projektinfo 03/98

BINE
Information Service

Solar-Powered Air Conditioning

Fig 1

- Best integration of low temperature heat with open cooling systems and adsorption cooling units
- Systems suitable for southern and central Europe
- High primary energy conservation by systems wich cool in summer as well as heat in winter

Air conditioning in a 330m³ conference room in Riesa, Saxony, is provided by a solar-assisted DEC unit which can also be used for heat recovery during the heating period.
(Source: FhG-ISE)

Air conditioning units – and that means all types – increase energy use, investment and building maintenance costs. The aim of all construction planning should thus be to minimise the need for air conditioning. But in many instances, there remains a need for active temperature and humidity control systems. In conference centres, theatres, department stores, high-rise buildings, etc., air conditioning can only be reliably regulated with air conditioning units. Up to now, air conditioning in buildings has usually involved compression cooling units. While in recent years, the ozone-depleting cooling agent used in such units has been replaced by FCHC-free substitutes, even these are not without their problems when it comes to climate protection. Compression cooling units use a lot of electricity, primarily at peak times if no means of storing the cooled medium is used.

This has sparked growing interest in heat-powered cooling and dehumidifying processes. Gas-powered absorption cooling units have taken a foothold in the market, particularly in the USA and Japan. They use free capacity in the gas network in summer and thus reduce peak demand on the electricity grid. With the high temperatures achieved with gas-powered units, a cooling output of up to 1.2 times heat input can be achieved.

Low temperature heat (<90 °C), like district heat, waste heat and solar heat, has only been used to power cooling units in a few cases. From a business perspective, increasing the role of this energy source means optimising available low-temperature cooling processes and developing new ones. Apart from closed systems like adsorption and absorption cooling units, open cooling and dehumidifying processes like sorption-assisted air conditioning are gaining in importance. A number of demonstrations have shown such systems to be suited to solar energy use. The Federal Ministry for Economics and Labour (BMWA) promotes development of system components and processes that use low-temperature heat sources for air conditioning.

Sorption Air Conditioning

Sorption-assisted air conditioning – also known as desiccative and evaporative cooling (DEC) technology – uses the cooling effect of evaporating water to regulate air temperature through controlled dehumidification and humidification of supply air. Fig. 2 shows a typical system design. Supply air flows through a rotating drying wheel in which sorbents like LiCl, molecular sieves or silica gel are absorbed. The released sorption heat increases the air temperature (adiabatic dehumidification). Inside a heat regenerator, the supply air gives off heat to building exhaust air that has been cooled by humidification to the point of saturation. The cooler supply air is then humidified by a humidifier until the desired comfort level is reached. During this process, the cooling effect of evaporation cools the air temperature further. The cooled air is then injected into the building. A drying wheel drives humidified sorbents into the exhaust stream, where they are dried (regenerated) by an external heat source.

In the case of chilled ceilings (16-18 °C) that contain cold water, more efficient energy use can be achieved by combining sorption-assisted air conditioning with a compression cooling unit. The exhaust heat from the cooling unit can be used to regenerate sorbents and the cooling unit itself operates at high efficiency levels because dehumidification no longer requires temperatures below dewpoint (6-8 °C).

Tab 1: Various Processes for Solar-Assisted Air Conditioning and their Solar Technology Demands

Process	Absorption (single phase)	Adsorption	DEC
Technology	Cold Water (e.g. chilled ceiling)	Cold Water (e.g. chilled ceiling)	Air Conditioning (cooling, dehumidification)
Temperature Level	65-130 °C	55-95 °C	45-95 °C
Coefficient of performance (COP)	0.6-0.75	0.3-0.8	
Output	20-5,000 kW	50 - 430 kW	20 - 350 kW
Solar Technology	Vacuum Collectors	Vacuum Collectors, Flat Collectors	Flat Collectors, Solar-Air Collectors

Sorption cooling processes that are powered by low temperatures are suited to solar cooling. Closed systems like adsorption and absorption cooling units usually place higher demands on the solar unit than open sorption-assisted air conditioning (DEC) (Tab. 1). Sorption-assisted air conditioning (see box) is especially suited to the use of low temperature heat for air conditioning purposes. The key advantage with DEC is that low temperatures (>45 °C) can be used to regenerate sorbents. This allows, for example, solar energy use with simple system components like flat and solar air collectors: various systems have been recommended and tested (Fig. 5).

