Refrigeration and air conditioning – application of Carbon dioxide as natural refrigerant

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ABSTARCT The refrigerant properties are very important for an energy efficient design of refrigeration system. The properties of carbon dioxide are compared with other chemical and natural refrigerants. It is slightly acidic and soluble in water, ethanol and acetone. Carbon dioxide has very good thermo-physical and transport properties as compared to other refrigerants. It is environmental friendly refrigerant since its ODP is zero and GWP is one. It is nonflammable; chemically inactive and compatible with polyester oil. Carbon dioxide has heat transfer coefficient 60 to 70% more than other refrigerants except ammonia. Due to the thermo physical properties of CO_2, the pressures of the refrigeration process are significantly higher than for commonly used fluids. This brings about particular working conditions for the compressor from which it may benefit if the design is adopted to these conditions. In this paper results from first experimental and theoretical investigations on $C0_2$ are discussed to bring out an idea for good and eco friendly refrigerant.

Key words: *Refrigeration and Air conditioning ,Carbon di oxide Natural refrigerant*

INTRODUCTION:

Air Conditioning:

Air conditioning is just what the name suggests, air that has been conditioned to meet the demands of the occupants of a home, office, factory or any internal space. Air conditioning provides and maintains internal air conditions at a set temperature, regardless of the time of year, the season or the country of residence. Homes and offices are typically designed to include an internal air temperature of 19-23^{0}C and relative humidity between 40% and 60%. Basic principles of heat energy is the motion of moving molecules and temperature is a measure of how fast these molecules are moving.

Refrigeration:

The job of a refrigeration plant is to cool articles or substances down to, and maintain them at a temperature lower than the ambient temperature. Refrigeration can be defined as a process that removes heat. The oldest and most well-known among refrigerants bare ice, water, and air. In the beginning, the sole purpose was to conserve food. The Chinese were the first to find out that ice increased the life and improved the taste of drinks and for centuries Eskimos have conserved food by freezing it.

CONDITIONS FOR GOOD REFRIGERANTS:

- The refrigerant should have low boiling point and low freezing point.
- It should be vapour at normal temperature and pressure.
- It should be non-flammable, non-explosive and should not have bad effects on the stored food material.
- It should have high thermal conductivity.
- The latent heat of vaporization of the refrigerant liquid must be large. When a small quantity of evaporates, a large amount of heat is removed and so the cooling will be more.
- The specific volume should be small in order to reduce the size of compressors.

EXEPERMENTAL:

CHEMISTRY OF REFRIGERANTS:

R 12 –dichlorodifluoromethane:

Dichlorodifluoromethane (R-12), is a colorless gas, and usually sold under the brand name Freon-12, is a chloro fluoro carbon_halomethane (CFC), used as a refrigerant and aerosol spray propellant. Its manufacture was banned due to concerns about damage to the ozone layer. It is soluble in many organic solvents.

Preparation:

It can be prepared by reacting carbon tetrachloride with hydrogen fluoride in the presence of a catalytic amount of antimony pentachloride:

$CCl_4 + 2HF \rightarrow CCl_2F_2 + 2HCl$

R-12 was used in most refrigeration and vehicle air conditioning applications prior to 1994 before being replaced by R-134a, which has a lower ozone depletion potential. In systems where R-134a is not practical, an R-409A blend (60% R-22; 25% R-124; 15% R-142b) may be directly added to an R-12 system without oil change although a filter change is always recommended. Manufacturer recommends that existing R-12 charge should be recovered.

R414a-1,1,1,2-Tetrafluoroethane:

1,1,1,2-Tetrafluoroethane, R-134a, Forane 134a, Genetron 134a is a haloalkane refrigerant with thermodynamic properties similar to R-12 (dichlorodifluoromethane), but with less ozone depletion potential. It has the formula CH_2FCF_3, and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure.

Uses:

1,1,1,2-Tetrafluoroethane is an inert gas used primarily as a "high-temperature" refrigerant for domestic refrigeration and automobile air conditioners. These devices began using 1,1,1,2-tetrafluoroethane in the early 1990s as a replacement for the more environmentally harmful R-12, and retrofit kits are available to convert units that were originally R-12-equipped. Other uses include plastic foam blowing, as a cleaning solvent, a propellant for the delivery of pharmaceuticals (e.g. bronchodilators), wine cork removers, gas dusters, and in air driers for removing the moisture from compressed air.

