Journal of Electron Devices, Vol. 2, 2003, pp. 40-44

ã JED [ISSN: 1682 -3427]

Journal of Electron Devices
www.j-elec-dev.org

AIR CONDITIONING BY SOLAR ENERGY

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***Abstract*--** **This paper presents a detailed survey and description of a new solar-based air-conditioning technique using a solid adsorption system. This technique uses solar energy to produce cold or hot air and does not pollute the environment. The key component of the system is a rotary desiccant wheel used for dehumidification.**

***Index Terms*--Air dehumidification, solid adsorption system, Rotary desiccant dehumidification.**

I. INTRODUCTION

There is three main types of refrigeration system: mechanical vapor compression, absorption and ejection compression. The mechanical vapor compression system is outstanding due to its higher coefficient of performance, flexibility and compactness in manufacturing and operation. However, the fact that it is generally powered by electricity results in the emission of a large amount of CO2, which, in turn, causes the greenhouse effect. In addition, CFCs used as the working medium seriously affect the ozone layer around the globe. The absorption system, powered by either electric or wasted heat, is mainly used in large air conditioning and refrigeration systems because of its complexity and high maintenance costs. The stream-jet ejector system cooling and refrigeration has existed since the early 1900s. Owing to the environmental problem caused by CFCs and the huge energy consumption of conventional cooling system, the solid adsorption refrigeration system has been developed, which accomplishes cooling cycles through cooling-adsorption and heating-desorption processes alternately. Adsorption has many advantages in refrigeration or heat pumping application such as: materials are environmentally friendly, chemically stable and the system can be powered by either solar energy or wasted heat [1]-[3].

Air conditioning systems assisted with the sorption technique called also adsorptive air conditioning systems are based in a new attractive technique, which provides a remarkable solution in the economical and ecological level. First, conditioned air is maintained inside a reactor with direct contact with a sorbent at atmospheric pressure. The properties of hygroscopic materials allow to take off the humidity from the conditioned air at a temperature below the dew point.

Next, the sorbent rich with humidity has to be regenerated in a desorber. The adsorptions can be achieved at low temperature. Therefore, it will be an effective approach to use solar energy.

Finally, the conditioned dry air is injected into the heat exchanger where it will be cooled.

II. PRINCIPLE

Three compartments constitute the installation of air-conditioning [4]:

- Compartment of air pre-cooling,
- Central Compartment of drying,
- Compartment of cooling/heating.

In these compartments we essentially find:

- a sorption rotor,
- a heat exchanger,
- systems of water pulverization,
- pumps,
- fans,
- valves,
- solar radiators,
- etc.

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The pre-cooling compartment insures a reduction of the temperature of the fresh air to be injected in the local, which is at ambient temperature. In the drying central compartment, the dehumidification of air takes place with the help of a sorption rotor constituted by layers of hygroscopique materiel. In the compartment of cooling/heating, the temperature of the cool air will be cooled or heated to the desired level.

I. HOW DESICCANT SYSTEMS WORK

Desiccants remove moisture from air by sorption. Because the surface of a desiccant has a lower water vapor pressure than that of humid air, moisture migrates to the desiccant. The air leaves the desiccant device drier than when it entered. This can either be a solid usually a silica gel, or a liquid solution such as lithium chloride. Both liquid and solid desiccant systems are used for industrial buildings and processes. In commercial buildings, solid desiccants are more common. The desiccant can be reactivated with air that is either hotter or dryer than the process air.

A wheel is the basic solid desiccant component. The desiccant materiel is impregnated into a support structure. This looks like a honeycomb, which is open on both ends. Air passes through the honeycomb passages, giving up moisture to the desiccant contained in the walls of the honeycomb cells. The desiccant structure is formed into the shape of a wheel. The wheel constantly rotates through two separate airstreams. The first airstream, called the process air takes outside air, or recirculated air or a combination and passes it over the desiccant that dries the air and supplies it to the building space.

The second airsteam, called the regeneration or reactivation air, takes outside air or air from the buildings and heats it. This air then passes through the desiccant wheel that has absorbed moisture from the process air and reactivates the desiccant. This resulting warm moist air is then rejected to the outside [5-6].

II. FUNCTIONING POSSIBILITIES

The installation described in this paper permits three functioning modes according to the season of the year and according to the climatic conditions.

A. Winter mode

The principle of working in this mode is presented in figure 1. The circuit followed by the cool air to be heated is formed by cycles 1, 2, 3, 4, 5, 6 and 7.
The circuit followed by the used air, is formed by cycles 8, 9, 10, 11, 12, 17, 19, 20 and 21. The aspirated cool air from the outside with the help of a fan (V1) and after having passed by the filter, crosses the heat exchanger (WT1) for a first pre-heating. Then, it is injected in the heat exchanger (WT2) and (WT3) before passing in the solar radiator in case of necessity and before its ventilation into the local.

