The Refrigerants those have low boiling point will be having high condense pressure.
- Evaporation pressure: It is an important physical property for refrigerants. The atmospheric air or content will leak and start freezing in the system at lower temperature if the value of evaporation pressure is negative. Hence, it will result in the clog and choke to the system. Sometime, it may result in explosion if flammability value of refrigerant is in variety.
- Critical pressure: It should be higher than the condenser pressure. Else condensation area decreases, with the occurrence of heat rejection.
- *Vapour density:* Higher is the value of vapour density, smaller will be the size required for compressor.
- Dielectric strength: To avoid short circuits, the refrigerant should have high dielectric strength.
- Enthalpy of vaporisation: According to the transfer of heat equation, higher enthalpy of vaporisation will produce low mass flow rate.
- Heat transfer coefficient: High value of heat transfer coefficient need small area and low pressure drop which will result in compact equipment that will reduce the production cost.

1.2.2. Volatility property:

- Toxic in nature*:* It is also a very important property of refrigerants. Refrigerants should be non-toxic in nature else it will be harmful for human beings.
- Oil miscibility: The lubricating oils used in refrigerants must be immiscible and the density of oil should be less than the refrigerants which is being used.
- Water Solubility: The refrigerant used should have low water solubility, therefore it will produce either base or acid with water, which will corrode and destroy valve, seals and rest all the metallic parts used in the refrigeration system.
- Reactivity: *The* Refrigerants which are going to be used in refrigeration system must be chemically inert with the material.

1.2.3. Environmental and Safety properties:

These properties are very important as a major factor in present times in deciding the adequacy of any refrigerant being used.

- Ozone Depletion Potential (ODP): The refrigerant should have zero ODP i.e. they should contain non- ozone depleting components. According to new rules and regulation refrigerant should not be containing either Chlorine (Cl) or Bromine (Br).
- Global Warming Potential (GWP): The refrigerant should have low GWP value which will be helpful in minimizing Global Warming problem.
- Total Equivalent Warming Index (TEWI): This index considers both contribution of refrigerant i.e. direct and indirect to global warming.

1.3. Economic Measures:

Aside from physical, chemical, environmental and safety measure, there is one more way to find ideal refrigerant that are as follows: -

- Cost of refrigerant: The cost of refrigerant will affect whole cost of refrigeration system. Therefore, it should be less as possible.

- Availability of refrigerant: It should be easily available in large quantity. Hence it will also help in reducing the overall cost of equipment.

- Handling and Storage: Refrigerant which is toxic or flammable is difficult to handle and store than which is non- toxic and non- flammable.

1.4. Classification Of Refrigerants:

They are broadly classified into following two groups: -

1.4.1. Primary refrigerants:

Those refrigerants which directly interact with the refrigeration system are known as primary refrigerants. Primary refrigerants are further classified into following categories: -

1.4.1.1.Halo- carbon or organic refrigerants:

These compounds are all synthetically manufactured as a Freon family of refrigerants and their classification depends upon chemical composition (chlorine, hydrogen and Fluorine).

- Chlorofluorocarbons (CFCs) – It includes R11, R113, R114, R12 and R115
- Hydrochlorofluorocarbon (HCFCs) - It includes R22 and R123
- Hydrofluorocarbons (HFCs) - It includes R134a, R407C, R410a and R404a

1.4.1.2.Azeotropic refrigerant:

There is an equivalent mixture of liquid phase composition and vapour phase composition with a wide scale of temperature. Some of the azeotropes are R500, R502, R503 and R504.

1.4.1.3.Inorganic refrigerants:

These are earlier used because of their thermodynamic and physical properties before halo- carbon refrigerants were introduced. Some of the inorganic refrigerant are R717, R729, R744, R764 and R118.

1.4.1.4.Hydro- carbon refrigerants:

These types of refrigerants are basically used for industrial and commercial purpose due to their thermodynamic properties which are highly inflammable and explosive.

1.4.2. Secondary refrigerant:

Those refrigerants which do not interact directly with the refrigeration system but are first cooled by primary refrigerant and then used further for cooling purposes are known as secondary refrigerants. These type of refrigerant generally, uses small size refrigerator with less amount of refrigerant. Some commonly used secondary refrigerant are water and brine solution of calcium/ sodium [5]–[7].

