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Preliminary Study of Desiccant Cooling System under Algerian Climates

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***Abstract*—**The interest in air conditioning using renewable energies is increasing. The thermal energy produced from the solar energy can be converted to useful cooling and heating through the thermochemical or thermophysical processes by using thermally activated energy conversion systems. The ambient air contains so much water that very high dehumidification rates are required. For a continuous dehumidification of the process air, the water adsorbed on the desiccant material has to be removed, which is done by allowing hot air to flow through the desiccant material (regeneration). A solid desiccant cooling system transfers moisture from the inlet air to the silica gel by using two processes: Absorption process and the regeneration process. The main aim of this paper is to study how the dehumidification rate, the generation temperature and many other factors influence the efficiency of a solid desiccant system by using TRNSYS software. The results show that the desiccant system could be used to decrease the humidity rate of the entering air.

***Keywords*—**Dehumidification, efficiency, humidity, TRNSYS.

I. Introduction

DURING last years, air conditioning demand is spreading, both in the commercial (shops, warehouses, offices, schools…) and in the residential sector. This caused a sensible increase in primary energy consumption in those sectors; therefore, it is very important to guarantee a high Indoor Air Quality (IAQ) and a thermal comfort. In fact, individuals perform more effectively in conditioned indoor air environments than in untreated ones.

The residential and tertiary sectors account for over 40% of final energy consumption in Algeria today [1]. According to Algerian energy agency the energy consumption has increased about 5% from 2013 to 2014. The situation is alarming and experts think about solutions to reduce this consumption by integrating a bioclimatic architecture.

For the residential consumer, the air conditioning is the largest energy use appliance followed by water heater, refrigeration, fans and lighting [1]. Several trends would emerge in the light of research and development carried out over the last decade.

Solid desiccant conditioning systems can be an interesting alternative approach with regard to the vapor compression systems [2]. Their basic characteristics refer to the capability to regulate both temperature and humidity of the conditioned space in one side and to its potential in electrical energy saving in the other side.

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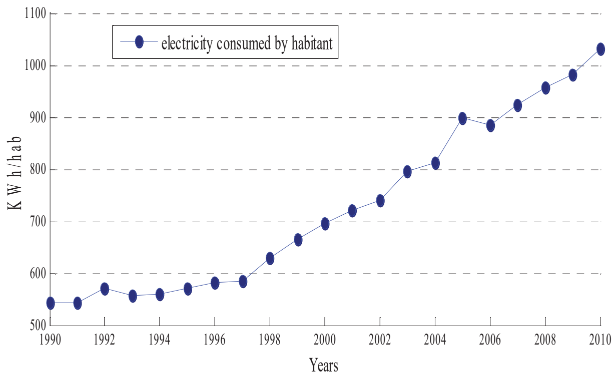

Fig. 1 Electricity consumption per Algerian habitant [1]

Desiccant dehumidification is not a new technology; it has a successful track record over more than 60 years for industrial applications such as product drying and corrosion prevention. [3]

Indoor humidity is closely related to health problems. Low humidity environment is associated with dryness of skin and throats, mucous membrane, sensory irritation of eyes [4]-[6]. High humidity environment may induce the growth of mould leading to respiratory discomfort and allergies [7], [8]. Therefore, keeping indoor humidity environment steady at the correct level is very important to ensure people's health in commercial building.

The increase of the ventilation air flow rate, favouring the dilution of pathogenic agents, is the commonly used strategy to guarantee a hygienic and comforting environment for the occupants. Unfortunately, the increase of ventilation flow rate determines higher air conditioning energy requirements; in fact, ventilation air represents the main source of latent load, especially in humid areas as in Mediterranean countries [9].

II. Using Desiccant System Instead of Conventional Systems

Traditional refrigeration plants are not suitable to control separately latent and sensible thermal loads. Often, the amount of latent and sensible load removed by the liquid desiccant cooling system is represented by sensible heat ratio (SHR) [10]:

$$SHR = \frac{SH}{SH + SL} \qquad (1)$$

SH: Sensible heat; SL: Latent heat. A low value of this quantity means that the total cooling load is predominately the latent load. This value has not changed for conventional AC for the last decades, while building loads have changed considerably. The energy efficiency improvement measures have been aimed almost exclusively at reducing sensible cooling loads (better roof and wall insulations, reduced windows U-values, increased solar shadings, more energy efficient lighting, etc.) while latent cooling loads (primarily due to ventilation, infiltration, and occupants) have not changed substantially. The effect for most new constructed or remodelled buildings is to raise the latent cooling load relative to the sensible cooling load at all conditions (design and part-load).

