SOLAR COOLING WITH ADSORPTION CHILLERS

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Abstract: Solar cooling for small-scale application is quite a new topic if it comes to practical applications. SorTech AG, founded in 2002, is one of the few manufactures of small scale adsorption chillers and on the market for 5 years now. Within this time over 200 projects were established all over the world. With these projects a lot of experience in planning, installation, and operations of thermal cooling systems has been gathered.
As an example a solar cooling installation in Austria will give an insight of performances, efficiencies, and potentials of this technology.

Keywords: solar cooling, thermal cooling, adsorption chiller, SorTech AG, SolCoolSys, solar cooling installation

1 OVERVIEW

The following paper shows an example of the strong influence of installation on the performance of a solar air-conditioning system. The data given are drawn from a project which was carried out within the German funded project “SolCoolSys”, targeting at the development of standard solar cooling applications. The installation was performed in Mürzzuschlag, Austria with the collaboration of the companies SOLVIS and PINK. The system was monitored by Fraunhofer ISE.

The paper exhibits the performance data after the first installation and again after a subsequent adaption of the hydraulics and the control strategy, which lead to a significant increase in cooling capacity and electrical COP. Furthermore, a detailed analysis is given how installation conditions are affecting the performance data of the adsorption chiller.

2 COMPANY’S PROFILE

SorTech AG, founded in 2002 as a spin-off of the German Fraunhofer-Institut für Solare Energiesysteme ISE, is one of the first companies in Europe which offers commercial products for small scale solar cooling application. Since 2007, SorTech offers silica gel based adsorption chillers with cooling capacities starting from 5 kW to 15 kW per unit (see Figure 1). In the meantime more than 200 projects mainly in Europe, but as well in Africa, North America, Asia, and Australia could be realized with cooling capacities up to 150 kW (e.g. Patent Office in Munich).

In addition to the adsorption chillers SorTech AG product portfolio covers:

- standard cooling packages, consisting of chiller, heat dissipation unit, and hydronic pump station,
- customized cooling systems,
- detailed planning and installation support.

Figure 1: Adsorption chiller ACS 08 / ACS 15

Besides silica gel technology SorTech acquired a deep know-how in zeolite coating technology (Figure 2), which provides coating of almost any aluminium (Al) alloy based three dimensional structures. Unique feature of this technology is the crystallization of zeolite directly on aluminum based surfaces. This provides high energy density and therefore compact heat exchanger for SorTech's next generation sorption chillers and heat pumps.

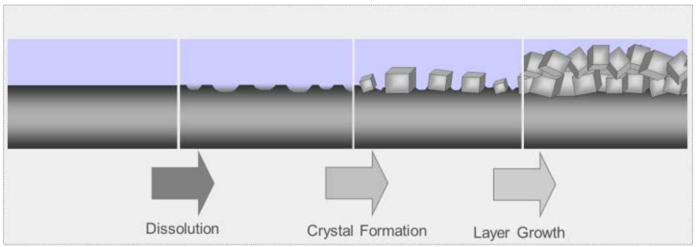

Figure 2: Crystallization process (left); Al-alloy sponge suitable for zeolite coating (right)

3 EXAMPLE OF SOLAR COOLING INSTALLATION

The following example of a solar cooling application provides an idea of the potential and performance of such a system. This solar cooling application has been established within the German funded project "SolCoolSys", targeting at the development of standard solar cooling applications.

Figure 3: Solar Cooling Professional School, Mürzzuschlag, Austria (left: Solar thermal collector; right: Adsorption Chiller ACS08)

3.1 Technical facts

Basic technical facts of the installation are shown in Table 1.

Table 1: Technical facts of installation

Chiller type	ACS08; 8kW cooling capacity at nominal conditions
Primary Heat (hot temperature) source	31 m²; flat panel
Secondary Heat source	gas burner
Heat (middle temperature) sink	heat dissipation unit with spraying system (type RC08)
Cooling task (chilled water):	Workshop studio and bureau via fan coil units
Year of commissioning	June, 2011

A gas burner and two hot water storages have been installed to provide the system with heat, independently of solar radiation and to bridge operation phases with high thermal energy consumption (e.g. at the beginning of each sorption cycle).

