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CRYOGENIC AIR CONDITIONING OF MOTOR VEHICLES

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Abstract- Cryogenics is the branch of physics and engineering that involves the study of very low temperatures (below 123 K), how to produce them, and how materials behave at those temperatures. It is frequently applied to low temperature refrigeration applications such as in the study of physical phenomena of materials at temperature approaching absolute zero and in the liquefaction of gases. Liquefied gases such as liquid nitrogen and liquid helium are used in many cryogenic applications. Using liquid nitrogen as a refrigerant reduces chloro-fluorocarbon (CFC) emission in atmosphere and it is an eco-friendly technique. This paper deals with usage of liquid nitrogen in air conditioning of motor vehicles. First the preparation of liquid nitrogen is discussed, followed by its storage and working as a refrigerant in air conditioning system. This is followed by its advantages and draw backs.

Keywords- *Cryogenic; Liquefied gases; Liquid Nitrogen; Refrigerant; Eco-friendly.*

I. INTRODUCTION

A liquid, such as liquid nitrogen, that boils at a temperature below about 110 K and used to obtain very low temperatures is known as cryogen. Air conditioning is a process by which air is cooled and dehumidified. An air conditioner especially operates on refrigeration at near ambient temperatures. There are many physical principles that relate to air conditioning. Basically, most air conditioning systems operate on the principle of evaporation and condensation of a refrigerant. If an environmental friendly refrigerant like liquid nitrogen is used, it will not cause atmospheric pollution. In the past, chloro-fluorocarbon (CFC) was used as a refrigerant for air conditioning in cars. As CFC (R-12) is detrimental to the earth's ozone layer, a more environmental friendly refrigerant R-134A has been mostly used since 1996. Using cryogens as refrigerants have more advantages compared to R-134A. A short report on the design and test of a semi-automatic liquid hydrogen refueling station for automobiles was given [1]. The use of the old refrigerant carbon dioxide offers a key to the complete solution of the environmental problems in many areas of refrigeration usage. Some examples of how carbon dioxide can be used as a refrigerant were presented [2, 3]. Exergy charts were presented for carbon dioxide (CO_2) based on the new fundamental equation of state and the results of a thermodynamic analysis of conventional and trans-critical vapour compression refrigeration cycles using the data thereof. The reasons why ammonia is so popular in industrial systems, the reasons why it is deemed less suitable for other applications and the possible benefits at local, national and international levels that might be gained by more general acceptance of ammonia as a refrigerant were assessed. The progression of refrigerants was reviewed, from early uses to the present [4 - 6]. A review was presented on current approaches in road food transport refrigeration, estimates of their environmental impacts and research on the development and application of alternative technologies to vapour compression refrigeration systems that have the potential to reduce the overall energy consumption and environmental impacts. It was shown that a new mixture R134a/R600a/R290 could be a promising substitute for the existing R12 systems and it could eliminate the use of hygroscopic PAG oil [7, 8]. A comprehensive review was presented on the past efforts in the field of adsorption air-conditioning systems for automobile. It was concluded that proposed intelligent energy management Control (IEMC) System developed based on Fuzzy Air Conditioning Controller with Look-Ahead (FAC-LA) method was a more efficient controller for vehicle air conditioning system than the previously developed Coordinated Energy Management Systems (CEMS) [9, 10]. Air-conditioning of automobiles using cryogens like liquid nitrogen is an eco-friendly technique.

II. CRYOGENIC AIR SEPARATION AND LIQUIFIER SYSTEMS

Cryogenic air separation processes are routinely used in medium to large scale plants to produce nitrogen, oxygen, and argon as gases and (or) liquid products. Cryogenic air separation is the preferred technology for producing very high purity oxygen and nitrogen. It is the most cost effective technology for high production rate plants. All plants producing liquefied industrial gas products utilize cryogenic technology. The complexity of the cryogenic air separation process, the physical sizes of equipment, and the energy required to operate the process vary with the number of gaseous and liquid products, required product purities and required delivery pressures. Nitrogen-only production plants are less complex and require less power to operate than an oxygen-only plant making the same amount of

product. Co-production of both products when both are needed increases capital and energy efficiency. Making these products in liquid form requires additional equipment and it doubles the amount of power required per unit of delivered product. When a large percentage of plant production must be produced as liquid product(s), a supplemental refrigeration unit must be added to a basic air separation plant. These units are called liquefiers and they mostly use nitrogen as the primary working fluid.

