10th International Symposium on District Heating and Cooling

September 3-5, 2006

Tuesday, 5 September 2006

Sektion 6 b

Substations and user behaviour

Innovative absorption chillers for air conditioning of small buildings

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Innovative Absorption Chillers for Air Conditioning of Small Buildings

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1 Abstract

Air conditioning (AC) of buildings gains increasingly weight in Germany and Europe in the future. Due to the climatic changes on the one hand and the increasing demand for air conditioning of commercial and residential buildings on the other hand there is a growing demand for AC technologies.

Today, innovative absorption chillers are available on the AC market which are characterized by compact size and which stands out by the fact that they are suitable for the connection either to a district heating network or to other kinds of external heat sources. These newly developed absorption chillers show a good performance ratio already at temperatures between 70 - 85 °C.

MVV Energie operates a small absorption chiller with a nominal refrigerating capacity of 10 kW as a field trial in an office building. MVV Energie regards this technology as relevant for the future, since the use of district heating (DH) as an energy source for AC is an ecological alternative to electricity-driven systems. For DH companies this technology promises an increase of sales during the summer period, for consumers it shows an economical alternative in times of rising electricity prices.

2 Introduction

The AC market is expanding rapidly in Europe, as shown in Figure 1. The growth of AC is partly related to the differences in climatic conditions but also to the development of the tertiary sector especially office buildings. Several previous studies show that the next two decades will see an increasing demand for AC technologies.

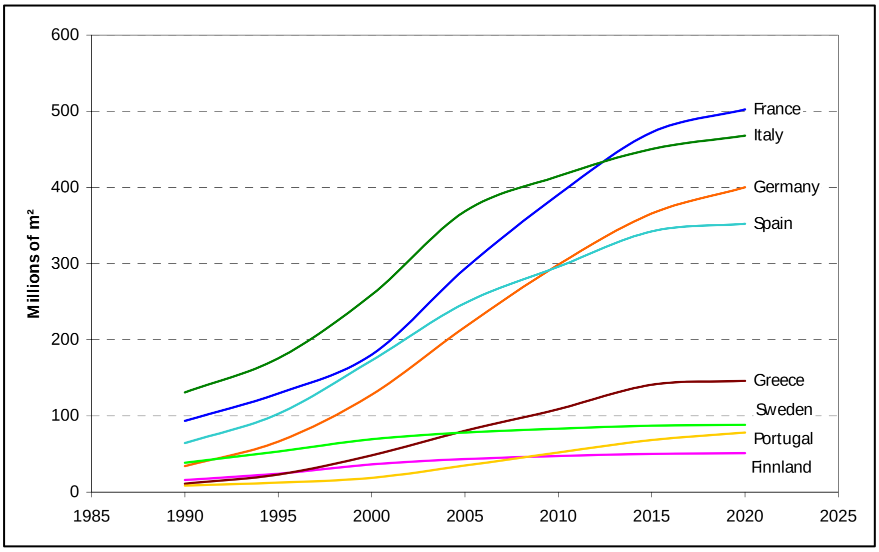

Figure 1: Evolution of cooled-floor area from 1990 to 2020 at the national level [1].

Referring to the EECCAC-Study from 2003 [1], the cooled area "per European" is projected to rise from 3 to 6 square meters over the next 20 years, resulting in a total demand for cooling of 300 TWh for EU-15 countries[1] in 2020. In Germany e.g. the demand for cooled-floor area will rise by a factor of 10 until the year 2020 (basis 1990). New results of the ECOHEATCOOL Project [2] predict an even stronger increase for EU-15 countries. According to the study the cooling demand for these countries will show a four fold increase between 2000 and 2018, corresponding to 500 TWh. For the German market which is in the focus of this paper the total cooling demand is predicted to rise from 45 TWh in 2000 up to 134 TWh in 2018, corresponding to an average annual increase of 17%.