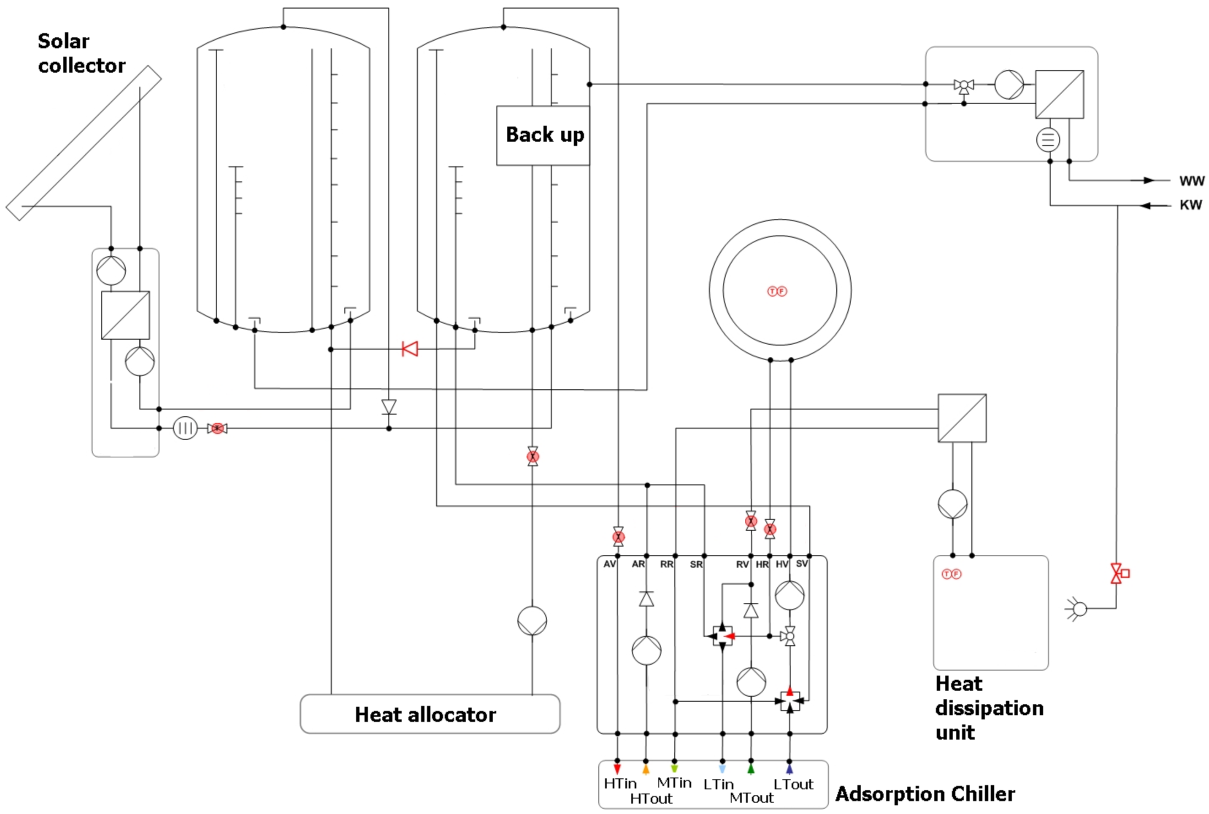

Figure 4: Hydronic diagram of connections

The system has been equipped with additional components to provide free cooling (using the heat dissipation unit for cooling at low ambient temperatures) and heating as well. Due to the lack of practical and performance experiences of solar cooling systems this system has been monitored. Therefore temperature sensors, flow meters, electric meters, etc. were installed in order to measure the behavior and the performance of the system. The results were analyzed and provide the basis for improvements of the system. The results of this monitoring are given in the next paragraph.

3.2 Results

The main focus of the monitoring is set to cooling capacity and electrical COP as performance and efficiency parameters. The cooling capacity is determined by the three temperature levels of the adsorption process. The electrical COP, as the ratio of cooling power and electrical consumption of common auxiliaries, is mainly determined by the heat dissipation unit with the highest electrical consumption of the system.

The definition of the electrical COP is similar to the definition of the COP of conventional systems and shows the main advantages of thermal cooling systems: electrical energy is only used for common auxiliaries (e.g. pumps, heat dissipation units, controlling). The electrical COP of thermal systems, therefore, can reach a multiple of conventional systems.

Figure 5 shows typical charts of the monitoring (displayed period: approx. 4 hours around midday):

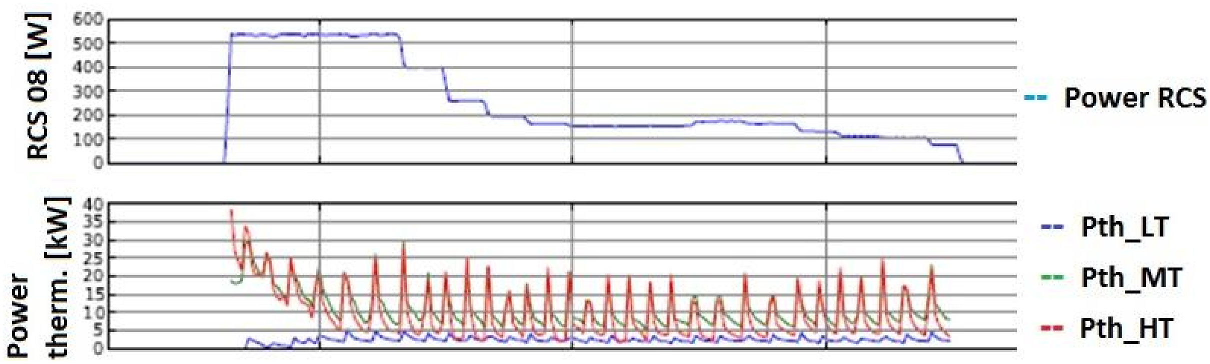

Figure 5: Chart example: characteristic of the solar cooling system

Upper diagram - electrical consumption of the heat dissipation unit:
To reduce the electrical consumption the heat dissipation unit adapts the speed of its fans to the cooling load – the lower the load, the lower the speed and electrical consumption. At the beginning of operation the heat dissipation unit runs at maximum speed to achieve the cooling task. Along with operation time the speed is reduced to a minimum due to lower cooling loads.

