ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

SOLAR AIR CONDITONING SYSTEM USING DESSICANTS

Arjit Sharma
Student, Mechanical Engineering Department
Medicaps Institute Of Technology & Management
arjit21sharma@gmail.com

ABSTRACT-

A new technology for cooling and dehumidifying buildings using desiccants is now entering the market. This technology, which can efficiently serve large latent loads, will greatly improve indoor air quality by both allowing more ventilation as well as more tightly controlling humidity. Furthermore, since a desiccant air conditioner can be packaged as a roof-top air-handler, it will compete directly with the most popular cooling system now .A desiccant dehumidifier in conjunction with evaporative coolers can reduce air conditioning operating costs significantly since the energy required to power a desiccant cooling system is small and the source of this required energy (solar, waste heat, natural gas) can be diverse .

My paper focuses on the use of solar energy for this purpose.

INTRODUCTION:

The basic principle behind (solar-) thermal driven cooling is the thermo-chemical process of sorption: a liquid or gaseous substance is either attached to a solid, porous material (adsorption) is taken in by a liquid or solid material (absorption). The sorbent (i.e. silica gel, a substance with a large inner surface area) is provided with heat (i.e. from a solar heater) and is dehumidified. After this "drying", or desorption, the process can be repeated in the opposite direction. When providing water vapor or steam, it is stored in the porous storage medium (adsorption) and simultaneously heat is released.

Processes are differentiated between closed refrigerant circulation systems (for producing cold water) and open systems according to the

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

way in which the process is carried out: that is, whether or not the refrigerant comes into contact with the atmosphere. The latter is used for dehumidification and evaporative cooling. Both processes can further be classified according to either liquid or solid sorbents. In addition to the available refrigerating capacity, the relationship between drive heat and realized cold energy (coefficient of performance; COP) is also an essential performance figure of such systems.

In Solar thermal driven air conditioning systems, the heat generated by the solar is used to power the cooling process. The Solar thermal air conditioning systems generally classified into two types:

Closed systems: refrigeration equipment powered by thermal carriers (hot water or steam) directly producing chilled water, which can be used in the air conditioning systems air handling unit (cooling, dehumidification) or distributed through a network of pipes decentralized terminal conditioning in several rooms to be conditioned (e.g., fan coil). These systems are already available in the markets long time ago, mostly not solar driven except few hundred units around the world (mainly in Europe) with growing interest for solar powered application. The most common ones are the absorption and adsorption chillers.

Open systems: The most common systems based on the principle of desiccant cooling and using rotary dryers with solid sorbents, these systems allow a full treatment of the air that is cooled and dehumidified to ensure the needs of comfort. The refrigerant is water, in direct contact with the ambient air.

Desiccants are chemicals with great affinity to moisture. They absorb (or release) moisture because of the difference in vapour pressure between the surface of the desiccant and the surrounding air. Dehumidification is said to occur when the vapour pressure of the surface of the desiccant is less than that of the surrounding air. Dehumidification continues until the desiccant material reaches equilibrium with the surrounding air. Regeneration of this desiccant is said to occur when the vapour pressure of the desiccant is larger than that of the surrounding air, which is usually achieved by heating the desiccant to its regeneration Temperature and exposing it to an airstream. Desiccants can be classifed as either adsorbents, which absorb moisture without accompanying physicaland chemical changes, or absorbents, which absorb moisture accompanied by physical or chemical changes. Desiccants can be solids or liquids and can hold moisture through adsorption or absorption as described earlier. Most absorbents are liquids and most adsorbents are solids. Several types of solid desiccants are widely used in desiccant cooling systems; silica gels, lithium chloride and molecular sieves.

Silica gels are solid desiccants and adsorbents and contain numerous pores and capillaries in which water is condensed and contained. Silica gel has a high capacity to absorb moisture and then release it at a higher temperature. It is low in cost and available in sizes from 3/16 inch beads to powder-like grains. Lithium chloride (LiCl) is an absorbent and is found in dry form when each LiCl molecule holds two water molecules. If each LiCl molecule holds more than two water molecules, for former becomes liquid and continues to absorb moisture.

