Overview on Small Capacity Systems

Dr. Uli Jakob
SolarNext AG
Nordstrasse 10, 83253 Rimsting, Germany
Tel.: +49 8051 6888-400
E-Mail: uli.jakob@solarnext.de
Internet: www.solarnext.de

1. Introduction

In Europe various new sorption chillers with small capacity have been developed during the last few years. Many of these absorption and adsorption chillers have now passed over from prototype stadium into field tests and production, so that a rising amount of products is expected within the next few years. The market potential for solar cooling with small capacity is very large, so that different companies are developing solar cooling systems for the product business. The sale figures of conventional electrically driven compressor chillers (split-units) with a cooling capacity range up to 5 kW are rising rapidly. In Europe the number of sold units has risen about 53% from 5.3 million in 2004 to predicted 8.1 million in 2007 [1]. Therefore an all-season use of renewable energy sources for hot water, space heating and solar cooling is here indispensable. Therefore the latest small capacity solar cooling system developments from system providers as well as sorption chiller manufacturers are presented.

2. Small Capacity Chillers on the Market

Since 1977 the company Yazaki, Japan has been offering water/lithium bromide (LiBr) absorption chillers with 35, 70 and 105 kW cooling capacity [2], whereas the 35 kW machine is the most used absorption chiller for solar cooling systems worldwide until now. A novel 17.5 kW LiBr chiller is offered in Europe since 2008, e.g. by SolarNext as chillii® WFC 18. EAW from Germany offers water/LiBr absorbers with 15 kW to 200 kW cooling capacity, which were developed for solar cooling and CHP applications, respectively. The company Sonnenklima, Germany carries out field tests on different European locations with a 10 kW LiBr chiller, the suninverse 10.
A further LiBr chiller with low cooling capacity is being developed and analyzed through field tests by Rotartica, Spain since a few years. With measured 4.2 to 5.1 kW cooling capacity COPs of approximately 0.42 were achieved [3], whereas the used rotating absorber enables working with dry re-cooling – an important advantage at small-scale systems. The table 1 shows the different technical specifications and performance data of these chillers.

Table 1: Comparison of different market available small capacity absorption chillers

Company	Yazaki	EAW	Sonnenklima	Rotortica
Product name	WFC-SC5, chillii® WFC18	Wegracal SE15	suninverse 10	Solar 045
Technology	Absorption	Absorption	Absorption	Absorption
Working pair	H_2O/LiBr	H_2O/LiBr	H_2O/LiBr	H_2O/LiBr
	 (source: Yazaki)	 (source: Schüco)	 (source: Sonnenklima)	 (source: Rotartica)
Cooling capacity [kW]	17.6	15	10	4.5
Heating temperature [°C]	88 / 83	90 / 80	75 / 65	90 / 85
Recooling temperature [°C]	31 / 35	30 / 35	27 / 35	30 / 35
Cold water temperature [°C]	12.5 / 7	17 / 11	18 / 15	13 / 10
COP	0.70	0.71	0.77	0.67
Dimensions (WxDxH) [m x m x m]	0.60 x 0.80 x 1.94	1.75 x 0.76 x 1.75	1.13 x 0.80 x 1.96	1.09 x 0.76 x 1.15
Weight [kg]	420	660	550	290
Power [W]	72	300	120	1,200 (incl. ventilator)

Avoiding crystallization in conventional absorption chillers causes high effort, but the company Climatewell in Sweden uses exactly this principle of crystallization of high concentrated lithium chloride solution (LiCl) to arise the internal storage tightness. To expel the refrigerant water out of the salt solution and to crystallize out two boxes with salt solution, totally 88 kWh thermal heating is needed. First chillers with a cooling capacity range of 7 to 10 kW have been in the field test in Spain since 2005 [4].