Climatic Requirements for Solar DEC

At the Fraunhofer Institute for Solar Energy Systems (ISE), a parameter study was conducted on the use of non-storage DEC systems with solar-air collectors. In central European climate zones (Freiburg), autonomous solar-powered air conditioning systems complied with the thresholds set out in DIN 1946 Part 2 with only marginal deviations (Fig. 5). For the wet-warm climates in southern Europe (Trapani, Sicily), combination systems with separate cooling and dehumidification are more suitable than the monovalent DEC system.

Fig 2: Schematic Diagram of a Sorption-Assisted Air Conditioning System

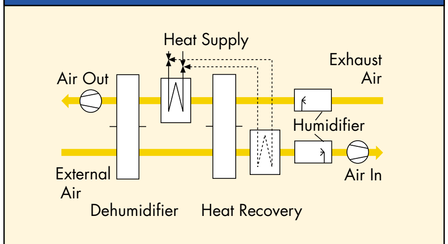
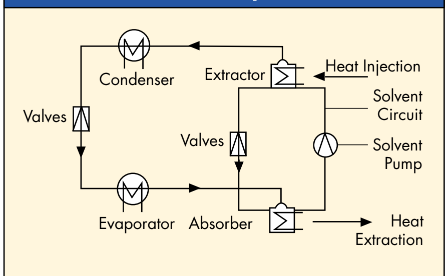


Fig 3: Workings of an Absorption Cooling Unit in the Example of LiBr/Water:



An external heat source forces water out of an LiBr/water solution in the extractor. As heat is given off, steam condenses in the condenser. The condensation arrives in the evaporator via a valve and evaporates at low pressure as heat is drawn in. The drop in temperature is used for cooling purposes. In the absorber, the solution is enriched as it gives off heat. The heat given off from the absorber and the condenser is extracted through a wet cooling tower.

Fig 4: Simulation Results for Freiburg and Tripani. The left-hand diagram shows the external air conditions for the simulation period May to October. Room temperatures were calculated for an autonomous thermal solar-air collector system (right) and a constant regeneration temperature of 80 °C (centre). The yellow box shows the comfort zone according to DIN 1946/2.

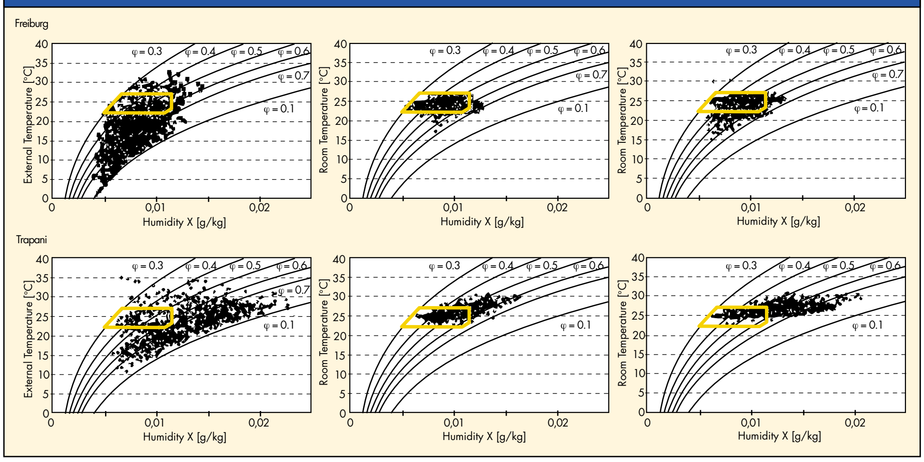
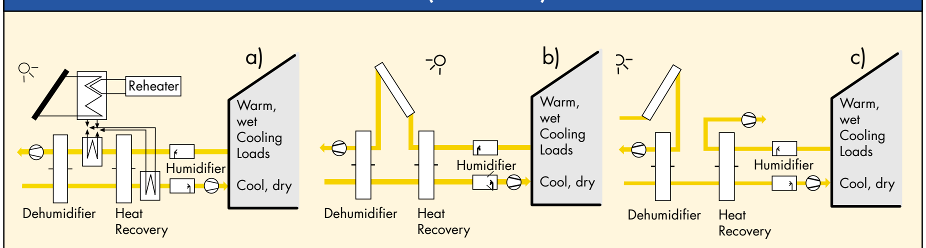


Fig 5: System variants for solar air conditioning. a) Liquid-filled collectors with a buffer storage unit; b) Integration of solar-air collectors in the exhaust stream; c) Solar-air collectors with exterior air suction (Source: ISE)



Sorption-Assisted Air Conditioning in a Conference Room in Riesa

In a pilot project in Riesa, Saxony, planned and managed by the Fraunhofer Institute for Solar Energy Systems (ISE), a 330 m^3 conference room is air conditioned using a solar-assisted DEC unit that can also be used for heat recovery during the heating period. The flat collector system measuring 20 m^2 is operated with a 2 m^3 buffer storage unit. Maximum cooling output is 18 kW. In the first cooling period, regulation strategies were developed and tested for optimised integration of solar energy for cooling and heating.

