Appendix 1a
Optical improvement of market available parabolic trough collectors

Subtask C2 – Development of new technologies for solar assisted air conditioning

1. Title of development

Optical improvement of market available parabolic trough collectors

2. Duration of project

Start Date: 01 / 06 / 1998 Termination Date: ongoing activity

3. Short description of project (objectives, work program, background,....)

After a period of research and commercial development of parabolic troughs in the 80s, Industrial Solar Technology (IST), a US manufacturer of parabolic trough solar plants, erected several process heat installations in the USA with up to 2700 m^2 of aperture area. At the Test Centre of the DLR (German Aerospace Research Institute) in Köln-Porz a system of 12 collectors (aperture area 168 m2) has been installed for test purposes.

Objectives are:

- Efficiency testing of the available system
- Feasibility study for application of parabolic troughs in Central Europe (solar process heat, solar district heat)
- Performance improvements by means of improvements of the optical efficiency of the collectors. These include:
  - Reflector materials with higher reflectivity and/or lower cost (within IEA SolarPACES)
  - Reduction of thermal losses by reduced absorber tube diameter (secondary concentrators) and/or improved selective coatings
  - Miscellaneous design improvements (reduction of losses at absorber tube fixation, reduction of shading and blocking by structural elements, etc.)

Appendix 1a
Optical improvement of market available parabolic trough collectors

4. Technical scheme (drawing)

5. Technical description

See section 3.

Appendix 1a
Optical improvement of market available parabolic trough collectors

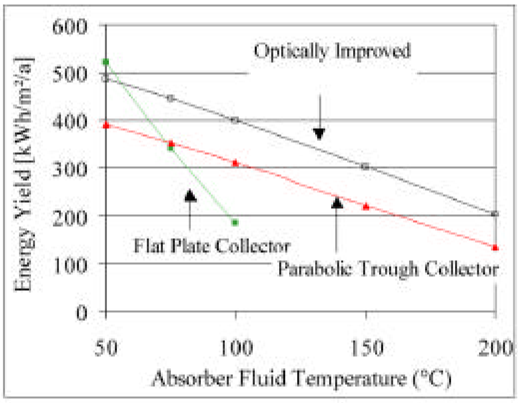
6. performance characteristic (efficiency curve, COP curve, tables....)

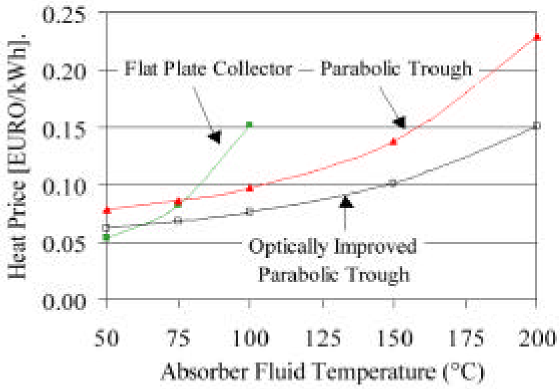
The energy performance of the collector was measured and can be represented by:

$$h = c_o - c_1 \times \frac{DT}{I_{DNI}} - c_2 \times \frac{DT^2}{I_{DNI}}$$

with c_0 = 0.6931, c_1 = 0.4755 and c_2 = 0.003128. ΔT is the temperature difference between absorber fluid and ambient temperature and I_{DNI} is the direct normal irradiation.

The following results were achieved with simulations using the TRY of Copenhagen.





7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

Performance tests were carried out.

Simulations showing that for temperatures >75°C parabolic troughs can compete to flat plate collectors even in central Europe regarding energy efficiency and economy were carried out.

Next steps are improving the optical efficiency by mainly two means:

- improving reflectivity of the reflectors
- integration of so called end-loss reflectors and
- studying the performance in real projects (solar district heat, solar process heat, solar cooling & A/C)

Appendix 1a
Optical improvement of market available parabolic trough collectors

8. participating companies and institutions			
8.1 company's name	Deutsches Zentrum für Luft- und Raumfahrt DLR – Solare Energie-technik		
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role in project	project coordinator		
8.2 company's name	Industrial Solar Technologies IST		
responsible person			
address			
phone		fax	
e-mail			
role in project			

9. references

- Dudley V. (1995). SANDIA report test results. Industrial Solar Technology Parabolic Trough Solar Collector. SAND94-117. Sandia National Laboratory, Albuquerque, USA
- Krüger D., Hoffschidt B., Hennecke K., Pitz-Paal R., Rietbrock P. and Fend Th. (2000): Results from Parabolic Trough Collectors for Process Heat at the DLR Cologne in: Proceedings of the 10th International Symposium on Solar Thermal Concentrating Technologies, 8-10 March, 2000, Sydney. Kreetz H., Lovegrove, K., Meike, W. (editors), pp. 113-120
- Krüger D., Hennecke K., Schwarzbözl P., Dokupil M. und Mahler B. (2000), Test eines Parabolrinnenkollektors für Prozesswärmeerzeugung in einem Klima mit niedriger direkter Strahlung in: OTTI Symposium für Thermische Solarenergie, OTTI Energie Kolleg (Editor), Regensburg, Germany
- Riffelmann, K.J., Fend. Th., Pitz-Paal, R. (2000), Parabolic Trough collector Efficiency Improvement Activities in: 10th International Symposium on Solar Thermal Concentrating Technologies, 8-10 March, 2000, Sydney. Kreetz H., Lovegrove, K., Meike, W. (editors), pp. 120-129

10. funding (national, EU, ...)

not known

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

Subtask C2 – Development of new technologies for solar assisted air conditioning

2. Title of development/project

Stagnation Proof Transparently Insulated Flat Plate Solar Collector (STATIC)

2. Duration of project

Start Date: 01 / 09 / 1998 Termination Date: 31 / 12 / 2000

3. Short description of project (objectives, work program, background,....)

The STATIC (Stagnation proof Transparently Insulated flat plate Solar Collector) project was a Craft Joule Project within the framework of the Non Nuclear Energy Programme Joule III co-ordinated by the Centre Tecnològic de Transferència de Calor, CTTC, of the Universitat Politècnica de Catalunya, UPC. The core group of SMEs involved in the project has its main economical activity in the field of solar thermal systems at low temperature level (domestic hot water, solar heating, etc.). Beyond this, a large application potential exists for solar heating at medium temperature level (from 80°C to 160°C): industrial process heat, solar cooling and air conditioning, solar drying, distillation and desalination. Three of the four SME proposers are locate in Southern Europe and in the Caribbean, where a continuous increase of the demand for air conditioning and cooling has been demonstrated in the last years.
The recent development of flat plate solar collectors with honeycomb-like transparent insulation cover has shown that this type of collectors can become a low cost alternative to evacuated tube and high concentrating CPC collectors in the medium temperature range from 80ºC to 160ºC. With the expected reduction of collector cost, that form 30%-50% of total system cost, a decisive break-through of solar thermal system using heat in the medium temperature range can be achieved.
The feasibility and good performance of these solar collectors has been proved in several prototypes. Nevertheless, up to now no commercial products are available. In order to reach this, the following developments of new concepts were necessary and were carried out within this project: solution of the problem of overheating; development of collector versions for different working temperatures; optimisation of the design with the support of high level numerical simulation.
Several prototypes of the new collectors have been tested. Two test arrays with the new prototypes have also been constructed and tested for different temperatures contained within 80ºC and 160ºC, covering different ranges of possible applications.

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

4. Technical scheme (drawing)

View of some of the stagnation proof transparently insulated collector prototypes mounted at the roof of the Escola Tècnica Superior d'Enginyers Industrials de Terrassa, Terrassa (Barcelona)

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

5. Technical description

Research approach and methodology
In order to achieve the goal of stagnation resistance and optimised design for flat plate TI collectors in the medium temperature range, research has been carried out in the following lines:

- Detailed numerical simulations (directly solving the governing equations).
- Numerical simulation with design tools based on global balances or one-dimensional balances that allow to estimate the collector efficiency and the influence of the different design parameters in the collector efficiency in a short time.
- Construction and testing of experimental set-ups in order to assess the credibility of the numerical results and in order to obtain additional information of interest.

Overview of the project
The project has been divided into 8 different Tasks apart from the Task concerning co-ordination.
Tasks 1 and 2 focussed on finding a technically and (potentially) low cost overheating protection device strategy for the TI collectors, and in optimising the collector design parameters. Basically two types of overheating protection systems/mechanisms were promising. The first one consists in mechanical shading devices and/or forced and natural ventilation to protect the collector for overheating. The technical difficulty was in designing the devices for low cost, secure operation and long life times. Especially the design of adequate ventilation concepts presented the problem of limiting the introduced additional thermal losses during normal operation. The second way to achieve that goal is to use thermotropic layers, i.e. layers that are composed of materials that change their transmittance with temperature. Concerning the collector design optimisation, the following concepts were investigated: working fluid and absorber configuration, cover configuration (different kind of TI materials, single or double glazing, surface treatment...), collector housing and connections. No information about the successes of the various concepts can be given here, since this information belongs to the participating companies.

Taking into account the results of these first Tasks, different prototypes have been designed, constructed and tested within Task 3 and 4, always comparing the obtained experimental data from the collector tests to the numerical data obtained from the numerical simulation tools. The prototypes have been optimised for three different temperature ranges:

- Range A: working temperatures from 80 to 120^{o}C (Prototype 5SCA in the figure in section 6)
- Range B: working temperatures from 120 to 160^{o}C
- Range 0: working temperatures up to 90^{o}C (Prototype 1SCA in the figure in section 6).

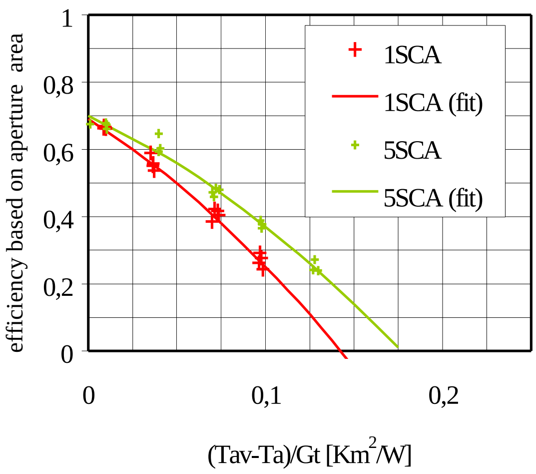
The results arisen from these Tasks and the experience gained in the construction and testing of the new prototypes have been discussed and integrated in Task 5 involving the participation of all the partners.

Two test arrays have been constructed and tested in Tasks 6 and 7 according to the concepts and criteria arisen in Task 5. These test arrays were made up by collectors optimised for different temperature ranges. Results and experience gained from the array mounting and testing have been integrated and discussed by all the partners in Task 8.

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

The collectors developed within the STATIC project are not commercial products yet. They are prototypes that still need some investment from the participating companies to become a commercial product. Expected mass production cost of these collectors is low; mush lower than for CPCs or evacuated tube collectors.

6. performance characteristic (efficiency curve, COP curve, tables....)



Steady state efficiency curves of two of the stagnation proof transparently insulated collector prototypes (called 1SCA and 5SCA, for use up to 90ºC and 120ºC respectively).
Experimental values obtained following the international standard procedure ISO 9806-1

The data show that the 1SCA prototype is comparable to high efficiency flat plate collectors that are already on the market. The prototype 5SCA has an efficiency comparable to evacuated tube collectors.

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

Technology and know-how has been transferred from the research and technical development performers of the project to the enterprises of the Consortium. The enterprises are carrying out the technological implementation plan for the future exploitation of the results.

8. participating companies and institutions

8.1 company's name	Centre Tecnològic de Transferència de Calor, CTTC		
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role in project	Research centre		

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

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role in project	Research centre		
8.3 company's name	Sunwind Energies S.a.r.l.		
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e-mail	Jacquessimonin@tvs2net.ch		
role in project	Solar system and equipment manufacturer		
8.4 company's name	Alternativas Energéticas S.A.		
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role in project	Solar energy systems installer		
8.5 company's name	Itelsa S.L.		
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e-mail	itelsa@infonegocio.com		
role in project	Solar energy ststems installer		
8.6 company's name	Marketing –und Technologie- Consult GmbH		
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e-mail	matec.gmbh@t-online.de		
role in project	Energy and renewables consultant		
8.7 company's name	MADE Energías Renovables, Grupo Endesa		
responsible person	J.C. Lavandeira		
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phone	34 983 837169	fax	34 983 804800
e-mail	jclavandeira@made.es		
role in project	Large scale solar thermal system and equipment manufacturer and installer		

9. references

Craft-Joule Project: Stagnation Proof Transparently Insulated Flat Plate Solar Collector (STATIC), UPC, FHG, SUNWIND, AESOL, ITELSA, MATEC, MADE. Proceedings of the ISES Millennium Solar Forum 2000, September 2000, Mexico.

Appendix 1b
Stagnation-proof transparently insulated flat plate solar collector (STATIC)

10. funding (national, EU, ...)

This project was funded in part by the European Commission in the framework of the Non Nuclear Energy Programme JOULE III

Appendix 2a
Residential solar air conditioning system (MAGESCLI)

Subtask C2 – Development of new technologies for solar assisted air conditioning

3. Title of development/project

Residential solar air conditioning system (MAGESCLI).

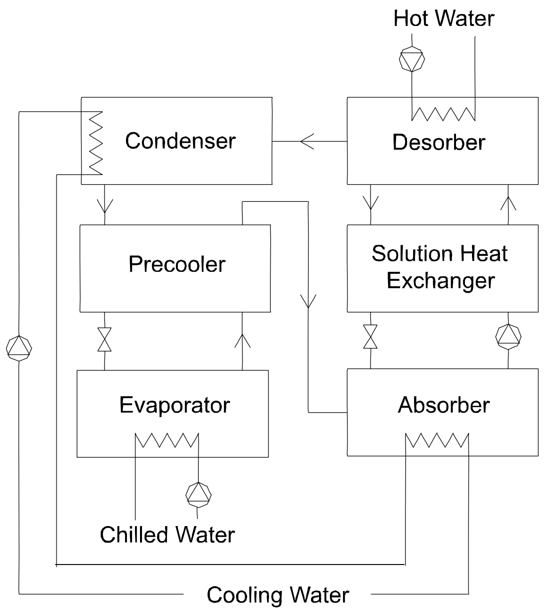
2. Duration of project

Start Date: 01-06-1999 Termination Date: 01-09-2001

3. Short description of project (objectives, work program, background,....)

Development of a market-ready solar air conditioning system for the residential market in Southern Europe. Reversible absorption machine, with a cooling capacity 5 kW and a heating capacity 9-10 kW. The absorption machine should not be larger than a domestic refrigerator (high model). The system will be designed for outdoor placement.

4. Technical scheme (drawing)



As shown the prototype is a simple effect absorption machine.

Appendix 2a
Residential solar air conditioning system (MAGESCLI)

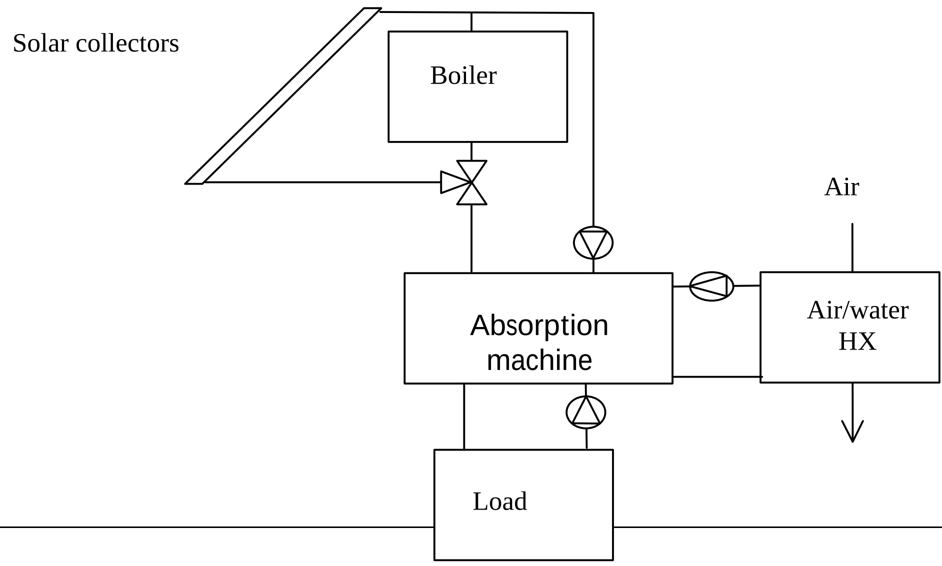
5. Technical description

The system consists of CPC collectors and an NH_3/H_2O absorption-cooling machine, built for this application.