Lithium chloride has a high capacity to absorb and hold moisture and is widely used in rotary wheel dehumidifiers. Among the above, silica gels and lithium chloride are the most widely used desiccant materials in desiccant cooling systems.

LITERATURE REVIEW:

The use of sorption air dehumidification – whether with the help of solid desiccant material or liquid desiccants – opens new possibilities in air-conditioning technology. This can offer an alternative to classic compression refrigeration equipment. Alternatively, if it is combined with standard vapour compression technology, it leads to higher efficiency by an increase of the required evaporator temperature of the

Compression cycle. Desiccant systems are used to produce conditioned fresh air directly. They are not intended to be used as systems where a cold liquid medium such as chilled water is used for heat removal, e.g., as for thermally driven chiller based systems. Therefore, they can be used only if the air-conditioning system includes some equipment to remove the surplus internal loads by supplying conditioned ventilation air to the

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

building. This air-flow consists of ambient air, which needs to be cooled and dehumidified in order to meet the required supply air conditions. Desiccant cooling machines are designed to carry out these tasks.

Economic advantages arise for desiccant cooling equipment when it is coupled with district heating or heat supplied from a combined heat and power (CHP) plant. Of particular interest is the coupling with thernal solar energy. The components of such systems are generally installed in an air-handling unit and are activated according to the operation mode of the air-conditioning system. These operation modes implement different physical processes for air treatment, depending on the load and the outdoor air conditions. These systems are based on the physical principle of evaporative and desiccant cooling. Unsaturated air is able to take up water until a state of equilibrium, namely saturation has been achieved. The lower the relative humidity of the air, the higher is the potential for evaporative cooling. The evaporative cooling process uses the evaporation of liquid water to cool an air stream. The evaporation heat that is necessary to transform liquid water into vapour is partially taken from the air. When water comes into contact with a primary warm air stream it evaporates and absorbs heat from the air, thus reducing the air temperature; at the same time, the water vapour content of the air increases. In this case, the supply air is cooled directly by humidfication and the process is referred to as direct evaporative cooling.

Indirect evaporative cooling involves the heat exchange with another air stream (usually exhaust air), which has been previously humidified and thus cooled. In this case, the water vapour content of the primary air stream is not influenced. These two techniques of evaporative cooling can also be combined in a process that is known as combined evaporative cooling. Complementing combined evaporative cooling with desiccant dehumidification enhances the cooling capacity of the cycle and thus it is

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

possible to reach even lower temperatures. This combined cooling process is referred to as *desiccant cooling*. Using evaporative cooling, either direct, indirect or in a combined process, it is not possible to reduce the vapour content of the ventilation air. But, using a desiccant cycle, in principle lowering of the temperature and the humidity ratio of ventilation air is possible. Fresh air conditions have a considerable effect on the amount of cooling that can be achieved. If the outdoor air is properly pre-treated, the ventilation air can be cooled to lower temperatures via subsequent indirect and direct evaporative cooling. For this purpose, the pre-treatment involved is the desiccant dehumidification process to enhance the potential of evaporative cooling without obtaining a disproportionate high humidity ratio.

The dehumidification process uses either liquid or solid desiccants. Systems working with solid desiccant materials use either rotating wheels or periodically operated, fixed-bed systems. Systems employing liquid desiccants use air-desiccant contactors in the form of packed towers or the like. Regeneration heat must be supplied in order to remove the adsorbed (absorbed) water from the desiccant material. The required heat is at a relatively low temperature, in the range of 50°C to 100°C, depending on the desiccant material and the degree of dehumidification. Moreover, the solar desiccant cooling system, depending on the cooling loads and environmental conditions, will use one of the above mentioned cooling modes, i.e., direct evaporative cooling and/or indirect evaporative cooling and/or desiccant cooling, with the aim of providing comfort conditions in the building. The most commonly used desiccant cooling process, which is based on the use of desiccant wheels.