Initial operating experience shows that DEC systems are operable with regeneration temperatures ranging between 50-70 °C. The utility level of solar energy largely depends on the regulation strategy. Initial metering and simulation calculations show an expected supply of 75% over the entire cooling period.

Solar-Assisted DEC Air Conditioning in Dresden

The Air Conditioning and Refrigeration Institute (ILK) in Dresden has air-conditioned a conference room using a solar DEC unit since 1996. In contrast to the one in use at Riesa, the air conditioning unit in Dresden is designed as a DEC cascade, i.e. with an integral heat pump between the supply and exhaust air vents. This does away with the need for humidification of supply air and reduces the level of dehumidification needed in summer.

In an efficiency study based on metering data and simulation calculations, it was shown that, compared with a conventional unit with heat recovery, the additional costs of a solar DEC unit could be saved through reduced energy use.

Solar Absorption Cooling Unit in Benidorm, Spain

An early example of solar-assisted air conditioning using an absorption cooling unit can be found in a hotel on the Costa Blanca. The solar system comprising 386 vacuum collectors and three buffer storage units (each 12 m^3) went into operation back in 1992, and has since supplied a large share of the energy required for cooling, heating and hot-water. In summer, it is powered by a 125 kW absorption cooling unit with a working temperature of 96 °C. Air conditioning occurs via the hotel's ventilation system which is connected to the cooling unit's cold water system by a water/air heat exchanger.

The solar unit's energy yield is approximately 367,000 kWh/a. Operation of the solar unit allowed a 500 kW oil boiler to be shut down. The hotel's energy needs were reduced by 30%. The project was implemented in cooperation with Dornier-Prinz Solartechnik GmbH and the company Serda, Belgium.

Solar Absorption Cooling Unit in Cologne

The Cologne example shows that solar-powered absorption cooling units can even be operated in milder climates. In the Pörz district of Cologne, two solar-powered LiBr/Water absorption cooling units provide cooling for the air conditioning in an office building built in the 1970s. The air-conditioned space measures 1,628 m^2 and is distributed over four floors. A maximum allowable room temperature of 26 °C results in a maximum cooling load of 77 kW which is carried through cooling pipes filled with cold water. The cooling unit has a 5 m^3 cold water storage buffer. The required heat output of maximum 107 kW supplies a collector area of 176 m^2. To achieve the rated upstream air temperature of 95 °C even in unfavourable conditions, vacuum tube collectors are used to support the low temperature heating system during the heating period. Apart from the cooling output of 120 MWh/a, the solar system saves around 19 MWh of heat. The project is funded by the EU and receives metering and scientific support from the University of Applied Science in Gießen-Friedberg.

Solar Adsorption System at the University Clinic, Freiburg

An 80 kW adsorption system is currently being installed at the University Clinic in Freiburg to supply cooling. The system is supplied thermally by a collector area of about 90 m^2 (vacuum tube collectors). The aim of the research project, which receives scientific support from the Fraunhofer ISE, is to perform an evaluation on combining adsorption cooling technology with solar-powered heating.

