Monitoring Results and Energy Performances Evaluation of Freescoo Solar DEC Systems

Original
Monitoring Results and Energy Performances Evaluation of Freescoo Solar DEC Systems / Finocchiaro, Pietro; Beccali, Marco; Brano, Valerio Lo; Gentile, VINCENZO MARIA. - ELETTRONICO. - 91:(2016), pp. 752-758. (Intervento presentato al convegno Solar Heating and Cooling for Buildings and Industry (SHC 2015) tenutosi a Proceedings of the 4th International Conference on Solar Heating and Cooling for Buildings and Industry (SHC 2015)) [10.1016/j.egypro.2016.06.240].

Availability:
This version is available at: 11583/2659467 since: 2016-12-16T09:32:58Z

Publisher:
Elsevier

Published
DOI:10.1016/j.egypro.2016.06.240

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 91 (2016) 752 – 758

Energy Procedia

SHC 2015, International Conference on Solar Heating and Cooling for Buildings and Industry

Monitoring results and energy performances evaluation of freescoo solar DEC systems

Pietro Finocchiaro*, Marco Beccali, Valerio Lo Brano, Vincenzo Gentile

DEIM - Università degli Studi di Palermo, Via delle Scienze bld. 9, Palermo 90128, Italy

Abstract

This work addresses the energy saving performances of some solar Desiccant and Evaporative Cooling (DEC) systems working with the freescoo technology. The innovative freescoo concept is based on the use two fixed and cooled adsorption beds and advanced indirect evaporative cooling processes. The main feature of this new adsorption bed concept is to allow the simultaneous dehumidification and cooling of air.

The systems analyzed have been installed in Italy last here and results based on field monitoring data are here presented. A description of the monitored systems and comparisons between the energy performances based on the main performance indicators such as EER, thermal COP, cooling power, off grid operation data are shown.

Systems are provided with solar PVT collectors which produce the necessary heat for the regeneration of the desiccant and fulfil most of the need of electricity.

Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG

Keywords: freescoo, Solar DEC, Adsorption fixed and cooled bed, PVT;

1. Introduction

In common DEC systems desiccant rotors are normally used. However the adsorption process realized by means of desiccant rotors presents the disadvantage of causing a temperature increase of the desiccant material [1, 2]. This phenomenon is caused by the release to the process air of adsorption heat due to water adsorption in the desiccant

* Corresponding author. Tel.: +39 091 238 61908 ; fax: +39 091 484425
E-mail address: pietro.finocchiaro@unipa.it

Peer-review by the scientific conference committee of SHC 2015 under responsibility of PSE AG
doi:10.1016/j.egypro.2016.06.240

material and by the carry-over of heat stored in the desiccant material from the regeneration section to the process section. An increase of the desiccant material temperatures is responsible for lower dehumidification capacity and higher regeneration temperatures required, with a consequent negative impact on the overall system performance. Moreover, with the desiccant rotor technology is not possible to store adsorption capacity into the desiccant material since rotors host only low mass of adsorbent [5]. Typical thermal COP values for DEC cycles based on desiccant rotors are in the range of 0.65 – 0.75.

In this work, three solar air conditioning systems working with the innovative *freescoo* concept are presented [3, 4]. All systems presented are based on the use of fixed and cooled adsorption beds and advanced two stage evaporative cooling process.

Nomenclature

AHU	Air Handing Unit	PV	Photovoltaic
COP_{th}	Thermal Coefficient of Performance [-]	PVT	Photovoltaic/thermal
EER	Energy Efficiency Ratio [-]	Rad	Solar radiation [W/m^2]
h	Specific Enthalpy [kJ/kg°C]	T	Temperature [°C]
HX	Heat Exchanger	x	Humidity ratio [g/kg]

2. Description of the work

The first systems presented in this work are two freescoo compact units shown in Fig. 1. The system used two cooled desiccant packed-beds, which are operated in a batch process, and two wet evaporative heat exchangers connected in series. The adsorption bed is made of a fin and tube heat exchanger with the spaces between the fins filled with silica gel grains. During the dehumidification process, the adsorption material is cooled by water flowing through the tubes. A system of air dumpers provides the commutation between the two adsorption beds in order to guarantee a continuous dehumidification process.