III. Presentation of the System

The principle of the system is simple. To maximize the effect of the water vaporization latent heat; the air is first dried out in the desiccant wheel which is the heart of the desiccant cooling system (Fig. 2). The wheel is composed of a circular matrix of glass or aluminum fiber on which is deposited the desiccant material. It is then cooled in an exchanger (in general a wheel exchanger), and then adiabatically cooled down in a humidifier. The desiccant wheel needs to be regenerated using a hot air stream. In general, the air extracted from the building is first cooled by an adiabatic humidifier, and then used to cool down the inlet air in a wheel exchanger, heated to high temperatures.

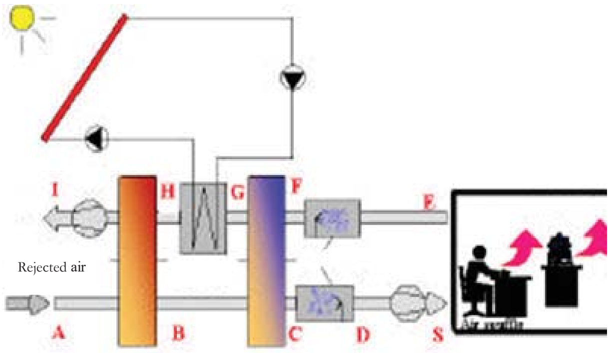

Fig. 2 Desiccant cooling system

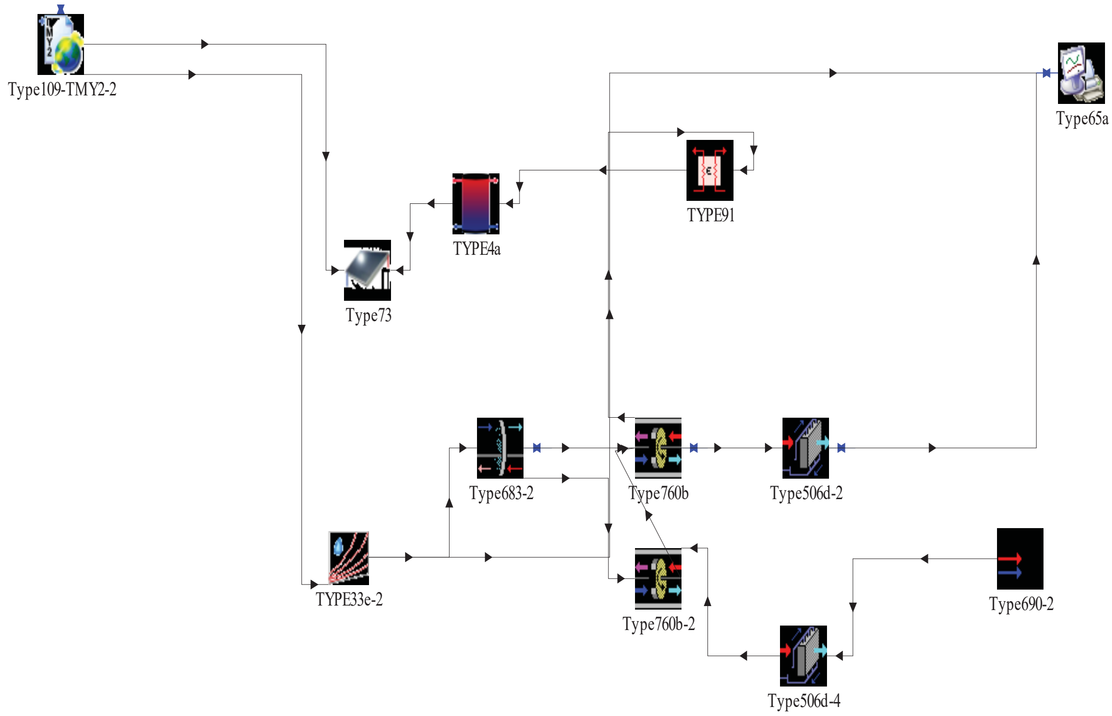

Fig. 3 Desiccant cooling system in TRNSYS interface

IV. Methods

We know three operating modes for desiccant systems: 1) **recirculation mode** where the unit treats return air from the building and uses outdoor air to regenerate the desiccant; 2) **ventilation mode:** the unit provides supply air to the room from the ambiance. The return air from the room after few processes, releases to the ambiance as an exhaust air; 3) **ventilation with heat recovery mode** where the unit conditions outdoor air being supplied to the space and uses exhaust air from the building to regenerate the desiccant.

In this study, we have used the ventilation mode since it represents the majority of applications for desiccant dehumidification systems.

A. TRNSYS Software