Since the end of the year 2006 the company SolarNext, Germany exclusively distribute a 10 kW ammonia/water (NH_3/H_2O) absorption chiller, the chillii® PSC10 as shown in Table 2. The chiller is a product of the company Pink in Austria, which uses a newly developed membrane pump [5]. The driving temperatures are according to cold water temperature and possibility of re-cooling (wet cooling tower or dry cooler) in the range of 75 to 85°C.

Table 2: Comparison of different market ready small capacity ab-/adsorption chillers

Company	Climatewell	SolarNext	SorTech	SJTU
Product name	Climatewell 10	chillii® PSC10	ACS 08 chillii® STC8	SWAC-10
Technology	Absorption	Absorption	Adsorption	Adsorption
Working pair	H_2O/LiCl	NH_3/H_2O	H_2O/Silica gel	H_2O/Silica gel
	 (source: Climatewell)	 (source: Pink/SolarNext)	 (source: SorTech)	 (source: SJTU)
Cooling capacity [kW]	10	10	7.5	10
Heating temperature [°C]	83 / -	85 / 78	75 / 67	85 / 79
Recooling temperature [°C]	30 / -	24 / 29	27 / 32	30 / 36
Cold water temperature [°C]	- / 15	12 / 6	18 / 15	15 / 10
COP	0.68	0.63	0.53	0.39
Dimensions (WxDxH) [m x m x m]	1.20 x 0.80 x 1.60	0.80 x 0.60 x 2.2	0.79 x 1.06 x 0.94	1.80 x 1.20 x 1.40
Weight [kg]	875	350	260	1,600
Power [W]	170	300	57	200

One problem of closed adsorption chillers is the poor heat transfer between the solid adsorber like packages around a heat exchanger and the heat transfer medium. A construction of adsorption chillers with very short cycle times in the area of minutes is only possible using coated heat exchangers with adsorption material. Two different small capacity adsorption chillers are available on the market (Table 2). The German company SorTech has developed a new water/silica gel adsorption chiller with 7.5 kW cooling capacity, which is for example being distributed as chillii® STC8 by SolarNext. A further 10 kW water/silica gel adsorber was developed by the Shanghai Jiao Tong University, China. The adsorber was produced yet by the Chinese company Jiangsu Shuangliang Air Conditioner Equipments [6].

3. Solar Cooling Systems

A few European solar companies have established during the last years on the market as system providers for small capacity solar cooling systems up to 30 kW cooling capacity. These solar cooling systems basically include solar thermal

collectors with attachments, hot water storage, pump-set, chiller, re-cooler and partly cold water storage and system control.

The average value of the specific collector surface of all until the year 2006 installed solar cooling systems (small to large capacity range) in Europe is about 3 m²/kW. A value from 3 to 3.5 m²/kW can be considered as a reference value for thermal driven absorption and adsorption chillers [7]. But these values are only rough reference values and can never replace the detailed design and simulation of a system. The specific total costs of installed solar cooling systems in Europe are so far between 5,000 and 8,000 EUR/kW. For 2008 system prices of 4,500 EUR/kW are reached, in the next two years 3,000 EUR/kW are expected for small capacity solar cooling systems.

3.1 CitrinSolar

At present the German company CitrinSolar uses the SorTech adsorber for there small capacity system. First experiences with the chillii® STC6 are gained since the beginning of the year 2007 at CitrinSolar Headquarter in Germany (Figure 1). The adsorption chiller is used for air-conditioning of the offices and training classrooms. A 16.5 kW dry cooler is applied, whose fan can be infinitely adjusted depending on fluid temperature and some further factors. The distribution of the cold is realized by both fan coils as well as with connection to the ventilation system. For simultaneous operation the driving energy is provided by 24 m² flat plate collectors. In order to ensure high solar fraction further collectors can be connected achieving an overall collector surface of up to 90 m². The surplus thermal heat is transferred into storage tanks with an overall volume of 7,500 litres. A further storage tank of 1,000 litre capacity is integrated into the cooling cycle thus enabling to preserve a specific quantity of cooling energy and cope with power peaks exceeding the nominal load of the chiller. An oil as well as biomass boiler is used as back-up. So far it can be stated that the chillii® STC6 is most suitable for the operation with solar heat. At heating temperatures at about 75ºC the nominal cooling capacity of 5.5 kW is achieved. The possibility of the adsorption chiller to still produce cold at a heating temperature of 55ºC is a most essential advantage compared with an absorption chiller.

