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A Review Paper on Natural and Synthetic Refrigerants

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ABSTRACT: The Montreal Protocol (1987) prohibited halogenated hydrocarbons with a high ozone depletion potential (ODP) because of their harmful effects on the ozone layer, which protects the earth from UV radiation. The greenhouse gases (GHG) utilized in contemporary refrigeration, air conditioning, and heat-pumping systems are subject to a time-limited permit term under the Kyoto Protocol (1997). The European Union law (2014) and the Paris Accord (2016) place a significant emphasis on the phase-out of hazardous synthetic refrigerants in order to prevent ozone depletion and reverse climate change impacts. The usage of natural refrigerants results in no net increase in greenhouse gas (GHG) emissions in the environment. Extensive research is being conducted globally to adapt and alter current cooling and heating systems utilizing natural refrigerants. This study uses the Refrigerant Qualitative Parametric (RQP) quantification model to examine timeworn, current, and next-generation refrigerants in order to aid the refrigerant selection process. It is calculated using the arithmetic sums of real refrigerant parametric values adjusted to corresponding ideal values. This model may aid in the selection of alternative refrigerants for temporary replacement of CFCs with HCFCs or HFCs, and eventual replacement of HCFCs or HFCs with low GWP and ODP synthetic and natural refrigerants.

KEYWORDS: Global Warming, Natural, Refrigerants, Synthetic, Transport.

I. INTRODUCTION

The refrigerant is a material or combination, usually a fluid, which undergoes a reversible phase change from a liquid to a gas and back in a heat cycle. Refrigerators, air conditioners, heat pumps, water heaters, and a variety of other appliances utilize refrigerants to transport heat between sources and sinks[1]. For specific cooling and heating applications, appropriate refrigerants are used. Even before the advent of electricity in the 1880s, human civilization used refrigeration technology. Oliver Evans (1805) is credited with inventing refrigeration via the use of ether. This concept was applied in Jacob Perkin's first refrigeration machine, which he constructed in 1834. Later, in their refrigeration systems, different researchers employed petrol (1860s), NH3 (1873), CO2 (1886), and SO2 (1890s) as mediating fluids. Ether, NH3, CO2, SO2, H20, CCl4, HCOOCH3, HCs, and CHCs were the most common refrigerants from 1830 to 1930. The majority of these refrigerants were poisonous, combustible, and extremely reactive, making them dangerous to use. In 1929, Dupont de Nemours developed (CCl2F2) molecules, which were commercially manufactured as Chlorofluorocarbon (CFC-12) refrigerants in 1932. There is no refrigerant in sight that offers all of the desirable characteristics. A short history of natural refrigerants in the past, present, and likely future[2]–[7].

Natural refrigerants were used in the early days of refrigeration (1800), but synthetic refrigerants with better thermal performance, safety, and durability were introduced in 1929. Because certain synthetic refrigerants, such as chlorofluorocarbons (CFCs), have been linked to ozone depletion in the stratosphere, they have been prohibited under the Montreal Protocol (1987). Hydro chlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) were suggested as a replacement in the 1980s. HCFCs have been linked to ozone depletion and have a significant potential for global warming[8].

HCFCs will be phased out by 2020–2030, while HFCs will be phased out by 2025–2040, according to the Kyoto Protocol (1997). Permission to use HFC for a limited time is an interim solution, not a reason. We are rapidly nearing the deadline, yet many nations are defiant, hesitant, and ignorant, or lack financial or technological means. This study examines the history, present and future prospects of refrigerants, as well as the decision-making process for switching from high to low GWP and natural refrigerants in current and future heating and cooling equipment. Also included is an updated overview of ozone depletion and global warming, as well as a critical assessment of the current state of affairs. Existing refrigerants are simulated for the conventional Vapour Compression Cycle (VCC) using the suggested model and original results are shown using REFPROP (NIST-23)[9].

