Application of a solar absorption refrigeration system for airconditioning of buildings

C.H.M. Machielsen[1)] and A.E. Hagendijk[2)]

1) Delft University of Technology, Laboratory of Refrigerating Engineering and Indoor Climate Technology; Mekelweg 2, NL 2628 CD Delft, The Netherlands.; e-mail: c.h.m.machielsen@wbmt.tudelft.nl
2) Ceeran Ltd, Training, Consultancy & Research, Oudstraat 62, NL 7423 EG Deventer, The Netherlands.

Abstract

This paper describes the Sofri project, a co-operation between Ceeran Ltd and The Delft University of Technology.
The main objective of this project is to develop the necessary knowledge and experience to commercialize solar-assisted air conditioning and dehumidification systems in the Dutch Caribbean. The project is motivated by the present needs of the Dutch Caribbean for renewable energy sources and the fact that the Caribbean has a high and uniform insolation throughout the year. Furthermore, hotels and offices in this area use more than 40% of their energy for air-conditioning purposes. Therefore, solar-assisted air conditioning systems are a logic approach in reducing the energy demand and to lower the peak electricity demands for the local power station.
Ceeran Ltd has the objective to reach full commercialisation of the proposed technologies in the Dutch Caribbean.

The research is concentrated on liquid absorption machines and solar collection systems such as flat plates with selective surfaces, heat pipe evacuated tubes flat plate collectors, and Compound Parabolic Concentrators.
The first demonstration unit is planned to be installed in an office building in Curaçao. The installation consists of a 35 kW $LiBr/H_2O$ absorption machine driven by 100 m^2 flat plate collectors with a gas backup system. The system will provide comfort air-conditioning for this these type of office buildings during daytime.

Introduction

Both Ceeran Ltd and the Delft University of Technology participate in Task 25 “Solar Assisted Air Conditioning of Buildings“ of the Solar Heating and Cooling Programme of the International Energy Agency (IEA).
The TU Delft has a lot of experience in building solar driven refrigerators.
In 1985 a 40 ltr vaccine cooler has been constructed and has been tested before shipment to Botswana by means of a solar simulator [1]. The capacity equals: 5 kg ice / 24 h.
A solar driven 50 m^3 cold-store driven by Philips vacuum tube collectors was tested in Sudan [2]. Both projects were financed by local or international governmental institutions and economical not attractive. Also in other countries in Europe and Latin America [3] a big increase in the interest on solar cooling has been observed during the last 10 years, i.e. at a time where cooling has been in public discussions anyway due to the problem of CFC replacement. However, in many countries activities had been stopped after a certain time due to too high costs.
Medio 1997 a joined partnership was established between a number of persons who were interested in renewable energy and innovation. They undertake activities under the encronym Ceeran.
The main objective is to couple the newest techniques available on the international market which can be economical attractive for certain applications in sunny area’s like the Caribbean.

Meteorological Data Test Area

Curaçao is one of the tropical islands in the Dutch Caribbean. It is situated just north of Venezuela. Although the largest of the Netherlands Antilles, Curaçao is only about 472 square kilometers. It is roughly bikini-top shaped and is 61 km long and from 5 to about 14 km wide. What makes Curaçao ‘livable’ is the constant breeze of the North-East Tradewind.
The population is about 145.000.
The following meteorological data are from the Meteorological Institute of the Netherlands Antilles and Aruba [4]:

Location	Curaçao	12 degrees Northern latitude; 68 deg.W
Wind velocity	7 m/s	
Wind direction	087 degr.	
Relative humidity	76.5 %	
Ambient temperature	30 °C	
Global radiation	3800 W.h/m^2/day (December) - 6300 W.h/m^2/day (July)	
Mean global radiation	5318 W.h/m^2/day (horizontal plane)	
Mean diffuse radiation	2391 W.h/m^2/day (horizontal plane)	
Optimal collector angle	15 degr.	
Practical use collector	9:00 - 15:00 ====> 6 hours	

Figure 1 shows the mean radiation on a horizontal plane in W.h / m^2 over the year at each hour of the day.
Table 1 summarises the data of the cooling load of a possible target building. A comparable conventional system can work either with split units or a chilled water system.

