

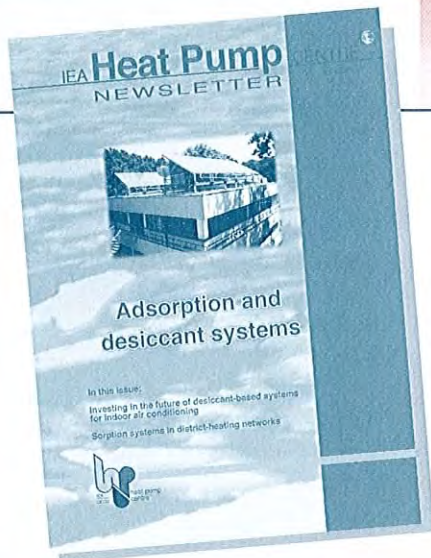


Adsorption and desiccant systems

In this issue:

Investing in the future of desiccant-based systems
for indoor air conditioning

Sorption systems in district-heating networks



In this issue

Adsorption and desiccant systems

This Newsletter focuses on adsorption- and desiccant-based systems for cooling, heating and dehumidification. The topics covered range from R&D to (large-scale) applications in residential, industrial and commercial buildings. The use of desiccant systems for cooling and dehumidification in large buildings and the successful application of adsorption technology in this area are covered in some depth.

TOPICAL ARTICLES

Front cover: Solar assisted desiccant system in Heemstede, the Netherlands

COLOPHON

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Adsorption and desiccant systems – an international overview

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Gerdi Breembroek, the Netherlands

The application of adsorption and desiccant systems for air conditioning has increased in recent years. This article gives an overview of the technologies involved, some recent technological developments, and the current state of the market and possible future developments.

Investing in the future of desiccant-based systems for indoor air conditioning

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James R. Sand, US

The US Department of Energy has selected three industry teams to design, build and test desiccant-based combined systems – the next generation of desiccant technology. The three winning proposals are a 'rooftop liquid desiccant air conditioner', a 'cost-effective and high efficiency active desiccant system' and a 'modular air handler for light commercial applications'.

Sorption systems in district-heating networks

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Richard Krottil and Hermann Halozan, Austria

A study of the district-heating network in Graz shows that heat-driven sorption systems can be integrated into such networks to provide consumers with an additional product – cooling – while at the same time increasing overall network efficiency. The availability of low-grade waste heat in such networks makes the use of sorption systems for cooling economically competitive, in addition to providing environmental benefits. However, it is essential that the technical and economic aspects be analysed for each location separately.

Solar-powered adsorptive desiccant-based air-conditioning systems for the hot and humid climate of Japan

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Akio Kodama and Tsutomu Hirose, Japan

A typical solar-powered single-stage adsorptive desiccant-based air-conditioning system was tested in the Japanese climate and found to perform adequately only at lower ambient humidities. A new two-stage system is proposed for use in hot and humid climates. Model calculations indicate that such a system would perform better at higher humidities.

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Sorptive dehumidification



The traditional way to dehumidify the outdoor air in an air-conditioning (A/C)-system is by cooling the air down below the dew point temperature. A refrigeration system is necessary to realise these low temperatures. However, the energy consumption can be substantial. An alternative method to dehumidify the air is by separating the processes of dehumidification and cooling.

The dehumidification process has great influence on the energy consumption involved in air conditioning during summer, even in regions with temperate climate. In order to reduce the energy input, the efficiency of the dehumidification process must be improved.

Alternatives to the traditional compression plants or closed absorption systems are open sorptive systems. Two different physical principles are used: Adsorption, the molecules of one substance are fixed on the surface of the other solid substance; Absorption, one substance penetrates the other fully and forms a homogeneous mixture. Adsorption always uses solid sorption materials. Absorption systems can be solid or liquid.

A main problem is to extract the heat of condensation of the water vapour out of the air. Therefore, heat exchangers need to be integrated in the systems. This can be done with rotating wheels, which act as heat exchanger and adsorption surface.