The CPC collectors have a slightly higher concentration factor than current market available collectors, in order to reach higher temperatures. The optimum system efficiency (incl. absorption heat pump) is with a water temperature of about 105-110 C. Aosol, manufacturer of CPC collectors, is one of the project partners. The collectors are equipped with a Teflon film for insulation. TIM (transparent insulation materials) will be tried as a next step. Double coated fins for solar collectors are rare on the market; both (!) available products could be improved.

The NH_3/H_2O system has been chosen because it does not need a cooling tower (air-cooled condenser), contrary to $LiBr/H_2O$ systems. 2 Prototypes have been built. The rectifier is sitting in the generator. Patents on this are in process. The second prototype is now being tested.

This is how the final set-up is being tested.



Appendix 2a
Residential solar air conditioning system (MAGESCLI)

6. performance characteristic (efficiency curve, COP curve, tables....)

The results of the first prototype are shown in the table below (for three different measurements):

COP	P_{high} (bar)	P_{low} (bar)	Q_{evap} (kW)	Q_{des} (kW)	X_p	X_{r+}	M_{r+} (kg/s)	T_{ger+} (ºC)	T_{evap} (ºC)
0.54	13.9	5.43	4.92	9.11	0.43	0.51	0.020	101.6	10.1
0.62	13.1	5.32	4.32	6.92	0.44	0.50	0.034	93.0	10.3
0.57	13.6	5.11	4.75	8.31	0.40	0.47	0.034	101.4	10.5

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

Prototype production

8. participating companies and institutions

8.1 company's name	Ao Sol		
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role in project	Developer of second prototype		
8.3 company's name	INETI		
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role in project	Developer of first prototype		

Appendix 2a
Residential solar air conditioning system (MAGESCLI)

9. references

Mendes, L. Filipe, Collares-Pereira, M., Ziegler, F. (1998) Supply of cooling and heating with solar assisted absorption heat pumps: and energetic approach, International Journal of Refrigeration, vol.21, n.2, pp116-125

Mendes, L. Filipe, Collares-Pereira, M. (1999) A solar assisted and air cooled absorption machine to provide small power heating and cooling, Proceedings of the International Sorption Heat Pump Conference, Munich, Germany, pp129-136

10. funding (national, EU, ...)

The project had a National Funding between 1999 and 2000 given by *Agência de Inovação*

Appendix 2b
Solar-driven diffusion absorption chiller

Subtask C2 – Development of new technologies for solar assisted air conditioning

4. Title of development/project

Design of a Solar Driven Cooling Unit based on the diffusion absorption principle

2. Duration of project

Start Date: 01.04.1999 Termination Date: 31.03.2001

3. Short description of project (objectives, work program, background,....)

In the project a Diffusion-Absorption Cooling Machine (DACM) with 2.5 kW cooling power driven by solar thermal collectors was developed, constructed and tested.

The diffusion absorption process based on ammonia-water solutions and an inert gas for pressure equilibration has been known for about a century, but the only machines constructed so far use high temperature generators directly powered by gas or electricity. To use solar thermal energy with commercial vacuum tube collectors new generators had to be designed which can operate at temperature levels between 100°C and 150°C. The expensive mechanical solution pump has been replaced by the thermally driven generator which includes a gas bubble pump.

The objectives of the project were mainly centred around the development, construction and testing of the Diffusion-Absorption machine. A prerequisite for the development was a complete analysis of the process, which involves software development for heat transfer calculations and component design.

The cooling machine has been tested using solar thermal energy with varying temperature levels as the heating input and the evaporator performance has been tested for temperature levels corresponding to cold production and air-conditioning purposes. From the experience with the prototype development, a market near unit should be developed, which should be lightweight, should use low cost components and should work with stable operating conditions.

Appendix 2b
Solar-driven diffusion absorption chiller

4. Technical scheme (drawing)

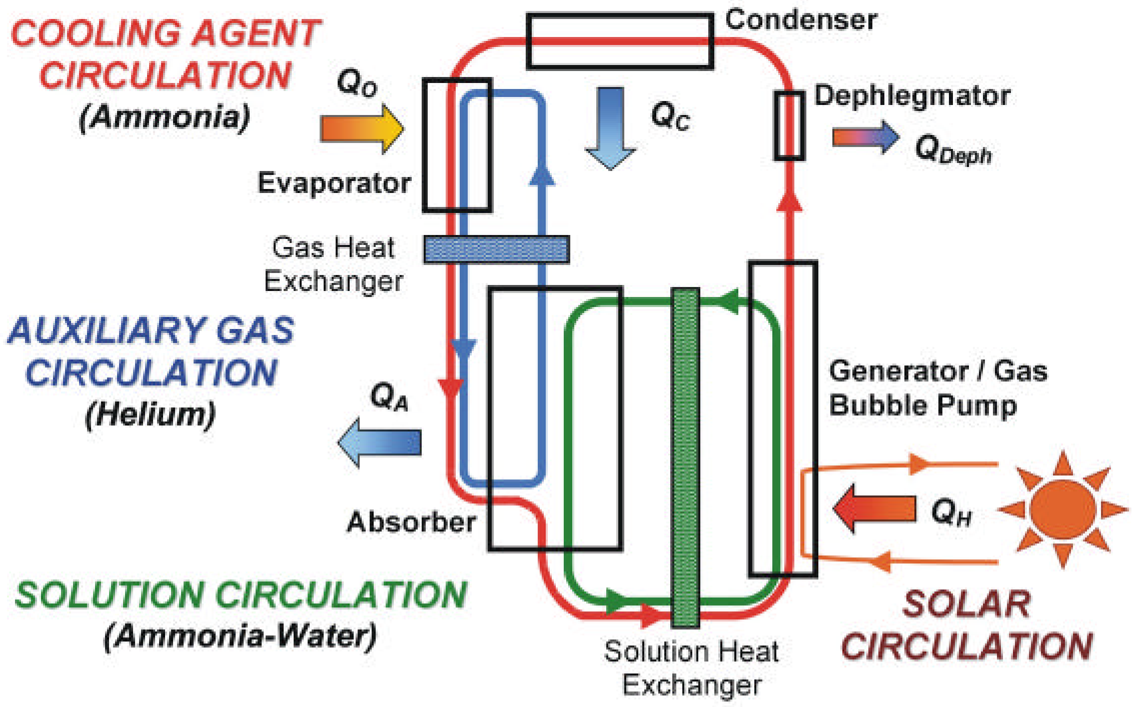

Figure 1: Principle of the solar driven Diffusion-Absorption Cooling Machine (DACM).

(Note: the dephlegmator is a specific type of rectifier)

5. Technical description

The main components of a DACM are the generator, condenser, evaporator and absorber (Figure 1). A solution heat exchanger in the solution circuit and a gas heat exchanger in the auxiliary gas circuit are also components of the DACM as well as a dephlegmator for the condensation of the evaporated solvent.

At low partial pressure in the evaporator the cooling agent evaporates and is absorbed in the absorber by the weak ammonia-water solution from the generator. In the indirectly solar powered generator with high heating temperatures the cooling agent is driven out of the rich ammonia-water solution and so a high cooling agent vapour pressure is generated which is enough for the condensation of the cooling agent in the condenser.

The usual mechanical solution pump of absorption cooling machines is replaced in a DACM by a thermal gas bubble pump. The circulation of the solution between the generator and absorber is maintained by vapour bubbles, which push up a liquid column. The pressure compensation between high and low-pressure level is realised by an inert auxiliary gas, helium or hydrogen. The auxiliary gas circulates between evaporator and absorber because of the temperature and density differences. In the whole cooling unit are no mechanically moving components and everywhere in the cooling unit is the same total pressure.

6. performance characteristic (efficiency curve, COP curve, tables....)

The Diffusion-Absorption Cooling Machine was designed for air-conditioning with the following temperature and heating/cooling capacity parameters:

Heat flows and design temperatures of the DACM pilot plant:

- generator (required heating power) Q_H = 5.2 kW; inlet $T_{G,rS}$ = + 101°C
  outlet $T_{G,wS}$ = + 112°C
- dephlegmator (required cooling) Q_{Deph} = 0.9 kW; T_{Deph} = + 50°C
- condenser (required cooling) Q_C = 2.8 kW; T_C = + 45°C
- evaporator (designed cooling power) Q_0 = 2.5 kW; T_O = + 5°C
- absorber (required cooling) Q_A = 4.0 kW; T_A = + 45°C
- ambient $T_{ambient\ air}$ = + 32°C
- collector outlet $T_{Coll,out}$ = + 127°C
- collector inlet $T_{Coll,in}$ = + 117°C

Total pressure (given by condenser temperature): p = 18,5 bar

Degassing wide in the generator (rich to weak solution): 5 %

- NH3-concentration rich solution X_{rS} 42 %
- NH3-concentration weak solution X_{wS} 37 %

For the investigations of the DACM the pilot plant was filled up with a 38 percent ammonia-water solution and helium as auxiliary gas. The complete pilot plant of the solar powered DACM is run and tested in the laboratory of the University of Applied Sciences Stuttgart with an indirect liquid heating circuit. Modelling of the performance of the DACM (Figure 2) resulted in a COP of 0.53 and with heat recovery of the rectification losses of about 0.72 for the design operating conditions.

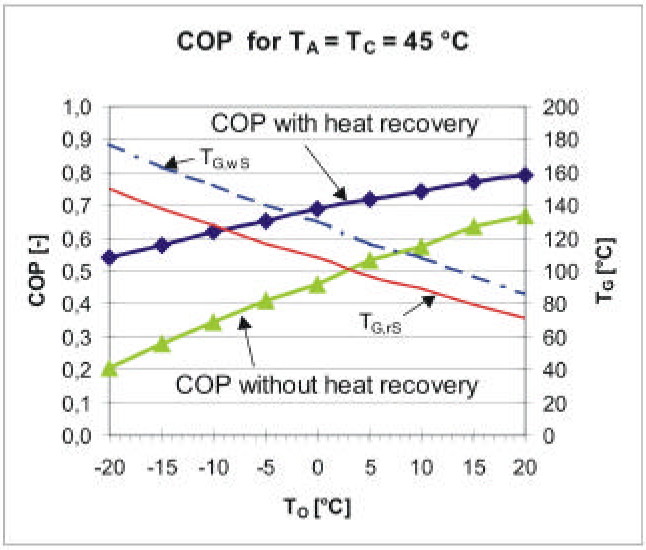

Figure 2: Coefficient of performances (COP) of the DACM with/without heat recovery for evaporator temperatures from –20 up to +20°C and for $T_A = T_C$ = 45°C (simulations).

Appendix 2b
Solar-driven diffusion absorption chiller

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

In this JOULE-CRAFT project "Design of a Solar Driven Cooling Unit based on the diffusion absorption principle", contract JOE3-CT98-7045, an innovative solar thermally driven absorption cooling machine of 2.5kW cooling power was designed and constructed. The indirectly heated generator with a thermally driven gas bubble pump as the main new component of the cooling machine was designed using computer simulation tools and tested on a new experimental facility with alternative material combinations (methanol/water).

Standard components such as condenser, absorber, gas and solution heat exchangers has been scaled up from the known power range for small refrigerators (<100W) to medium power levels. Extensive calculations had to be done to determine the heat exchange properties of these components in the presence of helium as an inert gas. Experiments on the completed prototype unit showed that stable system operation is critically dependent on temperature levels and heat flux densities and continuous operation can only be achieved if special algorithms for system control are used. The temperature levels required from the solar collectors for stable operation were 150°C.

Measurements were done with different evaporator temperature T_o from 0°C up to +25 °C. The reached evaporator capacities were in a range between 0.2 and 1.5 kW and the heating capacities were between 4.0 and 13.5 kW depending on flow rates or heating temperatures. The condenser and absorber cooling capacities were between 1.0 and 3.5 kW and the dephlegmator cooling capacity was 1.0 kW. Up to now the best ever reached cooling capacity of the pilot plant amounted to 1.5 kW. However, the results are very difficult to reproduce and a detailed analysis of the process stability and reproducibility has to be done. For increasing of the cooling capacity to the designed value of 2.5 kW, a further optimisation of the fluid cycles and a reduction of the heat losses is necessary. For the improvement of the performance from the latest reached COP of 0.20 to 0.25 to the calculated COP of the aggregate of 0.5 the internal fluid circulations and the single components generator, evaporator and gas heat exchanger have to be optimised.

As all components of the prototype were custom designed and constructed in the workshops of the University of Applied Sciences Stuttgart, the prototype had a weight of 800kg at 3.7m height. The main task of the development of a market near unit was the redesign of most components (apart from the generator) with the main criteria of cost, weight and height reduction. The final market near unit uses plate heat exchangers for the standard components (condenser, gas and fluid heat exchanger) and a common shell evaporator/absorber construction. The final aggregate could thus be reduced to a 2m high unit of 290kg weight, which can be easily placed in buildings.

An application for a national German Patent was done for the cooling machine and extended to a PCT patent application, which covers the European member states and additionally Australia, China, India, Japan, Canada and the United States.

8. participating companies and institutions

8.1 company's name	Fachhochschule Stuttgart - Hochschule für Technik – Joseph-von-Egle Institut		
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Appendix 2b
Solar-driven diffusion absorption chiller

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role in project	SME coordinator and SME partner; planning, construction, development prototype	
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role in project	SME partner; construction, plans of market near unit	
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role in project	SME partner; planning, development prototype	
8.5 company's name	Energy Consulting	
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e-mail	negro@energy-consulting.com or negro.ec@wanadoo.fr	
role in project	SME partner; simulation, visualisation	
8.6 company's name	AXIMA Refrigeration GmbH Lindau (former: Sulzer-Escher Wyss GmbH)	
Responsible person	Dr.-Ing. Martin Bierer / Dipl.-Ing.(FH) Werner Diepolder	
Address	Kemptener Strasse 11-15, 88131 Lindau, Germany	
Phone	+49 / (0)8382 / 706-284 / -460	fax -479
e-mail	Martin.Bierer@axima.eu.com / Werner.Diepolder@axima.eu.com	
role in project	RTD partner; calculation, planning, construction of market near unit	

Appendix 2b
Solar-driven diffusion absorption chiller

8.7 company's name	Universität Stuttgart – Institut für Thermodynamik und Wärmetechnik	
Responsible person	Dr.-Ing. Klaus Spindler / Dipl.-Ing. Thomas Brendel	
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Phone	+49 / (0)711 / 685-3533 / -3552	fax -3503
e-mail	spindler@itw.uni-stuttgart.de / brendel@itw.uni-stuttgart.de	
role in project	RTD partner; calculation and dimensioning of prototype	

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BRENDEL, T. and SPINDLER, K. and HAHNE, E. (2000). Anwendung eines Gleichungen lösenden Programms zur Berechnung von Kälteprozessen am Beispiel einer Diffusions-Absorptions-Kälteanlage (Use of a equation solver program for the calculation of refrigerating processes at the example of a Diffusion-Absorption Cooling Plant). Conference Report: DKV - Bremen 2000, Vol. 27. Deutscher Kälte- und Klimatechnischer Verein e.V. Stuttgart, Germany. Volume II.1, pp. 243-260. ISBN 3-932 715-32-2.

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Appendix 2b
Solar-driven diffusion absorption chiller

10. funding (national, EU, ...)

This project was funded in part by the European Commission in the framework of the Non Nuclear Energy Programme JOULE-CRAFT (contract number: JOE3–CT98–7045).

Appendix 2c
$NH_3/SrCl_2$ absorption chiller

Subtask C2 – Development of new technologies for solar assisted air conditioning

5. Title of development
Investigation, construction and experimental characterisation of matrix-heat-exchangers for solar assisted periodic cold processes

2. Field of R&D-project (please indicate)	☐ solar components
	☒ cooling or A/C components
	☐ others (please specify)

3. Short description of project (objectives, work program, background,....)

Project objective is the development of a dry absorption chiller based on ammonia-salt working pairs for production of cold from low temperature heat sources such as solar heat, waste heat or heat from combined heat and power (CHP) systems.

