

# DEVELOPMENT OF A SOLAR POWERED DIFFUSION ABSORPTION COOLING MACHINE

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## ABSTRACT

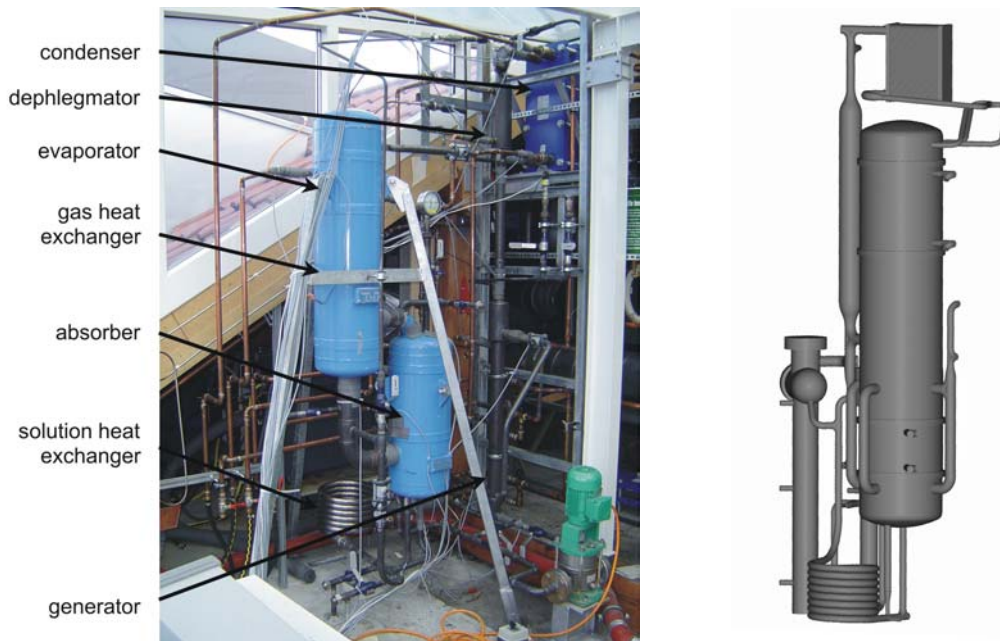
This paper is about the development, investigation and simulation of a single-effect solar powered ammonia/water (NH<sub>3</sub>/H<sub>2</sub>O) Diffusion-Absorption Cooling Machine (DACM). The designed cooling capacity of the cooling machine is 2.5 kW at evaporator temperatures ranging between -10°C and +5°C. The indirectly heated, solar powered generator with its bubble pump is the main new feature of this cooling machine. The challenges of this research project were the detailed investigation of the performance potential and the experimental characterisation of the DACM, especially of the newly-developed, indirectly heated generator, which could be analysed only with external measurement devices. Moreover an expanded, steady-state DACM model was set up, which is based on the characteristic equation of sorption chillers.

## INTRODUCTION

Solar thermal driven or assisted absorption cooling machines are gaining increasing importance due to the continually growing demand for air-conditioning in domestic housing as well as office and hotel buildings. Presently there are no thermally driven absorption cooling machines available on the market that can provide a smaller cooling capacity than 10 kW for cooling buildings.

For this reason, in 1998 the Stuttgart University of Applied Sciences started the development of a single-effect solar heated ammonia/water DACM with a design cooling capacity of 2.5 kW. For this project, two DACM prototypes were built and

operated and a third one is under construction (Figure 1). Data acquisition was conducted under laboratory conditions as well as under simulated field conditions for vacuum-tube collectors.



