NATURAL CLINOPTILOLITE IN SOLAR REFRIGERATION

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Abstract

Nowadays, the development of renewable energies is an issue of great interest worldwide. Therefore, the development of new technologies that diminish the problems men has caused to the planet are pursued. In this quest for new technologies, the solar refrigeration is a great alternative which enables the use of renewable technologies. The adsorption Solar Refrigeration System is environment friendly equipment because it accomplishes the main function of a common refrigerator without releasing gasses which affect or damage the ozone layer. In addition, it makes the preservation of food and medicine possible in zones where there are no electric energy sources.

In its application, solar refrigeration uses equipment called solar collectors. These consist of vacuum sealed tubes in which the adsorption-desorption process takes place. In this way, the systems efficiency or coefficient of performance (COP) is optimized. In such way, the necessary requirements are accomplished perfectly to complete the cooling cycle proposed by Clapeyron. As a consequence, a pair of adsorbate adsorbent is used. Thus, methanol/Zeolite, water/Zeolite, etc. can be used. Zeolites are aluminium silicates which adsorb, in their cavities, great amounts of cooling gases at environmental temperature. In such way that, if they are heated in a closed system, they desorbed these gases at considerably high pressure, allowing the substitution of mechanical compressors, frequently used in cooling equipment.

Based on the previously exposed, the design, construction and functioning ofan equipment that can generate cold from solar radiation and the adsorbate – adsorbent (Metanol Zeolite) which, in addition to having good expectations in its use, can also bring a break to the Earth. In this work, Zeolite is used as a natural clinoptilolite from the State of Oaxaca, Mexico.

Performed measurements in the Adsorption Solar Refrigeration Prototype allowed a coefficient of performance (COP) of 0.1, which is very favorable, given that in the literature is of 0.22. Nevertheless, improvements can be achieved in the system. It is because of this that, besides the functioning of this equipment, the development of a new system with four collectors is being raised. In such a way that the efficiency will be larger, it can benefit marginal communities, and so that the future investigations reduce the climate change provoked by men.

1. Introduction

Zeolites are aluminium silicates which adsorb, in their cavities, great amounts of cooling gases at environmental temperature. In such way that, if they are heated in a closed system, they desorbe these gases at considerably high pressure, which allows the substitution of mechanical compressors, frequently used in cooling equipment. If heat is supplied to the zeolite, these desorbe great amounts of the cooling gas at a high pressure, which will be condensed. A subsequent low pressure adsorption causes the cooling liquid evaporation living cooling as a result [De la Cruz et. al 1988, La Iglesia 1995, PiotrKowalczyk2006].

Zeolites offer a porous structure which allows adsorption of great quantities of H_2O, NH_3, and CO_2 steam, different chlorofluorocarbonand Hydrocarbonsat environmental temperature. According to thermodynamics, the principle used is the Arrhenius Equation because it implies a change of phase and describes the exponential variation of pressure in regards to the temperature. On the other hand, the zeolite gas adsorption equilibrium (type I isotherms) (Dubinin and Astakhov, 1971) gives as a result a great pressure variation during adsorption/desorption processes thus generating slight temperature variations on the zeolites. These properties allow zeolites, particularly natural clinoptilolite, to operate efficiently in cooling systems.[Bruce S. et al. 1984, Xiaodong Ma. 2006a, Xiaodong Ma, 2007b.).Particularly, natural clinoptilolite proceeding from Etla, Oaxaca, Mexico, adsorbs 30% in water weight after making the thermal and chemical treatment.

This way, adsorption solar refrigeration is intermittent, because it only produces cold during the adsorption stage. In the present work, the functioning and operation of solar refrigeration prototype that uses methanol-zeolite/activated carbon is described. This system is proposed for regions which lack electric energy and it is necessary to preserve food and medicines.

2. Operating principle

The ClasiusClapeyron Diagram (LnPvs 1/T) explains the adsorption refrigeration cycle consisting of four stages. Figure 1

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1. Solar rays heat the collector in which the cooling gas is already adsorbed. Therefore, the steam pressure and the temperature increase in the system.

2. When the saturation pressure corresponding to the condensation temperature is reached, the steam condenses and creates a flux towards the evaporator.

3. When the sun sets, the sensor is cold and the pressure diminishes in the system to reach the pressure in the evaporator. The cooling is favoured by air ducts inside the collector.

