Experimental results on a solar desiccant and evaporative cooling system equipped with wet heat exchangers

An innovative solar assisted desiccant and evaporative cooling (DEC) system for building air conditioning has been installed at the Solar Laboratory of the University of Palermo. In this system, air-to-air packaged wet heat exchangers are used to maximise the exploitation of the evaporative cooling potential associated with the exhaust air stream.
Results obtained are very positive, showing that DEC systems can benefit from the use of wet heat exchangers to efficiently cool the air stream after the adsorption process in the desiccant wheel, without any change in moisture content

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Risultati sperimentali di un sistema solare ad adsorbimento con raffreddamento evaporativo realizzato mediante scambiatori di calore bagnati

Un innovativo sistema solare di deumidificazione e raffreddamento evaporativo (DEC) da utilizzare per la climatizzazione degli edifici è stato installato presso il Laboratorio Solare dell'Università di Palermo. Il sistema utilizza scambiatori di calore aria-aria a pacco mantenuti bagnati sul lato secondario al fine di massimizzare il potenziale di raffreddamento evaporativo associato al flusso d 'aria di ritorno dall'edificio. I risultati ottenuti sono molto positivi e mostrano che i sistemi DEC possono beneficiare dell'uso di scambiatori di calore bagnati per realizzare un efficace raffreddamento sensibile del flusso d 'aria di processo dopo la fase di adsorbimento che avviene nella ruota deumidificante

The Solar DEC technology is an interesting and fascinating solution for applications in building air conditioning. It is a thermally driven open cooling cycle based on evaporative cooling and adsorption processes. In a solar desiccant cooling cycle, solar energy is used to regenerate a desiccant material that dehumidifies moist air by vapour adsorption; the resulting dry and warm air is cooled in a sensible heat exchanger (usually rotating) and then in a direct evaporative cooler. By associating different elementary treatments in moist air (dehumidification, sensible cooling and evaporative cooling) both in the process and exhaust air, the technique uses water as a refrigerant and mostly solar energy as driving heat. In a solar autonomous DEC system, electricity is only used in the auxiliaries, so the technique is environmentally friendly. If the pure DEC effect is not sufficient to guarantee indoor air conditions for the specific application, a hybrid

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DEC – conventional cooling cycle can be used by adding one or more traditional cooling coils connected with an electric water refrigerator to the standard DEC cycle [Henning, 2004].
Monthly results are presented and elaborated according to a monitoring procedure developed in the framework of the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme, Task 38 "Solar Air Conditioning and Refrigeration" [Sparber et al., 2008, Sparber et al., 2009].

Description of system layout

The layout of the DEC system is a hybrid configuration with two additional auxiliary cooling coils fed by a conventional vapour compression chiller integrated in the DEC air handling cycle (Figure 1). One coil is used for pre-dehumidification of the outside air stream; the other coil controls the air temperature if the desired supply temperature cannot be reached through indirect evaporative cooling alone. In the system 22.5 m^2 of solar flat plate collectors are used with a water tank of 0.65 m^3. Rated air flow rate of the air handling unit is 1250 m^3/h.
The main innovation in the DEC process is the use of cross flow plate heat exchangers. These devices are commonly used in air conditioning systems for heat recovery purposes during the winter. When indirect evaporative cooling is used, the same heat exchangers can be used to efficiently cool the outside air during summer, wetting the channels of the exhaust air with water [Rey Martìnez et al., 2004]. Therefore, this component can efficiently be integrated in a desiccant cooling cycle downstream of the adsorption process. Other authors have already considered the application of wet surface heat exchangers for indirect evaporative cooling, but only in few cases has the coupling with DEC system been investigated [Jain et al. 1995, Rowe et al. 2010].
The surface of secondary flow (return air from the building) air channels is wetted by water sprayed by nozzles, such that a water film evaporates into the cooling air and decreases the temperature of the heat exchange surface. Process air flowing in the primary airflow channels is cooled down due to the lower temperature surface of the separating wall of the heat exchangers.
The sensible heat exchanger normally used in DEC systems is thus replaced with two plate heat exchangers displaced in series for a continuous humidification of the secondary air flow. Thus return air is humidified in two steps before leaving the AHU after the heat exchange with the supply air stream. Desiccant wheel is regenerated by fresh air, which is heated by the two heating coils. It implies the use of an additional fan but, on the other hand, the regeneration airflow can be reduced. No bypass is used to limit solar heat consumption for the regeneration and to reduce pressure drops during the wintertime. Regeneration flow rate can be modulated independently of the return air flow. Another specific feature of the system is the use of part of the heat rejected by the refrigerator condenser to preheat regeneration airflow.
The air handling on the psychrometric chart is

