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# Research on an adsorption cooling system supplied by solar energy

Robert Sekret*, Michał Turski

*Faculty of Environmental Protection and Engineering, Czestochowa University of Technology, 60A Brzeznicka St., 42-200 Czestochowa, Poland*

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ABSTRACT

In the current article, research on the possibilities for ensuring thermal comfort through the use of an adsorption cooling system supplied by solar energy is presented. The main goal was to ensure an adequate level of cooling in a referential room of 40 $m^3$ in volume. Cooling was attained by an adsorption ice water generator (AIWG) that was supplied by energy from flat-plate solar collectors. Experiments on the AIWG working conditions and an analysis of the possibilities for using solar energy in a region of Czestochowa (Poland) to supply an adsorption cooling system are also presented. The real value of the cooling efficiency of the COP coefficient for the adsorption ice water generator was 0.27, and the real global efficiency of the adsorption cooling system was 0.23. On the basis of the results, it was assumed that, in climate conditions typical for Poland, it is possible to effectively use the adsorption cooling system to keep a constant level of thermal comfort during all months in which there is a demand for cooling, i.e., between April and October.

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## 1. Introduction

An increase in the efficiency of energy use and the integration of heating and cooling systems with a higher contribution of renewable sources of energy are considered to be among the key elements for the development of new technologies to meet the energy needs of the municipal and household sectors and public utility buildings, as has been previously suggested [1–5]. A continued effort to simultaneously reduce the level of energy-consumption and increase the leak-proofing of buildings is strictly connected to an increasing demand for cooling during the summertime. The higher demand for cooling is caused by the need to deliver fresh air to reduce the $CO_2$ concentration and lower the temperature and humidity to a permissible level inside of buildings, as determined by the quality norms for the interior environment [6,7]. Currently used refrigerating compressors are supplied by electric energy, so they are using a primary source of energy. Therefore, lowering the demands for energy for heating purposes in the wintertime causes an increase in the demand for primary energy for ventilation and air-conditioning in the summertime. To avoid the increase in the demand for primary energy in the summer months, some renewable energy sources or waste heat could be used to power refrigerating systems. Such possibilities include refrigerating machines supplied by solar energy. Their maximum cooling power is received at the highest level of solar radiation, which corresponds to the time when the highest demand for cooling is observed.

## 2. Development directions

The dominating technology in the European market of solar refrigerating installations is still absorption chillers; however, some newly developing trends currently observed are directed toward reducing the use of absorption chillers [8]. One reason for this situation is the possibility of taking advantage of alternative systems, such as adsorption and open systems, when the heating medium is below 90 °C. In the Polish climate, the demand for cooling is observed between April and October. During this time, the recorded temperatures of the heating medium – measured by means of commonly used solar collectors – range from 60 to 95 °C; however, the temperature of the heating medium is usually below 80 °C (very often between 60 and 70 °C). Although the COP coefficient of the absorption cooler may have a higher value, especially with temperatures above 80 °C, a possibility of supplying the heating medium with a temperature lower than 70 °C causes that among all of the available cooling systems supplied by solar energy, the adsorption refrigerating systems have been recognized as the most advantageous for cooling rooms in Polish climate conditions.

They use renewable sources of energy in the same way as other systems; however, when one takes into consideration the lowest parameters of operation, only open systems are competitive with the adsorption systems. When the temperature of the heating medium ranges from 60 to 95 °C, the coefficient of cooling efficiency for adsorption chillers is 0.6–0.7 [9–11]. With a solid sorbent, the coefficient of cooling efficiency (COP) in open systems is 0.6–1.0

* Corresponding author. Tel.: +48 664 758109; fax: +48 34 3721304.
*E-mail addresses:* rsekret@is.pcz.czest.pl, rsekret@wp.pl (R. Sekret).

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**Nomenclature**

| | |
|---|---|
| AIWG | adsorption ice water generator |
| $CO_2$ | carbon dioxide |
| COP | cooling efficiency coefficient |
| $I$ | solar radiation intensity (W/m$^2$) |
| $p$ | pressure (hPa) |
| $Q$ | power (kW) |
| $t$ | temperature (°C) |

*Greek symbols*

| | |
|---|---|
| $\tau$ | time (min) |

*Subscripts*

| | |
|---|---|
| c | cooling |
| dave | average 24-h external temperature |
| eva | evaporator |
| g | heating water circulation |
| h | heat |
| hsn | heat stream needed for a bed regeneration |
| $H_2O$ | water |
| max | maximum |
| tech | amount of useful heat produced form solar energy |
| teo | theoretical |
| + | excess |
| 0 | initial |

