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(Research Article)

Experimental Investigation of Solar Assisted Adsorption Refrigeration System Using Silica Gel-Water

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Abstract

Adsorption refrigeration systems have come into existence as an alternative to traditional systems, which rely on refrigerants that are detrimental to the environment and use enormous amounts of electricity. These systems are extremely relevant for meeting cooling needs in distant locations where the need for ice-making, air conditioning, water chillers, and other cooling need is critical, as well as for the preservation of food or medical supplies. They also have a lot of benefits, including as quiet operation, resistance to corrosion, and environmental friendliness. These advantages have motivated me to take on the challenge of creating an air conditioning solution. My topic is focused on developing a small system that makes use of a silica gel and water working pair to effectively produce air cooling while using solar energy.

Keywords: Adsorption, Environment, Silica Gel-Water, Solar energy

1. Introduction

Adsorption is the process by which atoms, molecules, or ions from a fluid (liquid/gas) or dissolved solid adhere to a surface [1,2]. It is a surface phenomenon that causes an adsorbate film to form on the adsorbent's surface [1,2].

Adsorbent refers to the solid surface on which adsorption takes place, while absorbate refers to the substance that attaches to adsorbent [1,2].

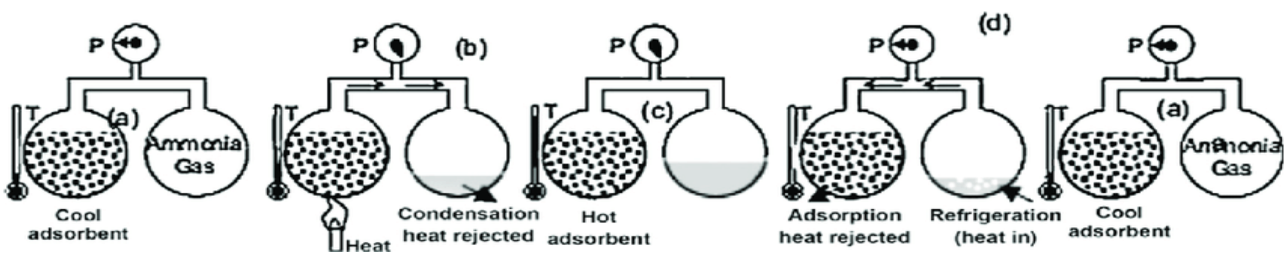

Figure 1. Fundamental of adsorption [3,4]

1.1 Thermodynamic cycle of adsorption refrigeration [4,5,22]: The thermodynamic process used in the adsorption refrigeration system's operation is shown in Figure 2.

- Process (a-b) isosteric desorption in state a, an adsorber or cool canister contains adsorbent that has been heavily saturated with refrigerant at a pressure just below Pevap. Cool adsorber is heated and isosterically (i.e., at constant total mass in the adsorber) desorbs refrigerant vapor to state b just above Pcond. At this stage, vapor is pushed out of the heated adsorber and into the condenser via a check valve.
- Process (b-c) isobaric desorption as more refrigerant is desorbed by isobaric heating, it is forced into the condenser until condition c is reached, where the adsorber is almost completely empty of refrigerant.
- Process (c-d) isosteric adsorption when the pressure drops below Pevap (state d), another check valve opens, allowing vapor from the evaporator to enter the hot adsorber. The hot adsorber is subsequently cooled isosterically (at constant total mass), leading to adsorption and depressurization.

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- Process (d-a) isobaric adsorption the cycle is completed when the refrigerant saturates the adsorbent during isobaric cooling to state a.

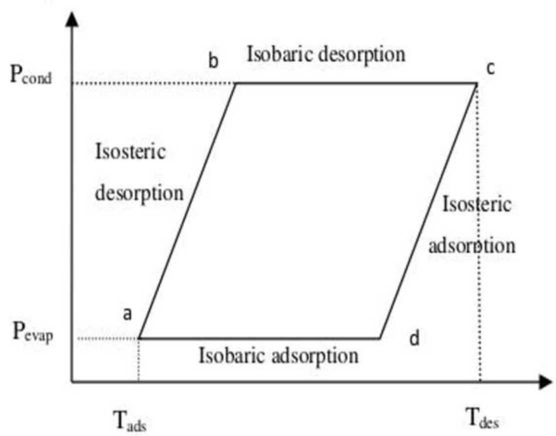

Figure 2. Thermodynamic cycle [4]

1.2 Basic components of adsorption refrigeration [1,22,23]: Adsorption The compressor, evaporator, throttle valve, and condenser are all parts of the refrigeration system, much like in a vapor compression refrigeration system. Instead, then using mechanical energy, it uses heat energy. As a result, the mechanical compressor in this system is replaced by the thermal compressor.