Fig 6: Operating Stages of the Solar Air Conditioning System at Riesa

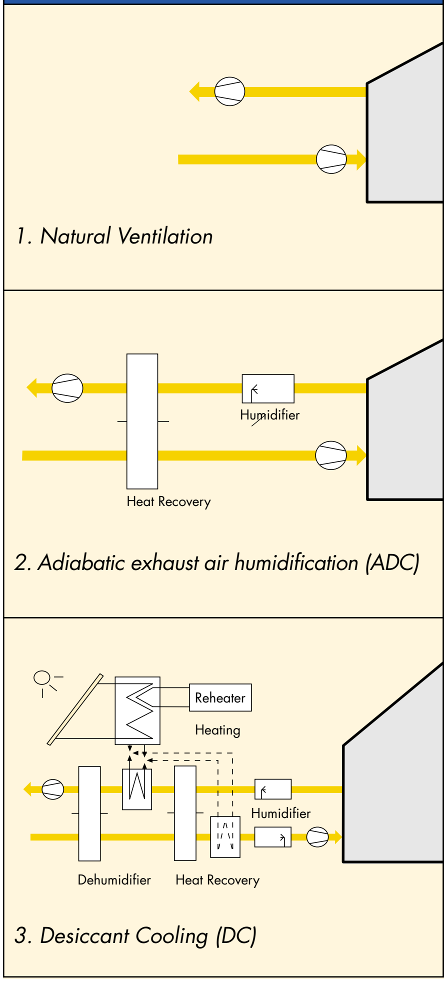
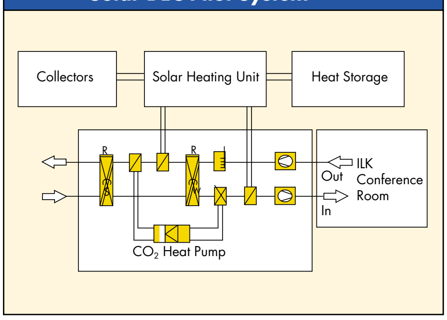


Fig 7: Schematic Diagram of the ILK Solar DEC Pilot System



Developing System Components

The development of a semi-continuous low temperature absorption pump with low to medium power is the goal of a working group at the RWTH Aachen Technical College. Ammoniac is used as the cooling agent and is absorbed by salts like $BaCl_2$ and $SrCl_2$. In contrast to continuous systems, the salt is fixed in the reaction container. Following the absorption phase, the system has to be regenerated through re-heating. The periodic process is ensured by switching between different reaction containers. At present, output levels of up to 170 W per litre reaction volume are achieved. Based on the data collected in the laboratory systems, a solar-powered field test system was equipped with an 8 m^2 flat collector system.

The suitability of different sorption materials to air conditioning with liquid sorption systems is currently being researched at the Institute for Applied Thermodynamics and Air Conditioning Technology in Essen. The main focus of the study covers water solutions containing $CaCl_2$ and LiCl, and mixtures like Klimat 390S. The substance properties are identified by testing and literature research.

▶ Outlook

The best conditions for the integration of low temperature heat are currently offered by open cooling systems with solid sorbents and adsorption cooling units. Adsorption cooling units are already used for district heating in Germany because of their low working temperatures. At 350 € - 1,600 € per kW, depending on cooling output, the costs are relatively high. The low output levels of the systems must also be optimised.

Solar-assisted air conditioning with sorption-assisted technology has only been implemented in a few demonstration projects. Experience gathered in Sintra, Portugal and in Riesa, Saxony, has shown that with practical system design solar supply shares of around 75-80% of operating energy can be achieved in both southern and central Europe. The necessary collector area for both climate zones is 7-8 m^2 per 1,000 m^3 airflow. Buffer storage units are particularly useful if the cooling demand and maximum input do not coincide. A heat storage buffer of around 50 l/m^2 collector allows an increase in solar supply of around 20% in Sintra. For central European climate zones, there are options for primary energy conservation, especially if the model provides for year-round use of the collectors for cooling in summer and additional heat in winter. Solar heat generation costs currently lie in the region of 0.14 to 0.15 €/kWh in Germany and 0.08-0.10 €/kWh in southern Europe. The use of networked solar-air collectors allows further cost reductions.

Absorption cooling units and open systems with liquid sorption agents offer promising options for the use of low temperature heat. Using high quality collectors, solar air conditioning has been demonstrated in both mild and southern climate zones.