Safety:

Contact of 1,1,1,2-tetrafluoroethane with flames or hot surfaces in excess of 250 °C (482 °F) may cause vapor decomposition and the emission of toxic gases including hydrogen fluoride and carbonyl halides. Aerosol cans containing 1,1,1,2-tetrafluoroethane, when inverted, become effective freeze sprays. Under pressure, 1,1,1,2-tetrafluoroethane is compressed into a liquid, which upon vaporization absorbs a significant amount of thermal energy. As a result, it will greatly lower the temperature of any object it contacts as it evaporates. This can result in frostbite when it contacts skin, as well as blindness upon eye contact.

Ammonia:

Ammonia or azane is a compound of nitrogen and hydrogen with the formula NH_3. It is a colourless gas with a characteristic pungent smell. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. Ammonia, either directly or indirectly, is also a building-block for the synthesis of many pharmaceuticals and is used in many commercial cleaning products. Although in wide use, ammonia is both caustic and hazardous. Ammonia, as used commercially, is often called *anhydrous ammonia.* This term emphasizes the absence of water in the material. Because NH_3 boils at −33.34 °C (−28.012 °F) at a pressure of 1 atmosphere, the liquid must be stored under high pressure or at low temperature. "Household ammonia" or "ammonium hydroxide" is a solution of NH_3 in water.

Properties:

Ammonia is a colourless gas with a characteristic pungent smell. It is lighter than air, its density being 0.589 times that of air. It is easily liquefied due to the strong hydrogen bonding between molecules; the liquid boils at −33.3 °C, and freezes at −77.7 °C to white crystals. The crystal symmetry is cubic. Liquid ammonia has a very high standard enthalpy change of vaporization (23.35 kJ/mol, *cf.* water 40.65 kJ/mol, methane 8.19 kJ/mol, phosphine 14.6 kJ/mol) and can therefore be used in laboratories in uninsulated vessels without additional refrigeration. It is miscible with water. Ammonia in an aqueous solution can be expelled by boiling. The aqueous solution of ammonia is basic.

Refrigeration – R717

Because of ammonia's vaporization properties, it is a useful refrigerant. It was commonly used prior to the popularisation of chlorofluorocarbons (Freons). Anhydrous ammonia is widely used in industrial refrigeration applications and hockey rinks because of its high energy efficiency and low cost.

However, it suffers from the disadvantages of toxicity which restrict its domestic and small scale use. Along with its use in modern vapor-compression refrigeration it was used in a mixture along with hydrogen and water in absorption refrigerators.

Carbondioxide:

Carbon dioxide (chemical formula CO_2) is a naturally occurring chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom. It is a gas at standard temperature and pressure and exists in Earth's atmosphere in this state, as a trace gas at a concentration of 0.039 per cent by volume. As part of the carbon cycle, plants, algae, and cyanobacteria use light energy to photosynthesize carbohydrate from carbon dioxide and water, with oxygen produced as a waste product. However, photosynthesis cannot occur in darkness and at night some carbon dioxide is produced by plants during respiration. Carbon dioxide is produced by combustion of coal or hydrocarbons, the fermentation of sugars in beer and winemaking and by respiration of all living organisms. It is exhaled in the breath of humans and land animals. It is emitted from volcanoes, hot springs, geysers and other places where the earth's crust is thin and is freed from carbonate rocks by dissolution. CO_2 is also found in lakes at depth under the sea, and commingled with oil and gas deposits. The environmental effects of carbon dioxide are of significant interest. Carbon dioxide is an important greenhouse gas, warming the Earth's surface to a higher temperature by reducing outward radiation. Atmospheric carbon dioxide is the primary source of carbon in life on Earth and its concentration in Earth's pre-industrial atmosphere since late in the Precambrian eon has been regulated by photosynthetic organisms.

Applications of CO_2 in other Areas:

Carbon dioxide has been used in refrigeration and cooling in solid and liquid form because it sublimates to gas at very low temperature of -78.5^{o}C giving total loss of refrigerant. It is widely used in brewing of soft drinks, beers, other alcoholic drinks. Recently, it is being used in softening water to avoid corrosion problems in long water distribution lines and also in producing potable drinking water. The use of carbon dioxide as fire extinguisher is known from century. It also finds application in petroleum industry to bubble out crude oil, sand blasting and hardening of metal castings.