A. *Natural refrigerants*

Organic propellants arise in humanity's environmental and physical mechanisms absent of human involvement. Naturally coolants include ammonium, co2, sulphur oxides, liquid, oxygen, and diethyl elixirs. From the 1800s through the 1930s, when increased synthesized compressed gases were produced, biological propellants were the foundation of the HVACR industry. A fast growth in manufactured refrigeration systems and dirty electricity produced depletion of the oxygen layer and climate change, compelling scientists and manufacturers to reject brominated compounds in preference of chlorofluorocarbons and coal energies in preference of based on alternative solutions. Figure 1 shows the histogram of synthetic and natural refrigerants.

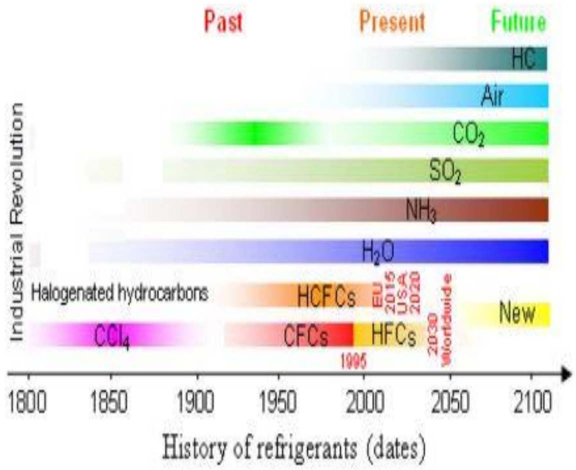

Figure 1: The above figure shows the histogram of synthetic and natural refrigerants.

a. Water (R-718)

Freshwater is a non-toxic, non-flammable fluid that is abundantly available across the world. Once particularly in comparison to CFCs, has a greater cold temperature, but requires 10 times the quantity flow rate for about the same cooling capability, increasing the cost of planar and rotational air conditioners. Lee cited a modelling study that used vapour as a refrigeration in a multi-stage centrifugal compression with inter-cooling approach, claiming that vapours had a 30% greater COP than manufactured R-134a at full weight. A framework correlation of R-718 with R-290, R-717, R-134a, R-22, and R-152a at vapour temperatures over 35 °C revealed that R-718 has a higher COP. The physicochemical characteristics of R-718 allow it to accomplish COP, but its high critical warm air and humidity, and the rising price of axisymmetric or impeller air conditioners, higher charge stream, mainly occurs procedure, and use of terms of heat recyclers, are having significant, causing it less attractive for heat pump proposal areas.[10].

b. Hydrocarbons (HCs)

Researchers in contact with industry have reported safety issues with HCs like propane, which appear to be excellent candidates. R-290 and R600 are flammable materials with similar properties to halogenated HCs. B. Saleh and his colleagues used the BACKBONE equation to come up with similar results. R-1270 is a good alternative to R-22 because it has a higher capacity and COP. HCs have ignition temperatures ranging from 420°C (R-600) to 600°C (R-50). HCs have excellent thermodynamic properties that are friendly to the environment, but they are flammable. As per Missenden et al., in household cooling scheme, a total of 200 g of HC coolant should indeed be utilised, with a limit of 0.40 g. Nevertheless, pursuant to ISO, EU, and IEC regulations, a compact enclosed device can produce up to 150 g. The thermal properties of helium is reduced when certain hydrogen ions are exchanged by chloride, fluoride, or halogen, but then began to cause adverse climatic consequences, prohibiting them from just being employed as chlorofluorocarbons. HCs compressed gases are used in refrigeration system, freezes, and coolers. Water heaters, soft drink and frozen yogurt machineries, tractor trailer kitchen appliances, and chillers ranging from 0.3 (1 kW) to 40 (150 kW) tons are among the commercial applications. R-290 and R-600a are commonly used in domestic refrigerators; R-170 (for sealed hermetic) is commonly used in commercial medium temperature equipment.

c. Air (R-729)

Air (R-279) is an ecologically acceptable refrigerator with a variety of temperatures of use with zero ODP and GWP. Although air has a crucial strength of 37.2 bar, the optimal temperatures is 140.32 °C. R-729 is a hydrocarbon used in aeroplanes, elevated trains, and commercial ultra-low temperatures refrigerants. He developed the core tenets of Compression Cycling Wind Conditioning with R-729 as the absorber in 1996. R-729 may be utilised in environment of continuous, confined process, and semi-open/closed cycle refrigerators by employing the reversing Brayton cycle. R-729's poor COP, high price, and huge configuration are all possible limitations as a facilitating liquid.