Fig. 1. Freescoo compact prototypes installed at ENEA in Rome (left) and at UNIPA in Palermo (right)

The systems were installed in 2014 and recently updated with the aim to optimize the operation of some core components. The compact systems are basically composed by a casing which comprises a solar PVT air collector, two adsorption beds, an integrated cooling tower, two plate wet heat exchangers, fans, batteries and all other auxiliaries needed to realize the air handling process also in stand-alone operation. The maximum total cooling power is 2,7 and 5,5 kW at standard summer conditions respectively for the smaller and larger machine ($T_{outside}$ = 36°C, $RH_{outside}$ = 50%, T_{bui} = 26°C, RH_{bui} = 50%). The two systems have a total flow rate of 500 m^3/h and a collector surface of 2.4 m^2 and the other having a flow rate of 1000 m^3/h and 4.8 m^2 of collector surface. Cooling power can be controlled through variable speed fans.

Fig. 2. Desiccant AHU based on the freescoo concept

The third system presented is a AHU working with the same technology having a supply air flow rate of 2000 m^3/h. The system has been installed in 2014 on the roof of the Solar Lab of the DEIM department at UNIPA and been monitored during summer 2015. In this case the regeneration of the desiccant is carried out using the heat provided by a PV/T solar shade shelter. The maximum cooling power is about 11 kW. Maximum electric power required is approximately 1.6 kW and is mainly due to the operation of two fans, two pumps and a cooling tower. Electricity demand can be covered by the PV panels integrated in the solar collectors.

In the following table mains technical data for the analyzed systems are summarized.

Table 1. Technical data of the systems

		UNIPA	ENEA	AHU
PVT air collector surface	[m^2]	2.4	4.8	36.3
PV surface rate	[%]	48	48	58
PV peak power	[W]	170	340	2660
Solar absorber	[-]	finned	finned	flat plate
Max thermal efficiency	[-]	85%	85%	45%
Max cooling power	[kW]	2.7	5.5	10.6
Max electric consumption	[kW]	150	250	1.6
Electric accumulator	[kWh]	1.6	2.4	6.0
Supply flow rate	[m^3/h]	500	1000	2000
Fresh air	[m^3/h]	250	500	800
Ambient volume	[m^3]	190	125	450

The thermodynamic cycle of the air handing process, which is common to all of the systems analyzed, is described in Fig. 3. A flow rate of outside air (1) is drawn through one of the adsorption beds for its dehumidification and partial cooling. Due to the simultaneous moisture and heat exchange, dehumidification process is carried out at almost constant temperature (2). Afterwards, dehumidified air is mixed with the return air from the building, which is at condition (4), reaching the conditions of point (3). The mixed air enters the wet heat exchangers reaching the supply conditions at point (5). In order to produce the cooling effect, at the outlet of the second wet heat exchanger, a portion of the air flow rate is drawn to the secondary side. The heat released in the adsorption bed is rejected to a water loop which is connected to the cooling tower. The air flowing through the cooling tower comes from the secondary side of the wet heat exchangers. In this case an external cooling tower is used to reject the adsorption heat generated in the desiccant bed during the dehumidification process.

		Description	x	T	h
		-	g/kg	°C	kJ/kg
Process air	1	Outside air	16.0	36.0	77.2
	2	Adsorption bed	8.0	34.0	54.6
	3	Mixing	9.4	28.6	52.6
	5	Outlet Wet HX - prim	9.4	19.0	42.8
Building	4	Return air	10.0	26.0	51.6
Secondary air in Wet HX	5	Inlet Wet HX - sec	9.4	19.0	42.8
	6	Outlet Wet HX - sec	10.7	17.0	44.2
Cooling tower	6	Inlet CT	18.0	24.0	69.9
	7	Outlet CT	25.5	29.5	94.8
Regeneration air	1	Outside air	16.0	36.0	77.2
	8	Solar collector	16.0	58.0	100.0
	9	Outlet Desorption	24.0	39.0	100.9

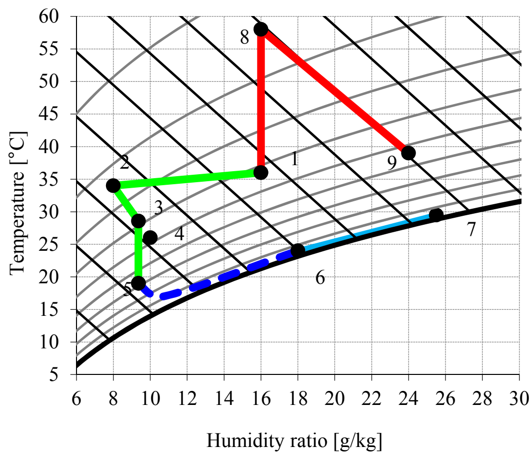

Fig. 3. Thermodynamic cycle of the freescoo concept on the psychrometric chart

3. Results and discussion

The systems presented have been monitored during the summer this year and performance results are here shown. Some information related to the monitoring conditions are given in table 2.