Taking this data as a basis for a future scenario it is obvious that there is a high potential for technological developments. Innovative products are needed which fulfil the demand for energy and cost efficiency as well as sustainability. Today, the global market for AC technologies is dominated by electricity based systems. Assuming, the expected growth of the market is achieved by installation of electricity-driven technologies, this will result in an additional load to electricity networks. Although there are regional differences throughout Europe, it is evident that today's networks are not dimensioned for these additional loads. Already today the electricity-driven AC systems cause a bottleneck in supply during hot summer days in southern Europe. Furthermore, the ongoing discussion on the environmental impacts of halogenated refrigerants used in today's compression chillers show the need for environmentally friendly solutions. Especially these two negative impacts of conventional systems result in a growing demand for alternatives.

Within this context absorptions chillers gain importance. Absorption chillers use heat as primary energy and not electrical power as it is the case for conventional compression chillers. The benefits of this technology compared to compression chillers are the dramatically reduced electrical power consumption and the more efficient use of primary energy. As an external heat source either a central DH system or a decentralised heat source such as solar heat or waste heat from a CHP plant could be utilized for chilled water generation. As the heat demand is seasonal and especially low during summer time, AC through an absorption chiller allows for an increase in efficiency of the heat plant while displacing less environmentally friendly alternatives [2].

The absorption technology is well-known in large scale for industrial and commercial buildings, e.g. shopping-centres, hospitals or office buildings. Statistical data for Germany give a number of 750 absorption chillers installed in the year 1998 with a total cooling capacity of approximately 1.000 MW [3].

[1] EU-15 countries according to EUROSTAT: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.

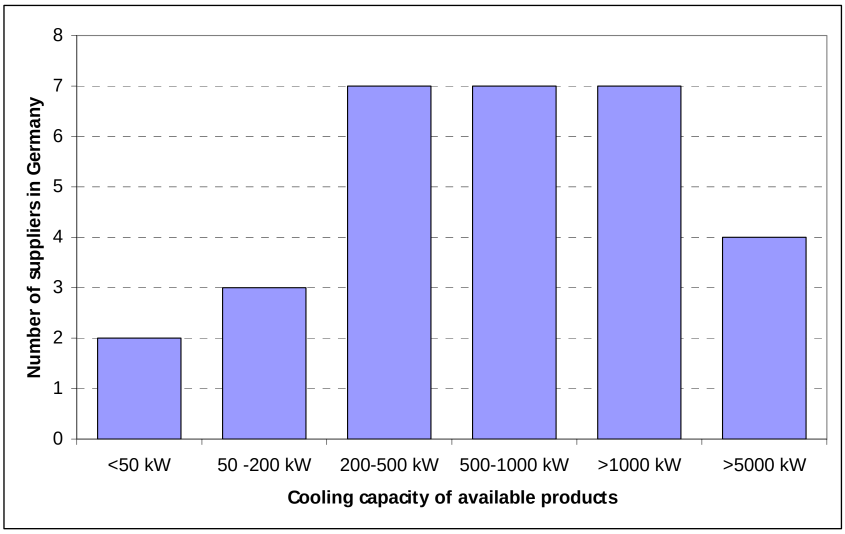

Figure 2: Survey of the German market for absorption chillers with LiBr/H_2O as refrigerant [3].

Figure 2 gives a survey of the German market for absorption chillers. One can see that most products are available in the range of 200 – 5000 kW cooling capacity. Only two suppliers offer products for AC with cooling capacity below 50 kW.

This paper focuses on an innovative absorption technology designed for the market sector of small buildings with a cooling demand below 50 kW. This segment of the total cooling market is up to now dominated by electricity-driven systems.

3 Material and Methods

3.1 Economical analysis

For an economical analysis a small absorption chiller with a refrigerating capacity of 10 kW was compared to two compression chillers of same nominal capacity. In order to ensure comparability of all three systems the following assumptions had to be made:

- All systems are connected to a cold water system with a supply temperature of 15°C and a return temperature of 18°C.
- The absorption chiller additionally needs a wet cooling tower and an heat exchanger as connection to the DH system.
- The absorption chiller is installed nearby the DH network. Extended connecting pipes are not necessary.
- Annual costs include costs of capital, costs for heat and electricity consumption, and operating costs.
- Capital Costs are calculated for a life cycle time of 15 years and an interest rate of 6%.
- Costs for energy and water are calculated depending on annual operating hours.
- Operating costs include costs for operation and maintenance.