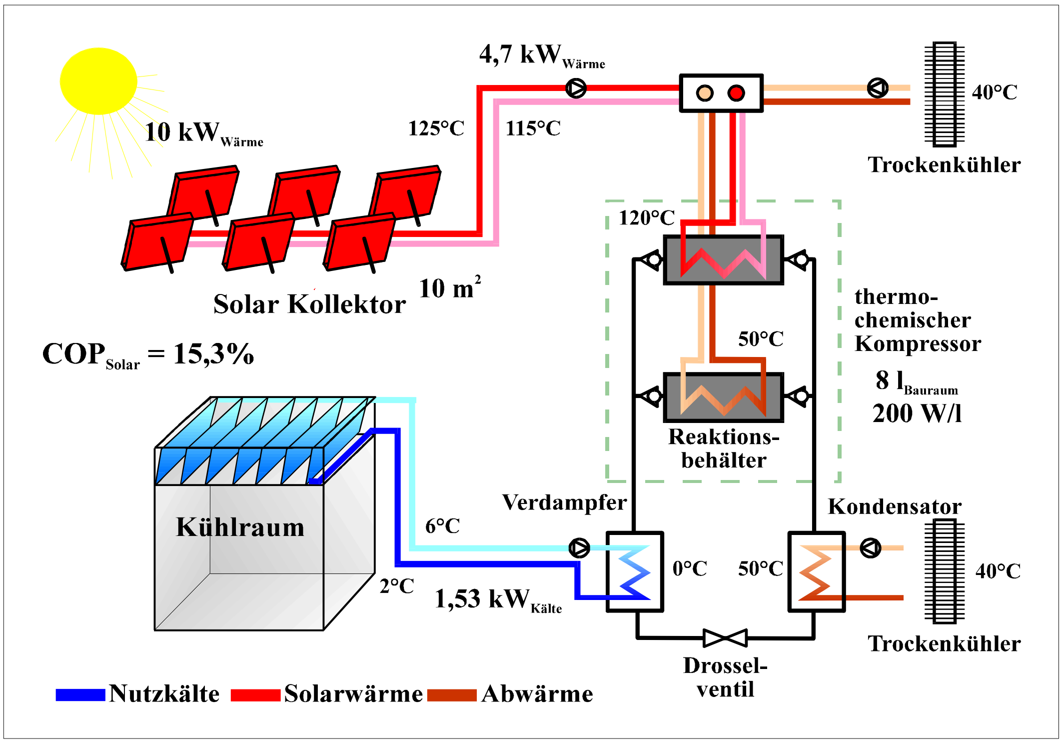
For this purpose a high efficient fixed bed matrix heat exchanger with high power density shall be developed which allows the operation of a quasi-continuous absorption chiller. The matrix heat exchanger shall be manufactured in a simple way close to a real production process.

Two main working areas can be identified:
Matrix-Heat-Exchanger: Production, test and optimisation of the matrix structures with specific consideration of the contact of the reactive layer (ammonia-salt + matrix) to the heat carrier. A standardised heat exchanger is to be developed which serves as basis for the construction of the reaction modules.

System Technology: Operation & control units have to be developed and to be tested together with the components. Results achieved during the operation of the solar driven field test plant and a thermodynamic analysis of the system components shall yield the data for the construction of prototype system (1-3 kW cooling capacity).

Appendix 2c
$NH_3/SrCl_2$ absorption chiller

4. Technical scheme (drawing)



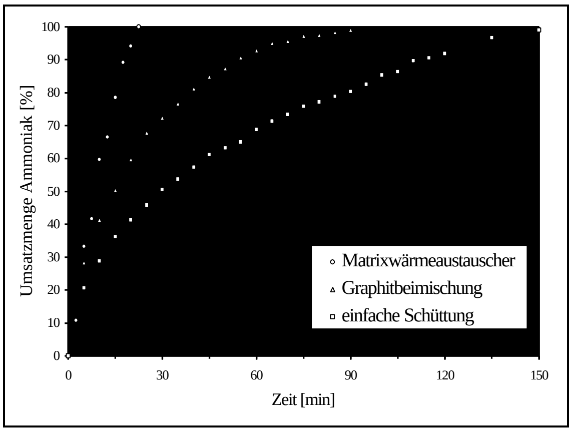
Explanation of German annotation: Trockenkühler - Dry cooler; Thermochemischer Kompressor – thermochemical compressor; Reaktionsbehälter – Reaction vessel; Verdampfer – Evaporator; Drosselventil – Throttle valve; Kühlraum – Cooled room; Nutzkälte – useful cooling; Solarwärme – solar heat; Abwärme – waste heat.

5. Technical description

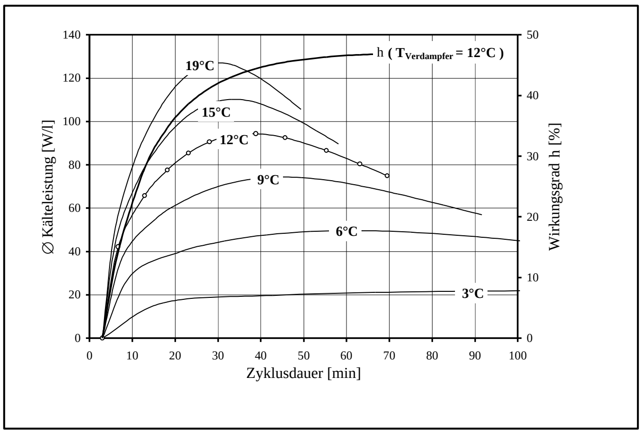
Periodic working dry absorption system with $SrCl_2$ as absorbent and ammonia as refrigerant. Two or more absorbers are used. Desorption takes place if the temperature in the absorber exceeds the equilibrium temperature of the absorbent at given pressure; the pressure is defined by the condenser conditions (condensation temperature).

Appendix 2c
$NH_3/SrCl_2$ absorption chiller

6. performance characteristic (efficiency curve, COP curve, tables....)



Characteristic of the matrix heat exchanger



Dependence of average cooling capacity from evaporator temperature and cycle time

These are modelled data.

Explanation of German text: Umsatzmenge Ammoniak – Ammonia conversion; Zeit – time; Matrixwärmetauscher – matrix heat exchanger; Graphitbeimischung – with graphite; Einfache Schüttung – granular bulk material; Kälteleistung – cooling capacity; Zyklusdauer – cycle time; Wirkungsgrad – efficiency; T_verdampfer – evaporator temperature.

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

The matrix structures were produced for a 1.5-kW-complex absorption machine. The dimension of one element is (200 x 80 x 30) mm³. The mass fraction of the matrix is 7 % and the average pore volume 15 ppi.

The test facility for solar cooling is installed in a container in which a chilled ceiling with an active area of 16.4 m^2 has been installed. On the roof of the container a solar collector of four modules has been installed (selectively coated flat plate collector). Solar energy can be used either to load a 300-l hot water storage tank or for direct cold production. The complex absorption chiller was constructed at the LEHR- & FORSCHUNGSGEBIET HOCHTEMPERATURTHERMODYNAMIK (LHT) and has a nominal capacity of 1 kW. The storage tank ensures that the cooling plant can be driven up to 3 hours without any solar gains.

A digital control of the connection vent between evaporator and the reactors enables a simple control of the cooling power. Moreover this allows to control the reaction rate, thus allowing an optimised switching between cold production and regeneration between the reaction containers.

Appendix 2c
$NH_3/SrCl_2$ absorption chiller

8. participating companies and institutions			
8.1 company's name	RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN, LEHR- & FORSCHUNGSGEBIET HOCHTEMPERATURTHERMO-DYNAMIK (LHT)		
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phone		fax	
e-mail			
role in project	Project coordination; main development work		
8.2 company's name	RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN, INSTITUT FÜR GIESSEREITECHNIK		
responsible person			
address			
phone		fax	
e-mail			
role in project			

9. references

Nahrendorf F., Blank, U., Saumweber, M. Stojanoff, C.G., Entwicklung einer solargetriebenen Absorptionskälteanlage. Workshop "Solar unterstützte Klimatisierung von Gebäuden mit Niedertemperaturverfahren", Forschungsverbund Sonnenenergie (hrsg. Hans-Martin Henning und Thomas Erpenbeck), Freiburg, 1995

10. funding (national, EU, ...)

This project was funded by the German Federal Ministry for Economy.

Appendix 2d
Low temperature absorption chiller for solar cooling of buildings

Subtask C2 – Development of new technologies for solar assisted air conditioning

1. Title of development/project

Air conditioning based on thermal solar energy:

Development of a low temperature absorption chiller for larger scale solar cooling in the building sector

2. Duration of project

Start Date: 02/2001 Termination Date: 02/2003

3. Short description of project (objectives, work program, background,....)

In recent years large scale solar thermal energy utilisation has seen considerable development in terms of the number and size of applications. Further potential and quite promising applications of thermal solar energy use include building air conditioning. Systems using solar thermal energy for building air conditioning are referred to as Solar Cooling Systems. A strong argument for the use of solar cooling systems is that the highest cooling demand occurs at the time of the highest solar energy availability. Despite the large potential demand for solar cooling systems in the building sector, their application has been limited to a small number of pilot and demonstration projects.

The main reason for this is the current level of technical and economic development. A wide range of research projects has been conducted in recent years focusing particularly on the technical improvement of chillers. One of these research projects was conducted in Austria between 1996 and 1999 by the Solarfrost research company. The project focused on the development of a <u>low temperature absorption chiller for use in small-scale applications</u> (< 400 W cooling capacity), employing ammonia (NH_3) as the coolant. This new Austrian development has been patented worldwide and is known as Advanced Ammonia Absorption Cooling, subsequently referred to as AAAC. The main difference between the new AAAC technology and a conventional absorption chiller technology is shown in the Figure in section 4.

As shown in the Figure in section 4, the difference between the conventional absorption chiller technology and AAAC is the development of the "bypass". This bypass permits a considerably higher concentration of ammonia in the water, thus reducing necessary heating temperatures. Further information on the AAAC technology (i.e. AAAC technology) can be found under http://www.solarfrost.co.

The proposed Research & Development activities shall result in:

(a) upscaling of cooling capacity to a minimum level typically required for air conditioning in buildings (the targeted refrigeration capacity of the AAAC machine in this project should be a minimum of 30 kW, but may reach 50 kW or above);
(b) the improvement of the technical / economic competitiveness of Large Scale Solar Cooling

systems, and
(c) a wide spread application on an European basis.

To reach the expected results seven Work Packages (WP) are envisaged. These are:

- ⇨ WP 1: Development and application of a simulation software to support AAAC based Solar Cooling System design and performance evaluation
- ⇨ WP 2: Planning and detail design of a AAAC based Solar Cooling System
- ⇨ WP 3: Construction and installation of the absorption chiller
- ⇨ WP 4: Performance evaluation of the absorption chiller
- ⇨ WP 5: Analysis of the technical and economic feasibility of LSSC systems
- ⇨ WP 6: Dissemination of Project Results
- ⇨ WP 7: Project Management

4. Technical scheme (drawing)

The main difference between the new technology and the conventional diffusion absorption chiller technology is shown in Figure 1.

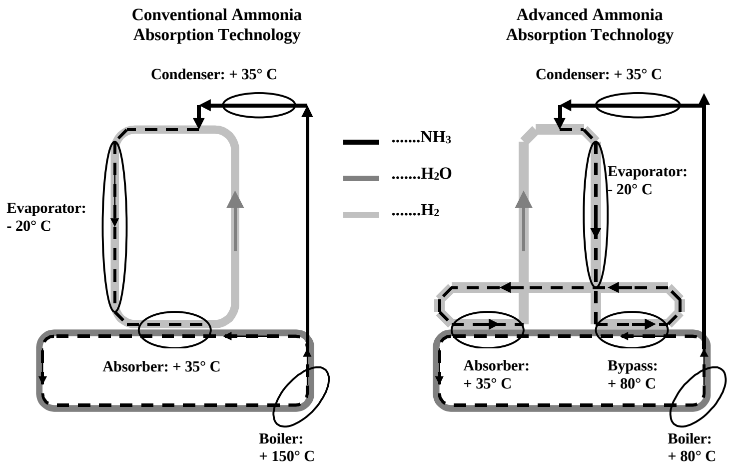

Figure 1: Advanced (Low Temperature) Ammonia Absorption Chiller versus conventional ammonia diffusion absorption chiller – Schematic

Appendix 2d
Low temperature absorption chiller for solar cooling of buildings

5. Technical description

As shown in Figure 1, the difference between the conventional absorption chiller technology and AAAC is the development of the “bypass”. This bypass permits a considerably higher concentration of ammonia in the water, thus reducing necessary heating temperatures. This is explained:

The basic operating principle is of the ammonia absorption cooling system is based on the fact, that ammonia (NH_3) is highly soluble in cold water but not in hot water. If a solution of ammonia in water (H_2O) is heated in the boiler, ammonia vapour is expelled at high pressure. Cooling this vapour in the Condenser to ambient temperature liquefies it. If this liquid ammonia enters the evaporator, where its partial pressure is low (the inert gas H_2 is present), it evaporates easily and absorbs heat from the ambient. This is the cooling effect. The ammonia hydrogen mixture is brought into contact with the water in the absorber at ambient temperature; ammonia is absorbed in the solution while the purified hydrogen goes back to the evaporator. The water cycle is moved by means of a bubble pump, a device used in every coffee machine. The advantage of the bubble pump is, that it has no moving parts and thus completely maintenance free and extremely cheap.

The patented basic feature of the improved ammonia absorption system is a bypass that allows the hydrogen coming from the evaporator to extract further ammonia from the hot solution leaving the boiler. Thus water with very low ammonia content goes to the absorber. Consequently hydrogen purification in the absorber works very well and cooling temperature in the evaporator is low. The high ammonia content of the hydrogen entering the absorber gives a very high ammonia concentration in the water cycle allowing for a considerably lower boiling temperature.

6. performance characteristic (efficiency curve, COP curve, tables....)

Targeted Performance indicators (simulation results)

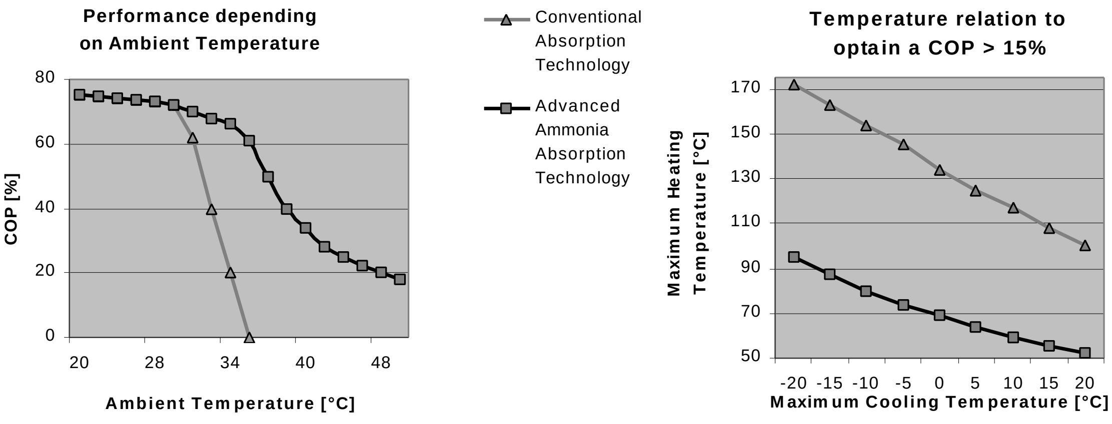

Figure 2: Low Temperature Absorption Chiller versus Conventional Absorption Chiller – Performance Indicators

Appendix 2d
Low temperature absorption chiller for solar cooling of buildings

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)
Testing of the first 500 W test machine

8. participating companies and institutions

8.1 company's name	iC interdisciplinäre Consulenten	
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Address	Kaiserstrasse 45, 1070 Vienna, Austria	
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Responsible person	Hubert Fechner	
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e-mail	fechner.h@arsenal.ac.at	
Role in project	Contractor	
8.3 company's name	Solid Gesellschaft für Solarinstallationen m.b.H.	
Responsible person	Christian Holter	
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e-mail	c.holter@solid.at	
Role in project	Contractor	
8.4 company's name	CIT Energy Management AB	
Responsible person	Jan Olof Dalenbäck	
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Phone	+46 (31) 77 21 - 153	fax -152
e-mail	jod@vsect.chalmers.se	
Role in project	Contractor	
8.5 company's name	World Solar Business and Investment Council	
Responsible person	Kevin Rosner	
Address	3 Rue de l´Arrivee, B.P. 247, 75749 Paris Cedex 15, France	
Phone	+33 (1) 43 20 09 16	fax: +33 (1) 43 22 34 72
e-mail	wsbic@yahoo.com	
role in project	Contractor	

9. references

10. funding (national, EU, ...)

