Zeolite-Water Adsorption Refrigeration System

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Abstract - This paper shows the usage of Zeolite 4A for application in adsorption refrigeration frameworks. The refrigeration framework model utilized as a part of the test comprises of two steel chambers, one containing Zeolite and the other containing refined water at a weight relating to the room temperature, three transports funnels having one valve each. The most reduced evaporator temperature accomplished was 9.80C with a C.O.P of 0.4

Keywords- Adsorption, Refrigeration, Coefficient of Performance, Zeolite, Vacuum.

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I. INTRODUCTION

The present mechanical vapor pressure frameworks are regularly used to fulfill the cooling request. This framework is well known and beneficial because of its high coefficient of execution, little size and low weight yet the framework accompanies a weakness of adding to a dangerous atmospheric devation, ozone layer exhaustion combined with high vitality utilization. The primary burden is that the refrigerant utilized as a part of such frameworks has chlorofluorocarbon (CFC), Hydro chlorofluorocarbon (CHFC) which thusly prompts a dangerous atmospheric devation and Ozone Layer Depletion.

A great deal of innovative work to present adsorption refrigeration framework utilizing adsorbent-refrigerant pair is being completed now-a-days. These frameworks makes utilization of the novel components of certain adsorbent refrigerant sets to finish refrigeration cycles for cooling purposes which are very much adjusted to basic innovation applications which work without moving parts and with poor quality warmth from various sources, for example, leftover warmth or sun based vitality.

The utilization of adsorption procedures to deliver refrigeration impact by utilizing adsorbents like Zeolite, silica gel, actuated carbon and alumina which have exceedingly permeable structures with surface-volume proportions in the request of a few hundred that can specifically catch and hold refrigerants (Wang, et.al 2010).

The most favored least temperature for the adsorption fridge is the room temperature; the breaking point ought to be ideally above 200C. Zeolite – water, Zeolite – methanol and initiated carbon methanol and so forth may be said among the adsorbent-adsorbate mixes that have been tried. Zeolite – water combine best to be utilized as a part of adsorption refrigeration in view of the way that they have to a great degree non-direct weight reliance of its adsorption isotherms. The isotherms soak at low halfway weight, after which the sum adsorbed turns out to be verging on free of weight. At encompassing temperature, zeolite can adsorb the vast majority of the vapor even at high halfway weight, relating to high condenser temperature. This one of a kind property of the zeolite turns into a critical element in high condenser

temperature and along these lines just a moderate recovery temperature may be utilized. The zeolite-water pair is a standout amongst the most favored adsorbent – adsorbate sets since water has a high dormant warmth of vaporization and a helpful breaking point (N. O. Omisanya, et.al 2012).

The adsorption cycle in this refrigeration framework is like the vapor pressure refrigeration cycle aside from the way that the adsorbent and adsorbate assumes the position of the compressor unit (Hassan et.al, 2011). The adsorption-desorption cycle comprises of four stages and is introduced by Clapeyron chart demonstrating the weight temperature fixation (p-T-x) by thick lines ABCD in the figure 1.
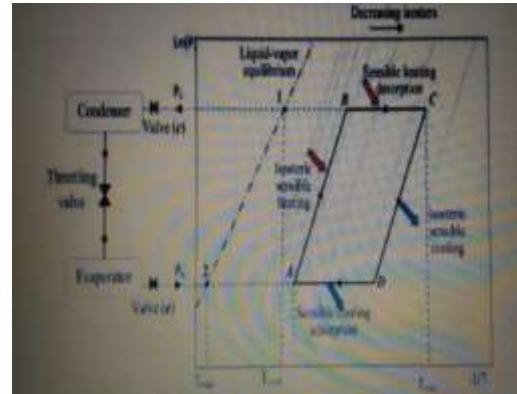

Figure 1: Clapeyron diagram for a conventional adsorption cycle

Step (A B): Isosteric heating
Step (B C): Desorption and condensation
Step (C D): Isosteric cooling
Step (D A): Adsorption and evaporation

Zeolite/water is useful for cooling and overcoming ecological issues identified with vapor pressure refrigeration frameworks since they have zero ozone layer consumption potential and no a worldwide temperature alteration potential(El Fadar et.al, 2009). The most imperative component of zeolite is that the zeolite precious stones are unceasing i.e. they can experience endless adsorption-desorption cycles.