The dehumidification system can also work with liquid hygroscopic material that gets into direct contact with the air in a cross-flow absorber integrated in a dehumidification unit. A comparison based on measurement shows that the range of dehumidification needed for comfortable supply air conditions can be obtained with liquid absorbers. The advantages are a reduction of the required electrical power input in the summer and a reduced energy requirement. These systems represent thus an alternative to air conditioning by application of a traditional refrigeration system. The result of an economic evaluation shows that a slightly higher price of the sorptive systems can be balanced by lower energy costs. As driving power for the sorptive dehumidification process, heat is needed only at lower temperature levels enabling the use of solar heat. By using tanks to store the weak and strong solution temporarily, it is possible to regenerate the absorber with for instance solar energy without losses, while providing air conditioning in buildings.

Fritz Steimle
Institute of Applied Thermodynamics and Air Conditioning
Technology
University of Essen, Germany

A computer model for dimensioning solar-powered desiccant evaporative cooling systems

D.J. Naron and G.J.H.A. Verhoeven, the Netherlands

Desiccant evaporative cooling, or DEC, is an alternative technology for indoor cooling, which is driven by thermal energy and uses no refrigerants. The use of solar thermal energy as the driving force for DEC is relatively new and promising. This paper presents a design tool that can be used to dimension and measure the effectiveness of solar-powered DEC indoor cooling systems.

NON-TOPICAL ARTICLE

"Hands-on experience with heat pumps in buildings"

Gerdi Breembroek, the Netherlands

The international workshop "Hands-on experience with heat pumps in buildings" was held in Arnhem, the Netherlands, 10 - 12 October 2001. This was the second workshop organised by the Heat Pump Centre together with the International Power Utility Heat Pump Committee. The workshop registered more than 100 participants from 13 countries.



Heat pump news

Networks of seawater-source heat pumps

Italy - Recent and earlier analysis shows the advantage of using seawater as a heat source for air conditioning, through heat pumps, in buildings and districts along the coast. This is especially so for Mediterranean countries, as there is a strong and increasing demand for summer cooling, and heating in winter is also required. The Mediterranean seawater temperature is high enough in winter and low enough in summer to allow modern heat pumps to operate at an extremely high level of efficiency.

A study by P. Avanzini in November 1999 reports that under the meteorological-marine conditions in the Italian region of Liguria, heat from the sea can be pumped with an average coefficient of performance (COP) of 5. Compared to air-source heat pumps, even where the Mediterranean climate along the coast is mild enough to permit their economic employment, the use of seawater as heat source can provide a 30% higher level of efficiency. This is essentially due to the more stable temperature of seawater, the small difference between source and sink temperature, and the fact that defrosting devices are not needed. Although the technology involved is well known and tested and the economic advantages are clear, such systems are not yet very widespread, at least in the Mediterranean countries. Only a small number of plants have been operating successfully for many years.

The barriers for the development of this market are:

- lack of familiarity of designers, urban architects and end users with the technology and lack of knowledge of its advantages;
- lack of certified references and operational results;
- lack of infrastructure to extend the benefits of the seawater heat source to users not located immediately near the shore.

The first two barriers can be overcome through information and training campaigns. The last barrier requires demonstration of the feasibility and economic benefits of installing networks for the distribution of seawater to heat pump equipped users.

The main problems encountered in the design and realisation of seawater-source heat pump systems concern seawater pumping equipment, protection against bio-fouling in seawater pipes and components, and the temperature of the water returned to the sea. Seawater pumping and throughput is an engineering issue that can become difficult if the pumping plant is exposed to strong and intense wave activity. Depending on local conditions, the pumping system may become very expensive to avoid the risk of service interruptions. This is one of the most important reasons why it is strongly suggested to design collective networks to distribute the seawater to a grid of users. A single pumping plant especially designed to cope with meteorological-marine conditions can feed the grid. The extra costs can then be shared between all users, thus reducing the economic impact.

Source: 7th Rehva World Congress, Clima 2000 Napoli 2001

Dr Ing Piergiulio Avanzini,

Fax: +39 010 6475 800

E-mail: avanzini@area.ge.cnr.it

New performance standards added to ARI's website

USA - Those who need the most up-to-date information about air-conditioning and refrigeration equipment performance requirements should know that the Air-Conditioning and Refrigeration Institute (ARI) has published a new equipment performance standard, ARI Standard 390-2001 "Single Package Vertical Air-Conditioners and Heat Pumps", and a revised ARI Standard 340/360-2000 "Commercial and Industrial Unitary Air Conditioning and Heat Pump Equipment." Both are available for free on ARI's Web site.

