DEVELOPMENT OF A NEW 2.5KW ADSORPTION CHILLER FOR HEAT DRIVEN COOLING

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SUMMARY

Besides (better) utilisation of available solar heat or waste heat, and thereby reduction of fossil fuel consumption, sorption cooling offers several other advantages compared to conventional compression cooling. Such as reduction of summer peaks in the electricity grid, natural refrigerants, and less noise & maintenance. Sorption cooling in itself is not a new development. However, the development of small scale sorption chillers (2-20kW) is new. This development allows sorption cooling to enter the markets for individual homes, small collective systems and small commercial applications. A second trend is gradual reduction of the driving temperatures of the sorption cycles allowing more solar and waste heat to be used. This article describes the design and performance of a new, innovative 2.5kW adsorption chiller, developed by ECN. For this chiller ECN is currently searching for suited commercial parties, for production and commercialization.

INTRODUCTION

Sorption cooling is a technology that uses heat to generate cooling. Compared to conventional compression cooling, sorption cooling offers several advantages, e.g.:

- Using heat instead of electricity reduces peaks on the electricity grids in the summer.
- Many sorption cycles are based on natural refrigerants.
- Using thermal compression reduces noise levels and maintenance requirements.

In recent years several companies have started development of small capacity sorption chillers, with cooling power below 20 kW, as was shown at the IEA Heat Pump

Conference 2008 in Zürich. Some of these efforts have already led to commercial products. With these new developments the market for thermally driven cooling in single family homes and small commercial applications is opening up. A second trend is gradual reduction of the driving temperatures of sorption cycles to well under 100°C (typically 80-90°C). This allows for an increase in the use of e.g. solar heat and industrial waste heat (via district heating systems).

Triggered by the national potential of waste heat (e.g. from industry) and renewable heat (e.g. from the sun) the Energy research Centre of the Netherlands (ECN) has initiated development of sorption cooling technology several years ago. As a working pair silica gel – water was chosen, a choice that has proven successful so far.

WORKING PRINCIPLE ADSORPTION COOLING

Just like a conventional compression chiller, an adsorption chiller uses a cycle where a refrigerant condenses at high pressure/temperature and evaporates at low pressure/temperature. However, this cycle is not driven by a mechanical compressor but by a thermal compressor, based on the sorption reaction of silica gel and water, using heat as driving force. Dry silica gel (a porous, glass-like solid) attracts and adsorbs water vapour, until it's saturated. Then it needs to be regenerated; heating the silica gel releases the water vapour at a pressure that allows it to condense at ambient temperatures. Then the cycle of adsorption and desorption can be repeated.

This cycle is not unlike absorption cycles (with e.g. LiBr-solution), however there are 2 important differences: 1. the silica gel can be regenerated efficiently at lower driving temperatures and 2. the silica gel is a solid that can not be pumped from generator to absorber. The silica gel is applied on heat exchangers which are supplied intermittently with hot and cooling water. The adsorption cycle is a batch process and for quasi-continuous cooling at least 2 silica gel beds (reactors) are needed, operating in counter-phase.

The lowest possible chilled water temperature of this adsorption cycle is about 4°C, making it perfectly suited for air-conditioning and chilled water systems in the built environment and in industry.