III. GENERAL PROCESS DESCRIPTION OF CRYOGENIC AIR SEPARATION

The first process step in any air separation plant is filtering, compressing and cooling the incoming air. The next major step is removal of impurities, in particular, but not limited to, residual water vapour plus carbon dioxide. The next step is additional heat transfer against product and waste gas streams to bring the air feed to cryogenic temperature. The next step in the air separation / product purification process is distillation, which separates the air into desired products. Refrigeration is produced at cryogenic temperature levels to compensate for heat leak into the cold equipment and for imperfect heat exchange between incoming and outgoing gaseous streams.

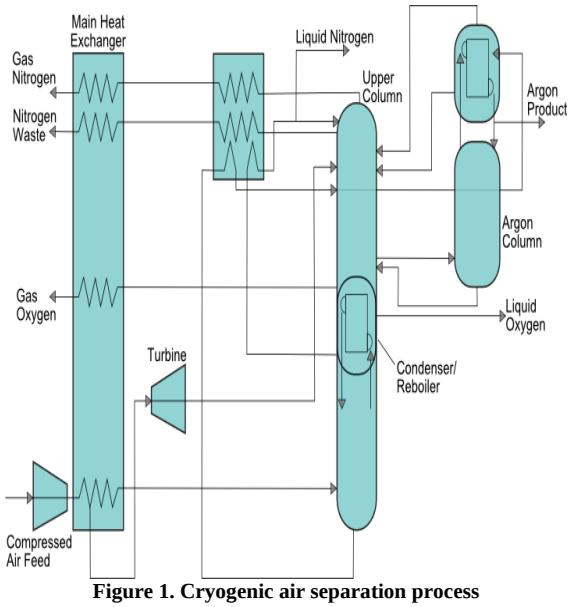

Figure 1. Cryogenic air separation process

IV. CRYOGENIC LIQUID STORAGE

A. Dewar

The typical container used to store and handle cryogenic fluids is the dewar. The dewar is multi-walled designed with a vacuum jacket for insulation and pressure relief valves to protect against over-pressurization. Cryogens normally are stored at low pressures. Liquid nitrogen dewars have one pressure relief valve set at 1.517×10^5 N/m^2.

Figure 2 Dewar for storing liquid nitrogen

B. Cryotank

Cryotank or cryogenic tank is a tank that is used to store frozen biological material. Liquid nitrogen storage tanks are available with liquid storage capacities up to 300,000 liters.

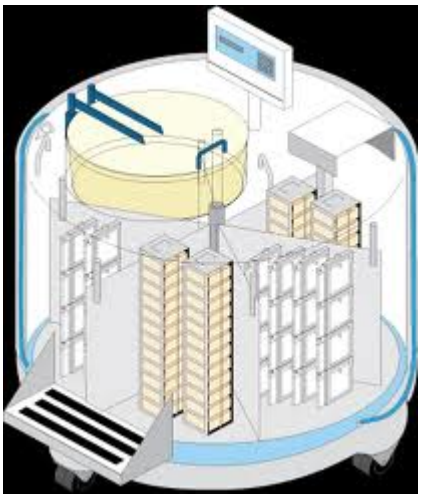

Figure 3. Cryotank

V. CRYOGENIC AIR CONDITIONING SYSTEM IN A MOTOR VEHICLE

The air conditioning unit repeats the phase transitions, evaporation of liquid to gas and condensation of gas to liquid, in a continuous cycle to carry heat from an evaporator inside a compartment to be released at a condenser outside.

VI. WORKING OF AIR CONDITIOING SYSTEM USING LIQUID NITROGEN AS REFRIGERANT

Air conditioning like it says 'conditions' the air. It not only cools it down, but also reduces the moisture content, or humidity. Turning on the air conditioner actually reduces the number of kilometers per liter of a car. There is energy used in removing the heat and moisture from the air in the car and this consumes