B. Summer mode with pre-cooling of air

The principle of working in this situation is presented in figure 2. The circuit followed by the fresh air to be cooled is formed by cycles 1, 2, 3, 4, 5, 6 and 7. The circuit followed by the used air, is formed by cycles 8, 9, 10, 11, 12, 17, 19, 20 and 21. The fresh air aspirated from the outside with the help of a fan (V1) and after having passed by the filter, crosses the heat exchanger (WT1) for a pre-cooling.
The pre-cooling is insured with the help of the cooled air aspirated from the outside by an axial fan (V3) and after being humidified with pulverized water under pressure. Then, this air is rejected toward the outside by the cycles 18, 19, 20 and 21.

Next, pre-cooled air is injected into the sorption rotor for its dehumidification. Then, it passes through a second heat exchanger for a second pre-cooling. Finally, it passes in a third heat exchanger for a final cooling. The final cooling station uses the same principle as the first one, except that the cooling air in the exchanger comes from the conditioned local and is further humidified by pulverization to decrease its temperature.

The used air, after having passed by heat exchanger (WT3) and (WT2), with the help of a fan (V2) is ventilated into the sorption rotor, for regeneration of the hygroscopic materials characteristics after passing by the heat exchanger (WT4) and the solar radiator (WT5). At the outlet, the hot air of the sorption rotor is transported toward the heat exchanger (WT4) to assure the pre-heating of the flowing air injected toward the rotor before being thrown to the outside.

The psychrometric chart shown in figure 3 illustrates the cooling/dehumidification process.
1: hot and humid outdoor air enters the desiccant wheel at point 1 on the psychrometric chart.
1-2: the hot and humid outdoor air stream is cooled by passing through heat exchanger.
2-(3,4): Dehumidification—as the moisture from the air is removed by sorption. Air leaves the process side of the desiccant wheel hotter, and much drier than when it entered the system. In most cases, this air is too hot to send directly to the building. It must be cooled.
4-5: post-cooling — the dehumidified outdoor air enters heat exchanger, where it exchanges heat with the exhaust (return) air stream from the conditioned space. In this process, the hot and dry outdoor air cools down, and the cold exhaust air is pre-heated for reactivating the desiccant wheel.
5-(6,7): Supplemental cooling — the air leaving the heat exchanger is colder than the air leaving the

desiccant wheel, but further cooling is often required before it humidifies. In this state, it is too cold to be circulated into the conditioned space.

8: the exhaust air leaves the conditioned space (state 8).

8-9: the hot and humid outdoor air stream is cooled until it reaches saturation.

9-10 and 10-(11,12): the exhaust air stream enters two heat exchanger where it exchanges heat with the hot and dry air leaving the desiccant wheel.

13-14: the hot exhaust air is further heated to increase the vapor pressure at the desiccant.

14-15: Reactivation—the hot exhaust air stream dries and reactivates the saturated desiccant.

C. *Summer mode without pre-cooling of air*

The principle of working in this mode is presented in figure 4. Cycles1, 3, 4, 5, 6 and 7 forms the circuit followed by the fresh air to be cooled. The circuit followed by used air to be rejected is formed by cycles 8, 9, 10, 11, 12.

III. CONCLUSIONS

The design procedure suggested is simple and does not require high technology. This type of unit can be used widely in the regions with abundant solar resources due to such advantages as environmental protection, energy saving and low operation costs.

The experimental tests that are planned on the prototype unit will permit to verify its performance. Furthermore, we are interested to analyze some parameters, such as, ambient conditions, mass airflow rate and the effectiveness of the heat exchanger, etc., which affect the performance of the system.