Specific annual cost *c* are calculated according to equation 1:

$$c = \frac{C_C + C_O + C_E}{Q_C} \qquad \text{equation 1}$$

with

C_C: costs for capital [EUR],

C_O: costs for operation and maintenance [EUR],

C_E: costs for energy supply (heat, electricity) [EUR],

Q_C: annual cooling energy [kWh].

3.2 Pilot installation

MVV Energie operates a 10 kW absorption chiller as a field trial in cooperation with PHÖNIX SonnenWärme AG, Berlin. In the demonstration project the PHÖNIX absorption chiller uses heat from the DH network as an energy source. The chiller is connected to the chilled water system of an office building. The wet cooling tower has been installed outside the building on the roof.

3.3 Technical data

The PHÖNIX absorption chiller is a compact single-stage machine designed for low driving temperature (table. 1). The chiller runs similar to the general absorption process with a H_2O/LiBr-solution as refrigerant [4]. The chiller supplies chilled water at 15/18°C (nominal evaporator capacity 10 kW) using a hot water driving temperature of 75/65°C (nominal generator output power 14 kW) and cooling water of 27/35°C. The refrigerating capacity supplied by the chiller can be modulated between 4 and 16 kW by shifting the temperature of the hot water between 55°C and 105°C. In this range a coefficient of performance (COP) > 0,78 can be achieved [5].

COP is calculated according to equation 2:

$$COP = \frac{\dot{Q}_E}{\dot{Q}_G + P_{el}} \qquad \text{equation 2}$$

with

$\dot{Q}_E$: evaporator capacity [kW],

$\dot{Q}_G$: generator power [kW],

P_{el}: electrical power [kW].

Specifications		Unit	PHÖNIX DA 1	
nominal refrigerating capacity		kW	8,8	10
nominal refrigerating capacity		USRT	2,5	2,8
nominal refrigerating capacity		BTU/h	30026	34120
chilled	temperature (in-out)	°C	12-6	18-15
water circle	mass flow	m^3	1,3	2,9
	internal pressure drop	mbar	350	
	connection		1" outside thread	
hot water	temperature (in-out)	°C	85-75	72-62
circle	mass flow	m^3/h	1,2	1,2
	internal pressure drop	mbar	200	
	connection		¾" tube	
cold water	temperature (in-out)	°C	35-27	35-27
circle	mass flow	m^3/h	2,6	2,6
	internal pressure drop	mbar	320	
	connection		1" outside thread	
electrical	voltage	V	230~1 ph 50Hz	
connection	solution pump	W	70	
	refrigeration pump	W	50	
Dimensions	hight	mm	1847	
	width	mm	653	
	depth	mm	855	
weight	operation	kg	350	
	transport	kg	300	

Table 1: Technical data of the PHÖNIX Absorption Chiller 10 kW [4].

3.4 Experimental setup

Figure 3 shows a schematic of the pilot installation. The generator is connected to the DH network, the evaporator feeds the central chilled water system. These two water cycles are hydraulically separated by heat exchangers. A wet cooling tower is installed outside the building. As the building has a much higher cooling load than 10 kW, the absorption chiller supplies the base load. As a consequence the machine runs at constant power output for an average summer day. The absorption chiller is equipped with an control unit including data logger for external temperatures and mass flow. All water cycles are equipped with flow meters as well as sensors for temperature and pressure. Power input and output is calculated according to equation 3:

$$\dot{Q}_i = \dot{m}_i \cdot c_P \cdot \Delta T_i \qquad \text{equation 3}$$

with

$\dot{Q}_i$: power [kW],
$\dot{m}_i$: mass flow [kg/s],
c_P: specific heat coefficient [J/kg K],
ΔT_i: gradient between supply and return temperature [K],
i: index for type of cycle (hot-, cold- and chilled water).