TRNSYS (Transient Systems Simulation program) is a flexible tool for modeling the performances of the system energetically.

We have used the software TRNSYS to create the model for a desiccant cooling system with certain parameters and inputs to understand the behavior of system components and possible operating modes of desiccant dehumidification [11]. To simulate the operation of a system in its entirety, the user must first define the various components of the system from a type library and connect them together to form the complete system. A graphical interface called ISIIBAT allows one to view all the components of a system.

B. Sites Considered

Climates in the different parts of the world vary with season of the year and with geographical locations, indeed, Algerian climate is characterized by a mixture of hot, humid and dry. In this study we have focused on three sites that have humid weather: Annaba, Oran, and hot (Tlemcen). Fig. 4 shows the situation of each considered site.

Fig. 4 Geographical situations of the three sites

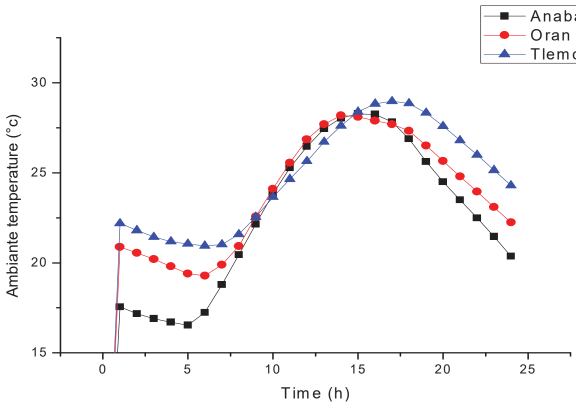

Fig. 5 Ambient temperatures versus time for each site

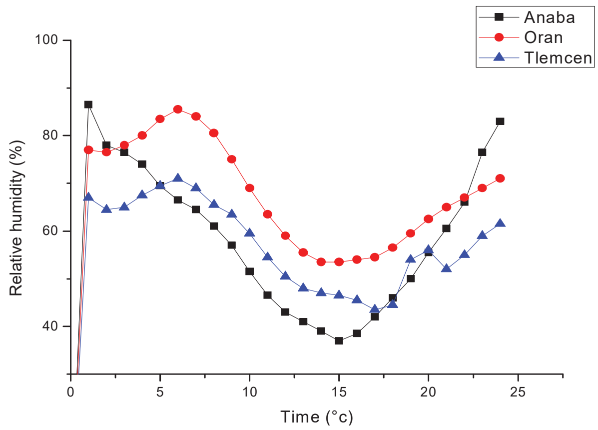

Fig. 6 Relative humidity versus time for each site

The ambient temperature for the three considered sites (Fig. 5) varied from 15 °C and 30 °C, the ambient temperature gets its maximum approximately at 14 h.

Coastal cities have a high relative humidity compared with inland cities such as Tlemcen.

V. Results and Discussions

The results exposed below represent the influence of some parameters on the cooling process in order to decide the feasibility of the process.