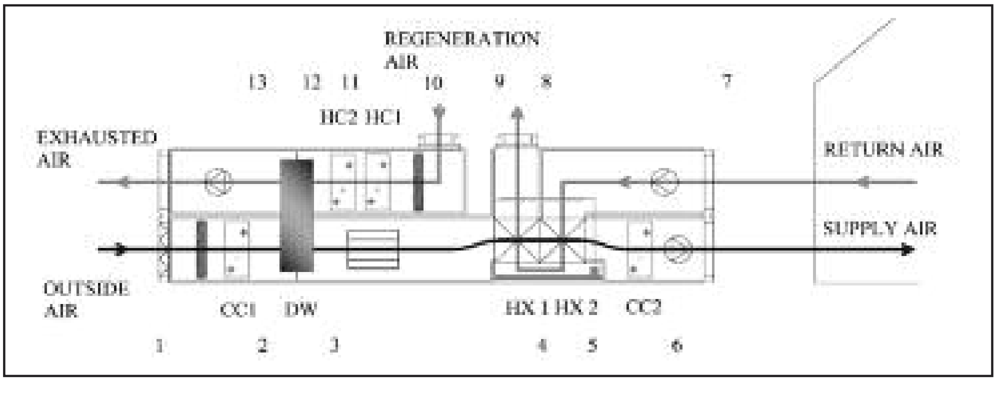

FIGURE 1

Layout of the DEC AHU with wet heat exchangers

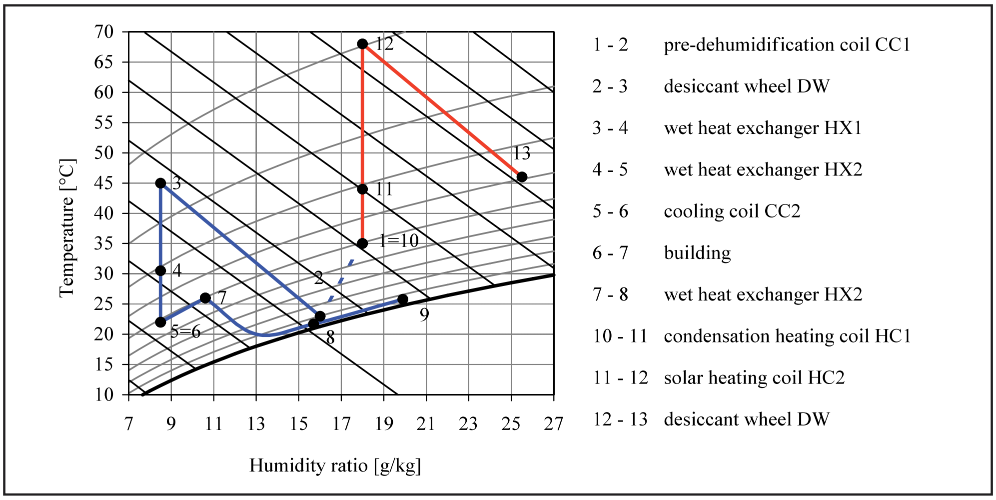

FIGURE 2 Sequence of air handling on return and supply air stream for typical summer conditions on the psychrometric chart

shown for typical summer operation conditions in Figure 2. The total cooling power of both wet heat exchangers is the enthalpy difference between points 3 and 5. It can be noted that no additional cooling coil is used to reach the supply temperature of 22 °C.

Experimental results

Monitoring data were collected during Aug - Sept 2010 and June - July 2011 and results are shown both in terms of seasonal energy performances.
Figure 3 shows the cold distribution in the AHU where DEC indicates the contribution of the desiccant cooling process to the whole cooling energy delivered. It can be noted that the contribution of the temperature controlling coil CC2 is very low being the desired supply temperature of the AHU typically reached without any use of the cooling coil.
The total contribution of the desiccant and evaporative cooling effect to the total cooling energy delivered is about 70%. The water consumption in the new DEC configuration is due to evaporation occurring on the secondary side of the wet heat exchangers HX1 and HX2. A daily mean value of water consumption of about 70 lt/day was calculated.
Finally, a comparison between the DEC system and a conventional system was performed. The conventional system considered is an AHU fed by a water electric chiller. The analysis was conducted according to the mentioned monitoring procedure developed in the framework of the IEA Task 38. Monitoring results show a primary energy saving of 53.7% as seasonal mean value. In the calculation it 's taken into account that, in a conventional system, additional cooling energy is needed for the dehumidification process to reach dew point temperatures, with consequent re-heating of the air up to the desired inlet temperature conditions [Beccali M. et al. 2012].

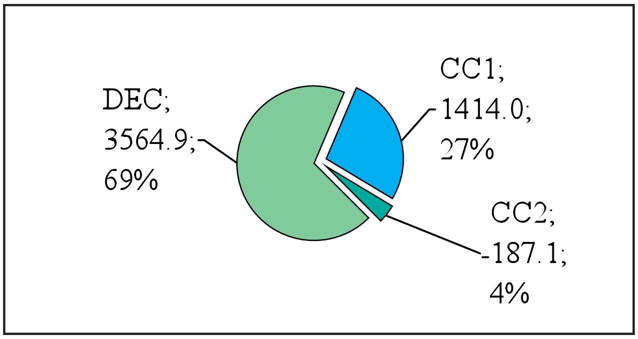

FIGURE 3 Distribution of the seasonal cooling energy in kWh produced by the DEC AHU

Conclusions

In the present work, an innovative desiccant cooling cycle using wet heat exchangers is presented. The

system presented is a Solar DEC air handling unit, which was recently modified and updated according to a new concept mainly based on the use of wet plate heat exchangers. Monitoring results related to the modified configuration showed that, due to the optimisation of the indirect evaporative cooling process, a supply temperature in the range of 21-22 °C can be achieved without the use of an auxiliary cooling coil. Therefore, the electricity consumption of the auxiliary cooling machine in the new system configuration can be significantly reduced in comparison to the previous one.
Monitoring data show very good operation and high efficiency of wet plate heat exchangers. Furthermore, the use of the plate heat exchanger eliminates the possible moisture carryover that can occur in the rotative heat exchangers normally used in DEC systems and air leakages between two airflows.
The use of a dedicated fan for the regeneration of the desiccant wheel seems to be a good solution permitting an independent control of the regeneration process.
The authors are working on the efficiency assessment of wet heat exchangers through targeted experimental tests carried out in a specific facility. Numerical simulations of the whole DEC system will be utilized to evaluate performances in other climatic conditions.

Acknowledgments

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