The material most often used as solid desiccants are silica gel, lithium bromide, zeolites (aluminum silicate, molecular sieves), various metal oxides or combination thereof (Lindholm 2000). Of those silica gel and zeolites seem to be most commonly used. Salts like lithium chloride, and lithium bromide have the disadvantage when they get saturated with water they turn from solid

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

phase to liquid, thus there is a risk of carryover of these highly corrosive substances.

A common way of utilizing solid desiccants is in a desiccant wheel illustrate in figure 2.52. The wheel consists of a honeycomb structure coated with desiccant. The air to be dehumidified flows through the cells on the process side of the wheel. As the moist air comes into contact with the desiccant, water vapor is ab/ad-sorbed by the desiccant.

When the water vapor is ab/ad-sorbed it releases its heat of evaporation and its heat of absorption and since there is no internal cooling of the system the air temperature increases. This process is illustrated in figure 2.53 and is approximately the opposite of the evaporative cooling process (see section 2.2.4). Simultaneously a heated airflow, the regeneration flow, flows through the regeneration side of the wheel. This airflow heats up the desiccant and as a result the vapor pressure of the desiccant becomes higher than the partial pressure of water in the regeneration airflow. Thus water vapor evaporates from the desiccant and is taken up by the regeneration airflow. By slowly rotating the wheel a constant shift of saturated cells from the process side to the regeneration side and of regenerated cells from the regeneration side to the process side is achieved. The function of the purge sector is to cool down the cells before entering the process flow. This is needed because dehumidification cannot take place if the desiccant is to hot (because the desiccant will the have to high vapor pressure).

AIM OF PAPER:

To study the working and complete functioning of the desiccant type solar air conditioning system, to examine the feasibility and reliability of this type of air conditioning system.

I will study and show the commercialization prospects of this air-conditioning system with its comparison with conventional air conditioning systems

METHODOLOGY:

The below schematic diagram shows how a solar air conditioner works using a desiccant wheel.

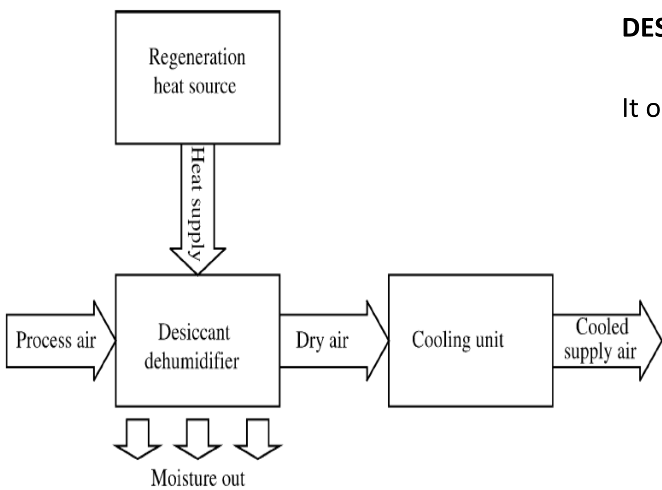
The cooling process occurs in two cycles :

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

1) Cooling air process

2) Desiccant recovery cycle

COOLING AIR PROCESS



Desiccant wheel made up of silica gel pellets.

Recovery wheel made up of aluminum fins

1. Hot and humid ambient air is made to paas through the desiccant wheel which vapour pressure is very low so it ab\adsorbs the humidity from the ambient air.

2. This now hot and dry air is made to pass through a cooling unit .

3. This cool and dry air is passed through the evaporative cooler to increase the humidity of the totally dry air up to required level.

which is used to condition the space.

DESICCANT RECOVERY CYCLE

It occurs in 2 steps :

1. **Solar collector** heats up water and transfers heat to air through heat exchanger.

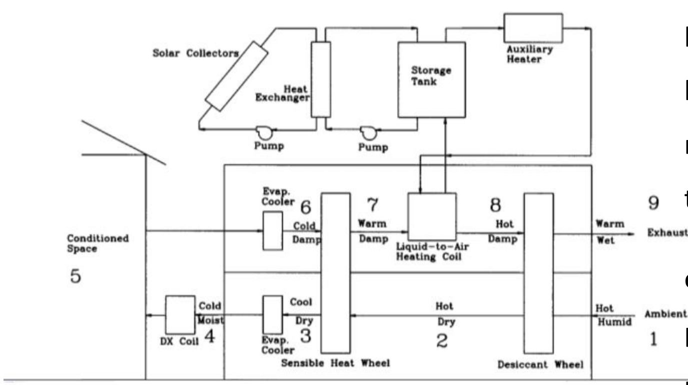
2. To recover the absorptive properties of the desiccant wheel; solar heated air is blown into a portion of the desiccant wheel.