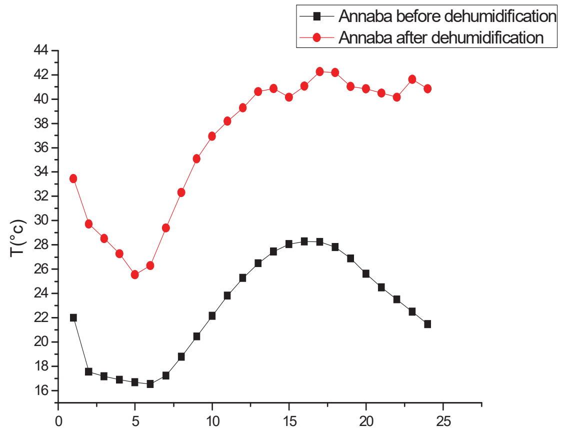

Fig. 7 Dehumidification process in Annaba site

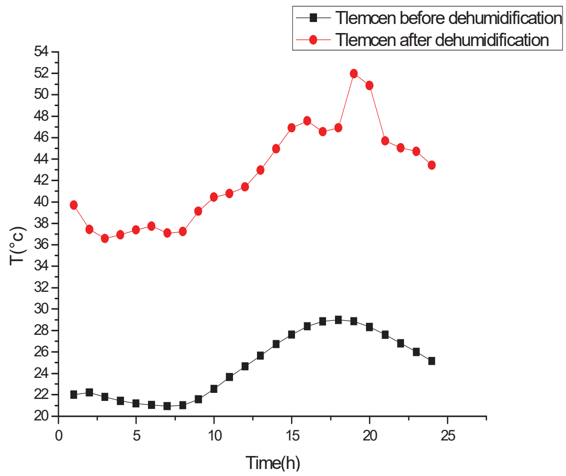

Fig. 8 Dehumidification process in Tlemcen site

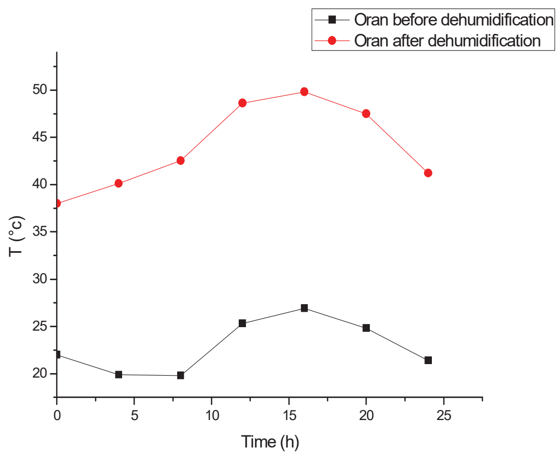

Fig. 9 Dehumidification process in Oran site

The desiccant wheel is the main component of the desiccant system; it absorbs the water content in the air using the absorption quality of the silica gel.

The silica gel dries the process air so its temperature increases as described by Figs. 7-9.

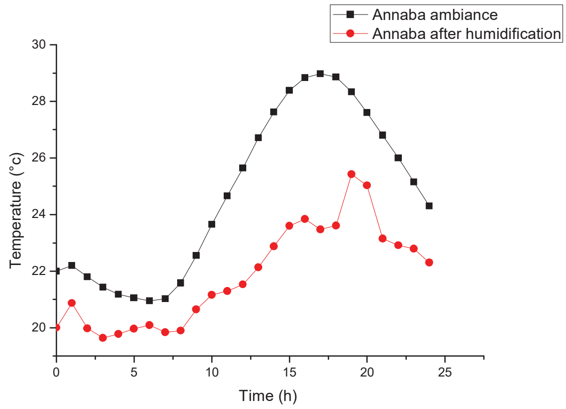

Fig. 10 Humidification process in Annaba site

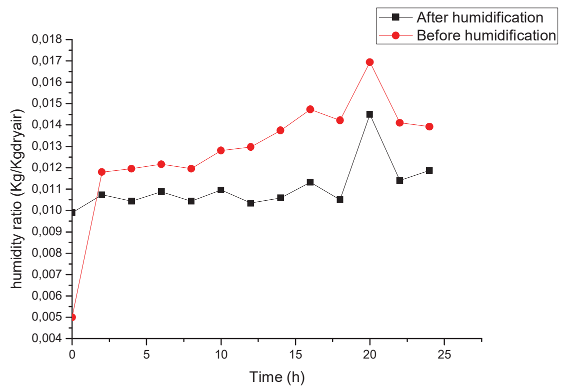

Fig. 11 Humidification process in Annaba site (humidity ratio)

