HIGH EFFICIENCY DESICCANT SYSTEMS FOR AIR CONDITIONING APPLICATIONS

Luigi Schibuola

Dipartimento di Fisica Tecnica, Università di Padova, Italy

ABSTRACT

Suitable combinations of desiccant and evaporative cooling systems permit air processes alternative to the traditional ones for air conditioning applications. But owing to the high costs of desiccant wheels, we need very strong energy savings in order to demonstrate an economy validity. These savings can be possible today by the last generation of desiccant wheels where the most part of the regeneration heat can be supplied by heat recovery from chillers. In this paper the performances of metal-silicate wheels are investigated and presented in the case of their applications in European typical climatic conditions. The results seem very promising.

INTRODUCTION

The convenience and sometimes the necessity to use chemical adsorption, when low thermal or humidity levels are required, are just well-known. But the recent developments of new adsorbent materials have led to the introduction of desiccant rotors characterized by a strong increment of dehumidification efficiency. In this way it is possible today to achieve dehumidification capacities compatible with air conditioning treatment requirements also in presence of low regeneration thermal levels obtainable, for example, with heat recovery from chiller condenser.

In this paper a ventilation air treatment, based on a high efficiency desiccant system, is proposed and studied for a typical application in an office building.

THE PLANTS

The performances of a high efficiency metal-silicate wheel has been considered. Here a metal-silicate ($MgSiO_3$) is tightly fixed, by chemically synthesizing, on a ceramic fiber laminate which forms the honeycomb-shaped matrix of the rotor. Its performances, provided by the manufacturer, are reported in figures 1 and 2 , In detail figure 1 shows the output moisture for various input moistures and temperatures of process air in presence of regeneration air temperature of 40°C or 60°C. The figure 2 shows the corresponding output temperatures of the process air. The rotor wheel is 200 mm depth with a regeneration area equal to 40% and the rest reserved for process. Process and regeneration air flows are equal. The comparison with the normal performances of the traditional chemical wheels saturated of lithium chloride [1, 2, 3] points out the net increment of the possibility to achieve, also with low regeneration temperature, an acceptable dehumidification efficiency. Figure 3 shows the sketch of the desiccant plant for primary air treatment here studied (type A) while in figure 4 the corresponding air processes are reported in the psychrometric diagram. After dehumidification the process air is cooled in two cross flow type heat exhangers by outside or return air, first cooled by adiabatic humidification. If this is not enough, a final traditional cooling coil contributes to obtain supply air design temperature (20°C). In each exchanger, the two air flows are equal. This is the reason why the return air flow rate, normally less of supply air, is partially integrated with outside air. Heat recovery from chillers provides regeneration air heating only until 40°C. If the absorption capacity corresponding to this regeneration temperature is not enough, the building humidity control rises up the regeneration temperature, as much as required, by modulating further auxiliary heating in the second heating coil supplied by hot water from traditional boiler.

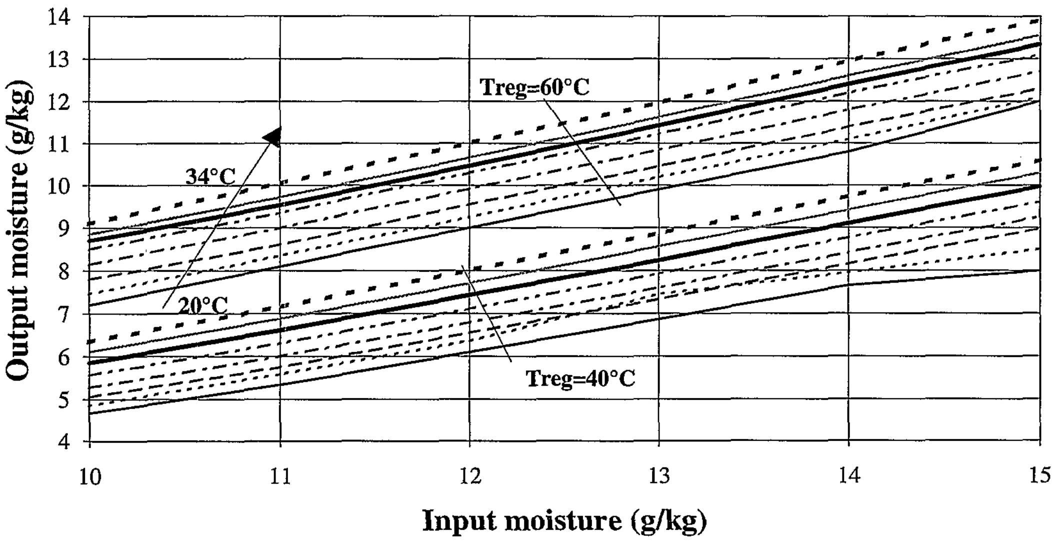

Figure 1. Process air output moisture as a function of input moisture for various input temperatures. The values refer to regeneration temperatures of 40°C or 60°C.