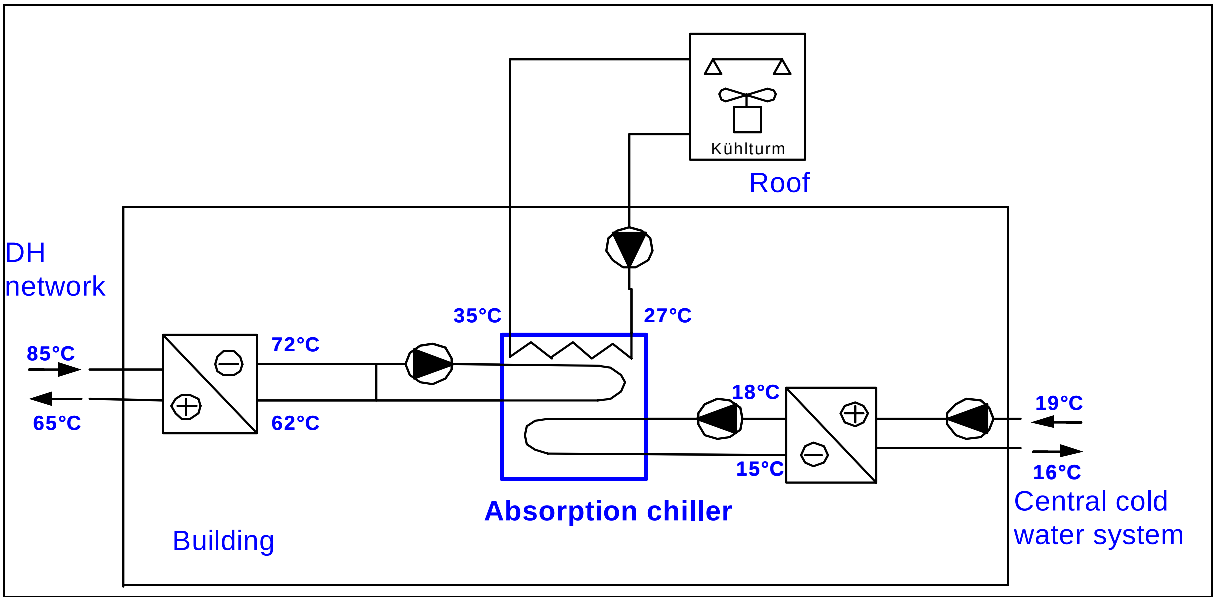

Figure 3: Schematic of the pilot installation at MVV Energie

4 Results and Discussion

4.1 Economic comparison

Results from an economical comparison of three alternative chillers are depicted in Table 2. The calculation reveals that specific costs for AC decline with rising annual operation time. Specific costs range between 0,30 EUR/kWh at 700 h and 0,08 EUR/kWh at 4700 operating hours. An operating time of 700 h represents an average office building in Germany with five working days per week. 4700 hours are characteristic for an office building with additional continuous AC of an IT-server room.

The analysis shows that annual operating time has an significant influence on economics of AC systems. The importance of a long operation period predominates compared with the type of technology that is used.

The results of the study reveal that compression chillers have only minor economic advantages in the class of small AC systems. Only at very low annual operation hours compression chillers show relevant advantages compared to the absorption chiller.

Annual operating time	**[h]**	**4730**	**2560**	**1350**	**970**	**700**
Absorption Chiller	[EUR/kWh]	0,09	0,12	0,18	0,23	0,3
Compression Chiller 1	[EUR/kWh]	0,08	0,11	0,16	0,2	0,26
Compression Chiller 2	[EUR/kWh]	0,09	0,12	0,18	0,22	0,29

Table 2: Specific annual costs versus operating time for 10 kW chillers

4.2 Experimental data

Figure 4 and 5 show the typical performance of the absorption chiller at the pilot installation. Data was recorded on a sunny day in September with an average AC load of the building. Figure 4 gives the supply and return temperatures in the three water cycles in the course of a day. This diagram shows that the absorption chiller supplies the base load for the building. Therefore an almost constant temperature profile throughout the day was achieved.