ARI standards establish rating criteria and procedures for measuring and certifying product performance. In this way, products are rated on a uniform basis so that buyers and users can properly make selections for specific applications. By publishing free standards on the Internet, ARI manufacturers want to make it easier for architects, engineers, contractors and equipment specifiers to make choices based on easily accessed testing and rating information.

The purpose of Standard 390-2001 is to establish, for single package vertical air

conditioners and heat pump equipment: definitions, classifications, test requirements, rating requirements, minimum data requirements for published ratings, operating requirements, marking and nameplate data, and conformance conditions. Standard 390 applies to factory-made commercial and industrial single package vertical air conditioners and heat pump equipment.

Standard 340/360-2000 establishes for commercial and industrial unitary air conditioning and heat pump equipment: definitions, classifications, test

requirements, rating requirements, minimum data requirements for published ratings, operating requirements, marking and nameplate data, and conformance conditions. This standard applies to factory-made commercial and industrial unitary air conditioners and heat pumps.

Those wishing to obtain a copy of these standards can order them by visiting ARI's online bookstore at www.ari.org/bookstore/. For free copies of these standards go to www.ari.org/std.

Internet: <http://www.ari.org>



IIR Medals and Awards

France - Several IIR medals and awards will be given out at the 21st International Congress of Refrigeration, in Washington D.C., USA, 17-22 August, 2003. Candidature is not limited to individuals from IIR member countries. A separate set of rules governs each of the following three main awards:

IIR Gustav Lorentzen Medal
IIR Science And Technology Medal
IIR Young Researchers Awards

In the following fields:

- Cryophysics;
- Cryogenic engineering;
- Thermodynamics;
- Systems and equipment for refrigeration;
- Cryobiology, cryomedicine;
- Food science and engineering;
- Refrigerated storage and transport;
- Air conditioning and heat pumps.

Application packages can be obtained from the IIR. The IIR must receive nominations by 30 April 2002.

IIR Congress 2003

The call for proposals will be released on 30 April 2002. The deadline for abstract submittal for the Congress is 11 October 2002. Visit the congress web site at <http://www.icr2003.org>

IIR involvement in the next WSSD

UNEP (United Nations Environment Programme) has invited the IIR to prepare a report on the refrigeration industry achievements and challenges to serve as input to the World Summit on Sustainable Development (WSSD) to be held in Johannesburg in September 2002. Reports will be provided on 18 industry sectors. The reports comprise three sections in line with Agenda 21 objectives: Implementation of the three dimensions of sustainable development (social, economic and environmental); Means of implementation (strategies, achievements and limits) and Future challenges and goals for the next 10-30 years. The IIR has prepared a first draft with input from 15 experts from 11 different countries and the HPC. A review process is in progress.

Internet: <http://www.iifir.org>
 E-mail: iifir@iifir.org

Ground-source heat pumps in Turkey

Turkey - Turkish heating systems differ from those in other countries. Hydronic systems are commonly used for heat distribution, and coal and gas-fired stoves are common for heat generation. Recently, the number of space-conditioning devices for both heating and cooling has increased.

The use of ground-source heat pumps (GSHPs) in residential buildings is new in Turkey, but they have been used for years in developed countries and their performance is well documented. GSHPs have been available on the Turkish market for about three years. There are no Turkish GSHP manufacturers yet. Most of the installations are in the Marmara region of Turkey (in Istanbul). It is estimated that 43 units have presently been installed, representing a total heating capacity of 527 kW. This number is expected to increase rapidly in coming years. After completion of the projects currently in progress, the total installed capacity will be 3763 kW, with a total of 282 units ranging from 7.3 to 46.2 kW heating for both residential and commercial use. After completion of planned projects, which are at the design stage and involve a total of 130 villas with floor areas ranging from 120 to 310 m², the installed capacity will be about 5000 kW.

Of the GSHP systems installed to date, 80% are vertical ground-coupled systems, and about half are designed for both heating and cooling. The diameter of the U-bend tubes is 3.2 cm. The heating and cooling loads are approximately 80 and 95 W/m² respectively.