d. Ammonia (R-717)

Originally already when electrical was conceived, ammonium was employed as a solvent for air conditioner systems. R-717 has a lower ODP and GWP, strong thermodynamics characteristics, and a better thermal transport coefficients. R-717 is extensively used in the moderate and larger foods, beverages, and preserves sectors. A handful of writers have suggested that it may be utilised in gentle heat transfer situations, but it has yet to achieve mainstream adoption. In the vapour phase, R-717 gas is massless and readily soluble. It has a lower explosive limit of 15% and a temperatures of igniting of 651° Centigrade. Ammonia's turbine has a lower sweeping capacity since it has the smallest molecular concentration of all biological and manmade coolants. R-717 has a high residual energy of vaporisation, temperatures gradient, and pressures in compared to CFCs and HFCs, which appears to be helpful in term of COP for VCC. Ammonium was effectively employed in household water heater (9 kW) water warming with a COP of 3.8–4.8. Ammonium leaking may be recognised by its odour only at a frequency of 0.05 ppm, making it an identity gases. But even though the ammonium limit is 25 parts per million, it is only at 5000 parts per million that it has become lethal. It has a lesser combustibility in the environment when its concentrations is somewhere between 16 and 28 %. Ammonia, on the other hand, is incompatible with copper, zinc, and copper alloys, making it subject to legal and safety regulations. Because of the corrosive nature of water and ammonia, they are unable to replace existing copper tube networks. The use of ammonium as a condenser is forbidden in both household and industrial devices. A tractor trailer structure may well be the route out via subsequent cascades. Due to its limited melting points, a specialized mechanism for oil transfer to the compressors is required.

Ammonium has been utilised in the foods industry for over a decade, notwithstanding its combustible, toxic, and reactive properties. Nevertheless, parts of the systems and health issues are major considerations in gentle heat pumps installations.

e. Carbon dioxide (R-744)

CO2 is a naturally refrigeration with 0% ODP and the minimal efficient GWP of any native refrigeration. It's thicker than water, non-toxic, non-flammable, abundant in the environment, and an item of cellular of many economic activities. It was employed in maritime applications before 1950, but owing to its lower working pressures, it was eventually supplanted by synthetic refrigerants. R-744 is cheap, has a low liquid density, and therefore requires a smaller system and charge amount. Modern refrigeration and air conditioning systems need refrigerants with a low boiling point, a high critical temperature, and a moderate critical pressure. At extremely low critical temperatures, R-744 has almost 5.8 times the refrigeration ability of R-134a. For heat rejection, CO2's trans-critical characteristic requires supercritical pressure. It is used in the trans-critical domain in most refrigerated and thermal processes. Because of CO2's pressures and/or molecular weight, physical throughput and complete systems area are reduced. CO2 has a charcoal counterpart of one kilogramme CO2 equivalency per kilogramme, whereas NH3 and HFC have chemical counterparts of two and nine kilogrammes CO2eq per kilogramme, correspondingly. As a secondary refrigerant, CO2 (R-744) has replaced glycols and salt brines. In supermarkets, CO2 as a refrigerant has a better coefficient of performance than HFC-based systems for 90% of the year. Lorentzen invented the concept of transcritical CO2 automotive air conditioning, which is currently utilized as a refrigerant in transportation air-cooling. It operates at a ten-fold higher pressure than ammonia, necessitating specialized equipment, but it has a larger gas density, allowing for a stronger refrigerating effect. CO2 lowers the saturation temperature for pressure drop, enabling more mass to flow through the evaporator and suction pipes. At 30 to 50 °C, when greater efficiencies have been recorded, this impact becomes apparent. It is a common choice for both low-temperature freezers and high-temperature heat pumps. It is impossible to condense CO2 without temperature glide when the pressure reaches 73.8 bar.

