DEVELOPMENT AND INVESTIGATION OF AN AMMONIA/WATER ABSORPTION CHILLER - chillii® PSC - FOR A SOLAR COOLING SYSTEM

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Abstract

This paper presents the development and investigation of the solar thermally driven chillii® PSC, a novel single-effect, ammonia/water absorption chiller with nominal cooling capacities of 5, 10 and 20 kW, for a solar cooling system. The system is developed for residential, commercial, and district heating/cooling applications. The chillii® PSC has a compact design, which is based on the previous development of Pink GmbH and is currently optimised in cooperation with the SolarNext AG. The peculiarities of the chiller are the mechanical solution controller, the special design of the membrane pump for the solution circulation and the vertical falling-film tubular absorber, respectively. For air-conditioning the heating temperatures are 75/68°C (heat source: solar, district heat, CHP unit), at cooling water temperatures of 24/29°C (wet cooling tower) and cold water temperatures of 19/16°C for cooled ceilings.

1. Introduction

The market of solar cooling is still small: today in Europe approximately 12 MW of cooling capacity are installed [1]. These are about 100 up to 120 solar cooling systems, which use solar thermal collectors for the solar air-conditioning of buildings. Most of the systems are realized in Germany (39.1%), Spain (27.5%) and Greece (8.7%). The IEA SHC Task 38, Solar Air-conditioning and Refrigeration, determined that approximately 60% of the installed systems are absorption chillers. Therefore the SolarNext AG develops complete small-scale solar cooling systems based on the chillii® PSC to offer a well-engineered system to the market.

2. Absorption Chiller chillii® PSC

The chillii® PSC10 is an ammonia/water absorption chiller with 10 kW cooling capacity (Figure 1). For the air-conditioning system the heating temperatures are 75/68°C, cooling water temperatures of 24/29°C (wet cooling tower) and cold water temperatures of 19/16°C for cooled ceilings leads to a COP of 0.64. At the same recooling temperature producing cold water temperatures of 12/6°C for fan coils heating temperatures of 85/78°C are required. The dimensions (length x depth x height) are 0.8 x 0.6 x 2.2 m and the operation weight is approximataly 350 kg.

Figure 1: chillii® PSC10 absorption chiller

2.1 Novel Membrane Solution Pump

Centrifugal pumps according to standard cannot be used in small, continuously working absorption chillers with the working pair ammonia/water, since they have a low efficiency and the seals do not reach the necessary service life. The use of gear pumps is not possible due to the high wear and the large noise generation. Commercially available piston diaphragm pumps fulfill the requirements of these applications but they are large, heavy and cost 30 to 40% of the entire chiller. An appropriate solution pump was developed for this purpose and successfully used in a number of machines. The Figure 2 shows the latest generation of the solution pump which is even part of the latest chillii® PSC absorption chillers.

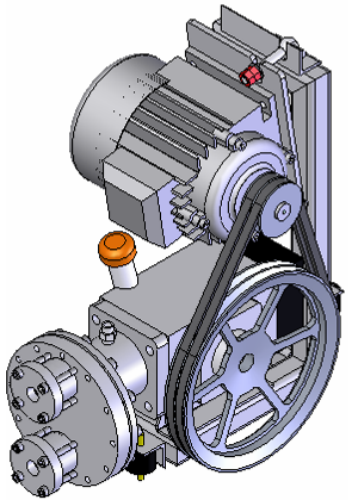

Figure 2: Novel membrane solution pump

The diaphragm head with the poppet valves is put on commercially available medium pressure piston pump. The free running diaphragm is moved by oil pad. The driving power transmission takes place via two v-belts from a 0.55 KW asynchronous engine (power consumption approximately 0.25 kW). The intake pressure and the outlet pressure are 2 to 20 bar, respectively.

2.2 Falling Film Absorber and Evaporator

To realize a compact absorber heat exchanger with high efficient mass and heat transfer the chillii® PSC absorption chiller is equipped with a self developed falling film tubular absorber. A unique distribution system feeds the inside of the heat exchanger pipes with a certain amount of the poor working solution. To control the speed and the thickness of the falling film it is stabilized by inserts within the pipes.
The advantages of the falling film technology are also used for the evaporator of the chillii® PSC. The vertical tubular evaporator is supplied from the top by a particularly developed feeding system for a uniform distribution of the refrigerant. Due to this design it is able to work as a dry evaporator. This fact allows an easy handling of the remaining water within the refrigerant without the need of a periodical emptying.

3. Solar cooling installation

The pilot plant of a complete solar cooling system with biomass back-up, based on the chillii® PSC, has been set up and installed during winter 2006 and spring 2007 in the new training centre and office building of Bachler Austria GmbH in Gröbming (Figure 3). The building is a two-storied building with façade and ground mounted flat plat collectors.

Figure 3: Training centre and office building Bachler Austria GmbH, Gröbming
(source: Bachler Austria)

This system (Figure 4) includes a 9 kW ammonia/water chillii® PSC, three 1.5 m³ hot water storage tanks with charge and discharge management, 40 m² of flat plate collectors, a 26 kW wet recooling tower and an additional swimming pool recooling system, which is in preparation. 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.