Table 2. Monitoring conditions

		UNIPA	ENEA	AHU
Daily hours of operation	[h]	12	10	8
Time of operation	[time]	8:00 – 18:00	8:00 – 18:00	9:00 – 17:00
Day of operation shown	[day]	40	44	13
Supply flow rate control	[-]	variable	variable	fixed

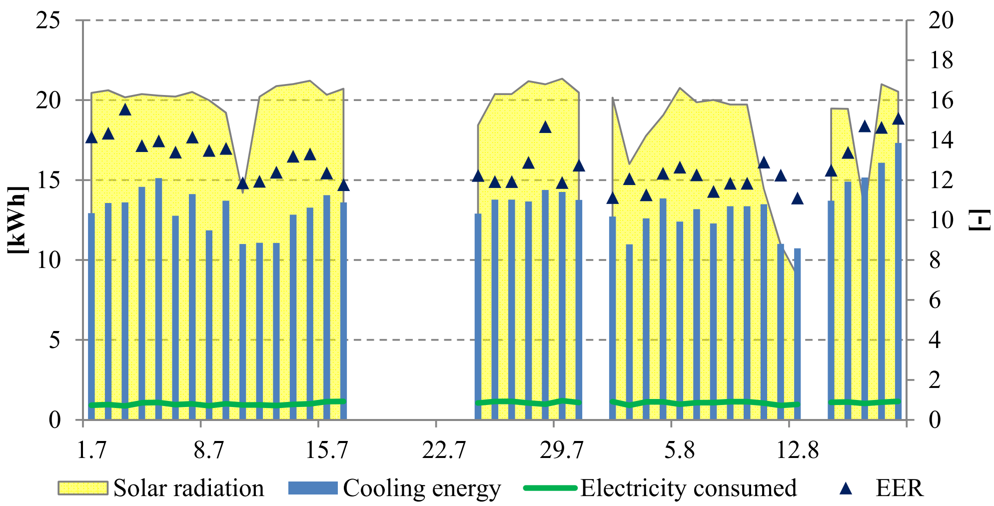

Fig. 4. Energy performance for the unit installed at UNIPA

As shown in Fig. 4, the unit installed at UNIPA could provide cooling energy from 11 to 17 kWh per day with EER values from 12 to 15. The values shown for electricity consumption and EER do not take into account the electricity produced by the PV modules. In this manner the intrinsic electric efficiency of the machine can be to assessed. The average EER calculated as the whole cooling energy delivered to the total electricity needed is 12.8 whereas the value rises up to 50.7 if only the electricity imported from the grid is considered.

Similar results have been registered for the unit installed at ENEA in Rome as shown in Fig. 5. In this case, the unit could provide daily cooling energy from 16 to 36 kWh per day with EER values from 8 to 18. The average EER calculated as the whole cooling energy delivered to the total electricity needed is now 12.4. If only the electricity imported from the grid is considered, the measured value is 43.7.