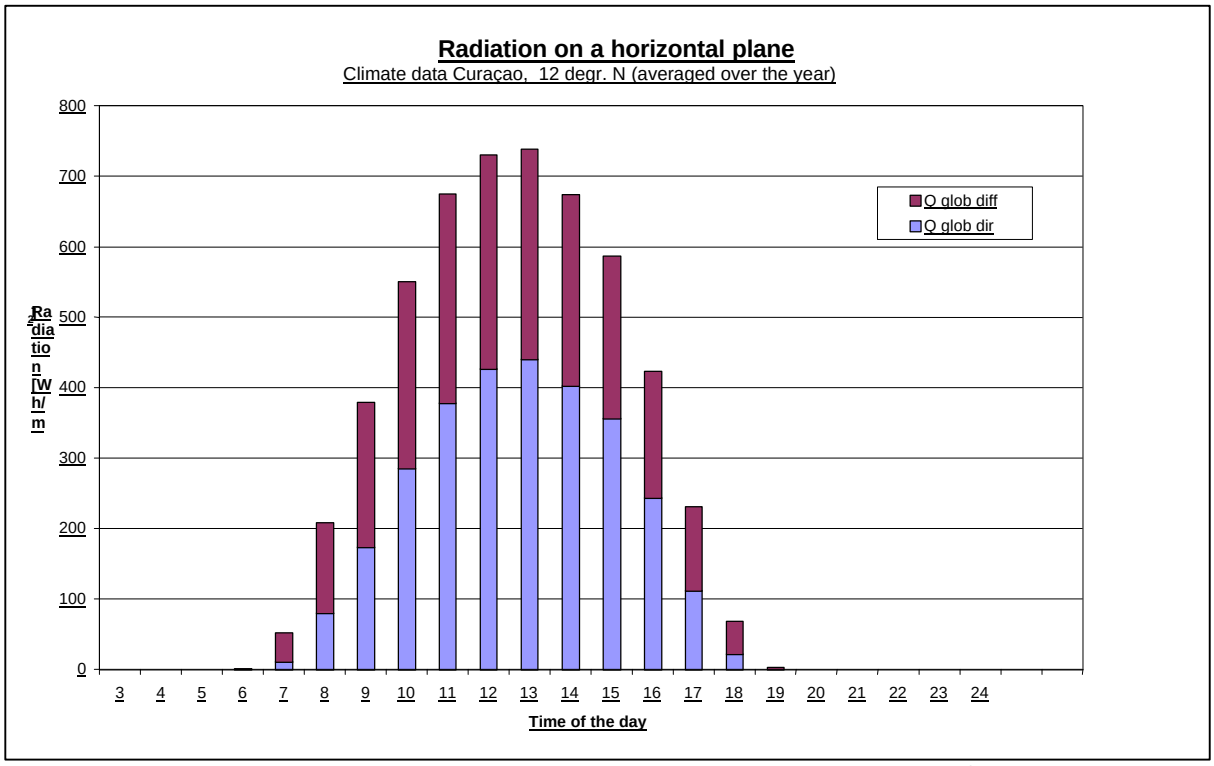

Figure 1: Mean radiation over the year on a horizontal plane in W.h / m^2 .

Table 1: Cooling load of the target building

Room	Cooling load in kW	Volume in m^3	Air circulation in m^3/h
Director	4	75	525
Employees	7	165	1551
Office manager	4	105	735
Meeting room	6	126	882
Total	21	471	3.693

Description of the Solar-assisted air conditioning system

The heart of the system is a low temperature driven closed loop Yazaki absorption chiller which is brought on the market in Europe by York.
Table 2 gives an overview of the additional components and figure 2 shows the general setup of Ceeran solar-assisted air conditioning system.