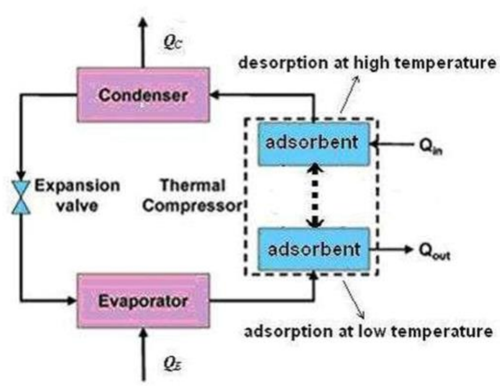

Figure 3. Basic components of adsorption refrigeration [22,23]

The surface of the adsorbent bed absorbs the refrigerant vapor. As a result, the adsorption/desorption properties of the adsorbent/refrigerant pair affect the system's performance. The following are the main elements of the system:

- Solar collector
- Thermal compressor (adsorber bad)
- Condenser
- Expansion device
- Evaporator

1.3 Types of adsorption processes and adsorbents [5]: The three forms of adsorption based on the adsorption process are,

- Physical adsorption
  - Activated carbon and carbon fiber.
  - Silica gel
  - Zeolite
- Chemical adsorption and combination of both
  - Metal chlorides
  - Salt and metal hydrides
  - Metal oxides
- Composite adsorption

Here we know some detail about silica gel – water because our experimentation base on that.

1.3.1 Silica gel and water: Another effective combination in adsorption refrigeration that makes use of water's ability to function as a refrigerant at lower pressure is silica gel. This pair's adsorption heat is around 2500 kJ/kg [5,6]. This pair has an extremely low desorption temperature requirement; it can be as low as 50°C. Desorption temperatures for this pair should normally be lower than 90°C and should not exceed 120°C [5,6]. The low adsorption quantity of the silica gel water adsorption pair, which is restricted to 0.2 kg/kg adsorbent, is a drawback. The fact that this pair cannot function below 0°C is another drawback [5,6].

In this system we used 14-kg silica gel and 5-liter water. The properties of silica gel and water shown in below table-1 and table-2.

Table 1. Properties of silica gel

Sr. No.	Properties	Limits
1	Assay (as SIo2)	Min 90%
2	Bulk density	0.55-065 g/ml
3	PH	4-8
4	Loss on drying	%<6
5	Adsorption capacity at 100% humidity	38-40
6	Chloride (as Nacl)	Max 0.5%
7	Cobalt (as coalt chloride)	Nil
8	Sulphate (Na2So4)	Max 0.5%
9	Friability	99.5
10	Particle size	3-8 mm

Table 2. Properties of water

Sr. No.	Properties	Limits
1	PH	7.2-7.8
2	Density	1 g/ml
3	TDS	500 ppm

2. Description of the Adsorption Refrigeration Test Unit

Shown in below photo general arrangement of adsorption refrigeration system. The specification of each component is specified in description of each component section.

The structure of set up built up by MS 30 mm angle, length 2 meter and width of .5 meter. All the components set up on that structure.

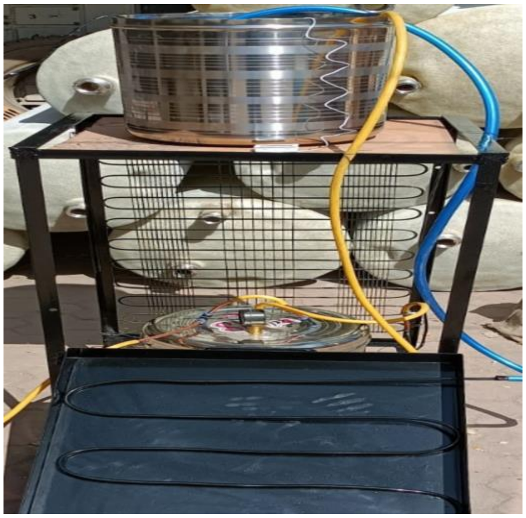

Figure 4. Developed adsorption refrigeration system.