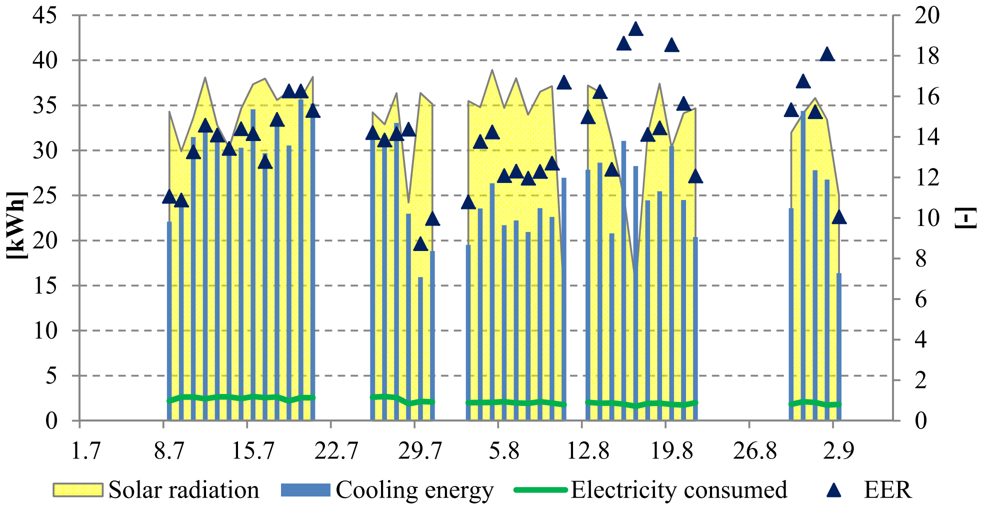

Fig. 5. Energy performance for the unit installed at ENEA in Rome

In the case of the AHU, results are quite different and in general lower performance have been registered. As shown in Fig. 6 the registered values of EER range from 3.5 to 6. The values of cooling energy delivered to the building during the considered days of operation range from 41 to 96 kWh. Electricity consumption is quite high in comparison to the compact units.

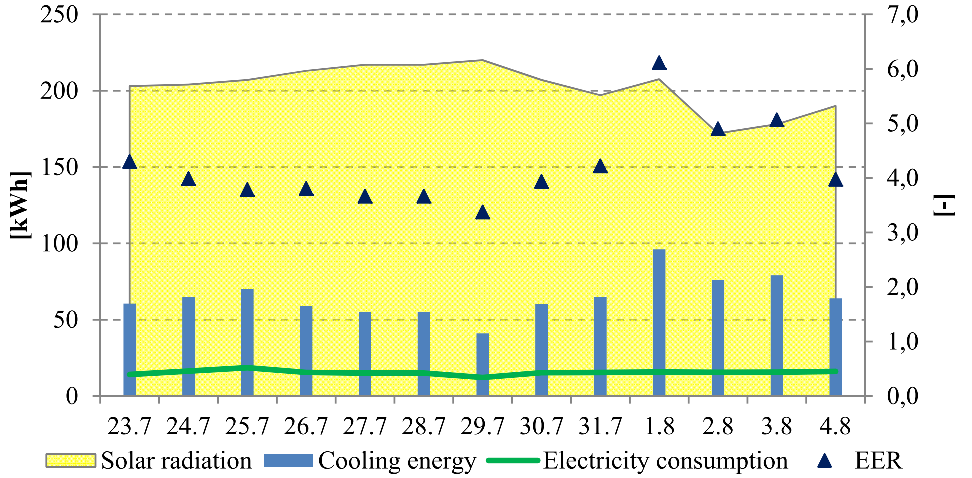

Fig. 6. Energy performance for the AHU installed at UNIPA

The reason for a lower performance in comparison to the compact units is mainly due to some air leakages in the sealing of the valves used to switch from one adsorption bed to the other and to the lower efficiency of some electrical components. In particular the efficiency of the solar fan was very poor and no speed control was included, this negatively affecting the overall electric performance of the systems.

In Fig. 7 and 8 a comparison between the systems on the basis of average daily values is shown. It has to be noted the difference between the solar radiation collected by the solar shelter of the AHU and the collectors of the compact units which is about 10 times the value for the small unit installed at UNIPA. With this regard, it has to be noted that the area of the solar shelter is about 15 times the one of the small compact unit whereas the heat production is only about 5 times. This is due to the simpler absorber used in the solar shelter which is has no fins. The measured average collector thermal efficiency is 28% for the solar shelter, 63% and 59% respectively for the UNIPA and ENEA unit. The daily thermal COP of the systems is 1,14 for the AHU, 1.10 and 1.36 respectively for the UNIPA and ENEA unit.