International Journal of Core Engineering & Management

ISSN: 2348 9510

International Journal Of Core Engineering & Management(IJCEM)

Volume 1, Issue 2, May 2014



Referring to the above figure

Warm and wet ambient air is introduced in the process air at State 1. This process air is dried while it passes over the desiccant, resulting in hot, dry air as it exits the dehumidiÞer of State 2. This increase in temperature is due to the release of heat of condensation of the water vapour when moisture is removed by the desiccant material. This hot and dry air is then cooled sensibly as it passes through the rotary regenerator and is allowed to transfer much of the heat to the return air stream. The now cool and dryprocess air at State 3 is further evaporatively cooled and humidifed by the process side evaporative cooler to State 4 and is then introduced to the conditioned space through the supply duct. This cool air provides the comfort condition necessary to meet the buildingÕs cooling demands. After removing the buildingÕs sensible and latent cooling loads, air returns to the desiccant air conditioner through the return ducts and is again

evaporatively cooled to State 6 from where it passes through the rotary regenerator and picks up the heat from the process air to attain the warm and damp State 7. The air then passes over the hot water coil, which circulates hot water obtained from the solar-auxiliary heater combination. Air is thus heated up to the required regeneration temperature of the desiccant material, and hence very hot and relatively humid air exits at State 8. This air then passes through the desiccant wheel in order to regenerate the desiccant. Even though this air is humid, it is su¦ciently hot to regenerate the desiccant in the rotary dehumidiÞer matrix. Finally warm and very humid air exists at State 9 where it is exhausted to the surroundings. The temperature of the return air at State 8 required to regenerate the desiccant is a function of the type of desiccant material used and the amount

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

of dehumidiÞcation required in the process from 1 to 2.

Analysis:

Assumptions:

1 Ton AC with a daily 8 hour use with 1.5 KW/h and 1 KWh being sold at 5 Rs.

Electric AC

If a normal AC of 1 ton is used for average 8 hrs per day, its input power would be1500W and the electricity consumption would be 12KWh per day.

Therefore,it would cost

12*5=60 Rs per day

Which makes it

60*30=*1800 Rs per month!*

Solar AC

SPECIFICATIONS –

Capacity -

Cooling : 12000Btu/h or 3500 W

Heating : 13000 Btu/h or 3800 w

Input power-

Cooling : 920 W

Heating : 930 w

Noise -

Indoor : 40 db (A)

Outdoor: 50 db (A)

Air Circulation : 720 m^3/h

Suitable Area : 15~25 m^2

EER : 3.8 w/w

Indoor Unit -

Size : 1010 x 325 x200 mm ; Weight - 15 Kg

Outdoor Unit

ISSN: 2348 9510
International Journal Of Core Engineering & Management(IJCEM)
Volume 1, Issue 2, May 2014

Net : 930 x 330 x 600 mm ; Weight - 51 Kg

Solar Panel Collector

Dimensions : 1000 x 550 x 87 mm

Weight : 14 Kg

The solar air conditioner would use only 900 W or about 40% of electricity ,

which means 900W x 8 = 7.2 KWH / day,

which saves 12-7.2= 4.8 KWH / day

and the total saving amount is 4.8x30 = 144 KWH per month.

Suppose the price of electricity is Rs 5 /KWH (Rs 10 kwh on diesel generator & Rs 15 / Kwh on solar/nuclear), then the total saved money would be Rs 720 in one month.... typically this gadget can pay for itself in around 8 years…..!