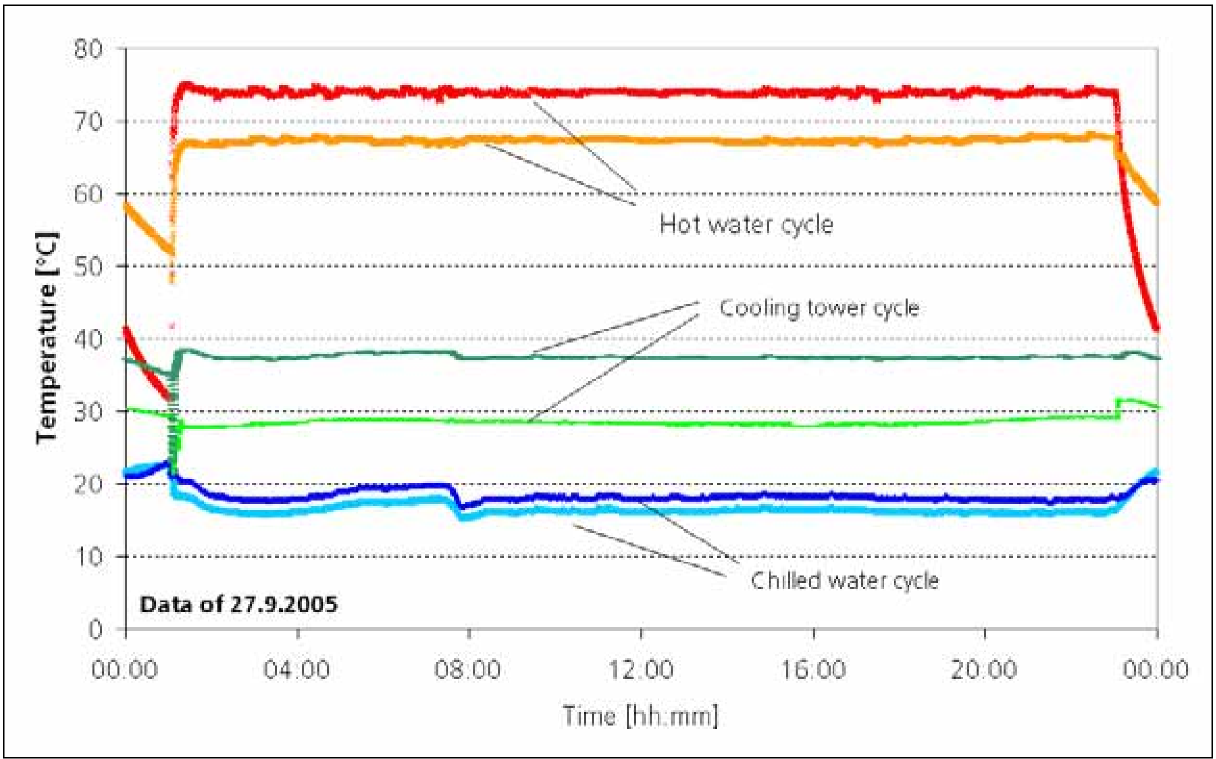

Figure 4: Supply and return temperatures of the absorption chiller at 65% load.

Figure 5 shows input and output power in the heating, chilling and cooling cycle, as well as the resulting COP for the same day. The absorption chiller runs at an average of 65% of nominal refrigerating capacity. The average power input from the DH system is 8,5 kW with a temperature gradient of 6,5 K. It can be observed that after an initial start-up period the evaporator capacity reaches a constant level throughout the day. The cooling tower capacity results from the evaporating capacity and the generator output power.

A drop in refrigerating capacity in the morning can be observed, which results from the beginning of the working day and the start of the central AC system.