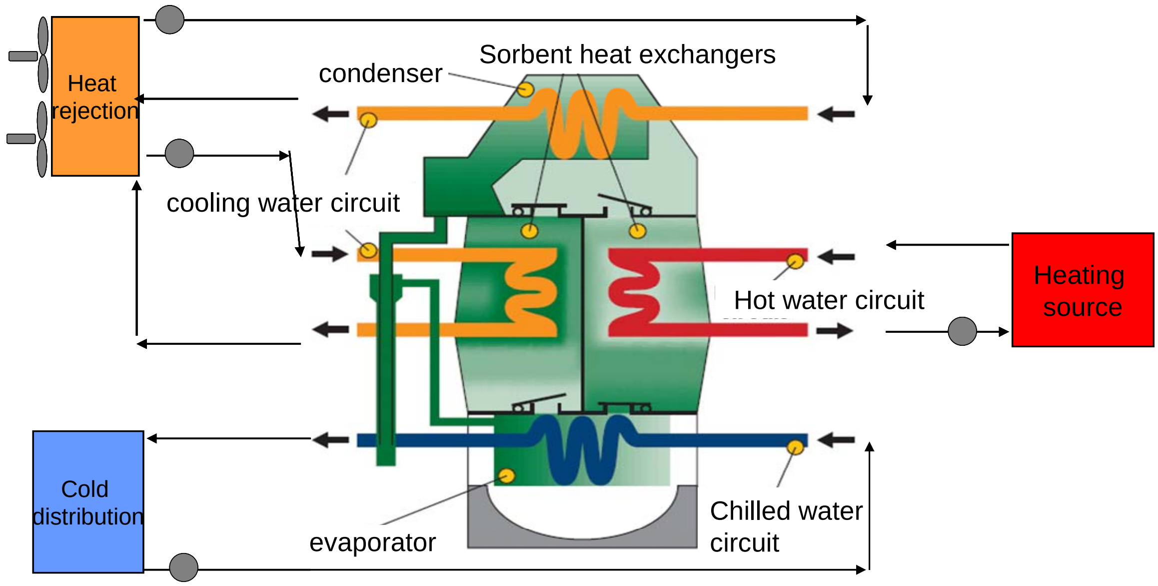

Figure 1: Schematic of adsorption chiller lay-out

DESIGN 2.5kW ADSORPTION CHILLER

Within the European project PolySMART (www.polysmart.org), ECN has developed a small-scale adsorption chiller, using silica gel - water as working pair, which will be tested and demonstrated. Starting point for this chiller is to supply sufficient cooling power for a modern single family house (2.5kW). For the size, a common (challenging!) standard for household appliances is used: a 60x60cm footprint (height is about 100cm).

In the design of this chiller compact light-weight aluminium heat exchangers from the automotive industry are used to apply the silica gel, creating a large surface while maintaining low weight and volume. For the same reason this type of heat exchanger is also used for the condenser and for the evaporator. Figure 2 shows the lay-out of the new chiller: the evaporator at the bottom, two silica gel reactors above the evaporator and on top the condenser.

Water vapour flows at low pressure from the evaporator (creating a cooling effect) and is adsorbed in one of the two silica gel reactors (adsorption phase). At the same time, water vapour flows from the other reactor to the condenser (desorption phase) at higher pressure. Between these components special check valves have been placed to prevent the water vapour from flowing back. This (low pressure) process requires that the system does not contain any other gases or vapours besides water vapour and that all components are hermetically sealed. The water from the condenser flows back to the evaporator via a condensate return line. The flow for heating and cooling of the silica gel is controlled by 8 valves, which intermittently supply both reactors. To control these valves and to monitor temperatures and pressures, a PLC unit is included in the chiller.

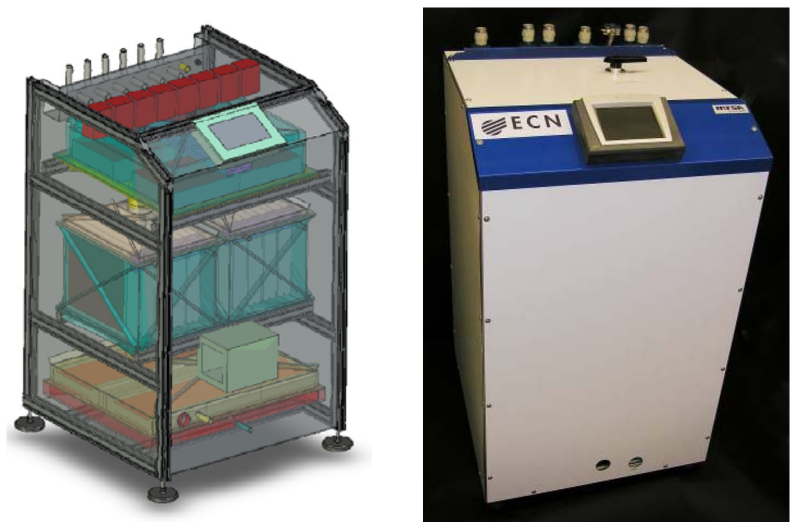

Figure 2: Design drawing and picture of the ECN 2.5kW adsorption chiller

ADSORPTION CHILLER PERFORMANCE

The adsorption chiller has been tested in an ECN laboratory, with the facilities to control flows and temperatures for hot, cooling and chilled water. Hot, cooling and chilled water temperatures strongly influence the chillers' performance. As nominal operating conditions the following inlet temperatures are set: 80°C, 30° and 15°C respectively. Under these conditions the influence of cycle time on thermal performance has been determined. The cycle time is the duration of a complete cycle of heating up and cooling down of one reactor. Figure 3 shows the cooling power (left axis) and Coefficient of

Performance (right axis, ratio of cooling power and driving heat). The graph shows that cycle times under 6 minutes are not useful, because both cooling power and COP show a decrease (because this short cycle time does not allow all silica gel to go through the complete temperature cycle). At increasing cycle times (>10 minutes) a decrease in cooling power is compensated by an increase in efficiency (because less changes between heating and cooling of a reactor means less thermal losses).

