Successive Improvement of Refrigerants in Vapour Compression Refrigeration System for Sustainable Environment

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ABSTRACT

In the present paper, it is presented about the drastic changes in refrigerants in VCRS from the past days keeping in mind the need of changing the past refrigerants due to the rapid depletion of our Ozone layer.

When the depletion of Ozone layer was observed increasing day by day Montreal Protocol was signed for prohibition of the use of the refrigerants like CFC, HCFC, HFC and their derivatives were prohibited worldwide. But the need of refrigerants were increasing rapidly day by day so new refrigerants were discovered like R-11, R-22 and many more which are efficient enough and eco-friendly too.

In this paper, it is also presented that the new drastic changes in the introduction of new refrigerants like R-410 A and R-417 A. Their efficiency, drawback, new implementations are also introduced in this paper.

Key words:- *Refrigerants, Vapour Compression Refrigeration, System, Trichlorofluoromethane, Dichlorodifluoromethane, Chlorodifluoromethane*

1. INTRODUCTION

In this rapidly technologically advancing world the refrigerants used in our past were also successively improved keeping a serious concentration on ozone depleting potential (ODP) and global warming potential (GWP) after the signing of Montreal Protocol which came into force on 1 January 1989 banning all the groups of halogenated hydrocarbon which play a significant role in ozone layer depletion.

But after the ban of many refrigerants which were hazardous to the environment like R-11 (Trichlorofluoromethane) R-14 (Tetrafluoromethane), R-22 (Chlorodifluoromethane) and many more. But the need of refrigerants in the Vapour Compression Refrigeration System cannot be left with a lack in refrigerants. Due to this massive demand of refrigerants having very low or negligible ozone depleting potential (OWP) and global warming potential (GWP) led the foundation of improvement of refrigerants in Vapour Compression Refrigeration System.

2. NEED OF INTRODUCTION OF NEW REFRIGERANTS

After the implementation of Montreal Protocol many refrigerants which possessed high ozone depletion potential (ODP) and global warming potential (GWP) were banned worldwide due to their hazardous effect leading to rapid increase in ozone layer depletion.

CFCs (Chlorofluorocarbons) and HCFCs (Hydrochlorofluorocarbons) were the main refrigerants which were the major hazardous one leading to ozone layer depletion. Except the refrigerant R-13B1 (Bromotrifluoromethane) all the CFCs and HCFCs contain chlorine which was the main danger to the ozone layer. R-13B1 contains bromine, which is stronger as a catalyst than chlorine hence it was mostly preferred to be used in pre-Montreal Protocol years.

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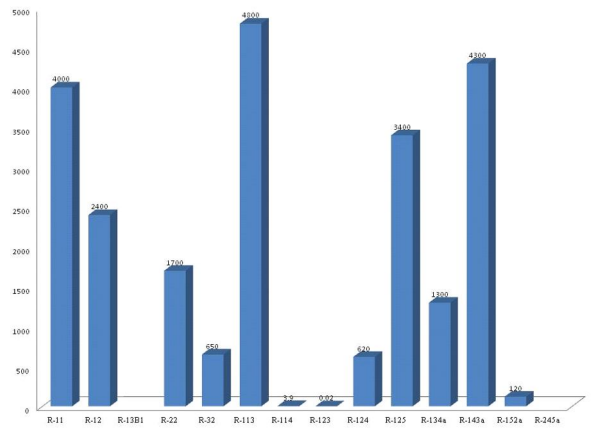
Global Warming Potential of various refrigerants used in past years



Due to these high GWPs of the refrigerants used in the past years were banned but because of the need and demand of refrigerants worldwide the introduction of new alternatives to those refrigerants occurred.

3. PAST REFRIGERANTS

The refrigerants used in the past which were possessing high ozone depletion potential (ODP) and global warming potential (GWP) are as follows:-

A. Chlorofluorocarbons (CFCs) refrigerants

These are the Chlorine, Fluorine, Carbon chemicals containing refrigerants, such as R11, R12, R113, R114, etc. These refrigerants were identified as the most harmful to Ozone layer by the Montreal Protocol, and were phased out in 2000. However they are still being used in the older machines, with precautions to minimize release in accordance with EPA regulations. The most common application of these refrigerants is in the large centrifugal chillers. R12 was also used commonly in the older cars for air condition.

B. *Hydrochlorofluorocarbons (HCFCs) refrigerants*

These are the Hydrogen, Chlorine, Fluorine and Carbon chemicals containing refrigerants, such as R22, R123, etc. These refrigerants were identified as slightly harmful to the Ozone layer by Montreal Protocol, and will be completely phased out by 2030. The R22 refrigerant is commonly used in reciprocating type of compressors, while R123 is used in centrifugal chillers as a temporary replacement for R11.