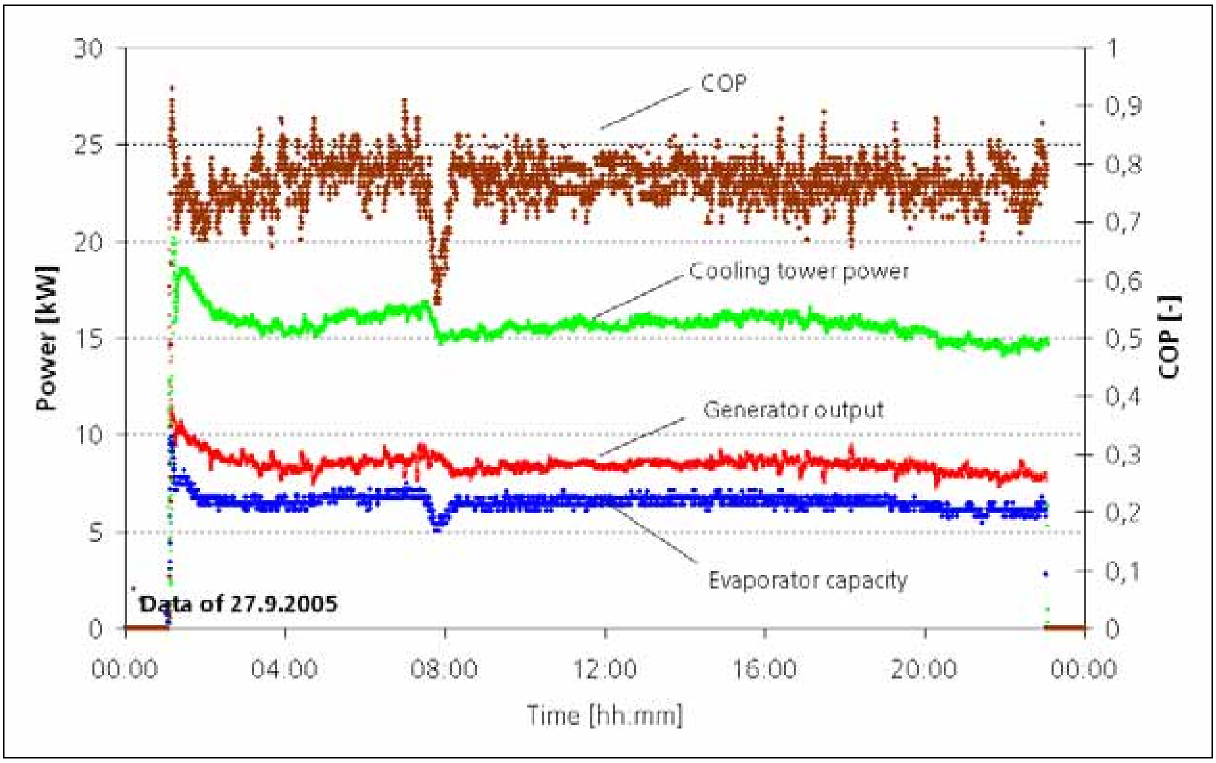

Fig 5: Input and output power of the absorption chiller at 65% load.

5 Conclusions

The economical and experimental results for the pilot installation with a newly developed absorption chiller of 10 kW nominal refrigerating capacity are promising. An economic analysis has shown that absorption chillers could become an interesting alternative to conventional compression chillers for the market segment of small office and residential buildings. Especially the ecological benefits of the absorption technology and the much lower electricity demand compared to compression chillers are unique selling positions.

The experimental data of the pilot installation confirm the expected performance of the machine. Although the pilot installation was operated at 65% of nominal capacity a COP of 0,8 was achieved. At a supply temperature of 74°C the absorption chiller can be utilized also in DH systems with reduced supply temperatures during the summer.

For DH companies this technology promises an increase of sales during the summer period, for consumers it shows an alternative to compression chillers in times of rising electricity prices.

6 References

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