This project is/was funded by: 50 % EU 5th Framework Project

Appendix 2d
Low temperature absorption chiller for solar cooling of buildings

Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)

Subtask C2 – Development of new technologies for solar assisted air conditioning

6. Title of development/project
Study and Development of Heating/Cooling Systems Using Renewable Energy European research project (JOR3-CT97-0181) financed in part by the E.C., DG XII

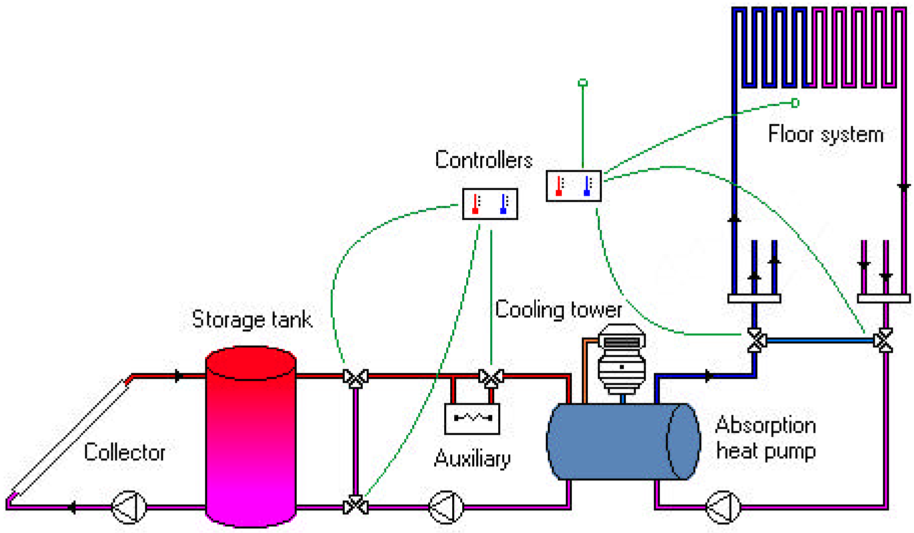
2. Duration of project	
Start Date: JAN 1998	Termination Date: NOV 2001

3. Short description of project (objectives, work program, background,....)
Development of a prototype of a European small size, single stage, LiBr absorption heat pump (about 10 kW) that is connected to improved performance flat plate or evacuated solar collectors and a water storage tank. The chilled water is supplied to a underfloor system. The system is also used for heating. The controller determines the operation of the auxiliary heating system, heat pump, water temperature outlet from A.H.P. and supply to floor system (i.e. to avoid condensation). A sensitivity analysis is performed through an extensive number of TRNSYS simulations for different system design parameters and European locations. The final deliverables include: a prototype 10 kW single stage absorption heat pump, improved performance solar collectors, technical data for a floor heating/cooling system, Design and application guidelines for the entire system. Experimental data are also available.

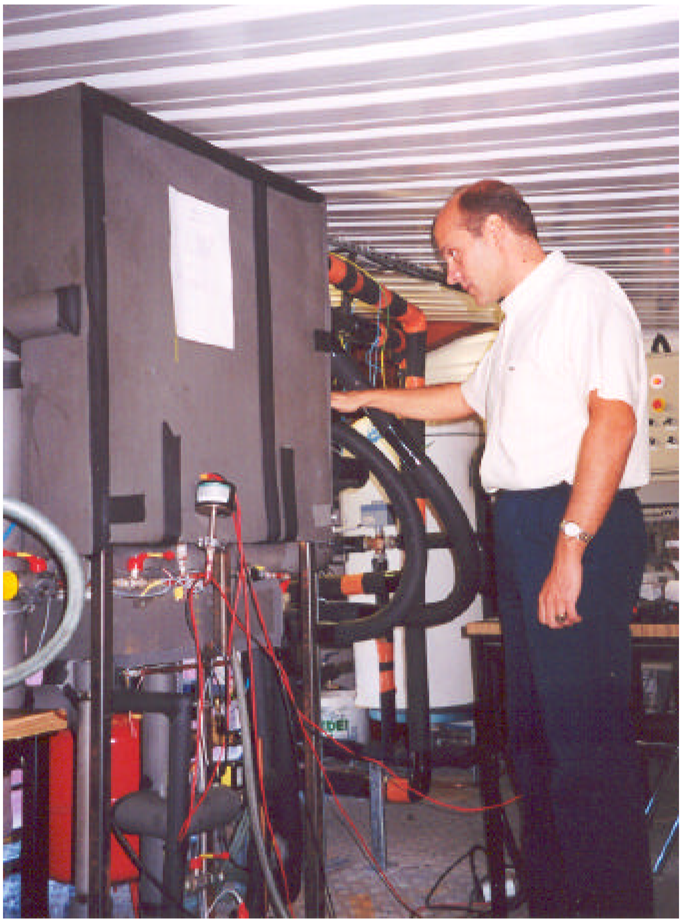
4. Technical scheme (drawing)

The overall system layout is illustrated in the following figure and includes:

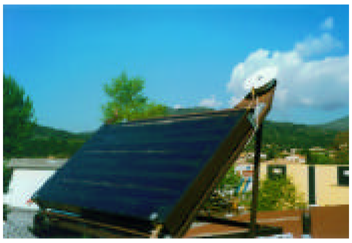
- A solar collector
- A stratified storage tank
- An auxiliary heater
- An absorption heat pump
- A cooling tower and
- A floor heating/cooling system.

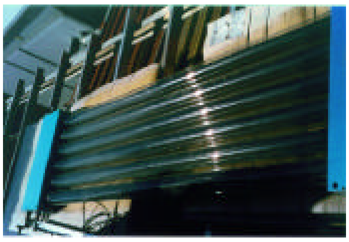


Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)



Prototype absorption heat pump





Solar collector types

Cooling tower

Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)

5. Technical description

The aim of the program was to design and manufacture a small single-stage LiBr absorption heat pump (about 10 kW) and improve the efficiency of flat plate and evacuated tube solar collectors, for heating and cooling of buildings through a floor system. A series of extensive simulations and experiments were used to study and optimise specific system components and the entire system by taking into account different climatic conditions, different building and solar collectors typologies, indoor thermal conditions and control methods for the floor system in order to avoid operational problems (i.e. condensation during summer).

The operation of the absorption heat pump (AHP) requires a hot water temperature supply higher than 77 °C. To reach this temperature, it is possible to use two type of solar collectors namely: flat plate collectors or evacuated tube solar collectors. The goal is to use the solar collectors to produce a hot water temperature of about 80 °C to 90 °C in order to limit the required collector surface and optimise the performance of the AHP.

The hot water temperature from the water storage tank is higher than 77 °C. An auxiliary heat source is used to heat the water when the water outlet temperature is smaller than the above limit.

The refrigerant-absorbent pair used with the absorption heat pump unit in this work is water-lithium bromide. The hot water temperature supply is higher than 77 °C. The AHP considered is a single stage machine.

A floor heating / cooling system is used to cover the heating and cooling loads. For heating, radiant floors operate with a hot water supply between 30 °C - 60 °C. The increased popularity of floor heating systems offers an additional advantage by providing the opportunity to use the existing infrastructure for also cooling purposes. The chilled water that circulates inside the floor provides the necessary cooling energy in order to achieve indoor thermal comfort. In the case of a cooling floor, the radiative exchanges account for 74 % of the heat transfer processes and dominate the phenomena in comparison with the convective exchanges. The chilled water supply temperature to the floor ranges between 7 °C - 24 °C limited by the dew point temperature in order to avoid floor condensation.

The control of the floor heating/cooling system is based in the outdoor - indoor air temperatures, in order to keep the space within the comfort zone. For each hourly time step the supply water temperature is regulated to meet the heating or cooling load of the various zones. For cooling, the chilled water is supplied to the floor system when the indoor air temperature is higher than 25 °C. The water flow rate and temperature is regulated in order to avoid floor condensation (the floor temperature must not be lower than the dew point temperature). For heating, the hot water comes directly from the water storage tank (additional heating is provided, if necessary, from the auxiliary heater) and is supplied to the floor system when the indoor air temperature is lower than 19 °C. The water temperature is regulated in order to avoid high floor surface temperatures (the floor temperature should not exceed 38 °C). Additional controls are used to regulate the water flow when the storage tank outlet water temperature is smaller than the required temperature by the AHP water inlet temperature, then the auxiliary heat source is activated.

Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)

6. performance characteristic (efficiency curve, COP curve, tables....)

On-going experimental testing. Detailed experimental data will become available at the end of the year.

Preliminary specifications:

1. Evaporator: Chilling capacity = 10 kW; chilled water inlet/outlet=20 / 15^{o}C; chilled water flow rate = 1.4 m^3/h
2. Generator: hot water capacity=13 kW; hot water inlet/outlet=95 / 85^{o}C; chilled water flow rate = 1.2 m^3/h
3. Absorber/Condenser: cooling capacity=23 kW; cooling water inlet/outlet=27 / 35^{o}C; cooling water flow rate = 2.6 m^3/h; part load capability = 20%-100%; COP = 0.77
4. Size & Weight: Length = 0.8 m; width = 0.4 m; height = 1.8 m, Weight=400 kg

Representative simulation results from Athens, Greece have shown that the optimised system in Athens includes evacuated tube solar collectors (37 - 45 m^2) and a water tank of 1000 lt. The absorption heat pump with a cooling capacity of 8.7 kW and a COP = 0.85 maintains acceptable indoor thermal comfort conditions for most of the cooling period (May to September). The resulting energy conservation is 20 % compared with the energy consumption of a conventional cooling system.

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

The absorption heat pump prototype has been constructed and is undergoing detailed experimental testing (performance curves, etc). Future developments: 1) Need to reduce weight from this precommercial design; 2) Problems with vacuum tightness (may introduce an automatic purge device); 3) Improve the design by minimising pump work (i.e. no evaporator pump, reliable solution pump).

Simulations have been completed and results are available for over 20000 simulations. The calculations were performed on an hourly basis for an entire year. The sensitivity analysis was performed for three representative European locations namely: (1) Athens, Hellas; (2) Limoges, France; (3) Wuerzburg, Germany. It also included three types of solar collectors with different geometric characteristics, two types of buildings and different operating characteristics of the various components. The sensitivity analysis was based on the calculated seasonal and annual performance of the system in terms of the solar performance of the system, indoor building conditions and economics.

Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)

8. participating companies and institutions			
8.1 company's name	COMITE SCIENTIFIQUE ET TECHNIQUE DES INDUSTRIES CLIMATIQUES – COSTIC		
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role in project	Coordinator		
8.2 company's name	ZAE BAYERN		
responsible person	CHRISTIAN SCHWEIGLER		
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e-mail			
role in project	Manufacturer of absorption heat pump		
8.3 company's name	NATIONAL OBSERVATORY OF ATHENS		
responsible person	C.A. BALARAS		
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phone	+301-8103231	Fax	+301-8103236
e-mail	costas@meteo.noa.gr		
role in project	Simulations		
8.4 company's name	JACQUES GIORDANO INDUSTRIES		
responsible person	D. VILLIER		
address	Z.I. des Paluds, 529 avenue de la Fleuride, 13685 Aubagne, France		
phone	+33 4 42845800	Fax	+33 4 42700870
e-mail			
role in project	Solar collectors		
8.5 company's name	D.F. LIEDELT VELTA		
responsible person	B. OLESEN		
address	Hans-Bockler-Ring 41, D-22851 Norderstedt, Germany		
phone	+49 / 40/ 52902-0	Fax	+49 / 40/ 52902-599
e-mail	Dr.Olesen@velta.de		
role in project	Floor heating / cooling systems		

9. References

- C.A. Balaras, ? .? . Argiriou, S.D. Kontoyiannidis. Solar Assisted Absorption Heat Pump Coupled with Floor Heating & Cooling. *CLIMA 2000 World Congress*, Naples, 15-18 September, (2001).
- "Study and Development of Heating/Cooling Systems Using Renewable Energy". JOULE Programme, Directorate General XII for Science, Research and Development (JOR3-CT97-0181), European Commission.

Appendix 2e
Absorption heat pump for solar assisted space conditioning of a small office (SOLHEATCOOL)

10. funding (national, EU, ...)

This project is/was funded by the European Commission in the framework of the JOULE programme (JOR3-CT97-0181) and national funds of the participating organisations.

Appendix 2f
Air-cooled H_2O/LiBr absorption chiller with a low capacity (ACABMA)

Subtask C2 – Development of new technologies for solar assisted air conditioning

7. Title of development/project

Air-Cooled Water-LiBr Absorption Cooling Machine of Low Capacity for Air Conditioning (ACABMA)

2. Duration of project

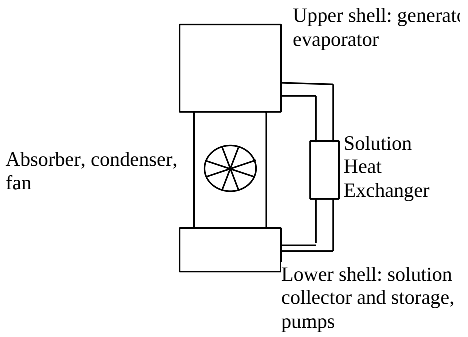
Start Date: 1-10-1998 Termination Date: 31-10-2001

3. Short description of project (objectives, work program, background,....)

The basic objective of this project is the development of a new air-cooled absorption cooling machine for air-conditioning, using the fluid pair water-LiBr for the domestic use, in the low power sector market.

This technology would avoid the expenses for a cooling tower, which is normally required for H_2O/LiBr chillers, and therewith reduce the investment cost by 25-30%. The price of the air-cooled absorption chiller should be similar conventional water-cooled systems.

4. Technical scheme (drawing)



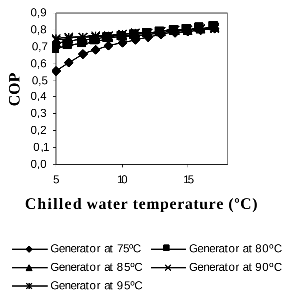
Layout of the system

Appendix 2f
Air-cooled H_2O/LiBr absorption chiller with a low capacity (ACABMA)

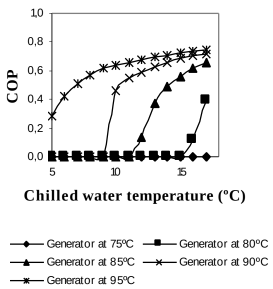
5. Technical description

The most important point of the project is the air-cooling, because in the low power sector market the cooling tower reduces the number of applications. The fluid pair water-LiBr will be used, because its greater performance but it implies the problem of crystallisation. Moreover, the air-cooling feature increases the crystallisation risk. For this reason, the optimisation of the heat transfer with the air is critical for the project. The most problematic one of the air-cooled elements is the absorber because the heat and mass transfer coefficients are smaller than in the other parts of the absorption machine. High level numerical simulation tools will support the study of the heat and mass transfer in the absorber. The numerical results obtained from the simulation of the air-cooling and the absorption processes in the absorber will be compared and validated with experimental test results obtained from small-scale absorbers.

6. performance characteristic (efficiency curve, COP curve, tables....)



Cooling air at 35°C



Cooling air at 45°C

Performance data from system simulations.

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

At present (March 2002) the laboratory prototype is being tested.