C. Hydrofluorocarbons (HFCs) refrigerants

These are the Hydrogen, Fluorine, Carbon chemicals containing refrigerants, such as R134a. These are the new refrigerants that do not harm the Ozone layer, and are being used in the newer machines to replace the CFC and HCFC. R134a is now commonly used as a replacement of R12 and R500, and in all new cars air conditioning systems. R407c is used as a replacement for R22. One of the other common HFC used in new equipment now is R410a.

4. REPLACEMENT OF PAST REFRIGERANTS BY NEW ALTERNATIVES

Since it is clear that many refrigerants were banned after Montreal Protocol so new alternatives were required to face the demand and need of refrigerants worldwide.

For so, new improved refrigerants were introduced worldwide which are as follows :-

Original Refrigerants	Alternative Refrigerants
R-11	R-123, R-245fa
R-114	R-236fa
R-12	R-134a, R-600a, R-290, R-717, R-744
R-500	R-134a
R-22	R-134a, R-407C, R-410A, R-290, R-717, R-744
R-502	R-404A, R-507
R-13B1	R-410A
R-13	R-23

The alternatives introduced possess approximate similar properties and efficiencies as the original refrigerants so that they can be easily used in Vapor Compression Refrigeration System (VCRS) following the Montreal Protocol.

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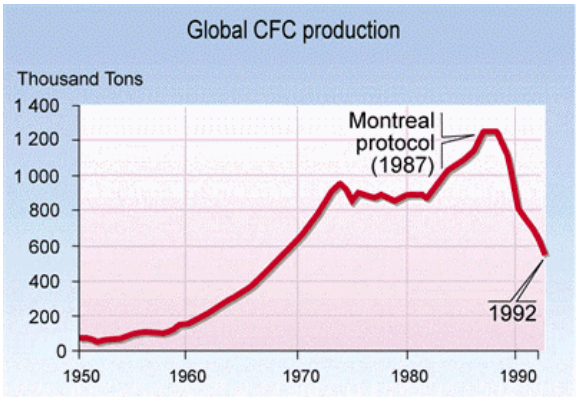
5. MONTREAL PROTOCOL

For controlling the rapid increase in ozone layer depletion as expected in future if the same increase in harmful emissions through various sources occurs a protocol was opened for signature on 16 September 1987 with 46 signatories came into force on 1 January 1989 known as Montreal Protocol.

This protocol was implemented to prohibit the use and production of several groups of halogenated hydrocarbons who are responsible in ozone layer depletion.

Its effect worldwide can clearly be observed with a remarkable reduction in the production of CFCs (Chlorofluorocarbons) the most hazardous chemical in ozone layer depletion.



The above graph clearly reflects the effect of Montreal Protocol in CFC production globally.

6. ALTERNATIVE REFRIGERANTS

After Montreal Protocol many refrigerants were banned worldwide so those refrigerants were replaced by some refrigerants which were used as an alternative in place of those banned refrigerants.

Some alternative refrigerants their applications and characteristics are given below:-

A. R442D (M029)

a. *Applications:* - Versatile R22 replacement in Vapour Compression Refrigeration System (VCRS) and equipments with direct evaporation (air-conditioning systems, chilled water and refrigeration systems for normal and low-temperature operation).

b. *Characteristics:* - Its performance and efficiency is similar to past refrigerants like R22. The usage of lower pressurized gas temperatures compared to R22 may extend the service life of the compressor in Vapour Compression Refrigeration System. Its refrigeration efficiency is +14% as compared to R22.

B. R417 (M059)

a. *Applications:* - Air-conditioning systems <15kW.

b. *Characteristics:* - The usage of refrigerants like R417 is energy savings when used in refrigeration systems like Vapour Compression Refrigeration Systems (VCRS). Its refrigeration efficiency is +1% as compared to R22.

C. R422A (M079)

a. *Applications:* - Suitable as replacement for: R502, R402, R403, R408 refrigerant mixtures and as R22 replacement in certain low-temperature refrigeration systems like Vapour Compression Refrigeration Systems and many more.

b. *Characteristics:* - Its performance is better as a refrigerant than R33 under a variety of operating conditions, with improvements of up to 15% in low-temperature refrigeration systems. Its usage also extends the compressor's service life. Its refrigeration efficiency is +16% as compared to R22.