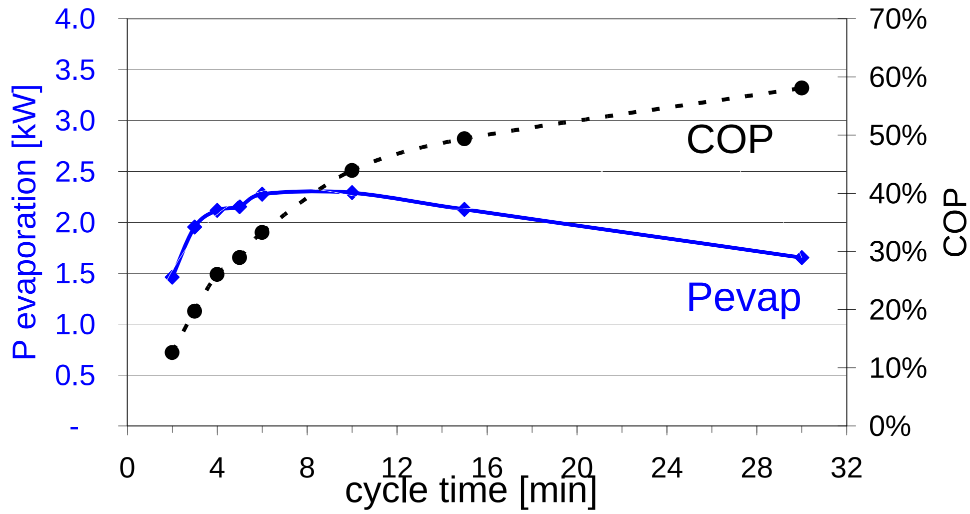

Figure 3: Influence of cycle time on thermal performance of the adsorption chiller

Figure 4 shows the influence of the cooling water and chilled water inlet temperature on the chillers' performance. Chiller performance clearly benefits from "high temperature cooling" and relatively low cooling water temperatures. When designing a complete (solar) cooling system these influences have to be taken into consideration.

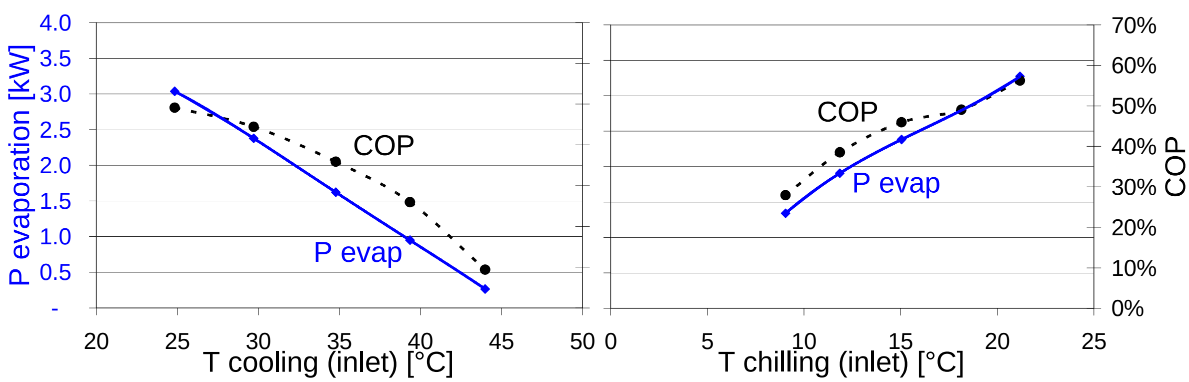

Figure 4: Influence of cooling water (left) and chilled water (right) inlet temperature

The laboratory tests show that the ambitious design specifications for this prototype have been achieved. Nearly 2.5kW cooling power can be produced with a very compact chiller (power density of about $7 kW/m^3$) at a very respectable COP.

OUTLOOK

This 2.5kW chiller has recently been installed in one of the research houses at the ECN premises in Petten, The Netherlands. These research houses are not inhabited, but nearly all aspects of user behaviour is simulated (such as domestic hot water use, internal heat production, and humidity and CO_2 production), offering a realistic but controlled test environment.

Within the framework of the PolySMART project, this chiller will be driven by a small cogeneration unit (microCHP), creating a unique micro-trigeneration system. For heat rejection a standard dry cooler is used. This configuration will be tested until the summer of 2010. Intention is to create a follow-up demo project with a solar cooling configuration. The thermal power of this chiller fits well with Stirling-based microCHP (or small-scale solar collector systems) for individual residences. When applied in combination with measures to reduce “overheating” in summer (e.g. solar shading, night ventilation), it’s expected 2.5kW cooling is sufficient to provide a comfortable indoor temperature. Especially if this cooling power can be used completely, when necessary, to tackle a commonly reported comfort problem (in Dutch residences): overheating of bedrooms.

Parallel to this “field test”, development of the 2.5kW sorption chiller continues, to turn it into a commercial product. Current emphasis is on redesign for manufacturability. For both production and commercialization ECN is currently looking for interested and suited commercial companies, to form a consortium that will transform the current prototype into a commercial product.