A simplified version of this plant (type B), with the only heat exchanger with return air, has also been considered. The performances of these plants, type A and B, have been compared with those of a traditional primary air handling unit based on a coil for cooling and dehumidification and a post-heating coil again supplied by heat recovery from chiller.

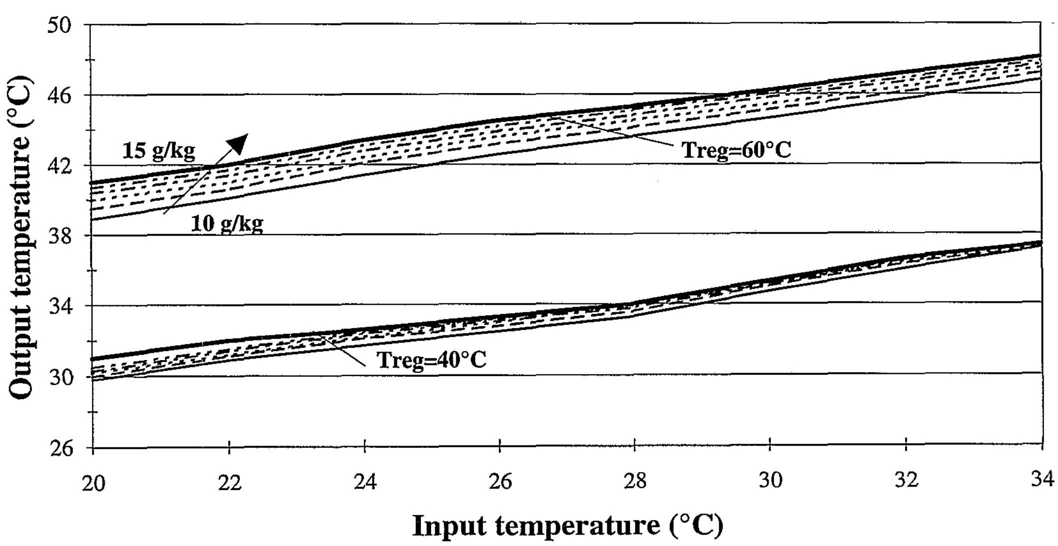

Figure 2. Process air output temperature as a function of input temperature for various input moistures. The values refer to regeneration temperatures of 40°C or 60°C.

The presence of a heat recuperator between inlet and return air has also been foreseen.
In all the plants here analysed, we have considered a thermal efficiency equal to 0.7 for the heat exchangers and a saturation efficiency equal to 0.9 for the sprayed pack units.

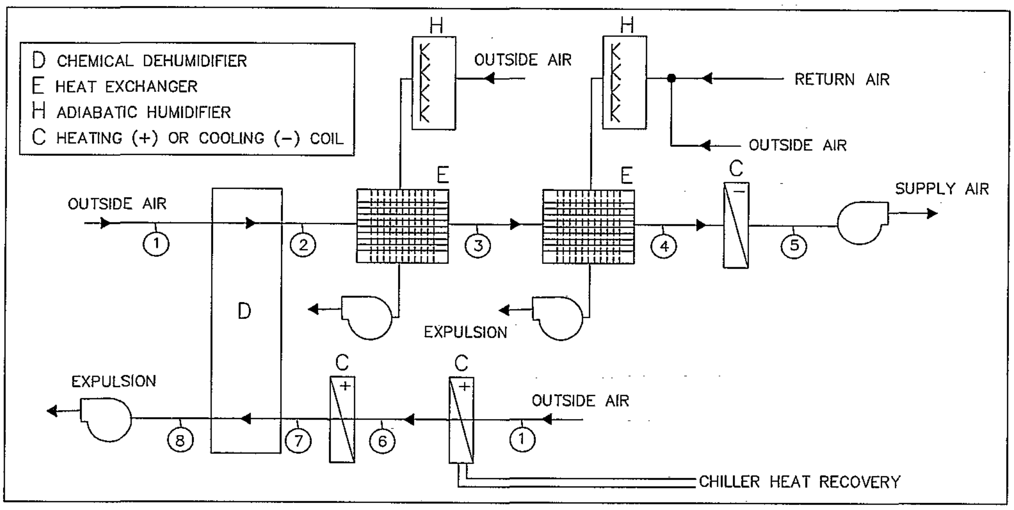

Figure 3. Sketch of the desiccant plant (type A).