(when the temperature of the heating medium ranges from 45 to 95 °C), whereas with a liquid sorbent the COP is about 1.0 (when the temperature of the heating medium ranges from 60 to 80 °C) [12]. However, the open systems, working as an aerial set, become particularly ineffective when the heat gains are significant. In that event it is necessary to remove heat excess from a building by increasing the air circulation in a room. A critical defect of open systems is the limited possibility of their use. They may be operated only in such conditions when the air is cooled at a central air-conditioning unit and when the air treatment depends on its cooling. An additional constraint is the inability to achieve a low temperature for the air supply. Using the temperature of external air at summertime, 30 °C, the calculated minimum temperature of the supply air which could be obtained is 18 °C. All these factors have a negative impact on obtaining the desired levels of the supply air. Therefore, the adsorption refrigerating systems supplied by solar energy appears to be the most promising solution to the problem [13].

The construction and use of adsorption refrigerating systems of low power, supplied by solar energy, is still an uninvestigated issue in Poland. As of yet, there are no official guidelines for constructing a low power adsorption ice water generator (AIWG) for Polish climate conditions. A deeper analysis of the possible use of a low power AIWG to obtain thermal comfort in rooms, relevant to external atmospheric conditions, has also not been conducted. After a critical analysis of the available literature as well as our own scientific experiments, a model low-power AIWG and cooling system supplied by solar energy has been constructed for the lowering of the temperature in buildings to obtain thermal comfort.

## 3. A concept for the adsorption cooling system

### 3.1. A referential room

The proposed concept of the adsorption cooling system supplied by solar radiation energy has been analyzed for a referential room with a volume of 40 m$^3$. The following parameters were determined for the room:

- External walls with surface area of 37.1 m$^2$, an internal cement-and-calcareous plaster work and a structural clay tile (MAX type), and thermal isolation consisting of expanded polystyrene, a net, and a thin-layer external plaster work.
- A glass surface with southern orientation and an area of 3 m$^2$.
- An Ackerman ceiling under a loft with an area of 15.8 m$^2$.
- A floor on a ground with an area of 15.9 m$^2$.

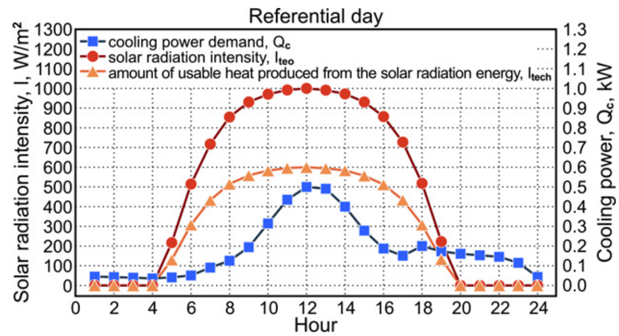


**Fig. 1.** The hourly demand for the cooling power for the referential room over the referential day.

In the conducted calculations, Polish climatic conditions were considered. The specific conditions were presented previously [14,15]. The maximum cooling power of an AIWG is related to the average hourly levels of solar radiation intensity for a referential day in the summertime. The day with the highest intensity of solar radiation was chosen. By conducting a balance of the excesses and losses of heat, the maximum level of the cooling power of the AIWG was found to be 500 W. A summary of data regarding the demand for cooling in the referential room, with regard to the intensity of the solar radiation, is presented in Fig. 1.

On the basis of the calculations, it was concluded that the maximum demand for the cooling power occurred after 12:00 h. In the considered case (i.e., during the day of the maximum heat profits), it was necessary to cool the room during the entire 24-h period, including at night. Between 20:00 and 4:00 h, the demand for the cooling power was in the range from 50 to 200 W. In calculations one took into account external heat profits from the solar energy, and also internal heat profits received from 2 persons as well as electrical devices and lighting system. In the period between 20:00 and 4:00 h the main role was played by the internal profits. In calculations one took into account external heat profits from the solar energy, and also internal heat profits received from 2 persons as well as electrical devices and lighting system. In the period between 20:00 and 4:00 h the main role was played by the internal profits.

To ensure the required level of heat to drive the refrigerating machine during the entire day-and-night period, it was also necessary to design accumulators of heat and coldness for the cooling system. These accumulators allowed for the storage of an excess of the thermal power that was used during the night to drive the AIWG. Analogously, the stored excess of coldness was used when the intensity of the solar radiation was insufficient.

### 3.2. Description of a test stand

The test stand comprised four basic modules: a generation module, an accumulation module, a transmission module and an energy usage module. A diagram of the test stand, with descriptions of the devices and locations of the measurement points, is presented in Fig. 2. The basic devices and their descriptions are given below:

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