Lower diagram - heat flows:
Here the typical characteristic of the heat flows (driving heat – red chart, dissipation heat – green chart, and cooling power – blue chart) are shown with its high peaks at the beginning of each sorption cycle.

In the following the improvement of the solar cooling system is shown. Therefore, the results for cooling capacity and electrical COP before and after system improvements are compared to each other. The results have been achieved under similar weather conditions and representing average values of a one day monitoring. The monitoring of the system started in summer 2011. During winter and spring 2012 the improvement of the system took place.

The results after commissioning of the solar cooling system are shown in Table 2.

Table 2: Results before improvements

Cooling capacity	max. 3 kW
Electrical COP	< 5

The performance and efficiency is below expectation. In order to improve the system's performance and efficiency both, constructional and control oriented adaptations have been done based on the monitoring results. Basic adaptations of the systems are shown in Table 3.

Table 3: Monitored effects and adaptation of the system

Monitored effect	Effect on the system	Reason & System adaptation
High temperature differences between heat dissipation unit and ambient temperature	• High heat dissipation temperature and therefore low cooling power and electrical COP	• Heat exchanger was connected wrongly → reconnecting heat exchanger • Wrong control strategy of heat dissipation unit → control algorithm has been updated
Cooling power to low	• Risk of condensation on cooling devices due to low temperature • Low electrical COP	• Full cooling load was not yet available → expanding cooling task

After the first monitoring phase the system could be improved due to the adaptations. Actual performance and efficiency of the system is shown in Table 4.

Table 4: Results after improvement

Cooling capacity	3 to 5 kW
Electrical COP	6 to 15

4 FACING CHALLENGES

These results and the experiences with other solar and thermal cooling systems show, performance and efficiency depend, like in any other applications, on correct planning, installation, and operation. Table 5 shows different operation parameters and the effect on performance and efficiency. To give an idea of the effects the impact of each parameter on performance and efficiency is given in numbers for a concrete example.

Example:
A cooling task is given with 5.5 kW cooling load and a predicted electrical COP of approx. 11.2.

Table 5: Effects on performance and efficiency

Parameters influencing the performance	Effect on performance
Flow rate of driving and cooling circuits are less than nominal flow rate (e.g. – 200l/h each)	- 10% (5kW instead of 5.5kW)
Insufficient air bleeding of hydronic system	- 5% (5,3kW instead of 5.5 kW)
Driving Heat temperature is less than planned (e.g. 65°C instead of 75°C)	- 25% (4.1kW instead of 5.5kW)
All effects	- 40% (3.3kW instead of 5.5 kW)

Parameters influencing the efficiency	Effect on efficiency
wrong pumps (e.g. low end pumps instead of high efficiency pumps)	- 10% (10.1 instead of 11.2)
higher ΔT in heat dissipation cycle due to wrong installation (e.g. heat exchanger)	- 38% (7 instead of 11.2)
All effects	-42% (6.5 instead of 11.2)

Our experiences of more than 5 years solar cooling for small scale application in Europe show:

- Robust operation mode of the adsorption chiller and good performance are shown in over 200 SorTech installations
- Solar Cooling means today: detailed planning
- Concept and dimensioning are crucial factors for the energetic and monetary outcome: „rules of thumb" do not work!
- Not every application is suited for thermal cooling! (e.g. very low cold water temperatures are reached only efficiently under certain conditions.

5 SUMMARY AND POTENTIAL

Experiences show that solar cooling can be a good alternative to conventional cooling systems. The market for thermal cooling, however, is still small but high potential due to ecological and economical advantages. Besides solar cooling application the market for thermal cooling using waste heat at low temperature level (<100°C for absorption systems; <80°C for adsorption systems) and the combination of co-generation units with sorption chiller is promising. Nevertheless, for market development the following issues are crucial for the success of thermal cooling in future:

- Reducing cost for both, chiller and components
- Increasing power-to-mass-ratio
- Developing of standard systems for easy installation and operation
- Increasing awareness level of solar cooling technology.

6 NOMENCLATURE

ACS08	Adsorption Chiller Silica Gel, 8 kW nominal cooling capacity
Electrical COP	ration of cooling power and electrical power of auxiliary equipment
Pth_MT	(thermal) dissipation heat
Pth_HT	(thermal) driving heat
Pth_LT	cooling power
RCS08	heat dissipation unit

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