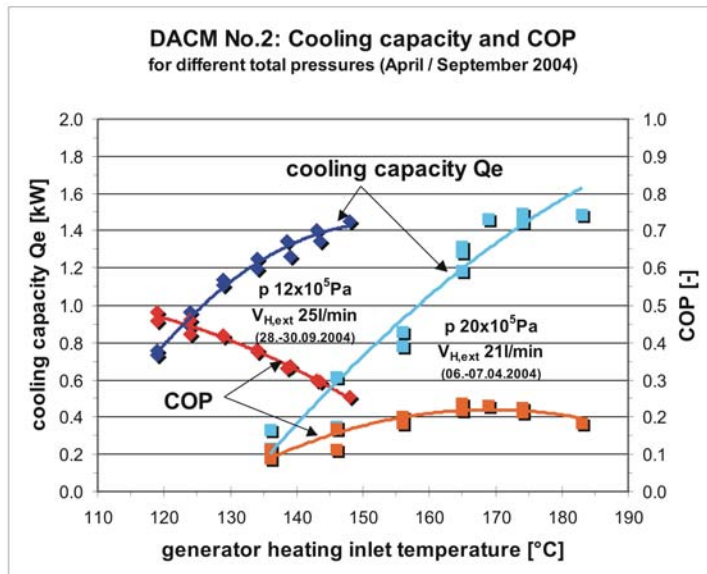
**Figure 1:** DACM No.2 at the laboratory of the Stuttgart University of Applied Sciences and illustration of the future DACM No.3.

## EXPERIMENTAL RESULTS

The first pilot plant of the DACM was set up in the Building Physics laboratories at the Stuttgart University of Applied Sciences, Germany in October of 2000. A series of measurements were performed from November of 2000 to March of 2002 on the pilot plant of the first DACM. The results showed that the coefficient of performance values (COP) ranged from 0.1 to 0.25 and that the evaporator cooling capacity of the pilot plant could reach 1.5 kW [1], but that the operation stability was insufficient. In most experiments the evaporator capacity decreased with time.

The second optimised and compacted prototype was built based on the experiences gained from the first, using partly standard components such as nickel soldered plate heat exchangers and a coaxial heat exchanger for the condenser and the solution heat exchanger (SHX), respectively. For this much more compact prototype, the auxiliary gas circuit was constructively reworked and a further generator was developed. The second prototype was put into operation in July of

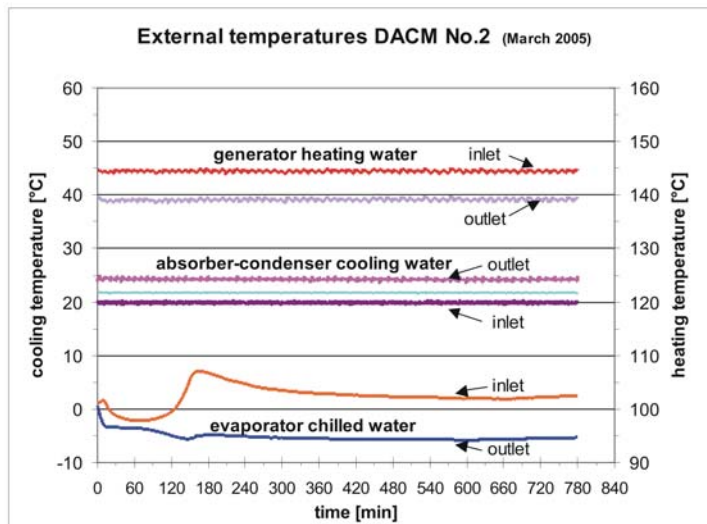
2003 and run till July of 2005. The achieved COPs were between 0.2 and 0.45 and the continuous evaporator cooling capacity up to 1.6 kW (Figure 2) at evaporator outlet temperatures for air-conditioning between 22°C and 15°C [3].



**Figure 2:** Measured cooling capacities and COPs of the DACM No.2 at different total pressures.

Due to insufficient evaporation efficiency a maximum cooling performance of 2.0 kW could only be reached if the

evaporator temperature was set to a value of 25°C. The generator heating inlet temperatures could be reduced from 135°C-185°C (DACM No.1 and DACM No.2 with plate heat SHX) down to 110°C-155°C (DACM No.2 with coaxial SHX). Up to now the lowest logged constant evaporator outlet temperature is -5°C at a generator heating inlet temperature of 145°C (Figure 3).