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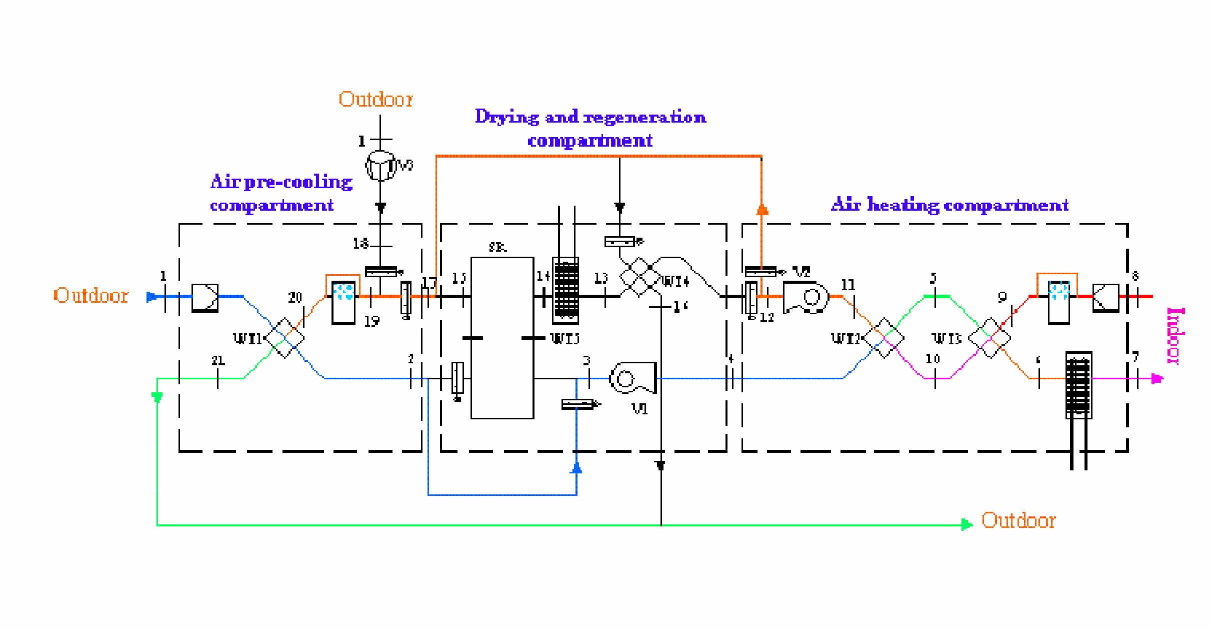