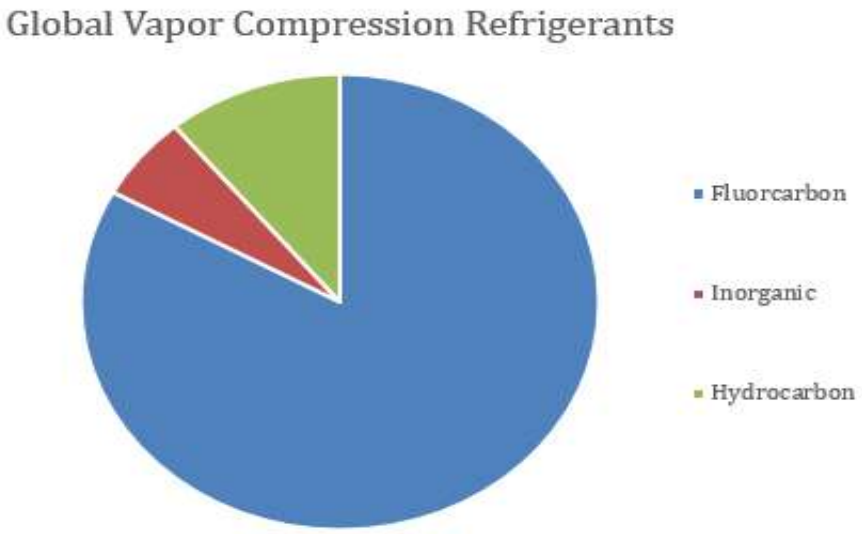

Figure 2: Illustrates types of Vapour Compression Refrigerant used globally.

The refrigerant market is explained as all types of refrigerant used in different application shown in figure 2.

2. LITERATURE REVIEW

P. Dhankhar, conducted research on refrigeration system which represents heat is being transferred from a low- temperature reservoir to a high-temperature reservoir. Refrigeration is a basic food preservation technique. The Reverse Carnot cycle, which describes Adiabatic and Isothermal Expansion and Compression, underpins all refrigeration systems for food preservation. Evaporator, Compressor, Condenser, and Expansion Valve are the basic components utilised in these cycles. The Vapor Compression Cycle is the most commonly utilised cycle. Vapor Absorption Cycle and Gas Cycle are two more cycles. Thermoelectric and Magnetic Refrigeration are two more innovative ways of refrigeration. In these cycles, several types of refrigerants are employed depending on their characteristics. Refrigeration is utilised commercially as a preservation strategy in a variety of food sectors, such as the dairy and meat processing industries [8].

M. Sruthi Emani et al. discussed the properties of R12 (dichlorodifluoromethane) which was the highly stable CFC popularly known as Freon , but the problem that have constricted the usage of CFCs is the high potential to cause ozone layer depletion Refrigeration and air conditioning are important in both household and industrial settings. They have a significant influence on our daily lives. They've also contributed to important global environmental concerns such as ozone depletion and global warming. From the days when refrigeration was unknown to the current day, the evolution of refrigeration systems and the refrigerants employed in them is fascinating. Different refrigerants were developed over time depending on safety, durability, and environmental effect concerns. The many generations of refrigerants have been addressed in this article, starting with those used before the invention of mechanical refrigeration systems and progressing to probable future generation refrigerants that are environmentally benign and can replace traditional refrigerants. Low-GWP refrigerants, such as hydrofluoroolefins, and natural refrigerants, such as ammonia and carbon dioxide, are regarded as environmentally benign next-generation refrigerants. Refrigeration is an ancient technology that has been around for a long time. Refrigeration is the act of removing heat from an enclosed area or a substance in order to maintain a temperature that is lower than the ambient temperature. Food preservation methods such as salting, spicing, smoking, pickling, and drying existed before to 1830. In India and Egypt, evaporative cooling was used. The temperature of water was found to drop when compounds like sodium nitrate or potassium nitrate were added. Prior to the invention of mechanical refrigeration systems, people chilled their food with ice brought in from the mountains, and ice was stored in snow cellars, pits excavated into the earth and insulated with wood and straw [9].

Parvinder Singh explored that only refrigerants were employed in the refrigeration process in the past, and they had a high global warming coefficient. Modern techniques are emerging as time passes, and with their aid, the refrigeration process has grown more efficient and safe in comparison to past atmospheric perspectives. This review study focuses on nanotechnologies that are now being employed in refrigeration systems such as vapour compression refrigeration, home refrigerators, and air conditioners. The Nano refrigerant is only a combination of Nano particles with refrigerant. Nano refrigerants may be made in two ways: (1) by combining Nano particles with refrigerant in a gaseous state, and (2) by mixing Nano particles with lubricant. To investigate the nature of thermo-physical characteristics in the refrigeration process, we will combine various Nano particles with the lubricant that have the same diameter and volume percent. This experiment may investigate certain factors like as energy consumption, heat transmission, and cop, among others [10].