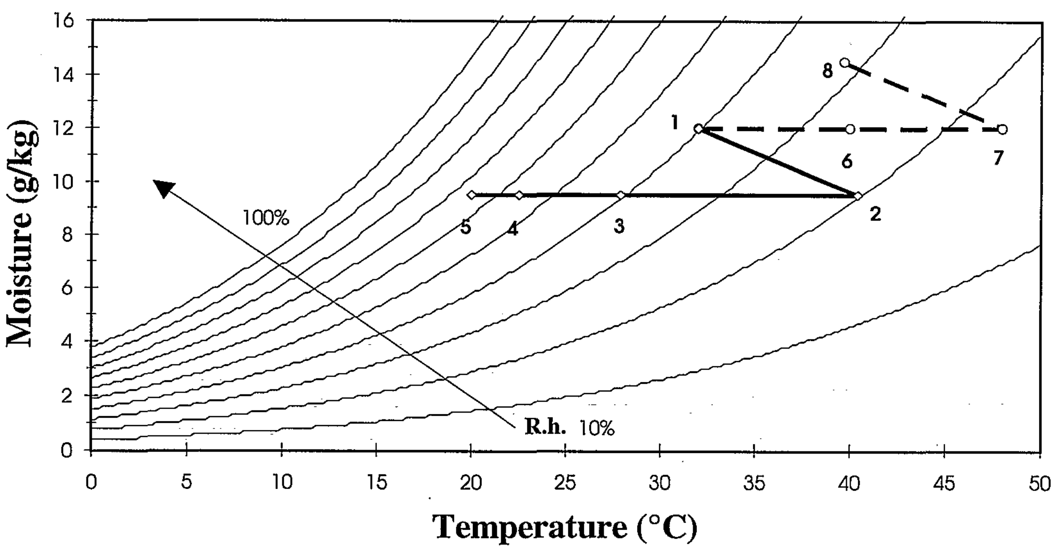

Figure 4. Representation of the air processes in the psychrometric diagram.

ENERGY PERFORMANCE COMPARISON

By long term simulations, the performances of the various air handling units have been compared in the case of a primary air and vent-coil plant for the air conditioning of a building with an internal volume of 8100 m^3 and an useful floor surface of 3000 m^2. Internal sensible cooling load is, for the most part, provided by vent-coils, instead primary air ensures humidity control and ventilation. Design internal climate is 26°C with a relative humidity equal to 50%. For primary air the immission temperature is always equal to 20°C. Building cooling loads and HVAC system performances have been calculated by DOE 2.1E program [4].

Three possible levels of occupancy have been considered: 1 person per 7 or 10 or 13 m^2 of floor. The moisture content of the primary air must take into account the latent heat internal gain (here 60 W per person). Also the effect of different supply air flow rates have been investigated and they are expressed in terms of hourly ventilation exchange rate for the building. So we have considered the possibility of 1.5, 2, 2.5, 3, 4 vol/h.