D. R438A (M099)

a. *Applications :* - Versatile R22 replacement in Vapour Compression Refrigeration System.

b. *Characteristics:* - Performance and efficiency is similar to past used refrigerants. Its usage also extends the service life of refrigeration systems like Vapour Compression Refrigeration Systems. Its refrigeration efficiency is +7% as compared to R22.

7. NATURAL REFRIGERANTS

A. Ammonia (NH_3) or R717

Ammonia is a naturally-occurring substance that can be used as an alternative for fluorocarbon refrigerants in refrigeration systems. Indeed, ammonia has been used as refrigerant since long before 1856.

Ammonia has both a zero ozone depletion potential (ODP) and a zero global warming potential (GWP). For many years ammonia has been the refrigerant of choice in large industrial refrigeration application. Having best suited environmental conditions ammonia is having a possible reason being used as a natural refrigerant worldwide.

B. Carbon Dioxide (CO_2) or R744

Carbon dioxide (CO_2) is a substance that has been used as a refrigerant since 1860s.Carbon dioxide has an ozone depletion potential (ODP) of zero and a global warming potential (GWP) of 1. It is generally regarded as a cheap and easily available refrigerant. It addition to basic environmental properties, carbon dioxide is non-toxic. It carries an A1 safety classification indicating that it has low toxicity and is non-flammable.

Carbon dioxide is already being used as a refrigerant in a number of applications around the world including Vapour Compression Refrigeration System (VCRS).

With all this best suited properties carbon dioxide is rapidly increasing in the field of refrigeration.

C. Hydrocarbons (HC) or R290, R600a

Hydrocarbons are refrigerants that can be used as an alternative to fluorocarbon refrigerants in some refrigeration and air conditioning applications.

Along with ammonia and carbon dioxide, hydrocarbons were commonly used as refrigerants before the invention of fluorocarbon refrigerants in the 1930s.

The term 'hydrocarbon' encompasses a range of substances. The hydrocarbons most commonly used as refrigerants are ethane (known as R170), propane (R290), butane (R600), isobutene (R600a) and propylene (R1270). While each of these substances has a different chemical composition, they all share the same basic environmental properties – an ozone depletion potential (ODP) of zero and a global warming potential (GWP) of 3.

Hydrocarbon refrigerants can be used either in systems designed specifically for their use, or as a replacement in a system designed for a fluorocarbon refrigerant.

With all this best suited properties, hydrocarbons are also widely used worldwide as refrigerant.

8. REFRIGERANTS OF FUTURE

After the implementation of Montreal Protocol many refrigerants were banned worldwide but after it due to the sudden need and demand of refrigerants worldwide suitable refrigerants were discovered which suit best to environment with low ozone depletion potential (ODP) and global warming potential (GWP).

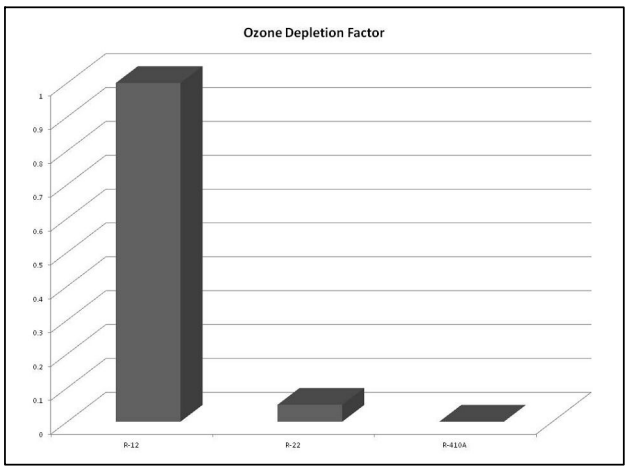
But now in the upcoming days the concentration of successive improvement in refrigerants in various refrigeration systems like Vapour Compression Refrigeration System (VCRS) shifts to the field of refrigerants with high efficiency too.

Keeping in concentration the new requirements and implementation required in refrigerants, the following refrigerants are discovered and marking as the refrigerants of future days. These refrigerants are as follows: -

A. R-410A: - R-410A is an azeotropic mixture of difluoromethane (CH_2F_2, called R-32) and Pentafluoroethane (CHF_2CF_3, called R-125) which is used as a refrigerant in air conditioning application and vapour compression refrigeration system (VCRS).

Unlike alkyl halide refrigerants that contain bromine and chlorine, R-410A does not contribute to ozone depletion, and is therefore becoming more widely used as ozone-depleting refrigerants like R-22 are phased out.

The zero ozone depletion factor is one of the main factor making R-410A, the refrigerant of future.