4. Following the cooling, the adsorbent is physically without any balance, therefore it “leans” against the adsorbent steam kept within the system. This steam is produced due to the liquid’s evaporation inside the evaporator, which produces the cooling desired effect. When the temperature in the evaporator reaches freezing point, an ice deposit is formed allowing the system to maintain a low temperature for the next day [7, 8, 9].

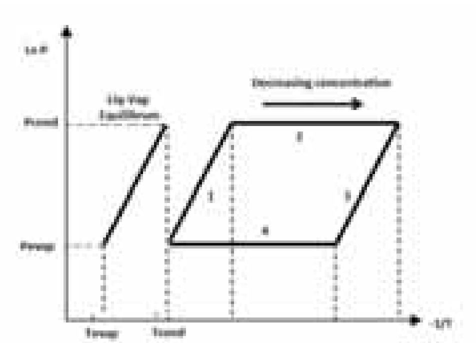

Figure 1.Clapeyron Diagram.

3. Characteristics of the par adsorbent – adsorbate

An important factor in the refrigeration processes by adsorption is to take into account that the adsorbent must have a high adsorption capacity at an environment temperature and low pressures. On the other hand, it must have a low capacity of adsorption at both high temperatures and pressures that correspond to the regeneration phase and low calorific capacity. This way, the adsorbate must have a fusion point below 0^oC. The size of molecule below 2 nm in order to facilitate adsorption in microporous and low boiling point.

Under these considerations, an adecuate adsorbent – adsorbate pair to be applyied for refrigeration are: natural clinoptilolite, which is a crystalline, microporous aluminum silicate, and methanol, which evaporates at temperatures below 0^oC, therefore they comply with the characteristics mentioned above, making this system an adequate working pair to be taken into account for refrigeration.

4. Design calculation

First of all, the amount of ice desired was defined; hence, it was considered equation No.1

$Q_1 = Cm\,\Delta t$(eq. 1)

Where C is the calorific capacity of water, m is water mass, Δt the temperature difference. Once the freezing temperature is reached, the solidifying heat Q_2 must be extracted to create the ice, which is related to its mass and fusion latent heatin equation 2

$Q_2 = L_m$.(eq. 2)

Therefore, the heat necessary to produce ice is:this given by equation 3

$Q_1 + Q_2$.(eq.3)

If the cold chamber is adiabatic, the heat is equal to the one generated by the methanol evaporation. Therefore, the mass that has to be evaporated is given by equation 4.

$m_m = Q/L_m$. (eq.4)

This information allows us to calculate the adsorbent quantity in the system through the Dubinin – Astakhov equation 5.

$$X = x_0 \exp\left[-k\left(\frac{T}{T_s} - 1\right)^n\right] \quad \text{(eq. 5)}$$

Where k and n parameters are for the working pair zeolite/ activated carbon, methanol, X_o is the adsorption capacity when equations 6 and 7 is the adsorption temperature. This result is explained by the methanol steam pressure and its concentration difference. In table 1, the values of zeolite/ activated carbon– methanol are given.

$T = T_s$ (eq. 6)

$P = P_{s,} T$ (eq. 7)

5. Experimental results

Zeolites can refrigerate and even create ice using solar radiation without applying any other kind of energy and without moving parts of the system. In addition to the low cost, the treatment required for its use is low cost, allowing a sustainable project. This result is explained by the methanol steam pressure and its concentration difference. In table 1, the values of zeolite–methanol are given.

It is important to mention that natural clinoptilolite proceeding from Etla, Oaxaca, Mexico comes with other cementing materials, which allows us to use the term material zeleotoid. These materials are clay, quartz, and feldspar among others, that when split from zeolites can reach a purity of 90% or more. The purity of used clinoptilolite used is of 86% the rest of the minerals accompaning that present cristal-structural properties and several binders like: orthoclase, kaolin, monmorillonite, quartz, feldspar, etc.

Table 1 Clinoptilolite-methanol of R.S ratio)

Ice quantity Kg	Methanol Volume $(m^3)10^3$	Clinoptilolite natural Volume$(m^3)10^3$
4	3.5	6.47223
2	1.754	3.236
1	0.87724	1.6180
0.5	0.43862	0.80902

5.1 Adsorption refrigeration system

The adsorption refrigeration system has a solar collector/adsorbent bed, a condenser and an evaporator. Components of the refrigerator: solar collector, condensator and evaporator.The design proposal implies a cylindrical collector, not one of flan bed, and the equipment longitude was obtained through the previously calculated volume shown on figures 2 and 3.

