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First results of a pilot installation of a solar thermally driven cold store

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ABSTRACT

Within the scope of the project AgroKühl, a pilot plant of a solar thermally driven cold store has been developed and installed near Freiburg in Germany. The system consists of a linear concentrating Fresnel collector system with mirror area of 88 m^2, an ammonia-water absorption chiller of 12 kW cooling capacity with an integrated cooling tower, two ice storages of 52 kWh latent storage capacity and a cold store of 100 m^3. With the aim to guarantee observation of quasi-realistic system behaviour and to avoid restrictions in the operation, the cold store was equipped with computer-controlled fan heaters and humidifiers. This allows the emulation of sensible and latent loads in the room. The system was installed in summer 2012 and since August 2012 it is in continuous operation during summer period. This publication describes the system in detail, summarizes the first operational results and highlights optimization potential of the plant.

Premiers résultats d'une installation pilote d'entrepôt frigorifique fonctionnant à l'énergie thermique solaire

Mots clés : Optimisation ; entrepôt frigorifique ; Absorption de NH_3/H_2O ; démonstration ; froid solaire

1. Introduction

In recent years the demand for cooling has risen worldwide in all sectors and further growth is expected also in the future (Sivak, 2009). A big share of the cooling demand is required for applications in the food industry. This particular cooling demand is increasing mainly driven by an increased need of food for a continuously growing world population. But also quality requirements like closed cold chains lead to a raising demand. E.g., for exports of produce into the European Community they are indispensable (EC, 2004). Last but not least the climate change contributes to this demand because of increasing ambient temperatures in the producing areas and storage regions.

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Abbreviations

AC	Absorption chiller
HT	High-temperature
IS	Ice storage
LT	Low-temperature
OM	Operation mode
dir	direct
el	electrical
th	thermal
COP	Coefficient of performance ($kW_{th}\ kW_{th}^{-1}$)
EER	Energy efficiency ratio ($kW_{th}\ kW_{el}^{-1}$)
I	Irradiation (kW)
P	Electrical power (kW)
Q	Heat (kW)

Instabilities and black outs in the electricity grids in many regions around the world force the operators of cold stores to produce their own electricity by diesel generators. These systems are often expensive, inefficient and require fossil fuel. Furthermore, the cold stores themselves have an energetic optimization potential due to the out-dated construction and quality standards, which cannot be neglected.

Because of the mentioned reasons the aim of the AgroKühl project is the development of a solar thermally driven and energy efficient cold store as an integrated system. The implementation of a completely autonomous driven cold store can only be reached with a highly reduced auxiliary electricity demand. While the use of solar thermally produced cold in general (Kim and Ferreira, 2008; Chidambaram et al., 2011; Weber et al., 2012) or specifically in food industries (Ayadi et al., 2008; Best et al., 2013) was under experimental investigation before, cold stores in particular have not been evaluated.

As a first step to achieve the aim a pilot plant has been designed and installed near Freiburg in Germany. The requirements for the pilot plant were:

- Cold store temperatures around 0 °C
- Ice storage option for demand shifting
- Heat rejection without water consumption

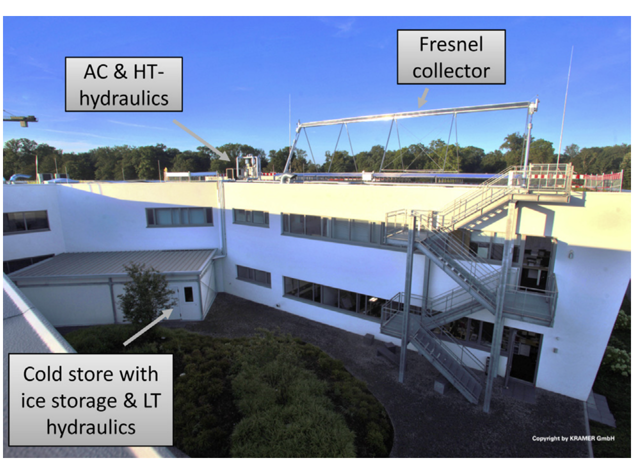

Fig. 1 – Overview of the pilot plant at the premises of Kramer GmbH near Freiburg.

- An electric power consumption of the system significantly lower than the conventional cooling technology

Fig. 1 shows a photo the complete system.

2. System description

The system consists of the following components:

- Linear concentrating Fresnel collector
- Single-stage ammonia-water absorption chiller (AC)
- An integrated dry cooling tower
- Two ice storages[1]
- A cold storage room

Attached to the cold store, a vestibule contains the ice storage, the hydraulics of the low-temperature circuit and the data acquisition and control unit of the entire system. Fig. 2 shows a schematic diagram of the plant. In the following sections the main components are described.

2.1. *Collector*

A linear concentrating Fresnel collector of the company Industrial Solar, Freiburg, provides the driving energy for the cooling process. It has an aperture – or mirror area – of 88 m^2 and a nominal capacity of 48.4 kW. The mirrors are aligned in rows with motors on their longitudinal axis. By moving the mirrors the direct solar radiation is reflected onto an absorber tube 4 m above the mirror plane (Fig. 3). By concentrating the solar radiation, the collector can reach temperatures of up to 400 °C. Due to technical limitations, 180 °C is the maximum allowed temperature in this installation. More information on the collector can be found in Häberle et al. (2007) and Zahler and Iglauer (2012).

The collector was oversized with respect to the thermal demand of the AC for two reasons. Because of the relatively short length of the collector a low position of the sun results in relatively high row-end losses lowering the effective capacity most time throughout the day. This effect would be compensated by a larger collector in bigger systems. Secondly, concentrating collector technology works only with direct radiation, which occurs less frequently in Germany than in the targeted arid areas of the project objective. Due to this non-ideal site, optimum operation conditions are not so often obtainable. A larger collector can expand the time of heat production to days and seasons with lower direct radiation, so as to provide a longer measuring period.

2.2. *Absorption chiller*

As a thermally driven chiller, a water-ammonia absorption chiller is used. As a special feature, the condenser and absorber are directly air cooled, avoiding the necessity for an additional hydraulic circuit and cooling tower. This machine is usually operated with gas, but was modified by the manufacturer specifically for use with pressurized hot water by the exchange of the gas burner with a fluid heat exchanger.

[1] Though there are two equal ice storage, they are referred to as singular ice storage since they are operated in parallel.