2.1 Solar collector: As shown in photo general arrangement of solar water collector. Made GI frame of size 750 x 475 mm for installation of copper tube. In which 8 mm copper tube used. The total length of copper tube is approx. 3700 mm

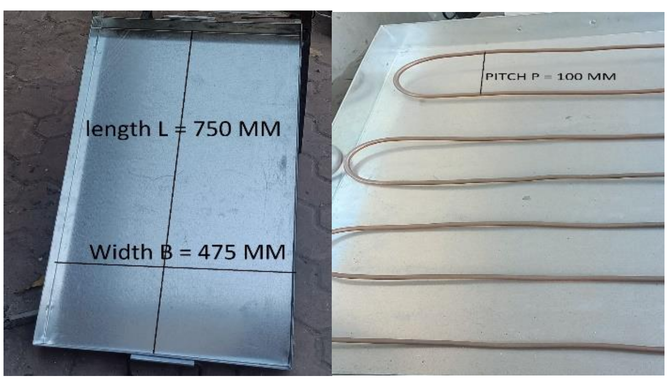

Figure 5. Solar collector

2.2 Generator/adsorber: I took standard 8 mm pipe for designing of adsorber. Pitch of helical coil is taken as 20 mm. The outside dia (OD) of coil is 130 mm and free length of coil is 230 mm. Helical coil gave better contact area, so heat transfer rate is increased.

The adsorber vessel inside dia (ID) is 320 mm. The height H of vessel is 325 mm. The volume in litters is around 26.14 litters. Inside this adsorber silica gel and water vapour mixture hold and via copper coil hot water circulation done with the help of pump.

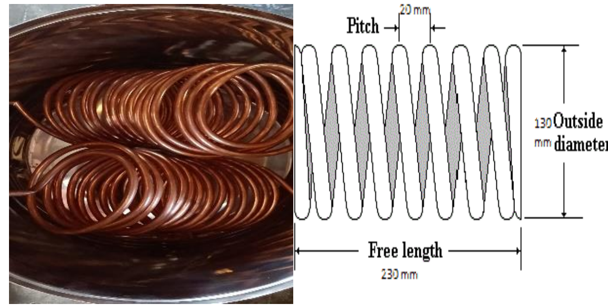

Figure 6. Fabricated adsorber bed

2.3 Condenser: The copper tube air cooled condenser used for water vapor condensation. Tube size is 6 mm and the condenser size are 18” x 32“

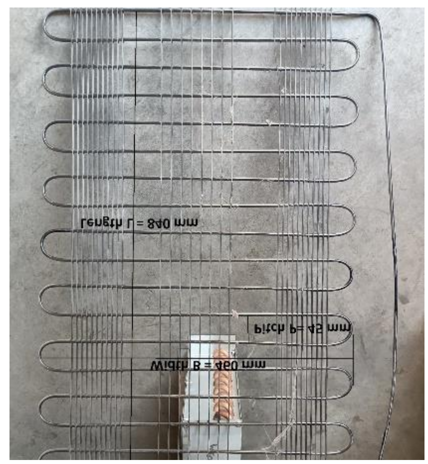

Figure 7. Condenser

2.4 Expansion device (capillary tube): I took standard expansion capillary tube for the setup because for the small capacity systems capillary tube are mostly suitable, the size of tube is ID 0.7 mm and OD 2 mm.

Figure 8. Expansion device

2.5 Evaporator: I took fin and tube type standard evaporator for setup because that increase the heat transfer surface area. The tube size of 8 mm and the coil no's is 8 loop and fin nos are 66. For better cooling used the fan size 6” and 230 Vac

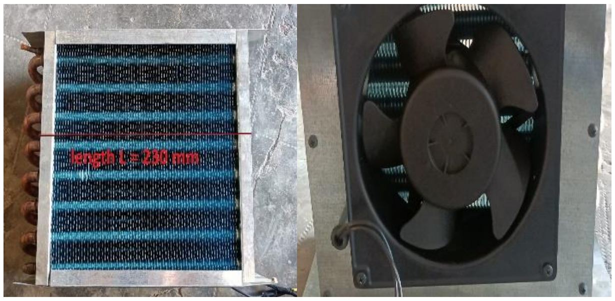

Figure 9. Evaporator

3. Result and Discussion

3.1 Effect of condenser temperature on COP: Graph shows how the condenser's temperature affects COP. As the condenser temperature drops, it is seen that COP decreases. This drop in COP was caused by a lessening of the cooling effect at the specified heat input. Having more mass of adsorbent in the system is important to maintain the evaporating capacity.