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II. LITERATURE REVIEW

The phenomenon of adsorption/desorption was discovered over two centuries ago by C. W. Scheele in 1773 and by the F. Fontana in 1777. In 1785, they found that when they heated charcoal contained in a test tube it desorbed gases. The gases then adsorbed back when the charcoal was cooled. The nature of adsorption/desorption has always been a controversial one throughout the nineteenth century. In a paper Faraday (1834) discussed the possibility that gases are held onto the surface by an electrical force and suggested that gases could react more easily once they were in the adsorbed state. However, Berzelius (1836) noted that the best adsorbent was highly porous materials. Therefore, Berzelius proposed that adsorption was a process where surface tension or some other force caused gas to be condensed into the pores of a porous media. The idea that most adsorption/desorption processes were really just pore condensations was actively debated in the literature in the 1850s to 1920s. However, other investigators found there was some data that were not in accord with the idea that pore condensation alone explained adsorption/desorption. (Vacuum should be maintained constant) and one cool advantage of this system is that the hotter it is outside, the more cold you can generate.

The basis of zeolite refrigeration is the ability of crystals to absorb enormous quantities of heat as they boil and evaporate. Professor William Cullen of the University of Edinburgh demonstrated in 1755 by placing some zeolites in thermal contact with ether under a receiver of a vacuum pump. The evaporation rate of ether increased due to the vacuum pump and water could be frozen. This process involves two thermodynamic concepts, the vapour pressure and the latent heat. A liquid is in thermal equilibrium with its own vapor at a pressure called the saturation pressure, which depends on the temperature alone. If the pressure is increased for example in a pressure cooker, the water boils at higher temperature. The second concept is that the evaporation of liquid requires latent heat during evaporation. If latent heat is extracted from the liquid, the liquid gets cooled. The temperature of ether will remain constant as long as the vacuum pump maintains a pressure equal to saturation pressure at the desired temperature. This requires the removal of all the vapors formed due to vaporization. If a lower temperature is desired, then a lower saturation pressure will have to be maintained by the vacuum pump. The component of the modern day refrigeration system where cooling is produced by this method is called evaporator. If this process of cooling is to be made continuous the vapors have to be recycled by condensation to the liquid state. The condensation process requires heat rejection to the surroundings. It can be condensed at atmospheric temperature by increasing its pressure. U.F. Clouet and G. Monge liquefied SO_2 in 1780 while van Marum and Van Troostwijk liquefied NH_3 in 1787. Hence, a compressor is required to maintain a high pressure so that the evaporating vapours can condense at a temperature greater than that of the surroundings. Oliver Evans in his book "Abortion of a young Steam Engineer's Guide" published in Philadelphia in 1805 described a closed refrigeration cycle to produce ice by ether under vacuum. Jacob Perkins, an American living in London actually designed such a system in1835. In his patent he stated "I am enabled to use volatile fluids for the purpose of producing the cooling or freezing of fluids, and yet at the same time constantly condensing such volatile fluids, and bringing them again into operation without waste".

III. TESTING PROCEDURE

The system operates in two loops, loop 1 is the desorption process and loop 2 is the adsorption process. The positioning of the Valves V_1, V_2 and V_3 is identical in the apparatus as shown in the figure 2. In the adsorption process, the valves V_1 and V_3 are opened, and the vacuum pump is used to extract all the air from the Zeolite cylinder and create complete vacuum inside it. The valve V_3 is then closed and the cylinder containing water is then connected to the vacuum pump by opening valves V_1 and V_2. The pressure inside the water cylinder is lowered (to 23mbar in this case) such that water starts boiling at room temperature. The valve V_1 is then closed and the two cylinders containing Zeolite and water are connected by opening the valves V_2 and V_3.The absorbent (Zeolite 4A) act as a water vapour pump and starts adsorbing the water vapour from the water cylinder and hence the temperature inside it starts decreasing while the temperature of the Zeolite starts increasing and thus a cooling effect is produced. As soon as the temperature inside the water cylinder reaches 0^0C, the remaining water inside the cylinder freezes and hence ice is formed which provides the refrigeration effect till the Zeolite becomes saturated.