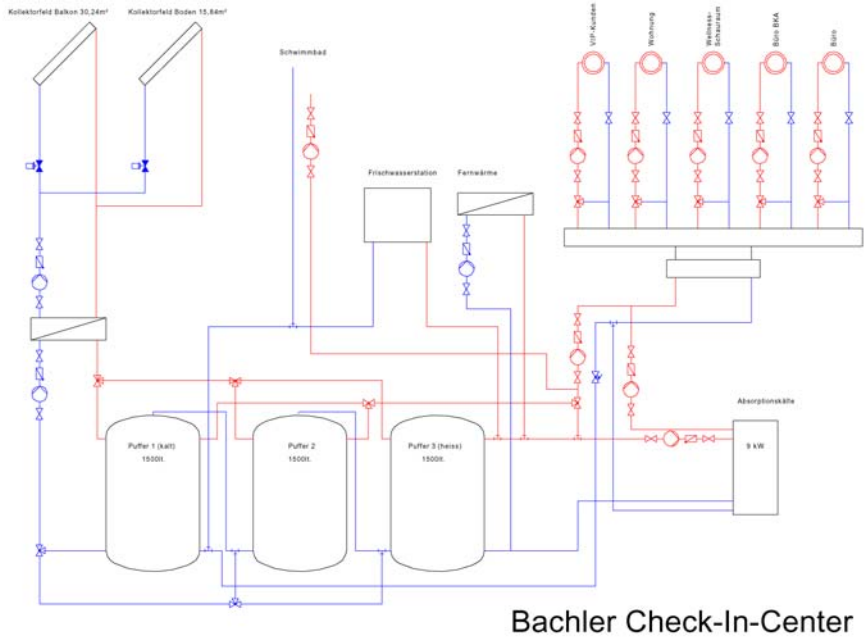

Figure 4: Simplified schematic view of the solar heating and cooling plant at Bachler Austria (source: Steiner-Haustechnik)

4. Experimental results

So far it can be stated that the chillii® PSC10 is most suitable for the operation with solar heat. At heating temperatures at about 75ºC the required cooling capacity of 9 kW is achieved at Bachler Austria (Figure 5). The lowest logged heating temperature to start the chillii® PSC is 65°C. With this low driving temperatures the chillii® PSC10 will assert its position under practical operation.

Figure 5: chillii® PSC10 with wet cooling tower

5. Test Stand

At the new test stand at Pink, which was installed in spring/summer 2007 (Figure 6), the performance date of any thermally driven chiller or heat pump up to 40 kW heating capacity and 60 kW recooling capacity can be evaluated. The hydraulic scheme allows to have three different circuits for hot water, cooling water and cold water while the cold water circuit is prepared to run with brine as well. This is an important option to be able to simulate even applications using cold water temperatures below 4°C. The complete site is controlled by a programmable logic controller (PLC) connected to a personal computer to allow automatic simulation runs and online data logging.

Figure 6: Test stand for the chillii® PSC at Pink

There is a further experimental test stand at SolarNext for testing closed absorption or adsorption chillers with cooling capacities up to 20 kW under various controlled conditions. The chillii® PSC10 will be implemented and tested during autumn 2007. Therefore inlet temperatures and flow rates of all of the three external circuits passing the chiller can be adjusted independently from each other over a wide range. This provides the possibility of testing the behaviour of chiller or heat pump in any condition. Absolute temperatures, temperature difference between inlet and outlet of every heat exchanger may be varied as well as every state of part load operation can

be simulated. The setup facilitates simultaneous testing of recooling components nearly independently from current chiller testing conditions as the circuits are indirectly in contact through a buffer storage but may as well be run almost stand alone. Current recooling devices are one dry cooling tower and alternatively for lower re-cooling temperatures a hybrid or wet cooling tower, all using ec-ventilators.

There is data acquisition with direct feedback for the controlled process variables. Data for operation modes like the simulation of solar based heating in the course of day, taking into consideration the effects on recooling and cooling demand corresponding to specific weather data files, may be externally given and all measurement values accordingly recorded. Thus this experimental setup provides a year round testing facility for all kind of small size heat pumps. The ability to simulate all user-defined conditions renders research of the potential of chillers especially within solar cooling systems possible.

6. Conclusion

A small-scale ammonia/water absorption chiller with nominal 10 kW cooling capacity, the chillii® PSC10, is presented for a novel solar cooling system. Up to now the first experiences of the installed solar cooling installation at Bachler Austria GmbH office building showed that the solar cooling system works very well. The lowest logged start heating temperature is 65°C.

The introduced test stands at Pink and SolarNext for testing the chillii® PSC with cooling capacities up to 20 kW shows the possibility of testing the behaviour of chillers in any condition.

References:

[1] Henning H.-M. “Overview on solar cooling”, Proceedings of the 3rd European Solar Thermal Energy Conference – estec 2007, Freiburg, Germany, 2007 June 19-20