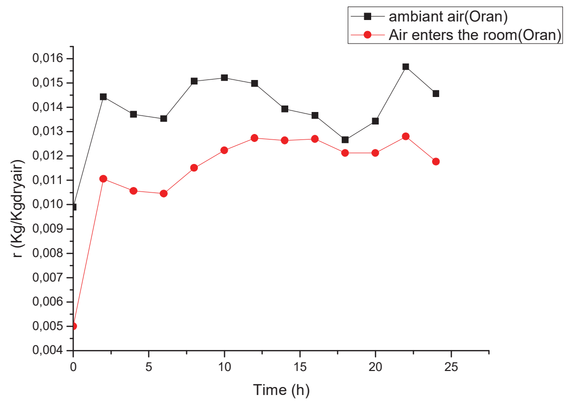

Fig. 12 Humidification process in Oran site (humidity ratio)

According to the curves presented in Figs. 10, 11 for the site of Annaba characterized by a humid climate, the air after humidification process enters the room with required temperature and humidity (comfort zone).

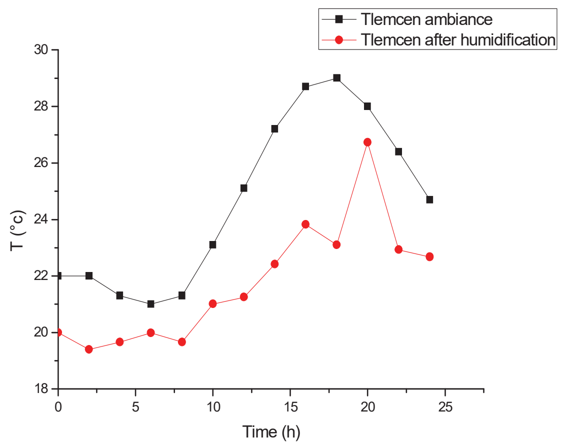

Fig. 13 Temperature of the air entering the room

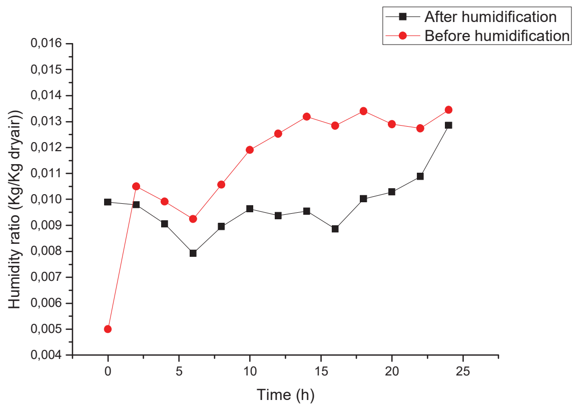

Fig. 14 Humidity ratio of the air entering the room

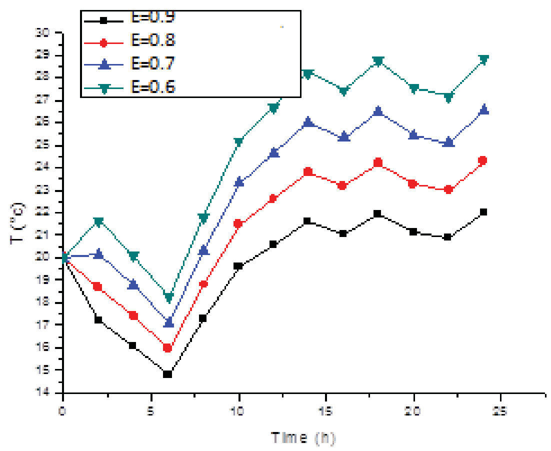

Fig. 15 Humidifier efficiency

VI. Conclusion

A desiccant evaporative cooling system offers a promising alternative to conventional air conditioning systems for climates with high latent load (humid climates).

The results showed that such system has proven its efficiency for decreasing uncomfortable zone by reducing the water content in the air.

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