petrol because of the extra engine load. Air conditioning's main principles are

- Evaporation
- Condensation,
- Compression
- Expansion

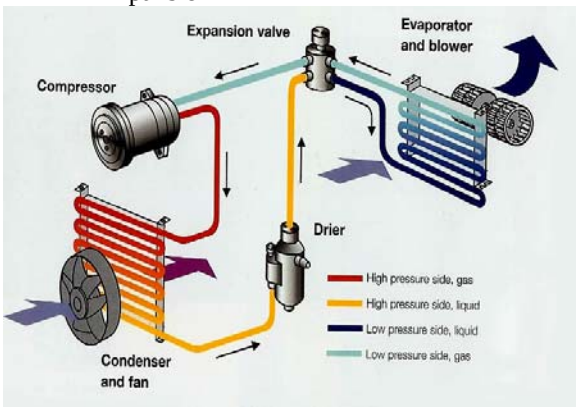

Figure 4. An automotive air conditioning system

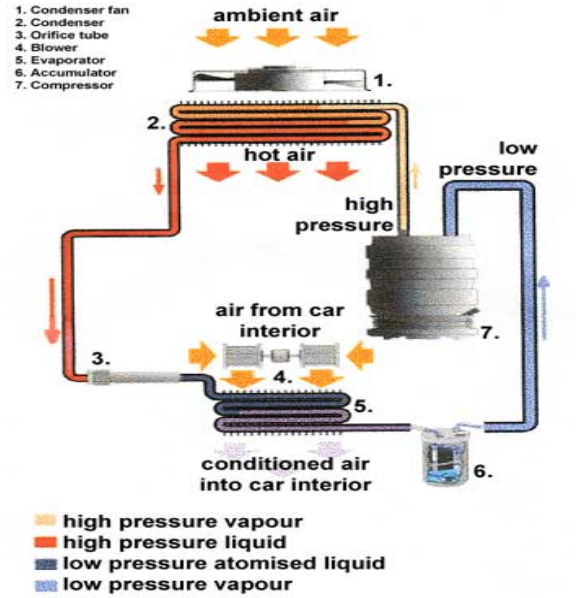

Figure 5. Air conditioning system using liquid nitrogen

Below discussed are the various components of an air conditioning system using liquid nitrogen in an automobile.

A. Compressor

The compressor is the work horse of the air conditioning system, powered by a drive belt connected to the crankshaft of the engine. When the air conditioning system is turned on, the compressor pumps nitrogen vapour under high pressure to the condenser.

B. Condenser

The condenser is a device used to change the high pressure nitrogen vapour to a liquid. It is mounted in front of the engine's radiator and it looks very similar to a radiator. The vapour is condensed to a liquid because of the high pressure that is driving it in and this generates great deal of heat. The heat is then in turn removed from the condenser by air flowing through the condenser outside.

C. Receiver

Now the liquid nitrogen moves to the receiver-dryer. This is a small reservoir vessel for the liquid nitrogen and removes any moisture that may have leaked into the nitrogen. Moisture in the system causes havoc, with ice crystals causing blockages and mechanical damage.

D. Expansion Valve

The pressurized nitrogen flows from the receiver-drier to the expansion valve. The valve removes pressure from the liquid nitrogen so that it can expand and become nitrogen vapour in the evaporator.

ADVANTAGES OF USING LIQUID NITROGEN IN AIR CONDITIONING

1. It is an eco-friendly technique. It does not release harmful pollutants to the atmosphere.
2. There is no risk of global warming & depletion of ozone layer.
3. As there is no release of carbon dioxide, greenhouse effect is avoided.
4. No lung or other respiratory related problems are caused due to the breathing of cooled air from a cryogenic air conditioner.
5. Due to the non-emission of carbon monoxide, it does not contribute to air pollution as well as acid rain.
6. Liquid nitrogen being the cheapest, most widely produced and most common cryogenic liquid, serves as an excellent refrigerant.
7. The temperature it puts out inside the vehicle is consistent and stable.

VII. DISADVANTAGES

1. Cold Embrittlement

At cryogenic temperatures, many materials such as rubber, plastic and carbon steel can become so brittle that very little stress can break the material. Hence, for storing liquid nitrogen there is a necessity to use a material that will withstand cryogenic temperature.

2. Pressure buildup and Explosions

Without adequate venting or pressure-relief devices on the containers, enormous pressures can build up on cryogen evaporation. A pressure relief vessel or a venting lid should be used in the liquid nitrogen storage containers to protect against pressure build-up.

3. Oxygen Enrichment

Nitrogen, which has a low boiling point than oxygen will evaporate first. This can leave an oxygen-

enriched condensate on the surface that can increase flammability of materials near the system creating potentially explosive conditions.

VIII. CONCLUSION

Cryogenic air conditioning in automobiles is an eco-friendly technique. There is no emission of CFC's and hence damage to the ozone layer is prevented. Due to the non-emission of carbon monoxide, it does not contribute to the air pollution as well as acid rain. There is no risk of green house effect as there is no emission of carbon dioxide. It is relatively cheaper and can maintain constant and stable temperatures inside the vehicle. There are no respiratory problems created due to the breathing of air from cryogenic air conditioners. Thus it is a new and effective technique that can be implemented in all vehicles.

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