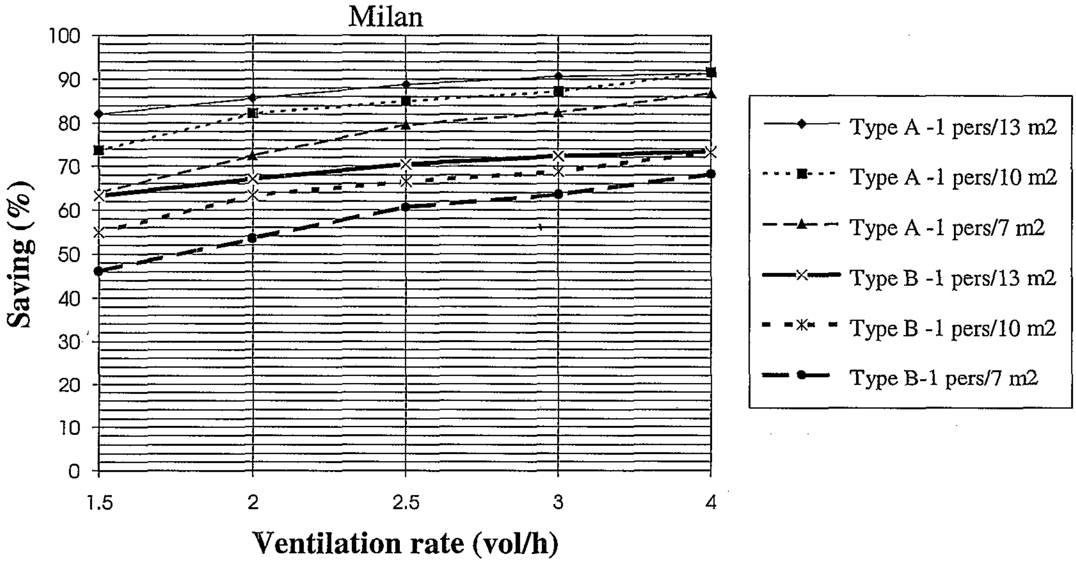

Figure 5 Percentage savings obtained in Milan by desiccant plants type A and B with various ventilation rates and different design occupancy.

The meteorological data used are Test Reference Years (TRY) from NOAA [4] and regard five European cities well distributed from the Northern part to the Southern one: Copenhagen, Zurich, Milan, Rome, Athens.

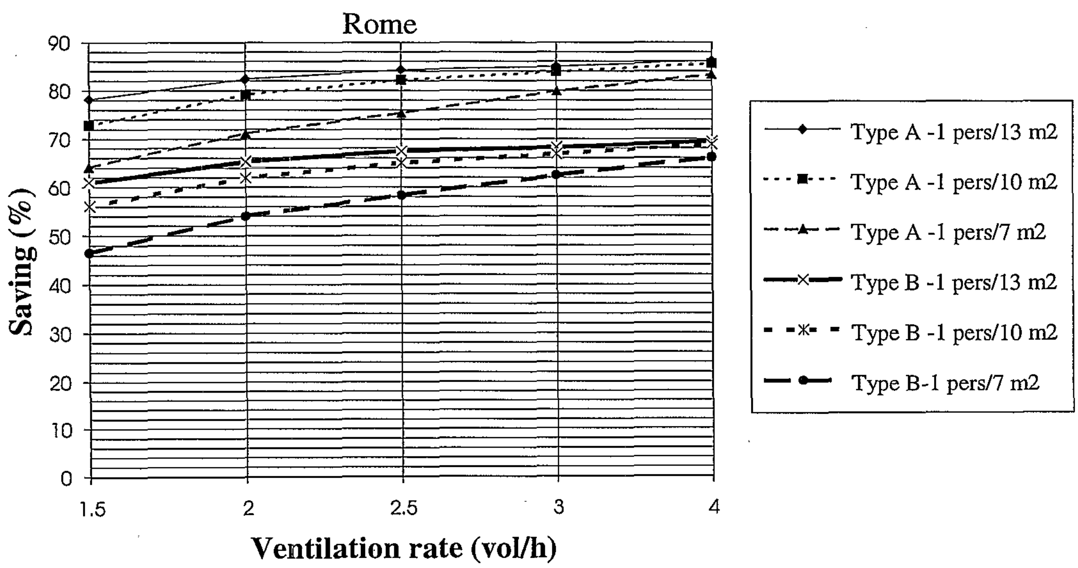

Figure 6 Percentage savings obtained in Rome by desiccant plants type A and B with various ventilation rates and different design occupancy.

The energy needs, in terms of primary energy, have been calculated for the various cases and the evaluation is extended to the period from April to September. The electric absorptions of chillers to supply traditional cooling coils have been calculated and also gas boiler consumptions to supply auxiliary heating coils if necessary.
To calculate primary energy a transformation ratio equal to 0.33 from thermal to electric energy and a boiler efficiency equal to 0.85 have been assumed.
In figures 5, 6 and 7 the percentage savings obtained by the two desiccant plants are reported respectively for Milan, Rome and Athens. These savings refer to the primary energy seasonal consumptions of the traditional air handling unit. For Copenhagen and Zurich the savings are in any case equal to 100%. In fact in these two climatic conditions, owing to the lower moisture of outside air, a regeneration temperature of 40°C is always sufficient. In this way no energy consumption is due to auxiliary heating coil. The desiccant plants use only the heat recovered from chillers working to supply vent-coils. The final cooling coil never works.
Anyway also for the other three cities, the figures show a remarkable energy saving which obviously increases with the occupancy level and ventilation flow rate because of the greater dehumidification requirement. Here the advantage to have the second heat exchanger with type A is always clear as its presence reduces the necessity of the final cooling by coil.