Closed Loop Absorption Chiller

Type	York (Yazaki WFC-10)
Working pair	$LiBr/H_2O$
Weight	780 kg
Cooling capacity	35 kW
Chilled water	1.75 l/s
temp. outlet	9 °C
temp. inlet	15.6 °C
Cooling water	4.25 l/s
temp. inlet	29.5 °C
temp. outlet	35.9 °C
Hot water	2.5 l/s
temp. inlet	85 °C (temp. diff. HEX 6.5 K)

Table 2: Additional components

component	**number**	**size**	**remark**
solar collector	50	100 m^2	flat plate with spectral selective layer
fan coil units	5		
circulating pumps	5		
wet cooling tower	1	100 kW	Evapco
gas boiler	1	75 kW	Modulated type
hot water storage tank	1	5 m^3	Insulated

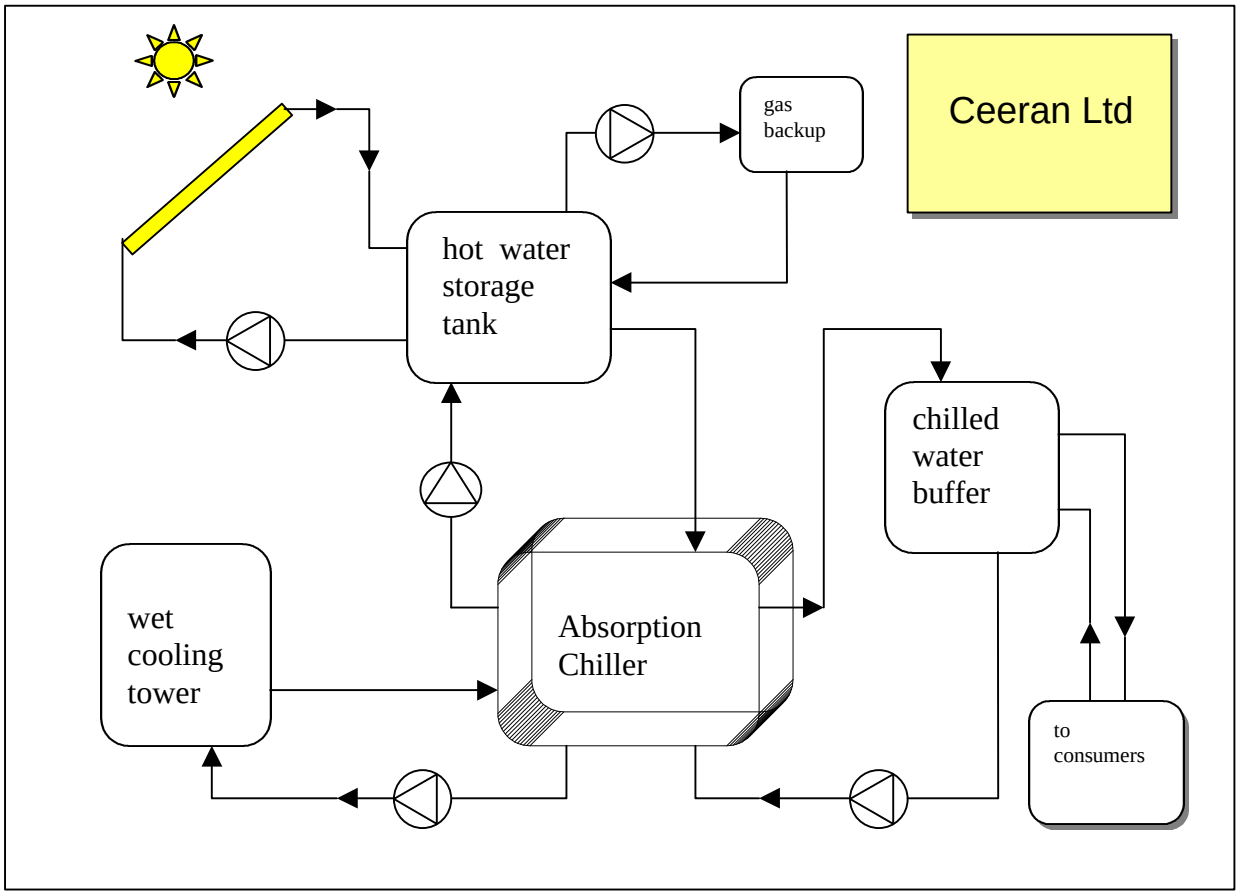

Figure 2: General setup of Ceeran solar-assisted air conditioning systems

Based on the performance data of the manufacturers of the absorption refrigeration machine and the solar collectors, it was possible to calculate the solar fraction of the air conditioning system.

According to the calculation results (see figures 3 and 4) it is obvious that with a 100 m^2 collector surface we always need a gas backup for start up and control.