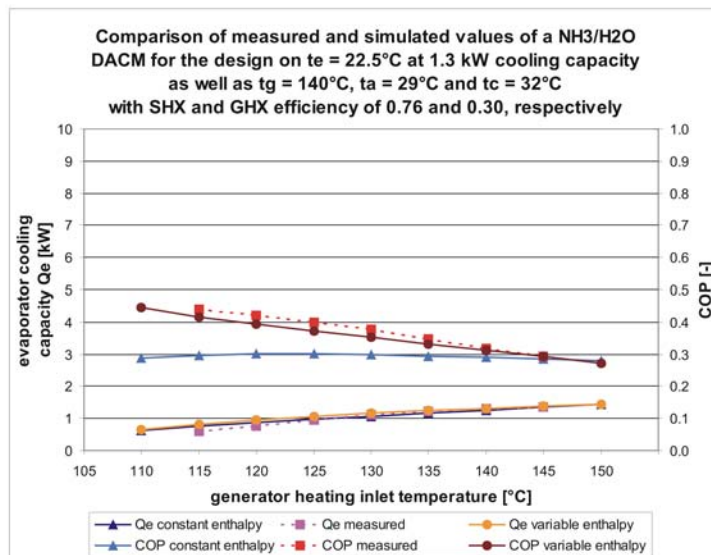
**Figure 3:** Long-term measured external temperatures of the DACM No.2.

In addition, the performance of the bubble pump as well as that of the falling film evaporator were investigated in detail using

experimental data [2,4]. The developed bubble pumps worked in a wide operation range at varied temperatures as well as external mass flows.

## MODELLING AND SIMULATION

The Diffusion-Absorption Cycle has been modelled starting from the constant characteristic equation of sorption chillers. An expanded, steady-state model was developed based on the exact solution of the internal mass and energy balances of each component as well as the heat transfer between external and internal temperature levels [4]. The internal enthalpies are calculated at each time step. The model was implemented in the simulation environment INSEL and validated by experimental data of the optimised pilot plant, DACM No.2 (Figure 4). The results of the simulation runs of the DACM showed that the performance of the DACM with variable enthalpy describes the experimental data points of the measured performance well, whereas with a constant enthalpy model the performance deviated from the measured one.



**Figure 4:** Comparison of measured and simulated values of the DACM No.2.

Furthermore a parameter study was carried out to determine the performance improvement of the DACM at different evaporator inlet as well

as cooling water temperatures and evaporator surface wetting factors as well as gas heat exchanger (GHX) heat recovery factors [4]. The COP as well as the evaporator cooling capacity decrease at lower evaporator temperatures. For the DACM No.2 with coaxial SHX, a surface wetting factor of 1.0 and a GHX efficiency of 0.3, the design cooling capacity of 2.5 kW could be reached for 12°C and 24°C evaporator inlet temperatures at a generator heating inlet temperature of 162°C as well as 123°C. The corresponding COPs are 0.38 and 0.85. Furthermore, the lower the absorber cooling inlet temperature, the higher is the resulting evaporator cooling capacity.

## CONCLUSION

The first DACM prototype showed that COPs range from 0.10 to 0.20 and the evaporator cooling capacity of the pilot plant could reach 1.5 kW (table 1), but that the operation stability was insufficient. The second optimised and compacted prototype showed stable and continuous temperature and pressure levels. The reached COPs were between 0.2 and 0.45 and the continuous cooling performance between 1.0 kW and 1.6 kW. A maximum cooling performance of 2.0 kW could be reached if the evaporator temperature was set to a value of 25°C. A third prototype, DACM No.3, will be set up till October 2005.

An expanded, steady-state model of the DACM based on the characteristic equation of sorption chillers showed a good accordance of the compared experimental and simulated data.

**Table 1:** Summary of DACM prototypes.

prototype	DACM No.1	DACM No.2	DACM No.3
evaporator cooling capacity	1.0 - 1.5 kW	1.0 - 2.0 kW	2.5 kW*
COP	0.10 - 0.20	0.20 - 0.45	0.50*
weight	800 kg	290 <sup>i)</sup> / 240 <sup>ii)</sup> kg	240 kg
dimensions	1.5 x 1.5 x 3.7 m	0.8 x 0.8 x 2.4 m	0.6 x 0.6 x 2.2 m

<sup>i)</sup>plate heat/<sup>ii)</sup>coaxial SHX      \* design values

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