There are only few Turkish standards relating to heat pumps. To date, 14 standards for heat pumps have been issued by the TSI (Turkish Standards Institution), of which only two apply to water-to-water type heat pumps. This means that standardisation studies are also new in Turkey.

For success in tomorrow's residential and commercial/institutional building market, the next generation of heat pump technology must meet demands for:

- emission management benefits;
- improved indoor environment (comfort and IAQ);
- personal comfort control and security;
- reduced utility peak load;
- performance throughout building life;
- environmental conditions relating to production, use, disposal;
- renovation and retrofit;
- improved cost effectiveness.

Source: 7th Rehva World Congress, Clima 2000 Napoli 2001
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 E-mail: hepbasli@bornova.ege.edu.tr,
hepbasli@egenet.com.tr

European Geothermal directory

Italy - The Commission of the European Communities appointed UGI, the Italian Geothermal Association, member of the European Geothermal Council EGEC, to issue the European Geothermal Directory. The Directory will provide a comprehensive overview of companies, consultants, research institutions and organisations supplying equipment or services for the geothermal sector, as well as plant operators. All European countries, inside and outside the EU will be covered, including part of the Russian Federation and Turkey. The Directory is intended as a tool to disseminate names and scope of interested parties, thus facilitating contacts and favouring inter-relations between European entities. The Directory will be available both as a volume and as a CD-ROM and will be accessible via Internet. Inclusion of your data in the Directory is free of charge.

Heat pump suppliers and drilling companies for ground-source heat pump systems may apply for listing in the directory by returning a questionnaire to be ordered from UGI.

E-mail: Questionnaire.ugi@tin.it
 Fax: +39-02-7602-0367



Quality label for earth probe drilling companies



Switzerland – Recently, the “earth probes” quality label commission of the FWS (Förderungsgemeinschaft Wärmepumpen Schweiz) launched the new label for drilling companies. This new label should help ensure a high level of quality, now and in future, in the manufacturing and application of earth probe systems.

Drilling companies with the quality label commit themselves to providing optimal guidance and customer service to building owners. They also guarantee use of the newest drilling techniques and that the system will be built in an environmentally sound manner.

The first quality labels were presented in October 2001, prior to which all candidate companies underwent a detailed check.

Source: Wärmepumpe News 2/2001
E-mail: wp@mkr.ch

Heat pump technology education at school

USA - The new Zeeland High School West in Zeeland (Michigan) will use a ground-coupled heat pump system for heating and cooling its 16,000 m² floor area. The system will use 108 heat pumps, with each classroom having its own heat pump and thermostat.

The school district expects to save USD 50,000 a year in energy costs and another USD 30,000 a year in maintenance costs. That results in 70% percent savings in heating costs and 50% savings in cooling costs. In fact, school officials say the new school will be so well insulated and heated, it will generate more heat than it can use during most of the year despite Michigan's blustery winters.

This ground-coupled system is just one energy-efficient feature of the school. Zeeland High School West's 900 students will learn about this and other energy-saving technology within their building as part of an educational science lab.

Source: Earth Comfort Update, September/October 2001

Swiss retrofit heat pump on its way

Switzerland - In the coming winter season, the Swiss retrofit heat pump has to prove itself. If all tests succeed, some 50 units will be built and set out in a pilot phase. The jury of the Federal Energy Office has selected the functional model of the firm Kälte-Wärme-Technik (KWT) in Belp for further tests as Swiss retrofit heat pump.

After the first experiments in practical heating operation from January until March 2001, the new retrofit heat pump will be put through an exhaustive test in two redevelopment projects during the heating season 2001/2002. Preparatory work has focused on two areas. First, improvements have been made to the heat pump based on the initial test results. Second efforts were made to achieve an optimum integration of the heat pump into the existing central-heating system.

As soon as the results of the tests for the heating season 2001/2002 are known, the Federal Energy Office will decide in May 2002 on awarding the “Swiss retrofit

heat pump”. If the result is positive, the heat pump will be applied in 50 redevelopment pilot projects.