B. R-424A (RS-44): - After the ban of refrigerants like R-22, the requirement of new refrigerant was replaced by introduction of new refrigerant of future which is R-424A.

R-424A acts as a suitable refrigerant of future days because of its best suitable properties according to demands:-

- Higher coefficient of performance.
- Lower discharge temperature.
- Zero ozone depletion potential.
- Non-flammable.
- Lower discharge potential.
- Similar capacity (as compared to past refrigerants).
- Compatible with existing oils.
- No hardware changes needed.

With all these best suitable properties R-424A is now the refrigerant of future upcoming days in refrigeration.

C.R-426A (RS-24):- R-426A is a new refrigerant introduced as an alternative for R12 (Dichlorodifluoromethane) which was banned after the implementation of Montreal Protocol.

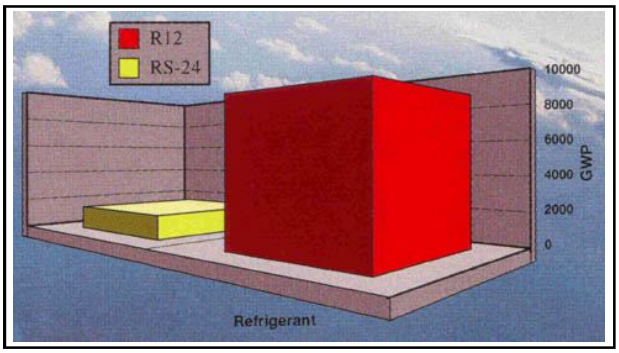
R-426A is now acting as a refrigerant of future due to its various properties which are: -

- Zero ozone depletion potential.
- Lower discharge temperatures.
- Non-flammable.
- No hardware changes required.
- The ideal replace of widely used refrigerant R12.

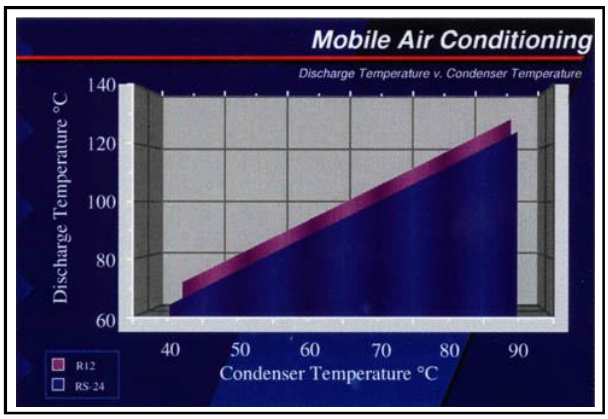
Due to these properties R-426A is now acting the refrigerant of future.

But the main factors of R426A which is enabling it to be the refrigerant of future are:-

- It's zero global warming potential (GWP), as shown in graph given below comparatively to R12.



- It's good performance in new refrigeration equipments like Mobile Air Conditioning as shown below: -



9. CONCLUSION

In this study, it can be clearly observed the need of new refrigerants to be implemented worldwide after the protocol banning all the refrigerants with ozone depleting potential (ODP) and global warming potential (GWP), the Montreal Protocol. It is also presented the various drawbacks faced by the various refrigerants used in our past and why they came to an end. In this study, it is also seen about the new alternatives implemented worldwide after the ban on the past refrigerants which are efficiently better than the previous ones to major extents. It is also given about the alternative refrigerants and the natural refrigerants used worldwide in various refrigeration equipments like in Vapour Compression Refrigeration System (VCRS). The main concentration in kept in this study on the new refrigerants of future which are grasping the world of refrigeration with the factors leading a better environment showing the successive improvement in refrigeration in worldwide.

NOMENCLATURE

Symbol	Meaning
VCRS	Vapour Compression Refrigeration System
ODP	Ozone Depletion Potential
GWP	Global Warming Potential
CFC	Chlorofluorocarbon
EPA	Environmental Protection Agency
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HC	Hydrocarbon
CO_2	Carbon dioxide
NH_3	Ammonia
R-11	Trichlorofluoromethane
R-12	Dichlorodifluoromethane
R-14	Tetrafluoromethane
R-13B1	Bromotrifluoromethane
R-32	Difluoromethane
R-113	1,1,2-Trochlorotrifluoroethane
R-114	1.2-Dichlorotetrafluoroethane
R-123	2,2-Dichloro-1,1,1-trifluoroethane
R-125	Pentafluoroethane
R134a	1,1,1,2-Tetrafluoroethane
R290	Propane

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