Figure 1: Solar air-conditioning system of CitrinSolar with flat plate collectors on the façade and on the flat roof as well as the chillii® STC6 adsorption chiller (sources: CitrinSolar)

3.2 Schüco

Schüco International, Germany distributes the LB 15 and LB30, both water/LiBr absorbers of EAW. Until now Schüco installed seven solar cooling systems in Europe [8]. One of these installations is realized at the company Buddenhagen in Germany [9]. The re-cooling of the waste heat of the Schüco LB15 with 15 kW cooling capacity occurs through fountain water. Furthermore the system consists of 37.5 m² roof-integrated flat plate collectors (Figure 2) as well as two 700 litre hot water storages and a 1 m³ cold water storage.

Figure 2: Roof-integrated flat plate collectors of the solar cooling system Buddenhagen and absorber LB 15 (sources: Schüco)

3.3 Phönix/Enus

The companies Phönix Sonnenwärme (e.g. Phönix Solaire in France) and Enus, Germany offer in Europe a solar cooling system based on the suninverse 10 from Sonnenklima. One of the latest installations in 2007 is the Haribo Museum in Uzés, France, where 35 m² flat plate collectors (Figure 3) and 3 m³ hot water storage are used for the heat source. The cold distribution of the water/lithium bromide suninverse 10 chiller is realized by floor cooling. For the recooling of the chiller spring water is used.

Figure 3: Building integrated flat plate collectors of the Haribo Museum in Uzéz, France and suninverse 10 in the technical room (sources: Sonnenklima)

3.4 SolarNext

Different small capacity chillii® Solar Cooling & Heating Kits based on the chillii® STC8, chillii® PSC10 and chillii® WFC18 are developed by SolarNext, Germany. SolarNext also use absorption chillers of EAW and Yazaki for its chillii® Solar Cooling Systems. In total 15 small capacity solar cooling systems are installed up to now in Germany, Austria, Malta, Canada and Australia [8]. One of these installations is the new training centre and office building of Bachler Austria, Austria. A complete solar cooling system with biomass back-up has been installed there between winter 2006 and spring 2007. The chiller that is used is a chillii® PSC10 for 9 kW required cooling capacity and as recooler a 26 kW wet cooling tower as well as in addition a swimming pool. The wet cooling tower is operated with very low re-cooling temperatures of 24/29°C for the Middle-European application. The requested solar heat is delivered by 40 m² flat plate collectors, which are mounted at the façade and on the ground (Figure 4) and is stored in three hot water storages with 1.5 m³ each. The cold distribution is done by concrete core activation (cooled ceilings) with cold water temperatures of 16/19°C and a dew point thimble for cooling of the training and office rooms.

Figure 4: Training centre and office building Bachler Austria with chillii® PSC10 (sources: SolarNext)

A retrofit installation in an existing office building is the chillii® solar cooling and heating system of SolarNext in Germany, which was realized 2007. For the office cooling an EAW Wegracal SE15 with 15 kW cooling capacity and a wet cooling tower with 35 kW re-cooling capacity at usual re-cooling temperatures of 27/33°C were installed. 37 m² flat plate and 34 m² vacuum tube collectors on the flat roof (Figure 5) are providing the necessary solar heat. An existing oil burner is used as back-up. Two 1,000 litre hot water storages and 1,000 litre cold water storage are installed in the system. The cold distribution is done at cold water temperatures of 18/15°C partly through cooled ceilings and fan coils. The system is also used for space heating during the winter.