Appendix 2f
Air-cooled H_2O/LiBr absorption chiller with a low capacity (ACABMA)

8. participating companies and institutions			
8.1 company's name	División Solar S.A.		
responsible person	Juan Carlos Martínez Escribano		
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role in project	SME prime proposer		
8.2 company's name	Sunwind Energies SARL		
responsible person	Jacques Simonin		
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e-mail	sunwind@outremer.com		
role in project	SME proposer		
8.3 company's name	Alternativas Energéticas Solares S.A.		
responsible person	Goñi Iturria		
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phone	34-48-74 06 50 / 70 37 76	fax	34-48-74 10 55
e-mail			
role in project	SME proposer		
8.4 company's name	Marketing- und Technologie-Consult GmbH		
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phone	49-89-90 05 96 13	fax	49-89-90 05 96 20
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role in project	SME proposer		
8.5 company's name	MADE Energías Renovables S.A.		
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role in project	Additional proposer		
8.6 institution name	Universitat Politècnica de Catalunya		
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role in project	RTD performer		
8.7 institution name	Instituto Nacional de Técnica Aeropespacial		
responsible person	Carmen Granados		
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phone	34 59 208844	fax	34 59 208857
e-mail	granados@inta.es		
role in project	RTD performer		

9. references

CRAFT-JOULE project: air-cooled water-LiBr absorption cooling machine of low capacity for air conditioning (ACABMA). A. Oliva, J. Castro, C.D. Pérez-Segarra, M.A. Lucena, J.C. Martínez, J. Simonin, G. Brachthäuser, M.J. Arrarás and J.C. Lavandeira. Proceedings of the ISES Forum 2000, paper number DSSA 10-09.

10. funding (national, EU, ...)

This project is/was funded by EU for SME Specific Measures Cooperative Research (CRAFT)

Appendix 3a
Hybrid adsorption cooling system with booster pump

Subtask C2 – Development of new technologies for solar assisted air conditioning

8. Title of development

Low temperature driven hybrid adsorption cooling system with a mechanical booster pump

2. Field of R&D-project (please indicate)

☐ solar components

☒ cooling or A/C components

☐ others (please specify)

3. Short description of project (objectives, work program, background,....)

A new adsorption chiller was planned with a mechanical booster pump which is placed in between adsorbent beds and condenser, to regenerate the beds by reducing the pressure inside the adsorption bed at temperatures below 60ºC (lower than otherwise required for regeneration). This work deals with the performance testing of a cooling system based on this new adsorption cycle with a cooling capacity of 50 kW, an estimated cooling COP larger than 10 (cooling power/electric power input).

4. Technical scheme (drawing)

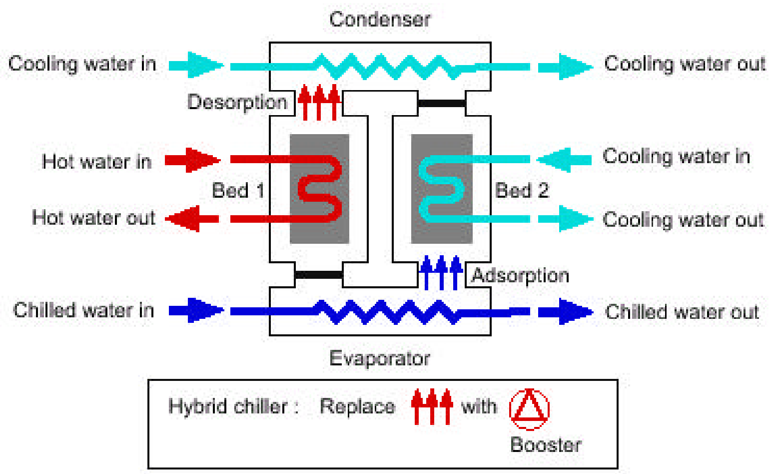

Fig. 1 Schematic of the chiller

Appendix 3a
Hybrid adsorption cooling system with booster pump

5. Technical description

As shown in Figure 1, the chiller consists of two beds packed with silica gel as adsorbent, a condenser, a mechanical booster pump and an evaporator.

In the bed-evaporator interaction, adsorption takes place in the adsorbent bed by rejecting heat to external heat source (cooling water), while evaporation of adsorbate occurs in the evaporator which absorbs heat from outside of the system (chilled water). This produces the useful cooling effect. Simultaneously, in the bed-condenser coupling, desorption takes place in the fully adsorbed bed by receiving heat from external heat source (hot water), while condensation of adsorbate occurs in the condenser to dissipate condensing heat to outside of the system (cooling water). In the following cycle, the two beds change their role, and thus the chiller can work continuously. Since adsorption and condensation are exothermic whereas desorption is endothermic, hence the cooling water and hot water supply are necessary to maintain the process.

In switching to the other process, that is, from the regeneration to the adsorption, the heated bed must be cooled and vice versa, in order to transfer to the next process. For this switching period all vapour valves are closed so as to be isosteric, i.e., neither adsorption nor desorption occurs.

When the mechanical booster pump is used to pump the vapour from the regeneration bed to the condenser, the bed can be regenerated easily and the required temperature of heat source can be reduced. The COP including the driving heat source is 0.52, see Figure 2.

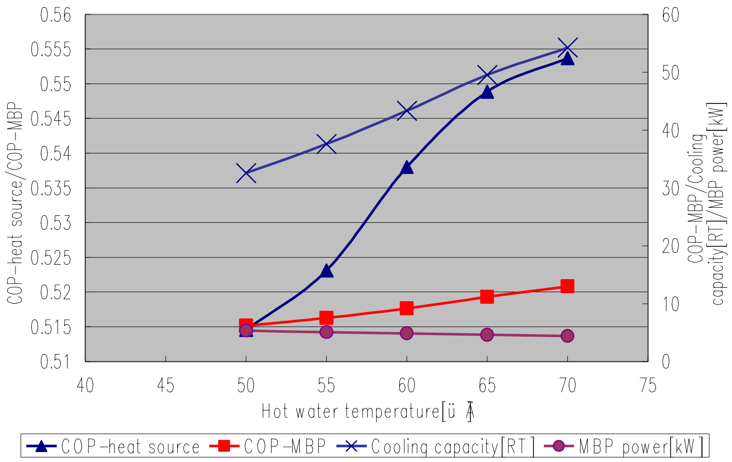

Figure 2: $COP_{heat\ sourcce}$, $COP_{booster\ pump}$ and cooling capacity versus hot water temperature

At driving temperatures below 65ºC, the adsorption chiller without booster pump cannot operate. Figure 2 shows that the machine operates down to driving heat temperatures of 50ºC with the booster pump added.

Appendix 3a
Hybrid adsorption cooling system with booster pump

Table 1: The specification of the pilot plant

Model	Unit	ADRh-50k
Adsorbent/refrigerant	–	Silica-gel/water
Cooling capacity	kW	50
COP	–	10.2
Chilled water Inlet/outlet temperature Flow rate	 ºC m^3/H	 14.0/9.0 8.6
Cooling water Inlet/outlet temperature Flow rate	 ºC m^3/H	 29/33 30.0
Hot water Inlet/outlet temperature Flow rate	 ºC m^3/H	 55.0/50.0 14.3
Amount of working refrigerant per unit adsorber	? q kg-H_2O/kg-silica-gel	0.05
Mechanical booster pump Throughput of pumping Power consumption	 m^3/min. kW	 33.6 4.5

6. performance characteristic (efficiency curve, COP curve, tables....)

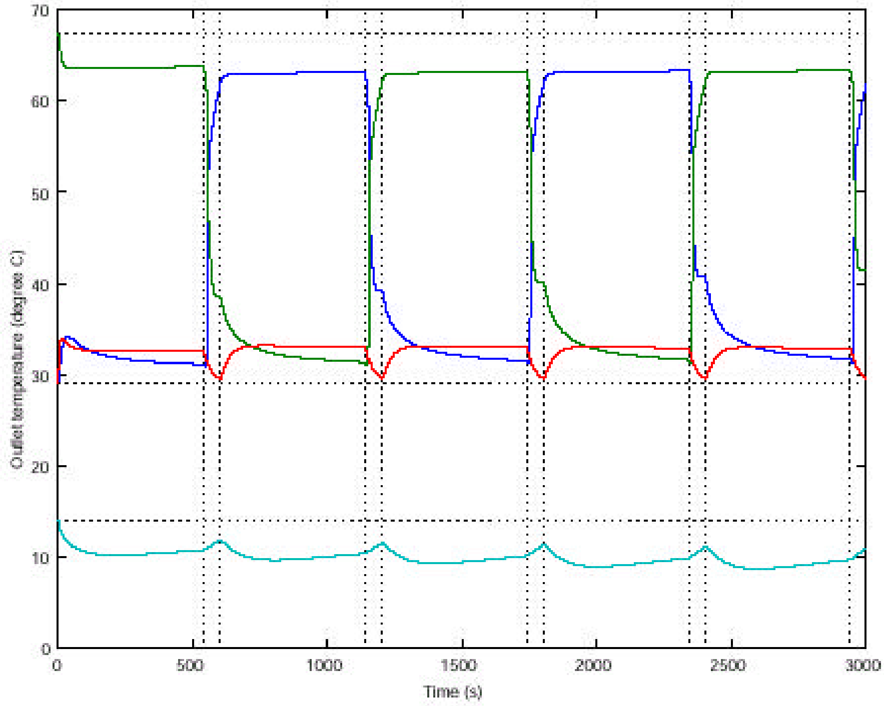

Figure 3 The time dependency of outlet temperatures and pressure in the bed.

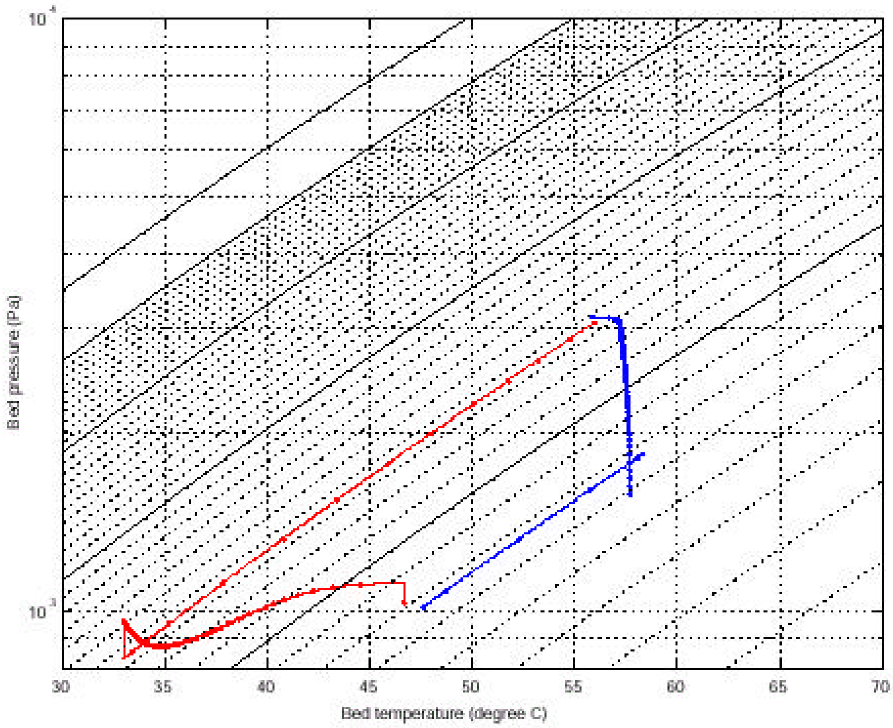

Figure 4 Duehring diagram of the cycle-steady -state condition of the beds.

Appendix 3a
Hybrid adsorption cooling system with booster pump

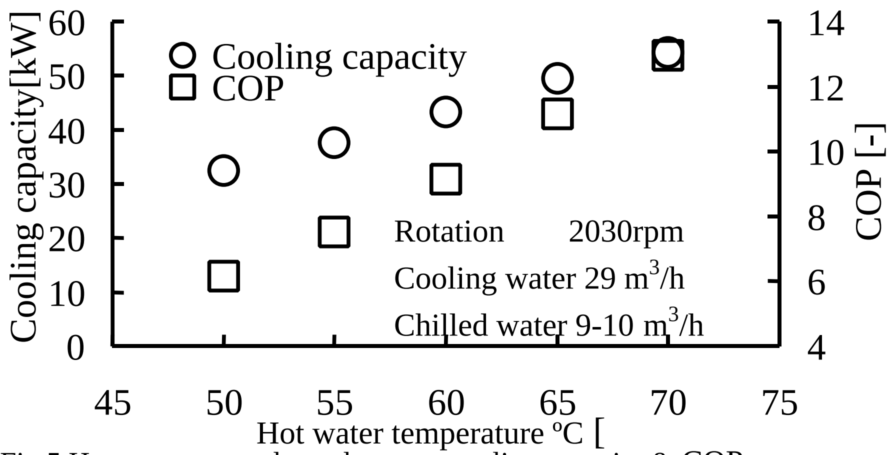

Fig.5 Hot water temp. dependency on cooling capacity & COP

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

Prototype testing. The capacities and COPs shown in figure 5 above are measured values.

8. participating companies and institutions

8.1 company's name	Advanced Tech. lab., Mayekawa Mfg. Co., Ltd.,		
responsible person	Hideharu Yanagi		
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role in project	Project Management ; main development work		
8.2 company's name	Electrical Eng. Dept., The Chubu Electric Power Co., Inc,		
responsible person	Michito. Kanamori		
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Phone		fax	+81-52-624-9234
e-mail	Kanamori.Michito@chuden.co.jp		
role in project	Co-development work		

9. references

10. funding (national, EU, ...)

This project is/was funded by Chubu Electric Power Co., Inc., and MYCOM.

Appendix 3b
Four-bed adsorption chiller

Subtask C2 – Development of new technologies for solar assisted air conditioning

1. Title of development/project

Four-bed adsorption chiller

2. Duration of project

Start Date: Termination Date:

3. Short description of project (objectives, work program, background,....)

The four-bed adsorption chiller can operate with low driving temperatures and delivers steady cooling with lower peak oscillation than two-bed adsorption chillers. Another advantage is that the temperature difference between driving heat input and outlet may be up to 20ºC, compared to 5ºC for a two-bed absorption chiller. More low-grade heat can be used,

The photo shows the prototype, a 5 RT (17.6 kW) cooling capacity machine.

Appendix 3b
Four-bed adsorption chiller

4. Technical scheme (drawing)

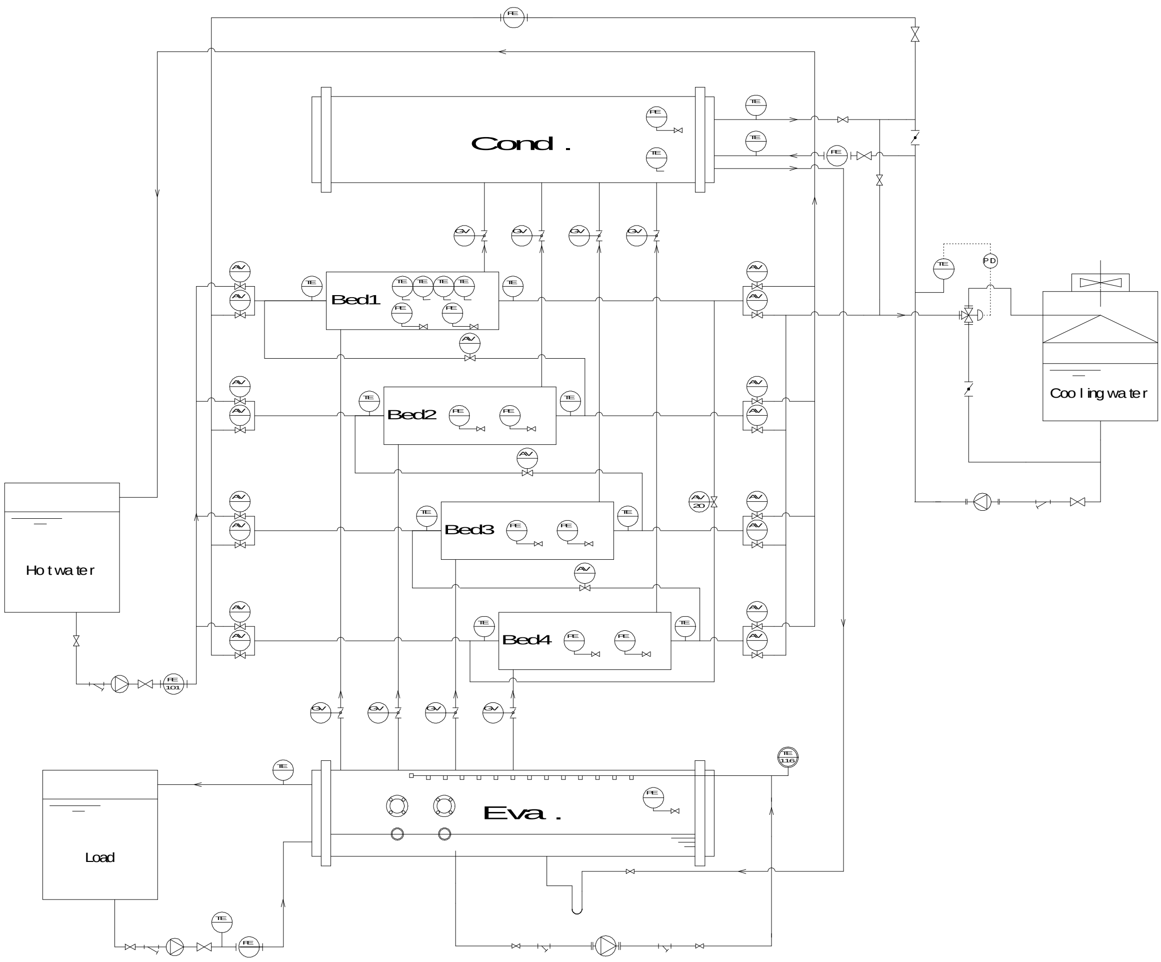

Figure 1: Schematic flow diagram of a 4-bed chiller

5. Technical description

The four-bed chiller is an extension of 2-bed operation. Table 1 shows the switching of functions of the beds for two cycles. “ads” is adsorption, “des” is desorption, and “sw” is switching from absorption to desorption and vice versa, receiving heating from “des1” or cooling from “ads1”. Number 1 – the bed receives the cooling stream directly from the condenser or the heating stream directly from the heat source. Number 2 – the bed receives cooling from “ads1” or heating from “des2”.