Normal A/C - 1 Ton, Split AC –

Initial Cost - Rs 20,000 (Including Taxes & Installation) ; Running Costs if used for 8 hours for 30 days - Rs 1,800 / month or Rs 21,600 / year or Rs 4,32,000 for 20 years.....Total : 20,000 + 4,32,000 = Rs 4,42,000 == ***Rs 4.5 Lakhs approx***....(maintenance cost not included).

Solar A/C - 1 Ton, Split AC –

Initial cost - Rs 75,000 (Including Taxes & Installation) ; Running Cost if used for 8 hours for 30 days - Rs 1,200 / month, Rs 14,400 / year or Rs 2,88,000 for 20 years....Total : 75,000 + 2,88,000 = Rs 3,63,000 == ***Rs 3.5 Lakhs approx***.....(maintenance cost not included).

RESULTS

- Solar cooling is still in the development phase
- There are technological problems that need to be addressed mainly concerning the hydraulic circuit and the controllers
- Enough applications exist, but not enough performance data
- Reliable performance data and experience are available only from few systems

Many factors affect the competition between a solar cooling system and one that primarily uses either gas or electricity.

These include

(1) Hardware costs,

(2) Energy prices,

(3)The length of the cooling season as well as the hourly variation of the cooling loads, and

(4) The buyer's criteria for purchasing decisions (e.g., payback, return on investment, etc.).

The study presented here is not a thorough investigation of how these factors impact the competitiveness of a solar cooling. Instead, we've presented a fairly simple analysis. i.e., only one application was studied under one set of economic assumptions. However, this one application does reflect conditions in a very important market for solar cooling: humid climates with long cooling seasons. The solar DAC is an economically viable technology for cooling and dehumidifying some of the world's buildings. Whether it displaces 5% or 50% of the fossil energy use for air conditioning will depend on both the maturation of the technology, global environmental issues and future energy prices.

REFERENCES

- Solar Air-Conditioning Systems Focus on components and their working principles Nathan Rona
- *Building Services Engineering , Department of Building Technology* CHALMERS UNIVERSITY OF TECHNOLOGY Göteborg , Sweden 5765/2004
- A SOLAR LIQUID-DESICCANT AIR CONDITIONER Andrew Lowenstein AIL Research, Inc. P.O. Box 3662 Princeton, NJ 08543 e-mail: ail@ailr.com
- Dr. Athanassios A. Argiriou University of Patras, Dept. of Physics

  AIR CONDITIONING BY SOLAR ENERGY Habib Ben Bacha1,2 , Mounir Elleuch1, Mounir Baccar1, Aref Y. Maalej1,2, and Hamed Ben Dhia2

  1 Laboratory of Electro-Mechanical Systems (LASEM)

2Laboratory of Water, Energy and Environement (LEEE)Department of Mechanical Engineering - Ecole Nationale d'Ingénieurs de Sfax,

B.P. W 3038, Sfax-Tunisia

Tel. 216-4-274 088; Fax 216-4-275 595;
email: habib.benbacha@enis.rnu.tn

- *AccesScience The online Encyclopedia of Science and Technology* (2003) http://www.accessscience.com/ Nov 6, 2003
- ASHRAE (2000) *HVAC Systems an Equipment* (SI edition) Atlanta: American Society of Heating. Refrigerating an Air-conditioning Engineers, Inc (2000 ASHRAE

  HANDBOOK)
- ASHRAE (2002) *Refrigeration* (SI edition) Atlanta: American Society of Heating.Refrigerating an Air-conditioning Engineers, Inc. (2002 ASHRAE HANDBOOK)
- ASHRAE (2004) *HVAC Systems an Equipment* (SI edition) Atlanta: American Society of Heating. Refrigerating an Air-conditioning Engineers, Inc (2004 ASHRAE

  HANDBOOK)
- BSR Solar Technologies (2002) http://www.bsrsolar.com Aug 21, 2003

  Grossman G. (2002) Solar-Powered systems for cooling, dehumidification and airconditioning
- *Solar energy* Vol. 72 No. 1 pp. 53-62 ISSN:0038-092x
- Desiccants and desiccant wheel http://en.wikipedia.org/wiki/Thermal_wheel#Desiccant_Wheel