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A new heat pump desiccant dehumidifier for supermarket application

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Abstract

Recently a new equipment for dehumidification was put onto the market. It is a self-regenerating liquid desiccant cooling system able to dehumidify, heating or cooling the ambient air by an electric heat pump that is a part of the equipment. Its operation is here studied in a supermarket application where air temperature and relative humidity play a very important role and the air-conditioning becomes necessary not only to assure a suitable thermal comfort, but also to make the refrigerated display cabinets operate properly. In this paper possible energy savings, compared to a traditional mechanical dehumidification, are evaluated by means of a numerical model that simulates a typical Italian supermarket.

Keywords: Chemical dehumidification; Supermarkets; Energy savings; Modelling

1. Introduction

The relative importance of the latent load is growing in air-conditioning. The latent load is due to people or particular activities such as cooking or drying. This increasing importance can be attributed to a better care in insulating and reducing solar gains by special glazing and to the use of higher air changes to reach good comfort standards. In fact, the outside humidity is normally well higher in summer than inside set values in many climates so that the contribution to the latent load can be absolutely prevalent [1].

This latent load is usually satisfied by cooling the air below dew point. The low temperature requested reduces the possible COP of cooling equipment and often obliges to provide the inefficient process of post-heating.

An interesting alternative is chemical dehumidification which is often produced in hygroscopic wheels via solid adsorption. Less widespread is the process of liquid absorption [2–5] that is utilised to our knowledge by only one manufacturer with the well known brand Kathabar.

2. The innovative machine

Recently a new equipment for dehumidification was put onto the market [6]. It is a self-regenerating liquid desiccant cooling system able to dehumidify, heating or cooling the ambient air by an electric heat pump that is a part of the equipment. It appears in the shape similar to a traditional air-handling unit (Fig. 1), but it puts together inside in a new way a chemical dehumidification system and an electric vapour compression heat pump: in such a way it can be defined as a hybrid machine.

Its operation can be followed by the numbers reported in the figure. Outside air or re-circulated is sucked in 1, through 2 it is filtered, dehumidified and cooled, finally in 3 the dry and cool air can be introduced into the ambients. Outside air for regeneration is taken in 4, in 5 one can find the control system and the heat pump compressor. Through 6 regeneration air is heated by the heat pump condenser. This hot air contacts the desiccant in 7 in a structured cellulose packing and regenerates it. Finally, reactivation air is exhausted in 8 at a higher humidity.

How the equipment works, it is better illustrated in Fig. 2, according to which the equipment can be subdivided in three parts: regeneration and dehumidification sections and the heat pump.

Starting from the right side, the air to be treated flows thorough a honeycomb cellulose media where enters in contact with the concentrated solution (LiCl–H_2O), previously cooled in the heat pump evaporator: the air flows out dehumidified and the solution gets diluted. The provided cooling does not only balance the exothermic effect of the absorption process that allows the dehumidification, but, if necessary, it can give an additional effect that produces cool dry air.

Now thermal energy is requested to regenerate the desiccant solution: this energy is supplied to the solution in a primary heat

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Nomenclature

AHU	air-handling unit
COP	coefficient of performance
HVAC	heating ventilation air-conditioning
t	temperature (°C)
Greeks letter	
φ	air relative humidity (%)
Subscripts	
a	store air
o	outside air

pump condenser and to the regeneration air in a secondary heat pump condenser (left side). Hot air enters in contact with hot diluted solution and removes water from it: so hot and wet air is exhausted and concentrated solution moves towards dehumidification section.

Just in the middle of the scheme the heat pump scroll compressor is represented: the refrigerant can be R22, R407c or R417a.

How the concentrated solution returns to the absorber and the diluted solution goes to the regenerator is not clear. This is operated in the information supplied by the manufacturer by a fluid equaliser, described as a patented device.

Adding a third condenser at the outlet of the process air, the machine can provide a slight post-heating: such an operation can satisfy a request of dehumidification and heating, typical in the Italian fall season.

In the provided data sheets (t_o = 30 °C, φ_o = 70%), COP varies from 3.2 to 4.2, depending on the capacity. The smallest model treats 250 m^3/h, removing 3 l/h of water from the processed air and cooling down it of 7 °C; the electric demand is about 1 kW. The highest capacity model (rooftop) can handle 4,760 m^3/h, removing 42 l/h of water from the air and providing at the meantime a cooling of 6 °C; the electric demand is about 9 kW.

3. Store and HVAC systems modelling

A model of a typical Italian supermarket is used to investigate on the energy requirements of a traditional air-conditioning management, that is a control of sensible and latent loads by means of mechanical dehumidification followed by post-heating process. All the assumptions about the supermarket modelling are detailed in [7]; here they are briefly reported.

We consider a conditioned space of 2,600 m^2 and a volume of about 10,000 m^3. As regards the outside conditions, we consider the weather data reported in the Test Reference Year [8] for the city of Rome, in the centre of Italy.

The thermal gains of the supermarket are due to the occupants with a maximum presence of 0.1 people/m^2, scaled in a typical daily profile. The contribution of the interior lights and other devices is assumed equal to 30 W/m^2. The opening hours are from 8 to 20 with Sunday opening.

The installed refrigerated case capacity is 100 kW of which 75 kW at normal temperature case (−5 °C) and 25 kW at low temperature case (−25 °C), with an equal distribution of vertical and horizontal cases. The coupling and the interactions between conditioned air and refrigerated display cabinets are discussed in detail in [9].

3.1. Traditional air-handling unit

The required fresh air is 9 l/s per person, hence a flow rate of 8,500 m^3/h considering the maximum occupancy; the total air

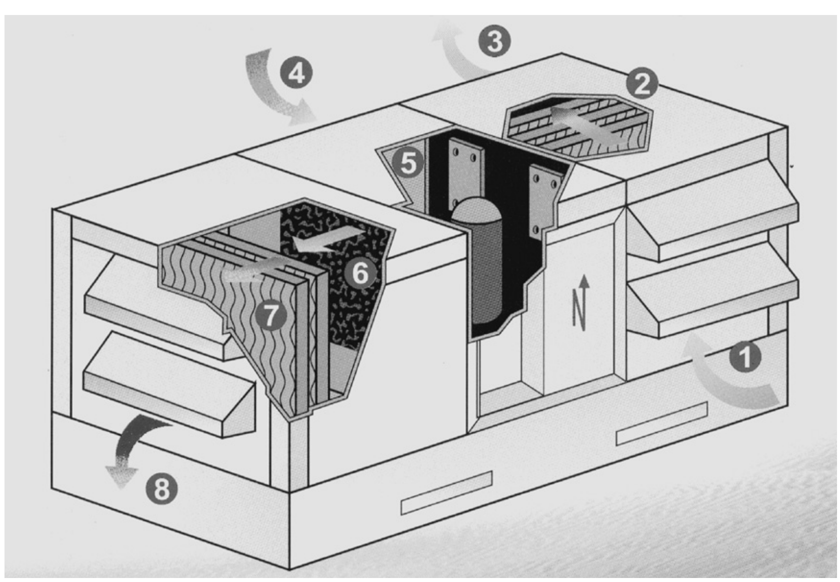

Fig. 1. The desiccant heat pump system studied [6]. (1) Inlet of outside or re-circulated air flow; (2) filtration, dehumidification and cooling section; (3) outlet of dry and cool processed air flow; (4) inlet of outside air flow; (5) heat pump section; (6) heating section by condenser; (7) regeneration section; (8) outlet of hot and wet regeneration air flow.