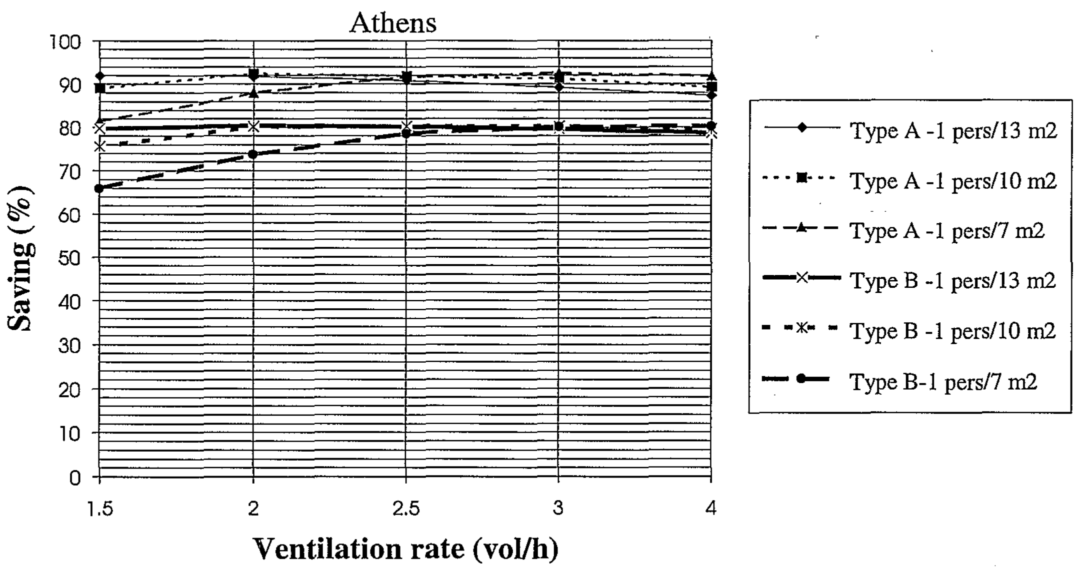

Figure 7 Percentage savings obtained in Athens by desiccant plants type A and B with various ventilation rates and different design occupancy.

ECONOMY EVALUATIONS

Referring to gas and electric rates in force, the economic savings of the alternative desiccant systems with respect to the management cost of the traditional primary air treatment have been calculated. For example in Milan in the case of 1 person per 10 m^2, the seasonal management cost, with the traditional solution, varies between 3200 euro with 1.5 vol/h flow rate and 6700 euro with 4 vol/h. In these conditions the economic savings, in percentage, obtained by desiccant systems are between 45% and 82% for plant type A, between 29% and 65% for plant type B. The advantage, also economic, to use a stronger cooling of process air by two heat exchangers is therefore easily shown.

In spite of these remarkable results, the financial analysis remains critical owing to the high costs of the desiccant rotors. In the end the pay back periods for the initial over-costs are between nine and five years. The financial interest for this investement is certainly ensured only in the case of the biggest sizes of the air handling units here considered.

CONCLUSIONS

In countries characterized by moderate moisture levels of the outside air, high efficiency desiccant rotors permit today to realize a humidity control by using only heat recovery. Anyway, also where the dehumidification requirement is greater, these systems permit a strong reduction of energy consumptions with peaks, in percentage, near to 100% and a less use of traditional refrigerating machines. The benefits for the environment and the savings in terms of management costs are consequent. But the high costs of the chemical devices don't ensure always a financial convenience for their installation. In order to spread their use for air conditioning applications in buildings, any effort must be now addressed to the reduction of the costs of these components.

Aknowledgements

The author would like to thank Mr Malaterra of Angelantoni SPA for the help and the informations about operating conditions of the Seibu Giken SSCR rotor.

REFERENCES

1. ASHRAE. 1988. Equipment Handbook, *Sorption Dehumidification and Pressure Drying Equipment*, chapter 7, pp 7.4-7.8.

2. Munters Group, *The dehumidification handbook*, internal report.

3. Cargocaire Engineering Corporation. 1982. *Dehumidification handbook.*

4. DOE, release 2.1E, Department of Energy program , Simulation Research Group, Lawrence Berkeley Laboratory, Berkeley, California 1994.

5. National Climatic Data Center. 1995. *Test Reference Years*, Federal Building, Asheville,North Carolina.