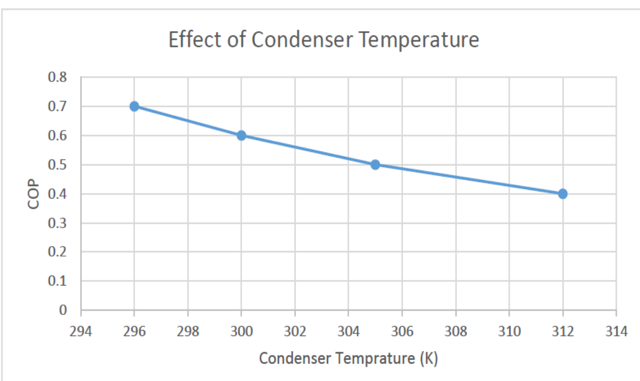

Figure 10. Effect of condenser temperature

3.2 Effect of evaporator temperature on COP: Graph Shows how COP varies with evaporator temperature. It has been shown that raising the evaporator temperature while maintaining the condenser temperature increases the refrigeration effect. So, for a given heat input, COP rises as evaporator temperature rises. It is further understood that the refrigerating action is diminished at higher condenser temperatures. This explains why COP decreases at higher condenser temperatures.

3.3 Effect of generation temperature on COP: Graph shows how COP is affected by generation temperature at various condenser temperatures. The mass of vapor desorbed increases as the desorption temperature rises, increasing the refrigerating capacity and, consequently, the system's coefficient of performance (COP). The drop-in concentration ratio, however, becomes quite important and has a significant impact on the COP after a specific desorption temperature. Heat of generation will increase as the change in mass concentration increases; hence COP tends to decrease. Further research shows that a higher condenser temperature lowers the system's coefficient of performance (COP).

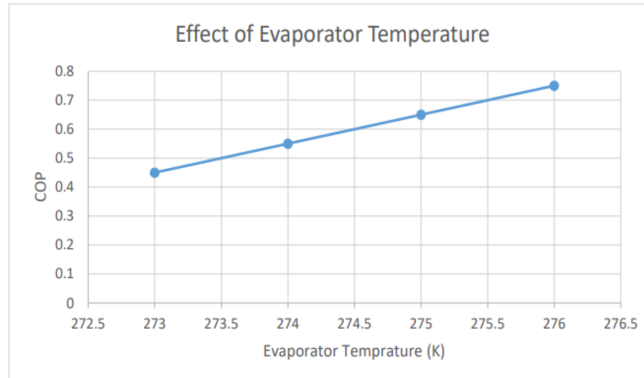

Figure 11. Effect of evaporator temperature

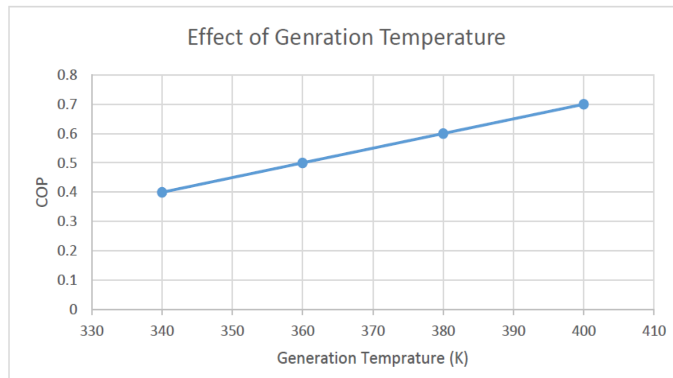

Figure 12. Effect of generation temperature

4. Conclusion

The system with the necessary specification can be developed effectively using the aforesaid architecture, and it can then be tested further.

The use of this system for the following purposes, such as ice-making, air conditioning, water chillers, and other cooling requirements in distant areas where energy is readily available. Even though extensive study has already been done in the subject of adsorption refrigeration, there is still much work to be done, and I am excited to do my part to advance this field for the benefit of human welfare.

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