As soon as the Zeolite becomes saturated and is incapable of absorbing more water, the Zeolite container is heated such that the Zeolite loses water and is gets collected in the water container. This is desorption cycle. As soon as the Zeolite becomes unsaturated again, the adsorption cycle is again carried out.
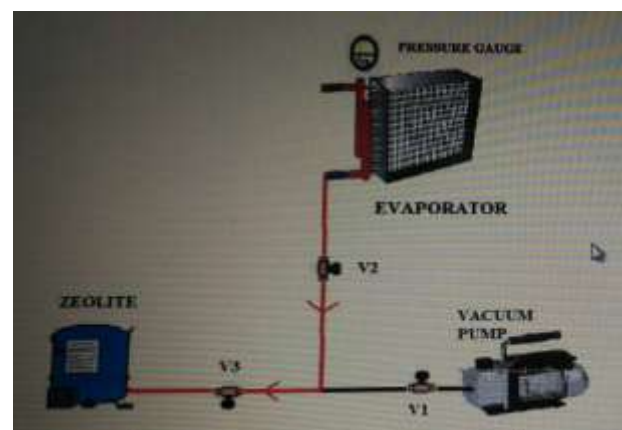

Figure 2: Zeolite-Water Refrigeration Schematic Mechanism

IV. COEFFICIENT OF PERFORMANCE

The coefficient of performance is defined as the ratio of the total refrigeration effect produced in the system to the total energy required for this effect.

C.O.P. = Refrigeration Effect
          Total Energy Input

$$C.O.P. = \frac{Q_1}{Q_2} = \frac{T_1}{T_2}$$

Where Q_1 is the heat exchanged between evaporator and the food particles and Q_2 is the heat used during the generation of the refrigerant.

Figure 3: Zeolite-Water Refrigeration Apparatus setup

V. TESTING PROCEDURE AND RESULT

The tests were done at the exploration focus. The zeolite was found to have a greatest adsorption limit of around 0.3kg of adsorbate/0.85kg of adsorbent as given in I. Golden et.al, 2013. In the first place, the Zeolite chamber was loaded with 0.6kg of zeolite which was associated with the water barrel containing 500ml of refined water. The framework is made water/air proof with the vehicle funnels and valves as appeared in figure 3. The framework is kept up at a weight beneath the air weight. The zeolite compartment is kept up at complete vacuum while the water barrel is kept at a weight such that the water bubbles at room temperature (23mbar for this situation).

Recovery of zeolite happens by warming the zeolite holder to around 2000C and opening the valves V2 and V3 such that the water lost by the zeolite comes to back to the water barrel. The desorption bends of zeolite at various weights and temperature as given in Miguel et.al, (2003), demonstrates that at 2500C, 2.5 hrs is required for the zeolite to accomplish 5% dampness with 84% of the water extricated and it takes 6 hours at 2000C to decrease stickiness to 10% along these lines removing 66% of water. The warmth misfortunes for the adsorber and the more drawn out time interims for the recovery of the zeolite alongside the utilization of steel compartment as evaporator having moderate rate of cooling rather than copper holder, were the principle purposes behind the poor execution of the framework.

The extraction of warmth from the items kept inside the icebox prompts the arrangement of vapors in the evaporator which are adsorbed by the Zeolite in this manner making cooling impact called Isosteric cooling. The most extreme adsorber temperature was 1150C which is much underneath the normal temperature of 2000C and the base evaporator temperature was 9.80 C. Refrigeration impact delivered and the COP of the framework are subject to the mass of the

refrigerant desorbed. The chart of the temperature recorded at different time interims is appeared in figure 4. The COP of the framework can go from 0.32 to 0.6 which is lower in contrast with the vapor pressure refrigeration frameworks having COP in the scope of 1.0 to 1.6.
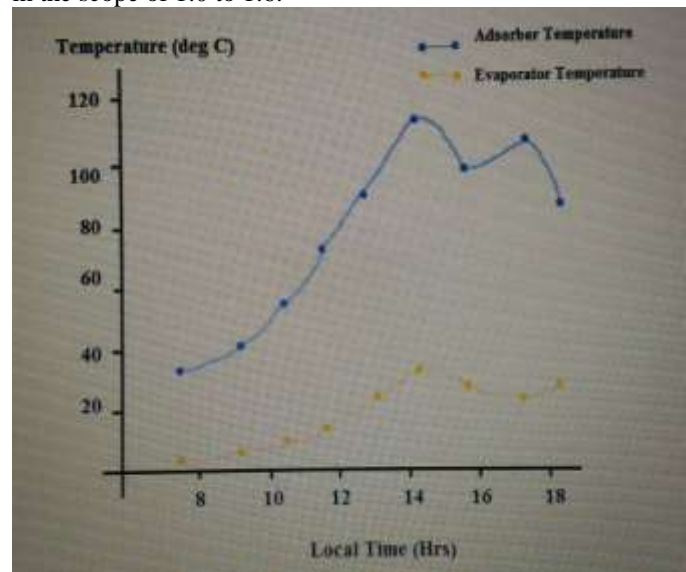

Figure 4: Graphs for C.O.P. Temperature (^{0}C) Vs Time (Hrs)

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