FABRICATION OF SOLAR THERMALVAPOUR ABSORPTION REFRIGERATION SYSTEM

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Abstract - ***There are some environmental concerns regarding the use of conventional refrigeration technologies as they contribute to ozone layer depletion and global warming. Refrigerators that contain CFCs, HCFCs or HFCs in their refrigerant cycle or insulation foam are very harmful. All these are environmentally destructive and potential global warming chemicals. Also, there is an energy concern regarding the use of commercially available refrigerators. The commercial systems operate in a vapor compression cycle, in which a compressor does the major work of compressing the refrigerant liquid for cooling. As the refrigerators are usually operated for 24 hours a day, there is considerable energy consumption. The use of solar energy to power refrigeration with replacing the compression cycle with vapour absorption cycle strives to minimize the negative impacts refrigerators have on the environment and energy. Replacing the electrical energy with solar energy will reduce the consumption of high grade electrical energy. Also the replacement of compression system with absorption system eliminates the energy consumption by compressors. Ammonia being an environmentally friendly gas reduces the effect of ozone layer depletion and global warming by artificial refrigerants. This paper deals with a model solar refrigeration system using NH3-H2O vapour absorption system.***

Key Words: *Energy, Solar, Vapour absorption, Electrolux*

1. INTRODUCTION

A refrigeration system is a system which can reduce the temperature or heat of a substance under a controlled condition. Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means. Refrigeration has many applications, including household refrigerators, industrial freezers, cryogenics, and air conditioning.

The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries. The history of refrigeration is very interesting since every aspect of it, the availability of refrigerants, the prime movers and the developments in compressors and the methods of refrigeration all are a part of it. In olden days refrigeration was achieved by natural means such as the use of ice or evaporative cooling. Now refrigeration is produced by artificial means. However, refrigeration technology has rapidly evolved in the last century.

2. PRESENT SCENARIO

Refrigeration is now one of the inevitable processes in our daily life. Refrigeration plays a vital role in our day to day life by preserving our food materials, medicinal products and other substances, giving human comfort via air conditioning. Also refrigeration is now inevitable in industries. In addition to human comfort, refrigeration is used to liquefy gases. In oil refineries, chemical plants, and petrochemical plants, refrigeration are used to maintain certain processes at their needed low temperatures. Metal workers use refrigeration to temper steel and cutlery. In transporting temperature-sensitive foodstuffs and other materials by trucks, trains, airplanes and seagoing vessels, refrigeration is a necessity.

Almost all of the domestic and industrial refrigerators that are used today work on a vapor compression cycle. In this cycle, a compressor is the main part. Compressor compresses the refrigerant liquid to high pressure and temperature. This refrigerant liquid is then condensed in a condenser to decrease the temperature. It is then passed on to an expansion valve to reduce the pressure. Now this low temperature, low pressure liquid goes to the evaporator and absorbs heat energy from the materials in the evaporator and become vapour. Thus a cooling is obtained in the evaporator. The refrigerant vapor is then moved to the compressor where it is compressed to high pressure and high temperature again. And the cycle thus continues.

Most of these refrigerators operate on electricity. The major share of electricity that is being supplied with a refrigerator is consumed by the compressor. Since a refrigerator is operated 24 hours a day, there is considerable energy consumption. Also the refrigerants used in these refrigerators are environmentally hazardous. The Freon gases that are popularly used in compression refrigerators are ozone depleting and add on to global warming. The huge energy consumption and environmental destruction caused by these refrigerators has to be reduced to the minimum possible level.

The replacement of compressor system with vapour absorption system will help in minimizing the above stated problems. The vapour absorption system replaces the compressor with a generator absorber set. Instead of the Freon gases, naturally available materials like ammonia or water can be used as refrigerants. Vapour absorption system is energized by providing heat energy to the generator. Low grade thermal energy can serve this purpose. Replacing the high grade electrical energy input to any other form of energy will reduce the electrical energy consumption. For that renewable energy sources or waste heat recovery systems can be adopted. Solar energy will be an excellent alternative in this case.

3. SOLAR VAPOUR ABSORPTION REFRIGERATION SYSTEM

The increasing energy demand and need for ozone layer protection and reduction of global warming paved the way to think for sustainable refrigeration. Sustainable refers to a system that gives better output without disturbing the environment and energy sector. Thus solar refrigeration gained importance. From a sustainability perspective, directly using solar energy as a primary energy source is attractive because of its universal availability, low environmental impact, and low or no ongoing fuel cost. The power from the sun intercepted by the earth is approximately 1.8x1011 MW which is much larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on the continuing basis. This makes it one of the most promising of the unconventional energy sources. In addition to its size, solar energy has two other factors in its favour. First, it is an environmental clean source of energy. Second, it is freely available in adequate quantities in almost all parts of the world where people live. However, there are many problems associated with its use. The main problem is that it is a dilute source of energy. A second problem associated with the use of solar energy is that its availability varies widely with time.