f. H2 (R-702)

The critical pressure of H2 (R-702) is modest (13 bar), while the critical temperature is very low. Helium (R-704) has a lesser threshold pressures but a higher specific heat (4 °C) than air and protons (268.93 bar). Hydrocarbon (R-50) and air (R-729) both have a sub-zero temperatures range and normal melting. Although propylene (R-1150) has a low temperatures range (9.2 °C) and freshwater has a core heat of 0 °C, these coolants really aren't suited for conventional refrigerator systems and are thus not included in this study. Owing to the higher essential low temperatures and maximum compression, other considerations such as cytotoxicity, flash point, and refrigerated capabilities must be made before a final selection is made. Some natural refrigerants' properties.

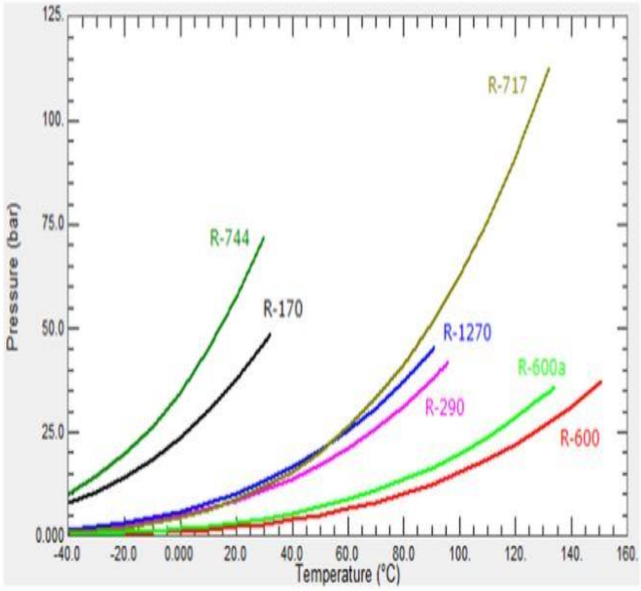

Figure 2: The above figure shows the Critical temperatures and pressures of some natural refrigerants.

II. DISCUSSION

The author has discussed about the World climate change, biological and manufactured inert gases When employing cryogenic long - term socio information, parameterized characterisation aids in making better decisions. CO2 (R744), Ammonium (R-717), and Alkenes (R-170) were demonstrated to be preferable candidates among some of the ASHREA indicated biological chlorofluorocarbons in this investigation. R-152a, R-1234yf, and R-1234ze are synthesized compressed gases that behave identically to R-717 and R-170 coolants. However, when using hydrocarbon refrigerants in heat pump systems, there are still issues regarding flammability and safety. Several synthetic refrigerants have acceptable quality weights, but due to environmental constraints, they are disregarded. This paper aids industries in selecting the optimal refrigerant choices in order to meet worldwide requirements and transition from CFCs to HCFC, HCFC to HFC or HFO, and HFC or HFO to natural refrigerants in a timely manner. There is no net increase in greenhouse gas (GHG) emissions in the environment when natural refrigerants are used. Globally, much research is being done to adapt and change existing natural refrigerant cooling and heating systems.

III. CONCLUSION

Even though the publishers are nearing the deadlines, several countries are still hesitant or ignorant. Authorization to use HFCs for a short period is a workaround, not an explanation. The purpose of this research was to develop a paradigm for quantitative assessment of naturally derived refrigeration systems to aid in judgement call. Probabilistic quantifying provides for a superior judgement when using hvac techno-economic data. Among the ASHREA suggested natural coolants, CO2, Ammonium, and Acetylene (R-170) were shown to be preferable alternatives in this study.

Manufactured chlorofluorocarbons with similar properties to R-717 and R-170 coolants. Nevertheless, when using hydrocarbons refrigeration units in air conditioning circuits, there are still worries concerning combustibility and security. Many synthesized coolants have sufficient qualitative characteristics, but due to ecological limitations, they are neglected. This guide aids businesses in determining the optimum refrigeration selections in particular to meet global responsibilities and migrate in a timely manner.

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