Fig. 1. Working in winter-mode

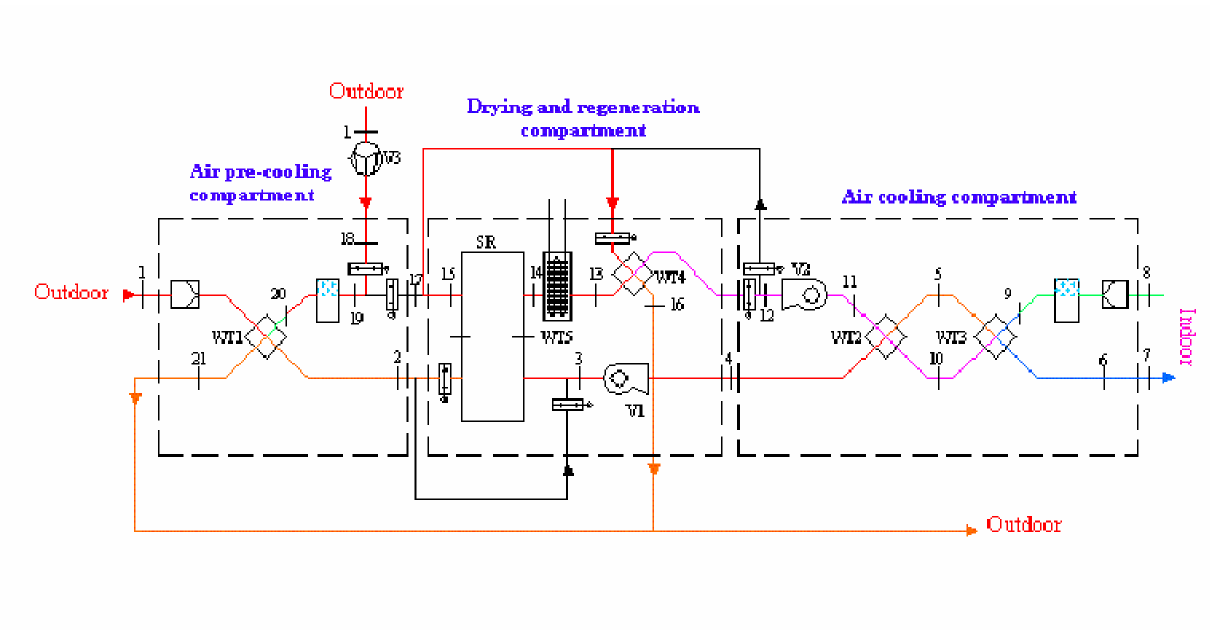

Fig. 2 . Working in summer-mode with pre-cooling of air

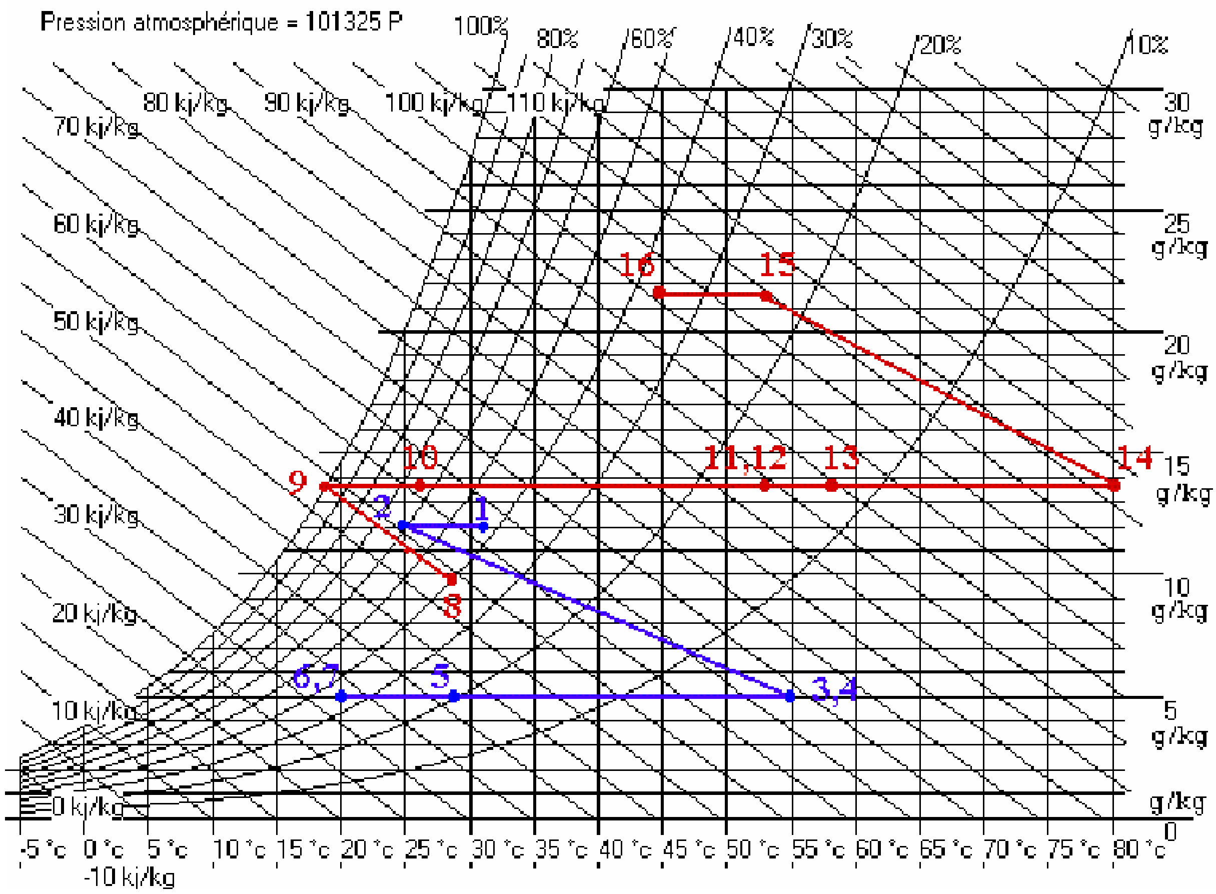

Fig. 3. Psychrometric chart – Example of the process principle

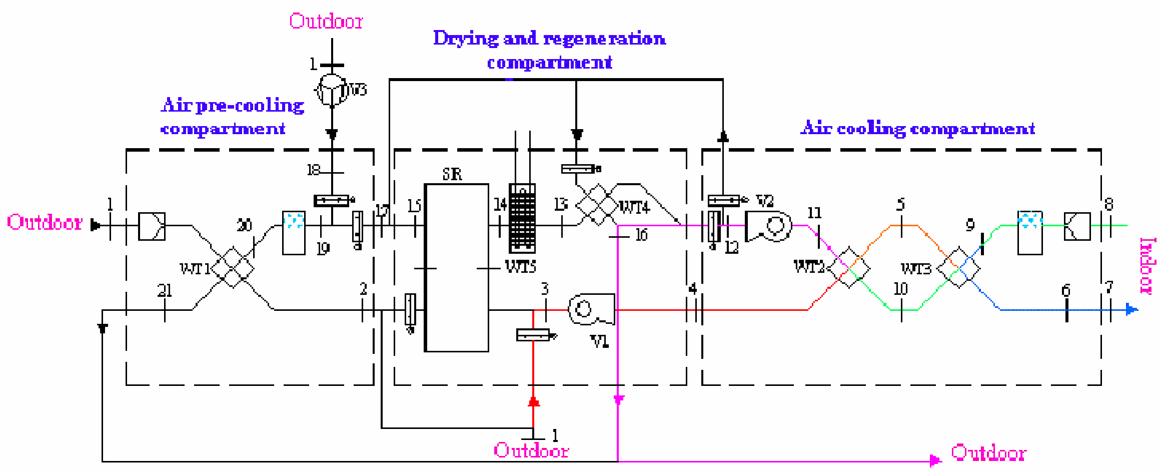

Fig. 4 . Working in summer-mode without pre-cooling of air