Estimated solar fraction for the test site

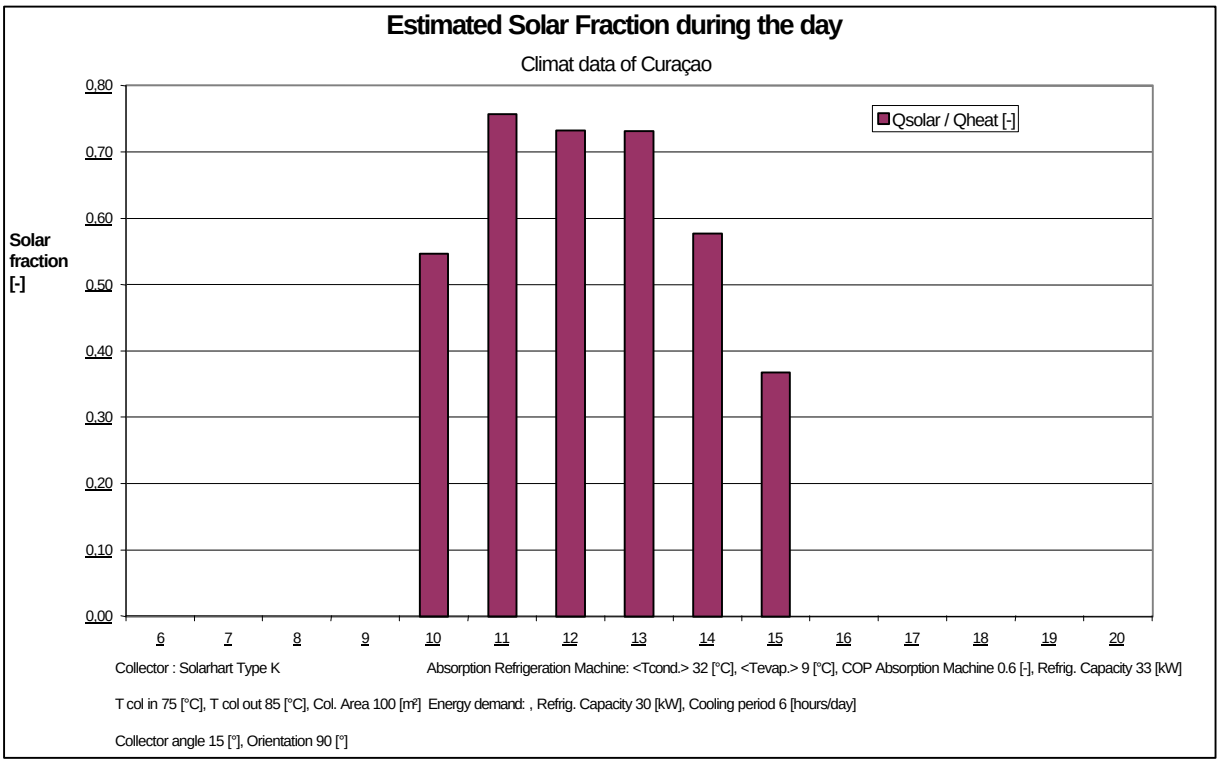

Figure 3: Estimated solar fraction during the day for the test site

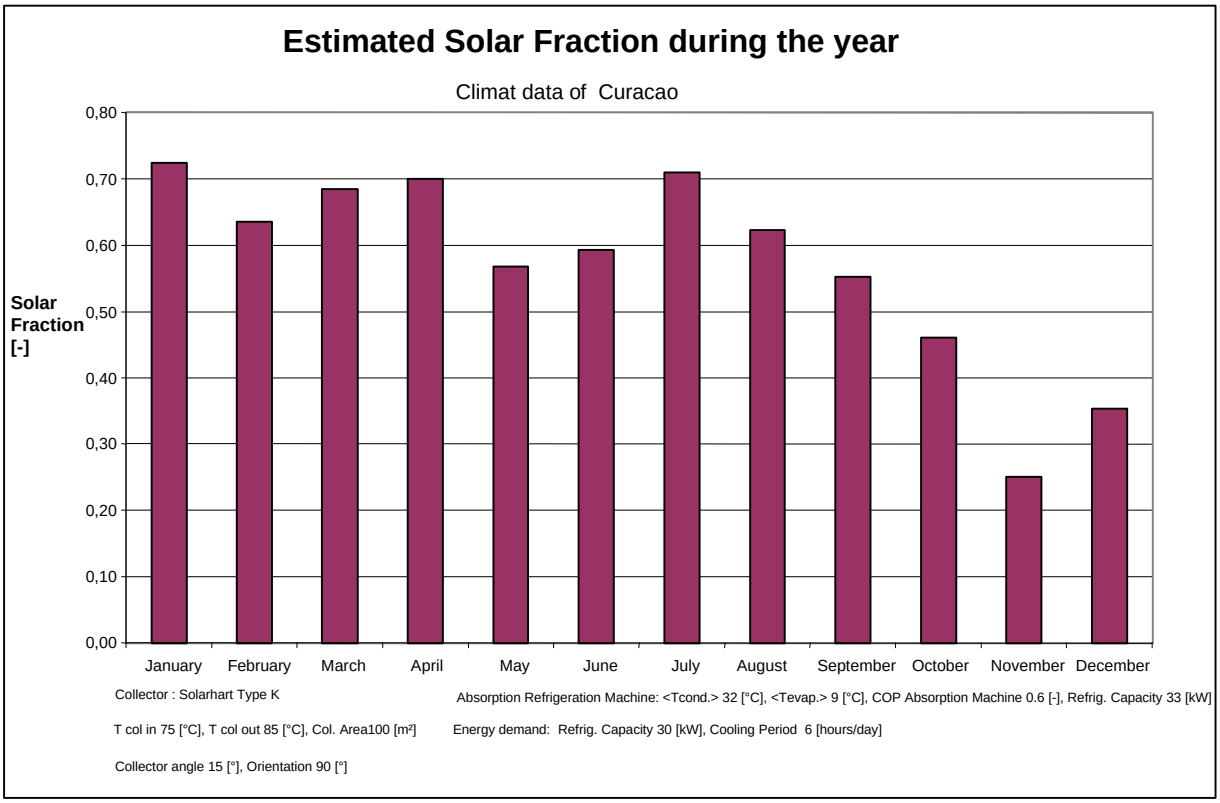

Figure 4: Estimated Solar Fraction during the year for the test site

Chiller cooling performance and costs

Figure 5 shows the estimated cooling capacity of the H_2O/LiBr chiller at condensor temperatures of 25, 29 and 32 °C and T_{evap} = 9 °C.