Consequently, the energy collected when the sun is shining must be stored for use during periods when it is not available. The need for storage significantly adds to the cost of the system. Thus, the real challenge of utilizing solar energy as an energy alternative is to address these drawbacks.

Solar refrigeration engages a system where solar power is used for cooling purposes. Solar energy can provide cheap and clean energy for cooling and refrigeration applications all over the world. Cooling can be achieved through two basic methods. The first is a PV based solar energy system, where solar energy is converted into electrical energy and used for refrigeration much like conventional methods. The second one utilizes a solar thermal cooling system, where a solar collector directly heats the refrigerant through collector tubes and circulates it to have cooling instead of using solar electric power.

Thermal cooling technology is preferred to PV based cooling systems because it can utilize more incident sunlight than a PV system. In the total incident solar energy, major part converts into heat, and a very small portion produces electricity in a PV system, with 65% of the incident rays (infrared rays, red and orange) converted into heat energy and only 35% useful for generating electricity in a silicon-based PV system. Therefore, thermal solar cooling is becoming more popular because a thermal solar collector directly converts light into heat.

3.1 Vapour Absorption Refrigeration System

In a VARS belong to the class of vapour cycles similar to vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems. Similar to vapour compression refrigeration systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications around the world. But they are not still popular in India. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water or ammonia they are environment friendly. The main components of the vapour absorption system are the generator, absorber, pump, condenser, expansion valve, evaporator and a heat input to the generator via a heat exchanger.

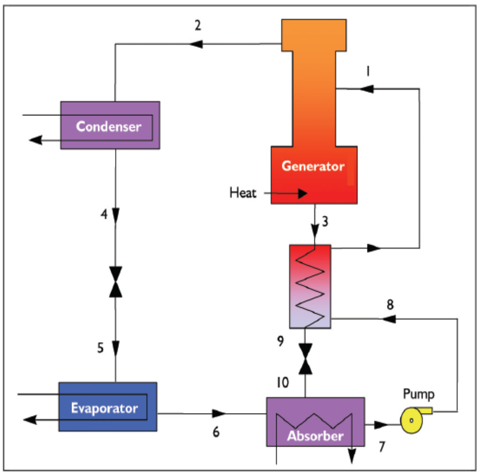

Fig -1 Vapour Absorption Refrigeration Cycle

The vapour absorption cycle is similar to the better known vapour compression cycle in that it employs a volatile refrigerant, e.g. ammonia, which alternately condenses under high pressure in the condenser by surrendering heat to the environment and vaporizes under low pressure in the evaporator by absorbing heat from the medium being cooled. Since the invention of absorption refrigeration system, NH_3-H_2O has been widely used. In this system, NH_3 is used as the refrigerant and H_2O is used as the absorbent. Ammonia is the only refrigerant from inorganic group which was used universally for many applications and still used to great extent at the present time. It possesses many properties required for an ideal refrigerant. It has wide applications because of its low volumetric displacement, low cost, low weight of liquid refrigerant per ton of refrigeration and high efficiency. Presently it is widely used in cold storages, ice manufacturing plants and skating rinks due to its low production and maintenance cost. Both NH_3 and water are highly stable for a wide range of operating temperature and pressure. NH_3 has a high latent heat of vaporization, which is necessary for efficient performance of the system. It can be used for low temperature applications, as the freezing point of NH_3 is -77°C. But since both NH_3 and water are volatile, the cycle requires a rectifier to strip away water that normally evaporates with NH_3. Without a rectifier, the water would accumulate in the evaporator and offset the system performance. There are other disadvantages such as its high pressure, toxicity, and corrosive action to copper and copper alloy. But the advantages overweigh the disadvantages. Efficient ammonia/water absorption chillers require water of at least 190 °F (88 °C).

5.ELECTROLUX REFRIGERATION SYSTEM

Electrolux system of refrigeration was invented in an idea to avoid the pump in the vapour absorption system.

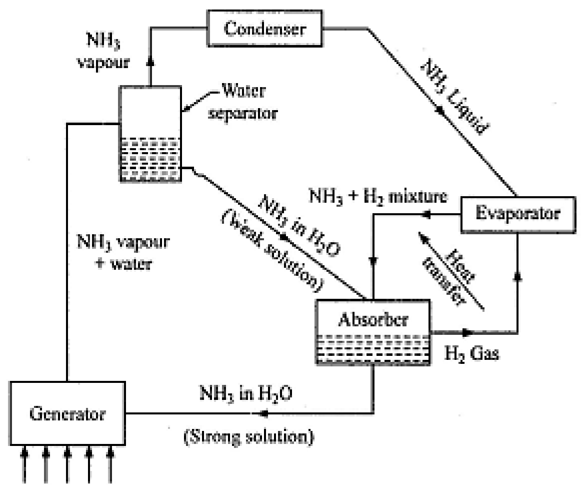

Fig - 2 Electrolux Refrigeration System

The most popular type of refrigerator which employs vapour absorption system is the Electrolux refrigerator. It works on three fluid absorption systems. A three fluid system employs a refrigerant, a solvent and an inert gas, and eliminate the aqua pump from the system thus making it completely free from moving parts. The system in this work uses water as absorbent, ammonia as refrigerant and hydrogen as a pressure equalizing inert gas in order to maintain the total pressure constant.