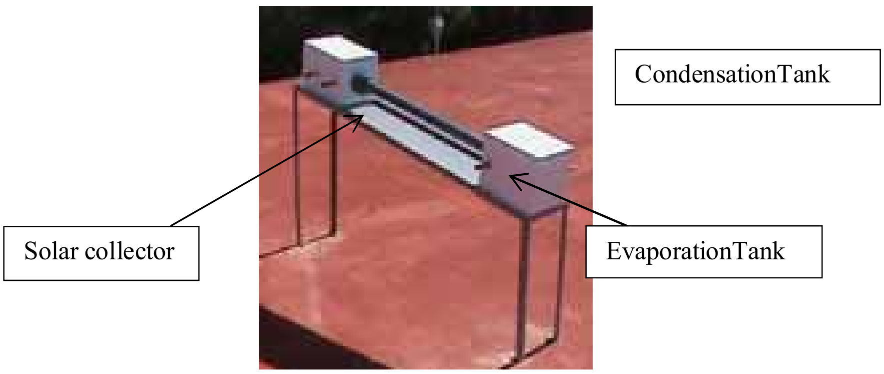

Figure 2.Solar cooling tube

When the adsorbent is heated by solar radiation in the system, the methanol is desorbed from its surface flowing towards the condensator and during the night, the adsorbate is reabsorbed over the clinoptilolite in the evaporator. In such way, that this behaviour can be observed in graph 1. It can be observed that in the desorption process, the system is heated by solar radiation from 7:00 am to 16:00 pm, finding its maximum value of 155|ºC, observing the evolution of temperature during the day, night and the values thrown by the condensator.

In order to obtain the system's efficiency defined as Coefficient of Performance(COP) of the adsorption cooling cycle, it was calculated according to:

$COP_{cicle}= (Q_{re} – Qce)/Q_{AD}$

The solar collector's efficiency is expressed:

$N_{col} =Q_{Ad}/ Q_{sol}$

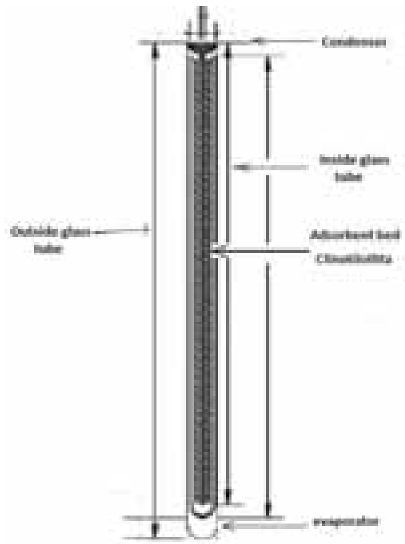

Figure 3.Solar refrigeration tube

6. Conclusions

This prototype's final goal is to search for new and better alternatives in the creation of cold to preserve food and medicines. Therefore, the necessary upgrades were done to it in order to achieve a good Coefficient of Performance.This equipment generates a COP of 0.1. The result seems favorable given that in the literature it is of 0.22, but it can still reach improvements within the system. Due to this, resides this equipments well functioning, the development of two new systems is been planned. One consists of more collectors so that the proficiency is larger, and the other one is of modular type.

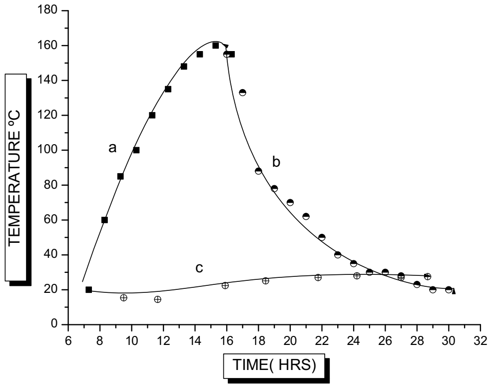

Figure 4. Monitoring of the shift of temperatura in the bed of the adsorbent and condensator a) during the day b)during the night c) adsorbent bed

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