Appendix 3b
Four-bed adsorption chiller

Table 1 Switching schedule for a 4-bed chillier over two cycles

Bed 1	sw	Ads2	ads1		Sw	des2	Des1	
Bed 2	des1		sw	ads2	ads1		sw	des2
Bed 3	sw	Des2	des1		Sw	ads2	Ads1	
Bed 4	ads1		sw	des2	des1		sw	ads2

Table 2 Specification of a prototype machine

Adsorbent/refrigerant Adsorbent weight/bed	Silica gel/water 36 kg
Cooling capacity	5 RT (17.6 kW)
COP	0.6
Chilled water inlet/outlet temperature Chilled water flow rate	14.0/9.0ºC 0.84 kg/s
Cooling water inlet temperature Cooling water flow rate	31ºC 0.8 kg/s
Hot water inlet temperature Hot water flow rate	85ºC 0.8 kg/s
Flow rate cooling water of condenser	2.1 kg/s

Appendix 3b
Four-bed adsorption chiller

6. performance characteristic (efficiency curve, COP curve, tables....)

Modelled performance of the 4-bed adsorption chiller:

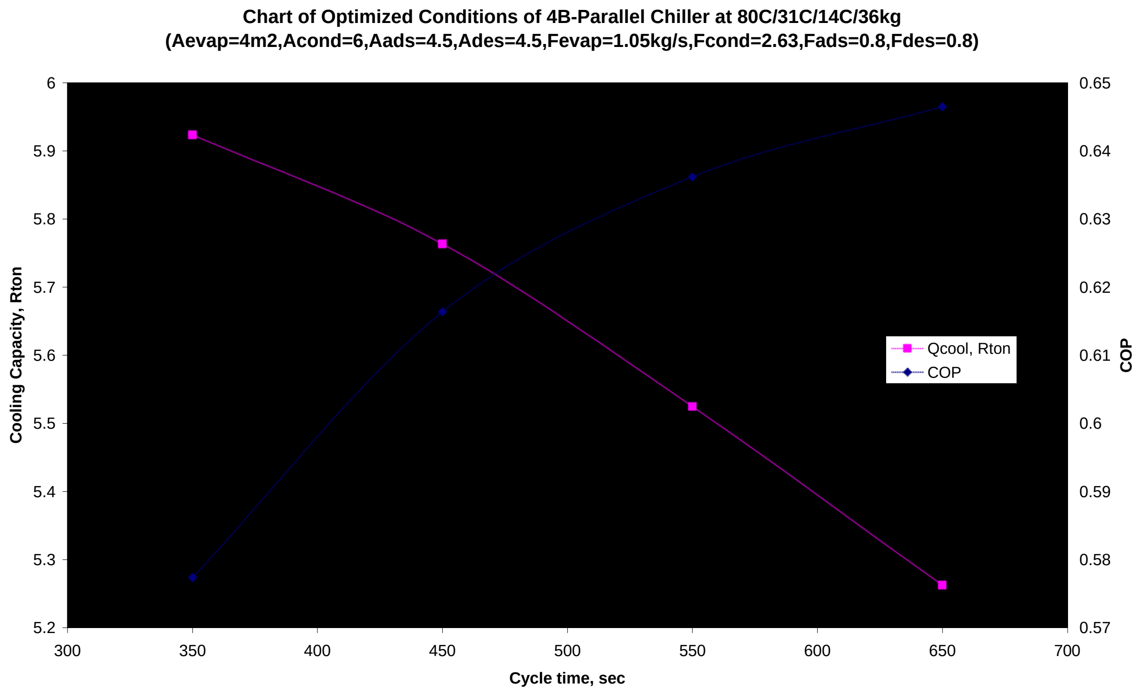

Figure 2: Cooling capacity and COP as a function of cycle time

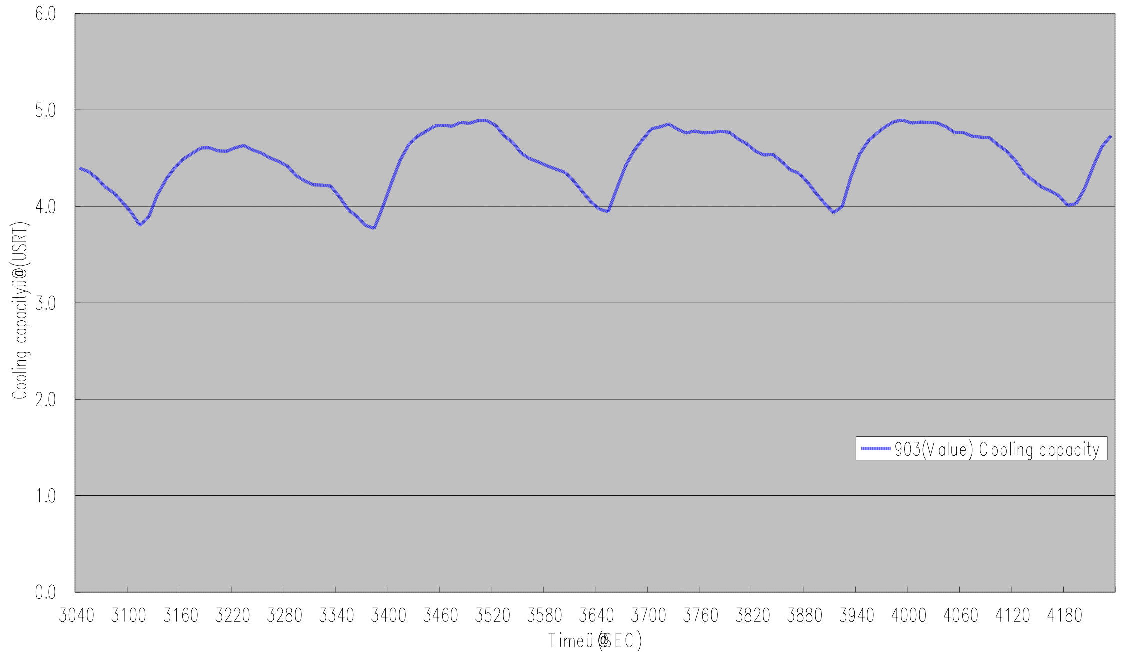

Figure 3: Cooling capacity profile of a 4-bed adsorption chiller

Appendix 3b
Four-bed adsorption chiller

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)
Prototype production

8. participating companies and institutions			
8.1 company's name	Advanced Tech. lab., Mayekawa Mfg. Co., Ltd.,		
Responsible person	Hideharu Yanagi		
Address	2000 Tatsuzawa,Moriya-Machi, Kitasooma-Gun, Ibaraki-Pref.302-0118, Japan		
Phone	+81-297-48-1364	fax	+81-297-48-5170
e-mail	MYK01013@nifty.ne.jp		
Role in project	Project Management ; main development work		
8.2 company's name			
Responsible person			
Address			
Phone		fax	
e-mail			
Role in project			
8.3 company's name			
Responsible person			
Address			
Phone		fax	
e-mail			
role in project			

9. references

10. funding (national, EU, ...)
This project is/was funded by …

Appendix 3c
Improved absorption chiller

Subtask C2 – Development of new technologies for solar assisted air conditioning

2. Title of development

Development of an adsorption chiller for the application of district heat between 50°C and 100°C for the production of chilled water (> 2°C) for cooling and air conditioning

2. Field of R&D-project (please indicate)

- ☐ solar components
- ☒ cooling or A/C components
- ☐ others

3. Short description of project (objectives, work program, background,....)

Objective is to construct an adsorption chiller working with the silica gel / water working pair in a modular way which can be adapted to cooling capacities over a wide range:

- use of low temperature heat in the range of 50°C to 100°C
- cooling capacity in the range of 10 kW up to 1 MW
- construction of specifically ribbed plate heat exchangers with improved heat transfer characteristics at low heat capacity of the heat exchanger matrix
- aims to achieve a high COP of about 0.8 by internal heat recovery means
- improved part load behaviour
- investment costs aimed to be not higher than 500 DEM per kW cooling capacity

The work program comprises:

- development of modular concept
- development of optimised plate heat exchanger
- development of optimised evaporator and condenser (high heat transfer, low heat capacity)
- development of an optimised rotating type switching system
- development of optimised control concept (COP-optimisation)

Two test modules with 20 kW and 360 kW, respectively, will be build for operation tests.

4. Technical scheme (drawing)

not yet available

Appendix 3c
Improved absorption chiller

5. Technical description

Periodic working adsorption system with silica gel as adsorbent and water as refrigerant. Two or more adsorbers are used. Desorption takes place if the temperature in the absorber exceeds the equilibrium temperature of the absorbent at given pressure; the pressure is defined by the condenser conditions (condensation temperature).

Heat recovery is employed in order to take use of the heat of the reactor which has been regenerated and to be cooled down to adsorption temperature; this heat is used to preheat the reactor that has to be regenerated, i.e., heated up from adsorption temperature to regeneration temperature.

6. performance characteristic (efficiency curve, COP curve, tables....)

Heat exchanger type	Conventional tube HX	Advanced plate HX
spec. heat transfer area	1,56 m²/kg silica gel	2,98 m²/kg silica gel
spec. gradient for heat transfer	~85 W/kg silica gel K	1,7 W/kg silica gel K
spec. mass of HX	1,25 kg/kg silica gel	0,76 kg/kg silica gel

Characteristics of the advanced adsorber heat exchanger

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

A first prototype with evaporator and condenser built as plate heat exchangers was finished. However, in this prototype the adsorber was constructed using conventional tube type heat exchanger since the plate heat exchange can not be constructed using market available equipment.

The next prototype will be built using a plate heat exchanger in the adsorption reactor. For this purpose specific tools for the production of the adsorber plate heat exchanger have been constructed.

8. participating companies and institutions

8.1 company's name	GBU Gesellschaft für Bodenanalytik und Umwelttechnik mbH		
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phone		Fax	
e-mail			
role in project	project coordinator		

Appendix 3c
Improved absorption chiller

9. references

none yet

10. funding (national, EU, ...)

This project is funded by the German Federal Ministry for Economy.

Appendix 4a
Solar-driven liquid desiccant dehumidification of ventilation air

Subtask C2 – Development of new technologies for solar assisted air conditioning

3. Title of development/project

Regenerative Air Conditioning of the Office Building “Email-Fabrik” in Amberg, Germany

2. Duration of project

Start Date: November 1999. Termination Date: December 2002.

3. Short description of project (objectives, work program, background,....)

Air conditioning of an office building using well water for structure cooling, using a liquid desiccant for air dehumidification. The desiccant is regenerated by solar energy and used as energy storage.

1. Installation of a multi zone structure cooling and heating system,

development, installation and test of

2. A prototype absorber for cooled air dehumidification and energy storage,
3. A desiccant regenerator for direct solar operation,
4. A desiccant handling system.

Appendix 4a
Solar-driven liquid desiccant dehumidification of ventilation air

4. Technical scheme (drawing)

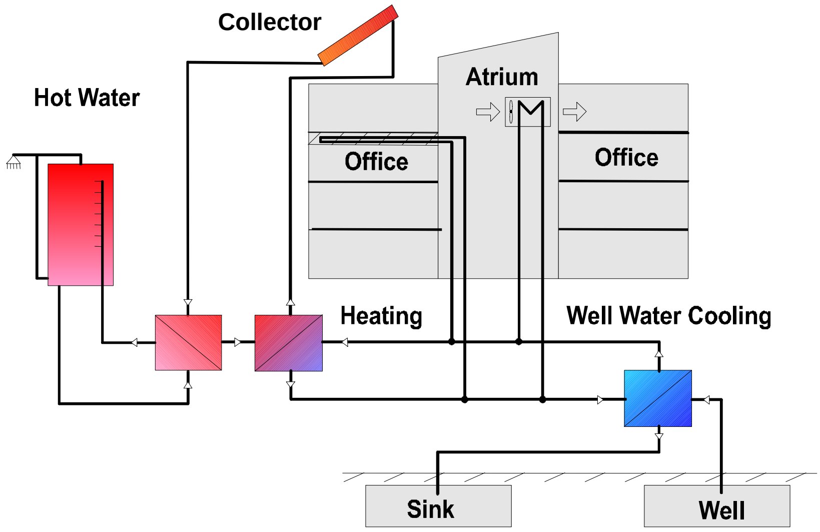

Figure 1: Structure cooling and heating. Solar hot water and optional solar space heating.

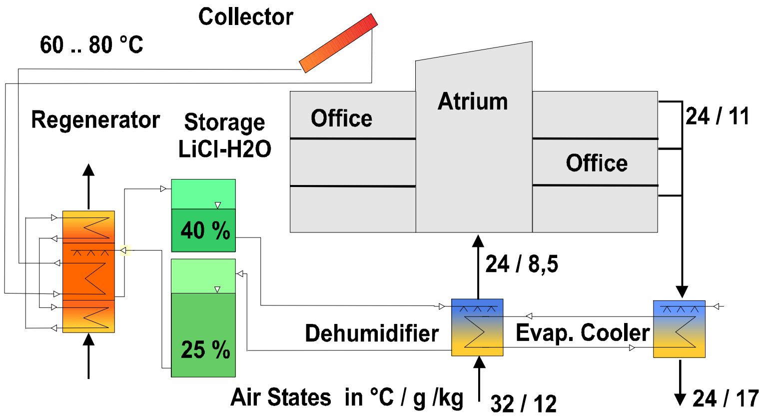

Figure 2. Solar air dehumidification and storage system

Appendix 4a
Solar-driven liquid desiccant dehumidification of ventilation air

5. Technical description

The 5000 m² office building is equipped with a multi zone heating and cooling system, and plastic piping moulded into the concrete ceilings, Fig. 1. Heating is operated by natural gas. Solar assistance is optional and not yet installed. For cooling well water is circulated through the plastic piping. For air dehumidification a solar powered liquid desiccant air dehumidification system is installed. In summer air dehumidification is required to operate the cooling efficiently and prevent from condensation on cold ceilings.

In Summer ambient air (30.000 m³/h) is cooled and dehumidified by a central absorber using a concentrated liquid desiccant solution (LiCl-H_2O) and blown into the atrium, Fig. 2. Decentralised air handling units take the air into the offices, Fig. 1, and provide further cooling on demand using the well water. The exhaust air is used in indirect evaporative coolers to cool the absorber and the supply air, Fig. 2. The special design of the absorber provides a significant concentration difference between concentrated and diluted desiccant solution. This feature is used to store energy by separating concentrated and diluted desiccant. The diluted desiccant is regenerated in a regenerator by solar heat at 70°C. The dehumidification process can be operated as long as concentrated desiccant is available.