Figure 5: Flat plate and vacuum tube collectors on the roof of the SolarNext provide the chillii® solar cooling and heating system, the heart of the system is an EAW Wegracal SE15 (sources: SolarNext)

3.5 Sol-ution

The Austrian company Sol-ution offers a small capacity solar cooling system based on the adsorption chiller from SorTech and different Alaska-Sets based on the absorption chillers of EAW. The previous headquarter of Sol-ution is cooled by solar since 2005. For this an EAW Wegracal SE15 chiller with 15 kW cooling capacity is used for the retrofit installation. The necessary driving heat is provided by 40.5 m² flat plate collectors (Figure 6). A 2.000 litre hot water storage acts as a buffer as well as a 800 litre cold storage. A wet cooling tower with 35 kW recooling capacity is used to reject the waste heat of the absorption chiller. The cold distribution is realized by cooled ceilings which are also used during winter time for heating of the office rooms.

Figure 6: Flat plate collectors on the roof and EAW Wegracal SE 15 absorption chiller in the technical room of Sol-ution in Sattledt, Austria (source Sol-ution, EAW)

4. Conclusion

Worldwide the energy consumption for cold and air-conditioning is rising rapidly. Thermal cooling by solar energy or district heating or waste heat from CHP units could be lead to a considerable reduction of energy consumption and CO_2 emissions. In the small capacity range up to 30 kW several water/lithium bromide absorption chillers, one ammonia/water absorber as well as two water/silica gel adsorption chillers are market-ready available in Europe. Assumptions for single-effect sorption chillers is above all a very high solar fraction (more than 70%) or, even better a complete solar cooling and heating system, because low COPs lead rapidly to higher primary energy consumptions, if an additional heating system has to be used. Because of the general trend in Europe to larger solar thermal plants for the heating support, small capacity sorption chillers offer good opportunities to use efficiently the summery heat. First system providers are acting on the market with small capacity solar cooling systems.

5. References

[1] 71 Mio. Klimageräte – neuer Weltrekord. *cci* (2007) No. 9, p. 30

[2] Niemeyer J., Absorption technology for solar air-conditioning. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 342-345

[3] Izquierdo M., Lizarte R., Marcos J.S., Palacios E. and Burguete A., Cooling with a 4.5 kW air-cooled single effect LiBr/H_2O absorption unit (Rotartica 045v). *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 612-617

[4] Bales C., Bolin G., Nordlander S. and Settenwall F., Solar driven chemical heat pump with integral storage – the thermo-chemical accumulator. *Proceedings of the 1st Int. Conference Solar Air-Conditioning* (2005) Bad Staffelstein, 6-7 October 2005, pp. 63-67

[5] Jakob U. and Spiegel K., Entwicklungen und Projekte mit Ammoniak-Wasser-Kältemaschinen kleiner Leistung, *Proceedings of the 5th Symposium Solares Kühlen in der Praxis* (2008) Stuttgart, 14-15 April 2008, pp. 167-176

[6] Wang D. Z., Xia Z. Z., Wu J. Y., Wang R. Z., Zhai H. and Dou W. D., Study of a novel silica gel-water adsorption chiller. Part I. Design and performance prediction. *International Journal of Refrigeration* (2005) Vol. 28, pp. 1073-1083

[7] Henning H.-M., Solare Klimatisierung – Stand der Entwicklung. *erneuerbare energien* (2005) No. 2, pp. 7-11

[8] Rosenthal W., Die kleinen Kühlmaschinen kommen. *Neue Wärme* (2008) No. 3, pp. 34-35

[9] Koeln H. and Heppelmann M., Product presentation of a solar assisted cooling system based on absorption technology. *Proceedings of the 2nd Int. Conference Solar Air-Conditioning* (2007) Tarragona, 18-19 October 2007, pp. 353-358