3. DISCUSSION

Variety of refrigerants are being used with an improvisation in terms of safety shown in Table 1, stability, economic and environmental measures which are giving a ray to present day research and development since long time. They are classified into different generations starting from early 19^{th} century with natural refrigerants like NH_3, SO_4, CH_3Cl etc. They all were highly reactive, toxic as well as flammable in nature. Due to their explosive property, many deadly incidents occur which leads to unveiling of second generation refrigerants in early 20^{th} century to overcome safety and stability problem which include chlorofluoro chemicals. CFCs are safe refrigerants as they are non – toxic, non-explosive and inflammable broadly used in air conditioning and refrigeration applications. R12 (dichlorodifluoromethane) was the highly stable CFC which is popularly known as Freon, but the problem that have constricted the usage of CFCs is the high potential to cause ozone layer depletion. Thus, R12 got replaced by other refrigerants such as: - R-401a, R-

134a, and R-401b. Throwing away million tons of CFCs into air, scientist found that the chlorine doesn't consumed in the reaction and continue to deplete ozone which protects all living beings living on earth from sun's UV radiation and in 2010 it's consumption is completely ended. Looking for some alternative with partly chlorinated refrigerants i.e. HCFCs (hydro chlorofluorocarbons) refrigerants dominated all over the second half of 20th century which was represented by R-22 and R-502. HCFCs are slightly preferable than CFCs, since they also carry Cl which is dangerous for the environment. Although, it was also used for long time but according to Government's plan of India, HCFCs will be cut off from India by 2030 and by 2020 in US. To get rid of chlorine in refrigerant after many experiment and researches performed comparing properties of refrigerant impacting the environment, HFC were manufactured which consists only carbon, fluorine and hydrogen molecules, wherein they also contribute to global warming, but still they are finer than HCFCs refrigerants as they don't diminish ozone layer. Most commonly used refrigerant in air conditioners is Hydro Fluorocarbon (R-410A) which is more preferable than R-22 in terms of ODP and efficient energy, which is a mixture of two other Hydro Fluorocarbon refrigerants, that are R-125 and R-32, which are providing greater cooling properties when they are exposed to high pressures, but still it is causing global warming. One or more Hydro Fluorocarbons which are commonly being used in ACs and Refrigerators are R-32 & R-134A. However, refrigerant R-32 in respect of GWP is more suitable than R-410A, but still it is an HFC. As per recent news, India has planned to cut off Hydro Fluorocarbon refrigerants in coming years. Presently, low GWP refrigerants such as R1234yf and 1234ze & halogen free refrigerants such as R-290 and R-600A founded as an appropriate option for coming future references as they are most environment friendly refrigerants. It is also said that manufacturers who have used this refrigerant claim that they are absolutely safe as there is no accident reported till date. Although the performance of vapour compression refrigeration system of HFO based refrigerant is slightly lower than R-134a but they are far beneficial in harming less to environment. Hydrofluoroolefins (HFO) based refrigerants i.e. R-513A is formed to take over R-134a in direct expansion, positive displacement, & medium-temperature commercialization. Also DR-55 will take over R-410A due to its low GWP value and easily convertible while offerings and energy performance. There is no possibility that there would be an ideal refrigerant but it should be less damaging for the environment.

Table 1: Represents the most commonly used refrigerants and their characteristics.

S.No	Refrigerant	Global warming potential	Ozone depletion potential	Flammability	Eco-friendly
1.	R-12	10900	1	NO	NO
2.	R-22	1810	0.055	NO	NO
3.	R-410A	2088	0	NO	SOMEWHAT
4.	R-32	675	0	YES	NO
5.	R-134	1430	0	NO	SOMEWHAT
6.	R-290	3	0	YES	YES
7.	R-600A	3	0	YES	YES
8.	R-1234ze	LOW	0	LOW	YES
9.	R-1234yf	LOW	0	LOW	YES

The more closely the refrigerants measures ODP value to 1, the more it will be contributing to depletion of ozone layer. If the GWP value is less than 150 it is considered as low GWP, 150-2500 is medium range and above 2500, the GWP is high. The refrigerants having '0' ODP but have medium or high value of GWP, they will be considered as environmentally safe but not counted as eco-friendly as they are contributing to global warming (Table 1).

4. CONCLUSION

This paper has undertaken a brief study of many types of refrigerants used in home – refrigerators air conditioners as well as used in industrial refrigeration system. After studying physical, chemical, and environmental as well as safety properties for various refrigerant, it was found that there is no such refrigerant available which can satisfy properties of an ideal refrigerant. With the advancement in the sector of refrigeration and air conditioners, therefore now the research is selecting or producing a best choice refrigerant that is environment friendly with the replacement of older refrigerants. The closure can be taken out from the review are Refrigerants of new generation should be manufactured based on '0' Ozone Depletion Potential and low Global Warming Potential to become both environmentally safe and eco-friendly, R1234yf and R1234ze are the appropriate substitution of R134a refrigerant, Air conditioners having R-290 and R-600A refrigerants are best option to contribute for energy efficiency and global warming, There is no possibility that there would be an ideal refrigerant but it should be less damaging for the environment.

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