5.1 Principle of Electrolux System

The principle involved makes use of the properties of gas-vapour mixtures. If a liquid is exposed to an inert atmosphere, it will evaporate until the atmosphere is saturated with the vapour of the liquid. This evaporation requires heat which is taken from the surroundings in which the evaporation takes place. A cooling effect is thus produced. The partial pressures of the refrigerant vapour (in this case ammonia) must be low in the evaporator, and higher in the condenser. The total pressure throughout the circuit must be constant so that the only movement of the working fluid is by convection currents. The partial pressure of ammonia is kept low in requisite parts of the circuit by concentrating hydrogen in those parts.

5.2 Working

The ammonia liquid leaving the condenser enters the evaporator and evaporates into the hydrogen at the low temperature corresponding to its low partial pressure. The mixture of ammonia and hydrogen passes to the absorber into which is also admitted water from the separator. The water absorbs the ammonia and the hydrogen returns to the evaporator. In the absorber the ammonia therefore passes from the ammonia circuit into water circuit as ammonia in water solution. This strong solution passes to the generator where it is heated and the vapour given off rises to the separator. The water with the vapour is separated out and a weak solution of ammonia is passed back to the absorber, thus completing the water circuit. The ammonia vapour rises from the separator to the condenser where it is condensed and then returned to the evaporator. Ammonia evaporates in the evaporator and the desired cooling is obtained.

6. EXPERIMENTAL SETUP

A schematic assembly diagram of the experimental set up is given in the Fig – 3.

The heat input to the generator is provided by solar energy. A solar parabolic dish collector is used for this. Water is stored in the container fixed at the focal point of the parabolic dish. When sunlight falls on to the dish, the rays are focussed on to the bottom of the container and the container gets heated up which in turn heats up the water stored inside. This water is circulated via a copper pipe through a heat exchanger. Heat from the hot water is transferred to the generator via this heat exchanger.

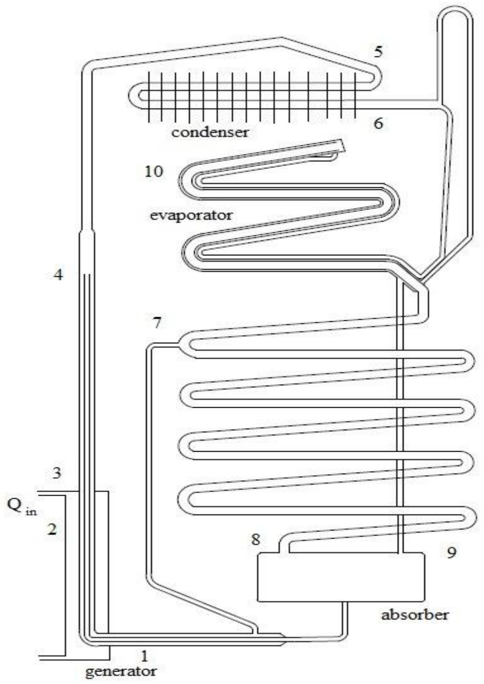

Fig - 3 Schematic View of Experimental Refrigerator

The system is pre-charged with three fluids namely water, ammonia and hydrogen. The absorber is initially filled with aqua ammonia solution. Hydrogen is used as an "inert gas" and does not undergo any phase change and heat transfer processes. Its purpose is to keep the pressure of the system constant. The heat energy from the hot water is transferred to the generator via a heat exchanger. This heat causes the ammonia vapour to evaporate from the solution. Since the difference in temperature of vaporisation of ammonia and water is not high, some traces of water also vaporises along with ammonia. These vapours are separated in a separator and pure ammonia enters the condenser where it is liquefied. The separated water vapour returns back to the absorber. The low temperature ammonia undergoes a pressure reduction in the expansion valve and enters the evaporator. The low temperature and low pressure liquid gain heat from the materials in the evaporator and changes it phase to vapour. This ammonia joins the weak aqua ammonia solution in the absorber. Thus the process continues.

9. CONCLUSION

A prototype of the refrigerating unit was fabricated and the whole system was coupled with a solar concentrating collector. The system was made to run and it was observed that a cooling effect was obtained at the evaporator. Ammonia absorption refrigeration technology has great potential to offer economical and innovative solutions to various refrigeration requirements. Absorption machine theory has existed for many years, however just recently this technology has reached a stage where it is also a commercially viable option. The small capacity application potential of ammonia absorption refrigeration technology makes it a strong candidate for the refrigeration technology of the millennium.

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