The rated capacity of the desiccant system is 70 kW dehumidification and additional 80 kW cooling, the rated capacity of well water cooling is 250 kW. 70 m² of high performance flat plate water collectors are installed. 7500 kg of a 40% lithium chloride solution provide a rated storage capacity of 2000 kWh dehumidification.

6. Performance characteristic (efficiency curve, COP curve, tables....)

not yet available (Status January 2002)

7. Project status (prototype production, pilot production, market introduction, unsolved problems,)

Demonstration project. Absorber and regenerator are prototypes. Status January 2002: components are installed, measurement and control equipment not yet fully installed. System is to be set into operation before June 2002.

8. participating companies and institutions

8.1 company's name	Prochek Immobilien GmbH & Co KG		
responsible person	Annette Baumann		
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role in project	Investor		

Appendix 4a
Solar-driven liquid desiccant dehumidification of ventilation air

8.2 company's name	Ingenieurbuero Michael Gammel GmbH		
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e-mail	g.fischer@gammel.de		
role in project	Project management, building services		
8.3 company's name	Bayerisches Zentrum für Angewandte Energieforschung, ZAE Bayern e.V.		
responsible person	Eberhard Laevemann		
address	Walther-Meissner-Strasse 6, D-85748 Garching,		
phone	++49 89 356250-18	Fax	++49 89 356250-23
e-mail	eberhard.laevemann@physik.uni-muenchen.de		
role in project	Development and design desiccant technology, scientific evaluation		

9. references

W. Kessling, E. Laevemann, M. Peltzer, **Open Cycle Liquid Desiccant Dehumidifier: Theoretical Potential, Experimental Results, Applications**, Proceedings of the International Sorption Heatpump Conference, ISHPC, Munich, Germany March 24-26,1999.

W. Kessling, E. Laevemann, M. Peltzer, **Energy Storage in Open Cycle Liquid Desiccant Cooling Systems**, International Journal of Refrigeration, Volume 21, Number 2, pp. 150 – 156, Elsevier Science Ltd and IIR, 1998

W. Kessling, E. Laevemann, C. Kapfhammer, **Energy Storage for Desiccant Cooling Systems, Component Development**, Solar Energy, Volume 64, Nos 4-6, pp. 209 – 221, Elsevier Science Ltd, 1998

W. Kessling, E. Laevemann, M. Peltzer, **Energy Storage for Solar Desiccant Cooling Systems**, Solar Engineering, Proceedings of the 1998 International Solar Energy Conference, June 14-17-1998, Albuquerque New Mexico, The American Society of Mechanical Engineers, New York 10017

10. funding (national, EU, ...)

This project is/was funded by: Bayerisches Staatsministerium für Wirtschaft, Verkehr und Technologie, (national)

Appendix 4b
Solar cooling, dehumidification and air conditioning using liquid desiccants (part of ASODECO).

Subtask C2 – Development of new technologies for solar assisted air conditioning

4. Title of development/project

Advanced Solar Driven Desiccant Cooling Systems for Central European and Mediterranean Climates (ASODECO): *Solar Cooling, Dehumidification and Air Conditioning using Liquid Desiccants.*

2. Duration of project

Start Date: May 1, 2000 Termination Date: April 30, 2003

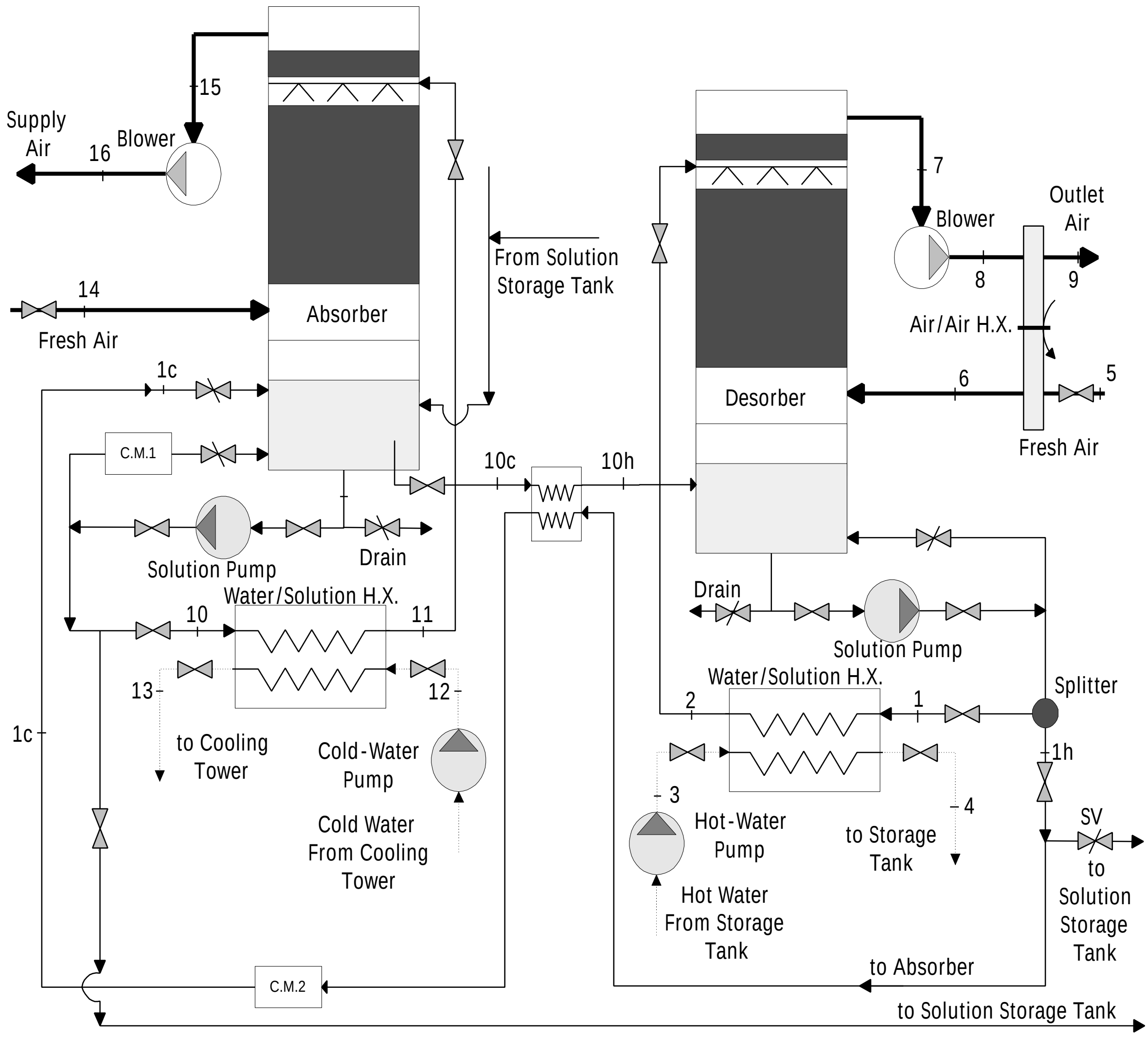
3. Short description of project (objectives, work program, background,....)

This project (Work Package 4 of EU Project ASODECO) is concerned with a solar air conditioning system based on controlled evaporation and dehumidification using liquid desiccants. The system uses as its source of power low-grade solar heat, obtainable from low-cost flat plate collectors. The system has the potential to provide both cooling and dehumidification in variable ratios, as required by the load. The liquid desiccant employed is an aqueous solution of lithium chloride.

Under this project, a fully-instrumented liquid desiccant cooling system is designed and built to air-condition a group of offices on the top floor of a building at the Technion – Israel Institute of Technology (Haifa, Israel). This system will serve as a prototype for larger systems, to be constructed at a later stage. The use of hygroscopic salts in direct contact with moist air provides an attractive alternative to conventional cooling systems employing ozone-depleting CFCs. The possibility of using low-grade energy goes a long way toward the elimination of pollution and utilising renewable and environmentally safe energy sources.

Appendix 4b
Solar cooling, dehumidification and air conditioning using liquid desiccants (part of ASODECO).

4. Technical scheme (drawing)



5. Technical description

The system under consideration is designed to air-condition a group of offices (total floor area of 35 m^2) on the top floor of the Energy Research Center building at the Technion – Israel Institute of Technology (Haifa, Israel). The city of Haifa is an ideal site to test such a system. Located on the Mediterranean coast at 33 degrees north latitude, it has the typical climate of Mediterranean cities. Outside summer conditions (typical for design) are 30^oC and 70% relative humidity. Room design conditions have been selected at 24^oC and 50% relative humidity. A load calculation for the three typically staffed and equipped offices shows about 4.2 kW with a room sensible heat factor (RSHF) of 0.92. At 30 cfm of fresh air per occupant (ASHRAE air quality recommendations), the additional fresh air–associated load is about 3.0 kW, most of which (2.4 kW) is latent. Thus, the total cooling capacity required is 7.2 kW, with a grand sensible heat factor (GSHF) of 0.62. The total supply air circulation needed (based on 12 air changes per hour) is 0.4 kg/sec (720 cfm). The desired conditions of the supply air are 14.7^oC and 86% relative humidity.

Appendix 4b
Solar cooling, dehumidification and air conditioning using liquid desiccants (part of ASODECO).

In considering the liquid desiccant system for performing the air conditioning task, two cooling options are available. Under option A, ambient air mixed with return air is dried in the dehumidifier (absorber, refer to drawing). Leaving the dehumidifier, the air is cooled first in a heat exchanger by cooling water or exhaust air, then cooled further in an auxiliary chiller (e.g. electrical heat pump) and still further in an evaporative cooler before being supplied to the conditioned space. In this option, the desiccant part of the system treats the total supply air (the return air together with the fresh air) and deals with the latent heat together with part of the sensible heat. The auxiliary chiller deals with the remaining part of the sensible load. In option B, the fresh (make-up) air, accounting for most of the latent load, is treated separately by the desiccant system while an auxiliary heat pump deals with the sensible load of the rest of the air. Under this option, the fresh air is dried in the dehumidifier, then cooled by heat exchange with the exhaust air in an air-to air heat exchanger, and supplied to the conditioned space. Calculations show that option A has a thermodynamic advantage only when exercising the option of employing an auxiliary chiller with an evaporator temperature considerably higher than normal (not requiring to cool the air below its dew point for dehumidification and hence operating at a higher efficiency). Otherwise, option B is preferable, providing a simpler way for controlling the complete system and for incorporating the auxiliary heat pump. Option B also requires considerably less pumping and fan power in the desiccant system than option A.

The desiccant solution is regenerated by solar heat, supplied by flat-plate solar collectors of conventional design, of the type widely employed in Israel for domestic water heating, but with better than average quality to enable higher efficiency at high temperatures. Solar-heated water serves as the heat carrier. The option of heating the regenerated solution directly, by exposing it to the sun and to ambient air simultaneously, had been explored but found to be somewhat problematic. The advantages of the current option are simpler construction technology, simpler storage ability, dirt control and simpler ability for using an air-to-air heat exchanger for heat recovery. With the total latent heat load of 2.75 kW, the solar energy demand was calculated to be 4.77 kW. Assuming ten hours of continuous operation daily, and taking a small safety factor, the solar collector area was selected at 20 m^2. Solution storage in the amount of 120 litres of LiCl solution at 43% concentration and a 1000 litre hot water tank added to the system make it possible to operate for a total of four hours with no insolation – a typical situation in the summer during the morning hours.

The liquid desiccant system (refer to drawing) consists of six major components: an air dehumidifier or absorber, a solution regenerator or desorber, two water-to-solution heat exchangers, a solution-to-solution heat exchanger, and an air-to-air heat exchanger. Arabic numerals indicate working fluids state points at specific locations. Air flow is represented by thick solid lines, solution flow by thin solid lines and water flow by dashed lines.

The dehumidifier (absorber) consists of a packed tower and operates in an adiabatic mode. Ambient air at state 14 entering the bottom of the absorber packed section is brought into contact with a concentrated absorbent solution entering the unit at state 11. Water vapour is removed from the air stream by being absorbed into the solution stream. The dehumidified warm air leaving the absorber at state 15 passes through the blower and leaves the system toward the air-conditioned space for some further treatment under options A or B (see the previous section) at state 16. The blower controls the flow of air, while raising its temperature slightly. Solution is pumped from the absorber pool at the bottom of the tower into the plate heat exchanger (state 10), where it is cooled by water from a cooling tower. The solution leaving the heat exchanger (state 11) then proceeds to the distributor at the top of the packing, from where it trickles down in counter-flow to the air stream and collects in the pool. A controlled solution stream is transferred from the absorber pool to the regenerator, as shown (state 10c). The return (pumped) stream from the regenerator (1c) goes directly into the pool.

As evident, the regenerator (desorber) device is very similar to the dehumidifier, and so are the flow system and associated components. The solution is heated in the liquid-to-liquid heat exchanger by solar-heated water (states 3-4). Ambient air at state 5 is pre-heated in the air-to-air heat exchanger by recovering heat from the exhaust air leaving the desorber (state 8). After pre-heating, the air stream (state 6) enters the desorber where it serves to re-concentrate the solution (state 2). The exhaust air leaves the desorber (state 7), passing through the blower, then pre-heats the entering air stream and is rejected to the environment. The solution-to-solution heat exchanger facilitates pre-heating of the weak solution leaving the dehumidifier (states 10c to 10h) and recovers heat from the hot strong solution leaving the regenerator (states 1h to 1c).

The above brief description of the system already reveals a number of advantages of this system over conventional absorption heat pump cycles: (1) The number of main components is reduced by one by transferring condensation of the refrigerant from a condenser to the environment. (2) Capital-intensive pressure-sealed units are avoided as the whole system operates at atmospheric pressure. (3) The amount of refrigerant (water) evaporated in the regenerator is independent of an evaporator, providing greater flexibility. (4) Efficient utilisation of very low heat source temperatures is possible.

6. Performance characteristic (efficiency curve, COP curve, tables....)

The system is still under construction. Simulation results are provided in the reference given under item 9 below.

7. Project status (prototype production, pilot production, market introduction, unsolved problems,....)

The system is in the final stages of construction and expected to be completed in May 2002. Testing will then begin and continue over the summer of 2002.

8. participating companies and institutions

8.1 company's name	Technion – Israel Institute of Technology		
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Role in project	Principal Investigator		

Additional member countries of the ASODECO Consortium are Germany, Austria and the Netherlands.

Appendix 4b
Solar cooling, dehumidification and air conditioning using liquid desiccants (part of ASODECO).

9. References

G. Gommed and G. Grossman: A liquid desiccant system for solar cooling and dehumidification. Presented at the *International Sorption Heat Pump Conference'02*, Shanghai, China, September 2002.

10. Funding (national, EU, ...)

This project is funded by the EU under contract number NNES- 1999-00531.