Environmental Impact:

Safety Issues with CO_2

Carbon dioxide has 3 to 4 times more vapour pressure as compared to other refrigerants so there is always question about the safety of carbon dioxide and thickness of materials required to hold this gas in heat exchangers, receivers and in tubes/hoses. Explosion/rupture strength of pressure vessels depends on following factors:

- Malfunctioning of safety equipments.
- Overcharging
- Overheating
- Incorrect operation practices
- Structural weaknesses in components like corrosion
- Mechanical impact

Carbon dioxide has very high volumetric heat capacity, so the charge quantity in the system reduces considerably even though the vapour pressures are very high on low and high side of the systems as compared to other refrigerants.

RESULTS AND DISCUSSION:

CO_2 Promising Refrigerant:

The density of carbon dioxide is second last in the least of most used refrigerants in industrial big capacity refrigeration plants and domestic refrigeration and air conditioning systems. As the percentage of carbon dioxide increases in the room, the air will get displaced out. Carbon dioxide is not only considered asphyxiate but it is known as narcotic agent and cerebral vasodilator. The vasodilator is substance which relaxes the blood vessel walls and reduced blood pressure. Carbon dioxide has also another effect on the red cells. If the percentage of carbon dioxide is more in the room air, then red cells get saturated with carbon dioxide and they lose their ability to exchange carbon dioxide for fresh oxygen. The percentage of carbon dioxide in air is 0.036%. If concentration goes up by 3% on volume basis then it cause hyperventilation, 5% will cause narcosis and 10% will cause a coma. The Immediate Danger to Life and Health (IDLH) concentration level is 4% by volume. The industry is well technologically advanced in handling the refrigerants much heavier and toxic than carbon dioxide so it is not a serious issue to use

carbon dioxide as refrigerant. Carbon dioxide is colorless, odorless, naturally occurring gas with melting point -56.6^{0}C at 101.325 kPa pressure. It appears white solid substance like snow with surface temperature -78.5^{0}C and can be converted into bricks to make dry ice. It is present in the atmosphere at a concentration of 350 ppm from millions of years. Carbon dioxide has played key role for sustainability of plants and human kind on this planet. The volumetric heat capacity of carbon dioxide is 3 to 4 times more than other refrigerants. Hence, it reduces considerably the charge quantity of refrigerant and the size of compressor, heat exchangers and tubing, etc. as compared to other refrigerants.

Selected characteristics and properties of various refrigerants

Refrigerant	**R12**	**R22**	**R134a**	**NH_3**	**CO_2**
Natural Fluid	**No**	**No**	**No**	**Yes**	**Yes**
Ozone Depletion Potential	**1.0**	**0.05**	**0**	**0**	**0**
Global Warming Potential 100years 20 years	**7100 7300**	**1500 4100**	**1200 3200**	**- -**	**1(0) 1(0)**
Critical Temperature in^{0}C in F	**112.0 233.6**	**96.2 205.2**	**101.2 214.2**	**132.4 270.3**	**31.1 88.0**
Critical Pressure in MPa in psi	**4.16 603.3**	**4.99 723.7**	**4.07 590.3**	**11.27 1634.5**	**7.38 1070.3**
Flammable or Explosive	**No**	**No**	**No**	**Yes**	**No**
Toxic/irritating decomposition products	**No**	**No**	**No**	**Yes**	**No**
Approximate relative price	**1**	**1**	**4**	**0.2**	**0.1**
Relative volumetric refrigeration capacity	**1**	**1.6**	**1**	**1.6**	**8.4**

Conclusion:

The green leafy plants are producing carbohydrates (plant food) through photosynthesis process by using carbon dioxide. Carbon dioxide is a green house gas and has stabilized the temperature of the planet above 0^{0}C otherwise we would have been in ice age. Carbon dioxide is naturally available, safe, environmental friendly refrigerant with best thermo-physical and transport properties after ammonia. The design of refrigeration system with carbon dioxide is depends on the low side temperature requirement of application and design ambient temperature. The thermo-physical properties of carbon dioxide are better than current refrigerants. The disadvantage of carbon dioxide is low critical point which makes cycle transcritical in high ambient climates. This results in loss of performance of the system. So it is necessary to match the design of carbon dioxide refrigeration with applications to produce cold and hot utilities simultaneous and derive better financial mileage over existing subcritical refrigeration systems. CO_2 is a safe and environmentally friendly refrigerant Especially for refrigeration applications with high leakage rates, like automotive air conditioning systems, the use of the environmentally benign fluid R7 44 ($C0_2$) as the refrigerants is a very promising option. The current investigations are a contribution to designing CO_2 as a highly efficient compressor for CO_2 as the refrigerant and by doing so, to support the CO_2 refrigeration technology to become a sensible alternative in tomorrow's world of refrigeration.

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