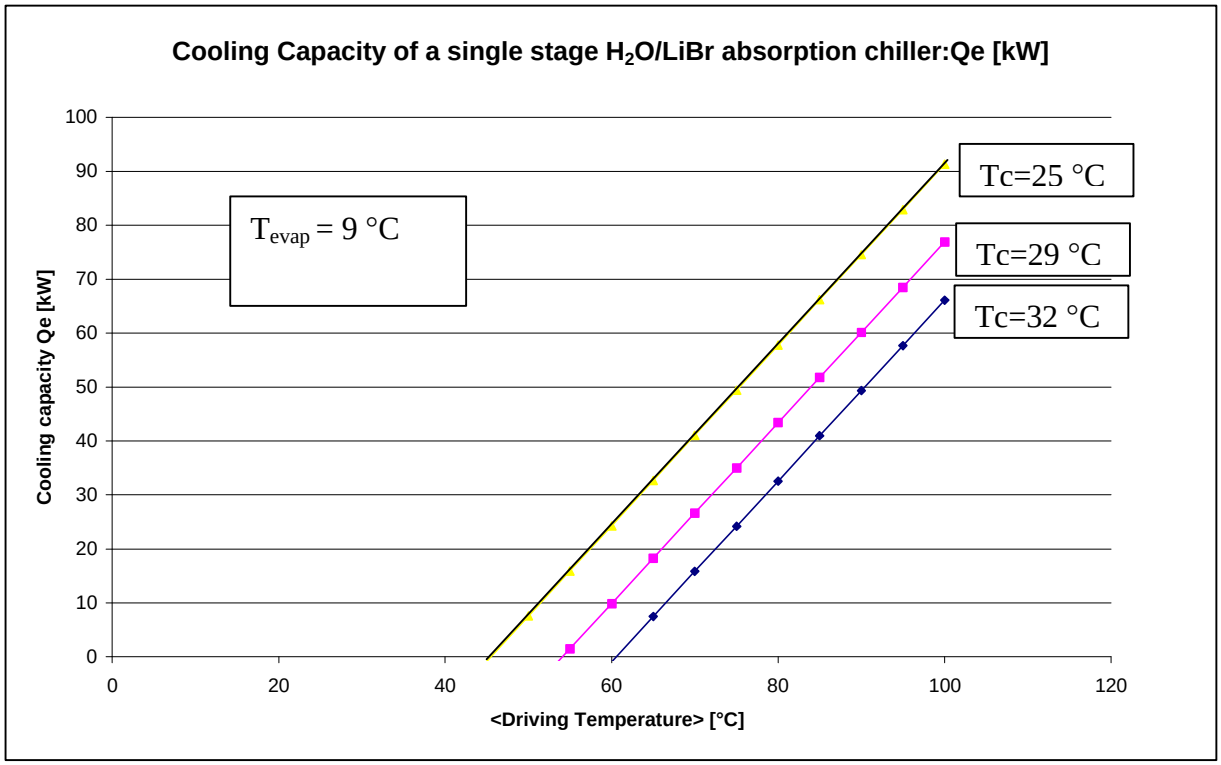

Figure 5: Estimated cooling capacity with the condensor temperature as parameter

At design conditions the optimal driving temperature for the total system will be 85 °C for flat plate collectors.
The total cost of the system is about US$ 50,000 (monitoring not included).
During the test period different collector types will be tested, including CPC.

Some key figures of this project:
- Energy saving: 50.000 kWh/year (electric)
- CO_2 reduction 18.500 kg/year
- Payback time of extra investment 3.5 year
- Collector surface 100 m²

Conclusion
In this project is made the choice for not 100 % powering the system with solar energy.
Hence the investment costs keep acceptable and makes the solar airco system not only technical but also economical feasible.
Much research is still required to improve the longterm efficiency of the collectors and the absorption technology to lower the pay back times of the extra investment costs.
For this reason Ceeran participates in national and international research programmes like IEA Task 25 (“Solar Assisted Air Conditioning of Buildings”) and EU Joule-Craft.

References

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