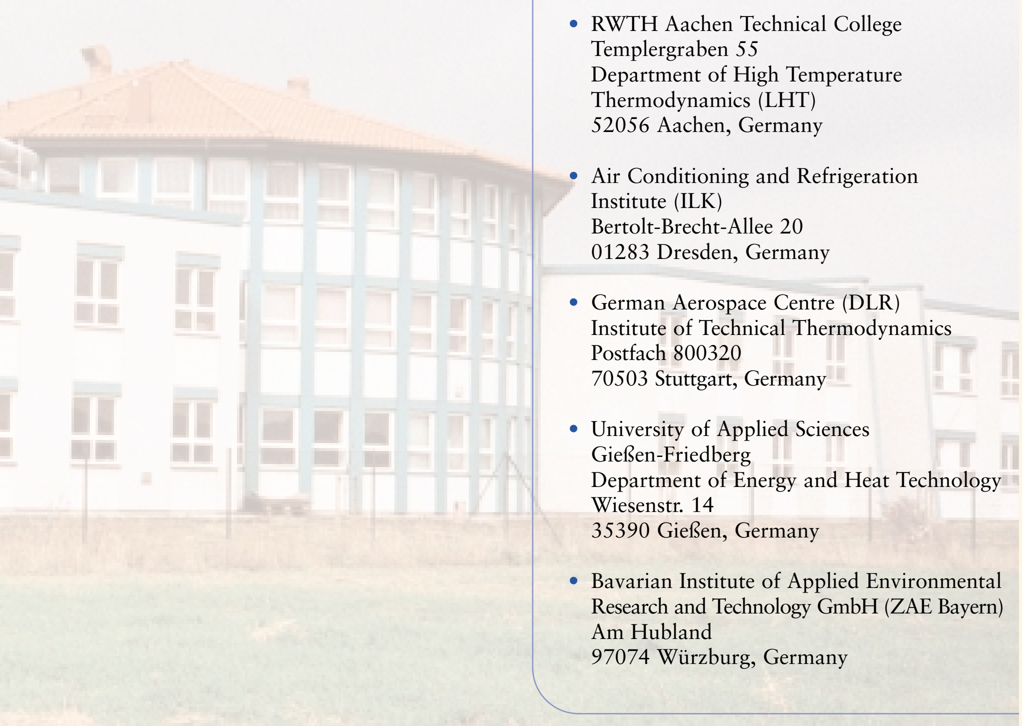
In a new phase of the IEA solar heating and cooling project, new processes are being studied for air conditioning for buildings. The preliminary working project was presented in November 1997. The main aims of the study are: producing reference material containing the relevant legal provisions, technology standards and meteorological data, development of simulation models, design regulations and procedures for efficiency calculations, studies on components and systems, and the implementation of demonstration projects in cooperation with researchers.

▸ ADDITIONAL INFORMATION

Literature

- Fachinstitut Gebäude-Klima e.V. Bietigheim-Bissingen, FIA-Projekt - Forschungs-Informations-Austausch (Eds.): Gebäudeklimatisierung mit Niedertemperaturverfahren. [1998]. 131 S.

▸ PROJECT ADDRESSES



- Fraunhofer Institute for Solar Energy Systems (ISE), Heidenhofstr. 2, 79110 Freiburg, Germany
- University of Essen, Institute for Applied Thermodynamics and Air Conditioning Technology, Universitätsstr. 2, 45117 Essen, Germany
- RWTH Aachen Technical College, Templergraben 55, Department of High Temperature Thermodynamics (LHT), 52056 Aachen, Germany
- Air Conditioning and Refrigeration Institute (ILK), Bertolt-Brecht-Allee 20, 01283 Dresden, Germany
- German Aerospace Centre (DLR), Institute of Technical Thermodynamics, Postfach 800320, 70503 Stuttgart, Germany
- University of Applied Sciences Gießen-Friedberg, Department of Energy and Heat Technology, Wiesenstr. 14, 35390 Gießen, Germany
- Bavarian Institute of Applied Environmental Research and Technology GmbH (ZAE Bayern), Am Hubland, 97074 Würzburg, Germany

PROJECT ORGANISATION

Project Funding
Federal Ministry of Economics and Labour (BMWA)
11019 Berlin
Germany

Project Coordination on behalf of BMWA:
Project Management Organisation Jülich
Research Centre Jülich
Jürgen Gehrmann
52425 Jülich
Germany

Project number
0329399B, 0329151J

IMPRINT

ISSN
0937 - 8367

Publisher
FIZ Karlsruhe
76344 Eggenstein-Leopoldshafen, Germany

Editor
Dr. Franz Meyer

BINE Information Service Energy Expertise

BINE provides information on energy efficient technologies and renewable energy:

Using a combination of free brochures, the BINE web site (www.bine.info) and a newsletter, BINE shows how innovative research ideas hold up in practice (in german).

The BINE information service is promoted by the Federal Ministry of Economics and Labour (BMWA).

Contact:
Would you like to know more about this project?
Call the BINE expert hotline at:
Tel. +49 228 92379-44

For more general information on energy and environmentally sound planning and construction, please contact us at:

BINE Information Service

FIZ Karlsruhe
Bonn Office
Mechenstrasse 57
53129 Bonn
Germany

Tel.: +49 228 92379-0
Fax: +49 228 92379-29
E-mail: bine@fiz-karlsruhe.de
www.bine.info

DESIGN WORKS, Bonn