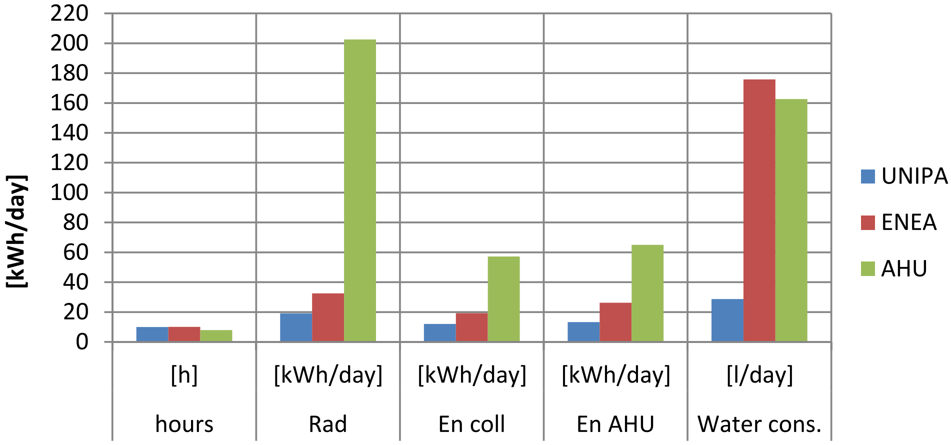

Fig. 7. Comparison of the thermal performance for the three systems

In Fig. 8 the electric performance of the three system are compared including also the indicator EER_{grid} which is the EER calculated on the basis of the energy taken from the grid. This shows that, despite the lower energy performances of the AHU in comparison to the compact units, very high EER_{grid} can be achieved using larger PV areas.

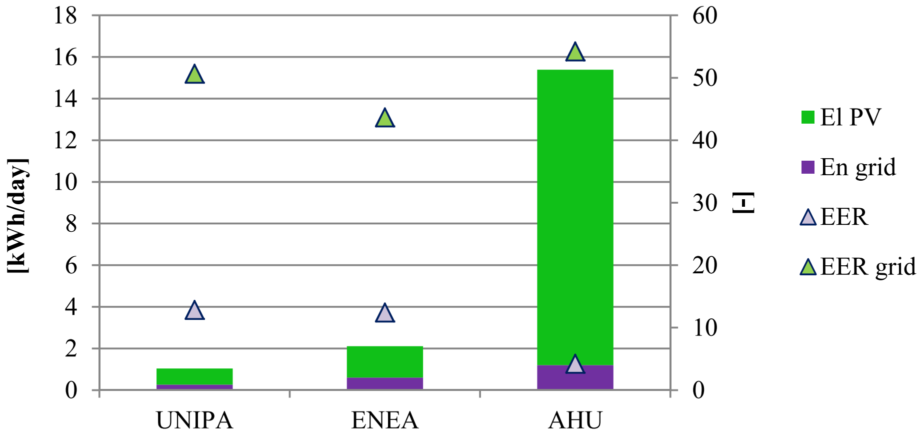

Fig. 8. Comparison of the electric performance for the three systems

4. Conclusions

This work aimed to the evaluation and comparison of monitoring results for three systems working with the freescoo technology. In general better results have been registered for the compact units in comparison to the AHU. Energy Efficiency Ratio of about 12 have been shown for the compact units whereas an average value of 4,2 was registered for the AHU. The explanation of the lower energy performance of the AHU can be given looking at some issues in the sealing of the valves of the adsorption beds and taking into account the lower efficiency of some electrical components such as the solar fan used.

Finally, if also the energy produced by the PV is included in the calculation of the EER, high values ranging from 40 to 50 are achieved.

Results presented clearly show the big energy saving potential that can be achieved using this technology in comparison to conventional air handing processes based on the use of vapor compression chillers.

Acknowledgements

This work present results related to activities carried out in the framework of two research projects, the project "*Innovative compact solar air conditioner designed for ventilation, dehumidification and cooling"* between the Italian MSE – ENEA and DEIM of University of Palermo and the Italian PON project "*Innovation for greeN Energy and eXchange in Transportation" (i-NEXT)* Activity 4.3.

References

[1] Beccali, M., Butera, F., Guanella, R., Adhikari, R.S., 2003. "Simplified models for the performance evaluation of desiccant wheel dehumidification", Int. J. Energy Res. 27, 17-29.

[2] Beccali, M., Butera, F., Franzitta V., Adhikari, R.S., 2004. "Update on desiccant wheel model", Int. J. Energy Res. 28, 1043-1049.

[3] Finocchiaro P, Beccali M, New DEC open cycle for air conditioning based on fixed cooled adsorption beds and wet heat exchangers. Proceedings of Australian Solar Cooling 2013 Conference, Australia: 11-12 Apr 2013.

[4] Finocchiaro P, Beccali M, Innovative compact solar air conditioner based on fixed and cooled adsorption beds and wet heat exchangers. *Energy Procedia* 2014; 819:827–48.

[5] Finocchiaro P, Beccali M, Gentile V. Experimental investigation of adsorption performances of an heat exchanger packed with silica gel for application in solar desiccant cooling systems. Proceedings of OTTI 5th Solar Air-Conditioning Conference, Black Forest: 25 – 27 Sept 2013, p. 210-215