Appendix 5a
Two-phase/two-component jet cycle chiller

Subtask C2 – Development of new technologies for solar assisted air conditioning

5. Title of development

Development of 2-phase/2-component-jet cycle for the use of solar low temperature heat

2. Field of R&D-project (please indicate)

☐ solar components

☒ cooling or A/C components

☐ others (please specify)

3. Short description of project (objectives, background,....)

Objective of the project is the development of a solar driven chiller for cooling and A/C. The core of the system is a 2-phase/2-component jet pump, which works with the ammonia/water working pair. Main characteristics are:

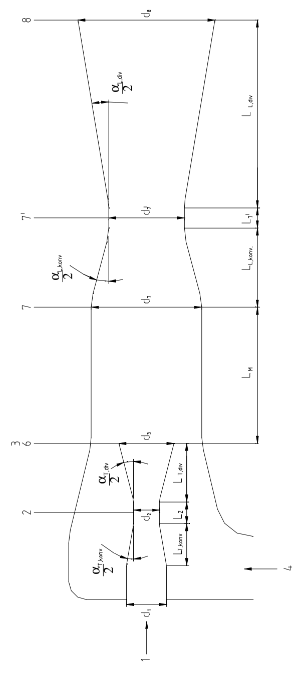
- use of low temperature heat ≤ 80°C
- cooling capacity in low capacity range (1 – approx. 20 kW)
- evaporator temperatures between –5°C and 5°C
- autonomous operation without energy supply by electricity of fuels

The work program comprises:

- thermodynamic design
- kinetic design of components and process simulation
- design, construction and operation of a test plant
- validation and modification of the simulation program
- economic performance assessment and documentation

Appendix 5a
Two-phase/two-component jet cycle chiller

4. Technical scheme (drawing)



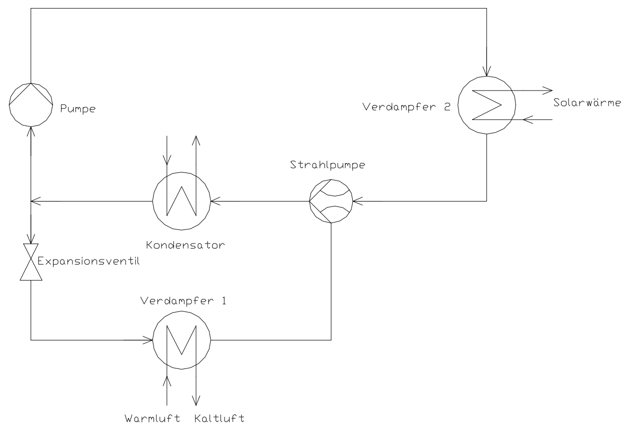


Figure 1: Ejector Figure 2: Process scheme

Translation of German terminology: Pumpe: pump; Verdampfer: evaporator; Solarwärme: solar heat; Strahlpumpe: Ejector; Kondensator: condenser; Warmluft: warm air; Kaltluft: chilled air; Expansionsventil: throttle valve.

5. Technical description

Figure 2 shows the design of the ejector refrigeration plant. In Evaporator 1, heat is absorbed (and useful cooling produced) by a two-phase flow. This mix flows into the suction side of the ejector, where the high-temperature, high-pressure primary flow brings it to a higher pressure and temperature. Subsequently, the flow, which is still a two-phase flow, is completely condensed in the condenser, giving off its heat to a cooling medium. After the condenser, the liquid stream is separated into two flows. One part undergoes an increase in pressure by means of a high-pressure pump and enters Evaporator 2. Here the low-temperature heat (at about 90ºC) is supplied so that again a two-phase stream develops, which is supplied to the ejector as the primary stream. The other part flows through a throttle valve to reduce the pressure, and enters Evaporator 1 again.

6. Performance characteristic (efficiency curve, COP curve, ...)

Modelling shows that pure ammonia is better than the ammonia/water mixture to reach high efficiencies. The figure below shows modelled results for 99% ammonia. The maximum COP is 0.3-0.35. Through the two-phase ejector, this COP is considerably higher than could otherwise be achieved, with a one-phase ejector. The vapour fraction of the secondary flow at the suction side has a major influence, see Figure 3. The influence of the vapour fraction in the primary flow is negligible.

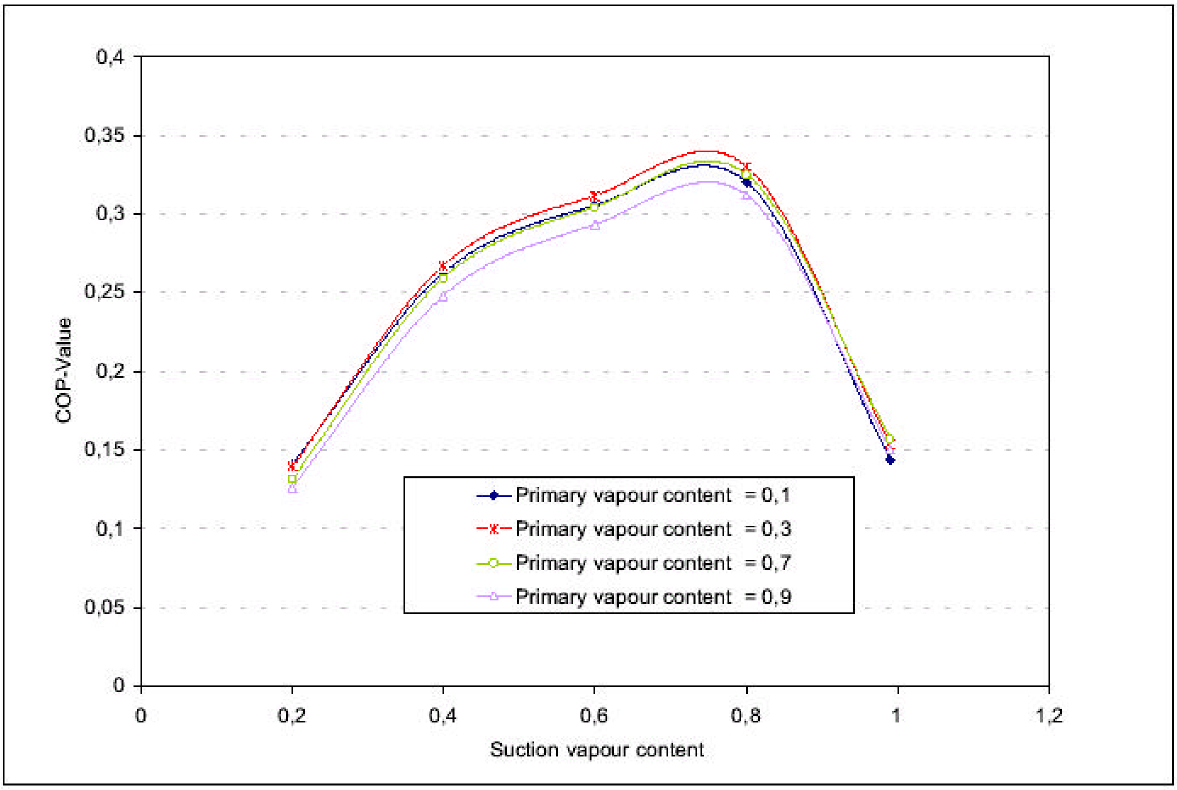


Figure 3: COP versus vapour content of the secondary flow, on suction side of the ejector, at various vapour contents of the primary flow for a composition of 99% ammonia and a mixing section efficiency of $?_M$ = 0.7 (the mixing section is part of the ejector).

7. Project status (prototype production, pilot production, market introduction, unsolved problems,....)

The actual status of the project is as follows:

- thermodynamic design was finished
- kinetic design of components and process simulation has been finished
- a test plant was designed and constructed
- operation tests and experimental work starts in October 2000

Appendix 5a
Two-phase/two-component jet cycle chiller

8. participating companies and institutions			
8.1 company's name	Technologietransferzentrum and der Hochschule Bremerhaven e.V.		
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role in project	project coordination		
8.2 company's name	Universität Stuttgart, Institut für Kernenergetik und Energiesysteme		
responsible person			
address			
phone		fax	
e-mail			
role in project			

9. references

Ch. Mostofizadeh, D. Bohne, *Theoretical and experimental investigation of a two-phase/two-component ejector for cold production,* Proc. Heat Powered Cycles 2001, Paris, France, CNAM, 2001.

10. funding (national, EU, ...)

This project is funded by the German Federal Ministry for Economy

Appendix 6a
Double effect absorption chiller driven by parabolic trough collectors

Subtask C2 – Development of new technologies for solar assisted air conditioning

1. Title of development/project

Double Effect Absorption Chiller driven by Parabolic Trough Collectors

2. Duration of project

Start Date: 1.1.2001 **Termination Date: 31.12.2002**

3. Short description of project (objectives, work program, background,....)

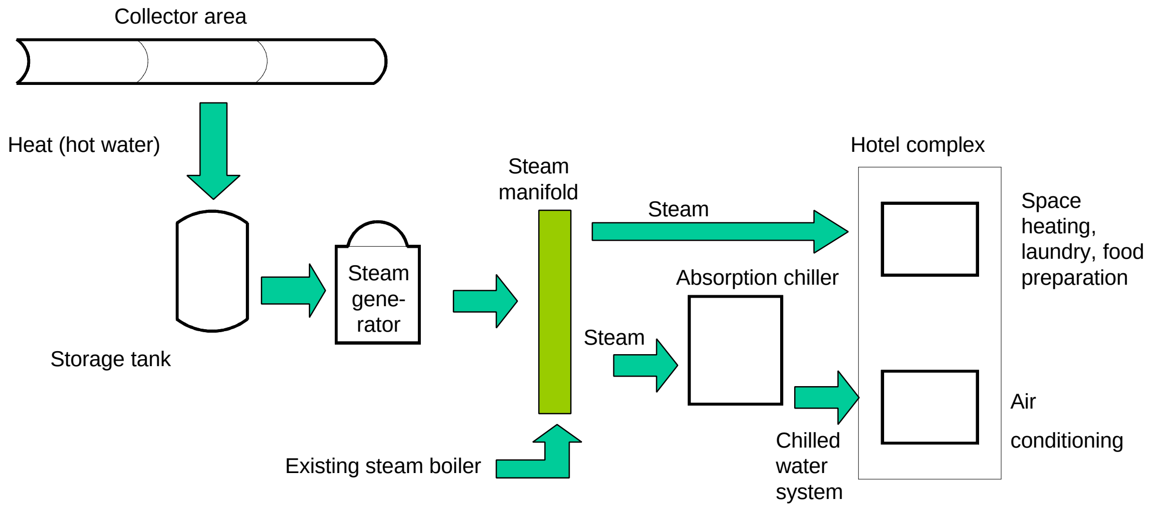
At a hotel at the Mediterranean coast of Turkey a double effect absorption cooling chiller driven by heat from parabolic trough collectors will be installed. The collectors also supply heat to other consumers as laundry and hot water.

The collectors have been newly designed for this pilot project and are currently under production in Turkey. Due to the necessities of the absorption cooling machine, the solar collector field has to run at 150°C inlet and 180°C outlet temperature.

Resulting from a market investigation and energetic simulations it was decided to install a double effect ACM from Broad, which has been installed in January 2002.

Appendix 6a
Double effect absorption chiller driven by parabolic trough collectors

4. Technical scheme (drawing)



Thermal energy flows in absorption air conditioning system operated through solar energy and supply with steam boiler

5. Technical description

The solar collector field runs at 150°C inlet and 180°C outlet temperature. It will be mounted on the hotel roof, delivering hot water to a short-term storage tank. The tank supplies a steam generator producing saturated steam at 4 bar (144°C).

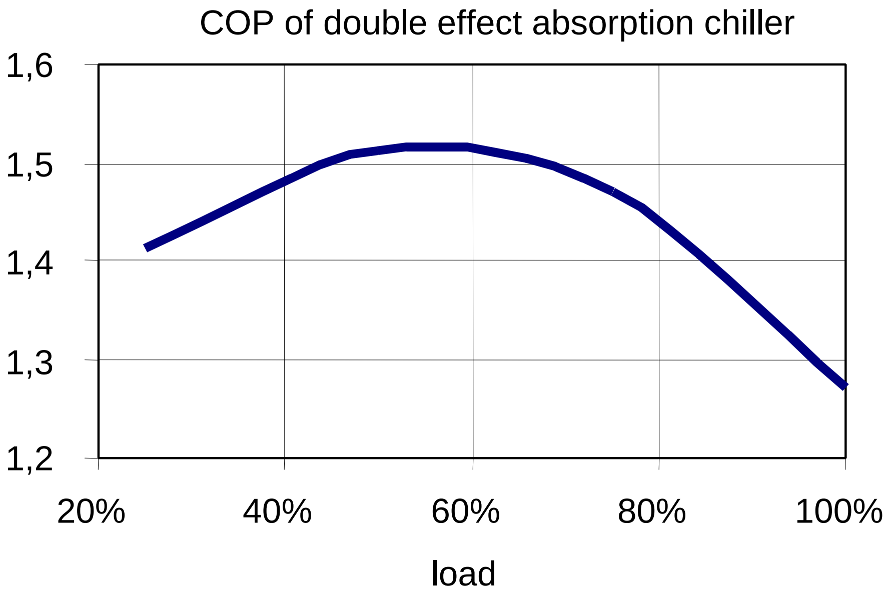
Part of the steam is consumed in the 2-stage absorption cooling machine (ACM) of the company Broad. With a nominal cooling capacity of 116 kW the ACM provides a share of the air conditioning of the hotel rooms.

Excessive steam is fed into the already existing 4 bar steam distribution for heat consumers of the hotel. The laundry is the main consumer running a 24-hour shift with a maximum capacity of 240 kW.

Appendix 6a
Double effect absorption chiller driven by parabolic trough collectors

6. performance characteristic (efficiency curve, COP curve, tables....)

In the beginning of the project a single effect and a double effect absorption chilling machine (ACM) both available on the market, were investigated in combination with various sizes of parabolic trough collector fields in TRNSYS-simulations. By using weather data for Antalya (south coast of Turkey), the hourly outputs of the solar array (including piping) and of the ACM were calculated for the cooling season between 15th of April and 30th of September. The COP of the ACMs has been modelled as a function of load.



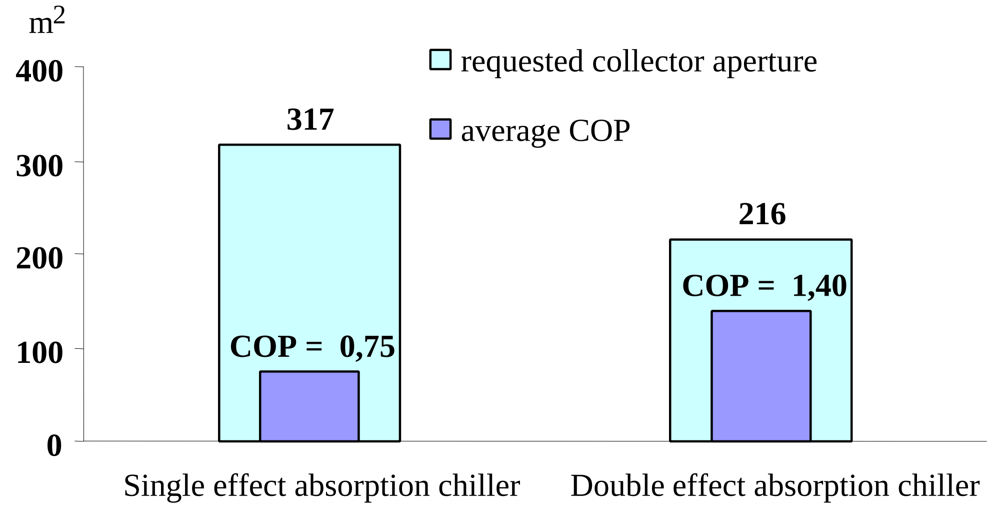
Change of COP values of double effect absorption chiller

The double effect chiller runs with a COP (Coefficient of performance) of 1.27 at full load and a COP of up to 1.5 at part load. For the single effect machine solar field temperatures are between 80°C and 110°C, for the double effect machine they are between 150°C and 180°C.

As can be expected, the high temperature level in the solar field supplying the double effect ACM leads to lower annual energy yields from the solar field of 565 kWh/m²a, compared to 760 kWh/m²a for the single effect ACM. The effect of high temperatures in the absorber of the collector leading to more thermal losses is fairly small and has no severe influence on the overall system. This is due to the relatively small absorber surface, which is inherent to concentrating solar systems.

Of more importance here is the high COP of the double effect ACM resulting in a lower fuel consumption of the back up firing and a drastically reduced collector field size.

Appendix 6a
Double effect absorption chiller driven by parabolic trough collectors



Comparison of solar powered chilling (Chilling capacity approximately 100 kW)

7. project status (prototype production, pilot production, market introduction, unsolved problems,....)

The cooling machine has been installed and will probably be in operation of from April 2002.

Collector production is ongoing, first experiences and measurements will be published in summer 2002.

Although both technologies, double effect chiller and parabolic trough collector, are not totally new technologies, experience has to be gained to know more about efficiency and operation, especially as the combination of both has not been assembled before.

8. participating companies and institutions

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role in project	Project Partner		

9. references

Information has been issued at various European and German solar conferences in 2002.

10. funding (national, EU, ...)

This project is funded by the Ministerium für Wirtschaft und Mittelstand, Energie und Verkehr des Landes NRW, Germany, within the framework of the Landesinitiative Zukunftsenergien