An initiative making headway in the Swiss market involves cooperation between Swiss heat pump manufacturers and other heating related organisations to establish a production association. Participation is open to all companies that are involved in manufacturing in Switzerland. More information can be found on the internet site <http://www.waermepumpe.ch/fe> under “Veranstaltung” (event).

Source: Wärmepumpe News 2/2001

Obituary Prof. Gilli - PVG

P.V. Gilli, born in 1924 in Vienna, has studied Mechanical Engineering in Graz, Austria and he received his Doctor degree in 1957. From 1952 to 1968 he was with Waagner Biro, a boiler manufacturer, where he held different positions in Austria and abroad. Since 1963 he was head of the nuclear department of this company. 1968 he became professor at the Graz University of Technology and Head of the Institute of Thermal Engineering.

Prof. Gilli came from the field of power generation and nuclear engineering, but from the very beginning he widened the scope of the Institute to energy conservation, protection of the environment, global warming and energy policies, as well as social effects arising from energy utilisation. Within the building sector, heat pumps became a special research topic, which received growing interest after the oil crisis. The Institute has carried out projects in several areas including SPF modelling, ground source heat pump systems and finally CO₂ as refrigerant for advanced heat pumping systems.

The international basis for his heat pump related activities was the IEA. Prof. Gilli was Operating Agent of the IEA Implementing Agreement on the Application of Heat Pumps to Energy Conservation from 1977 – 1980, Austrian delegate and Chairman of the Implementing Agreement Executive Committee on Advanced Heat Pumps from 1981 – 1984 and finally, from 1982 – 1985 Head of the Analysis Centre Graz of the IEA Heat Pump Centre. In autumn 2000 he was Austrian delegate to the IEA Working Party on End-Use Energy Technologies for 25 years.

Prof. Gilli was an active member of several international and national related organisations in the area of power generation and supply as well as heating, refrigerating and air conditioning. He has published more than 200 scientific papers, covering the whole field of thermal engineering. The most outstanding ones are on thermal storage, environmental effects of electricity supply and advancements in the efficiency of energy utilisation.

Prof. Gilli will leave a gap. Many will miss him, but all that knew him and who have worked with him together will never forget him. The trademark PVG will remain.

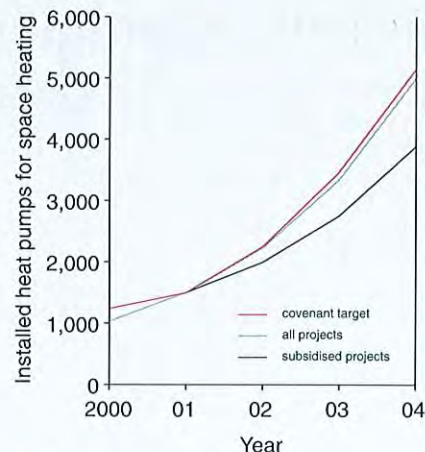
Dutch heat pump covenant very successful

The Netherlands - Since the signing of the 'Heat pump system covenant for the Dutch residential sector' on 20 April 2000, the covenant has, in the first one and a half year of its existence, largely achieved one of its goals for the covenant period 2000-2003 (**figure 1**). The goal of the covenant is to realise over 11,500 heat pump water heaters and more than 5,000 residential heat pumps for space heating installed by the end of 2003. By December 2001 Novem, the 'Netherlands Agency for Energy and the Environment' alone, who facilitates this covenant, will have subsidised around 35 projects that will realise almost 4,000 heat pumps for space heating by the end of 2003. Another 12 projects that were not granted in 2001 can add around 1,100 heat pumps.

The sustainable energy policy of the Dutch government aims at 10% energy supply by renewable sources in the year 2020. Heat pumps are one of the technologies that can contribute to realise this goal. In order to promote the introduction of heat pumps in the residential sector, the Ministry of Economic Affairs initiated the covenant, a strategic agreement between government and market parties. The Ministry of

Economic Affairs supports the covenant with an amount of about USD 4,000,000 yearly for residential demonstration projects and market stimulation.

More projects in the next two years are expected to result in a higher number of installed heat pumps than aimed for 2003. The Dutch residential heat pump market is doing well!



▲ **Figure 1:** Development of the Dutch residential heat pump market in the covenant period, 2000-2003, based on available information at the end of 2001.

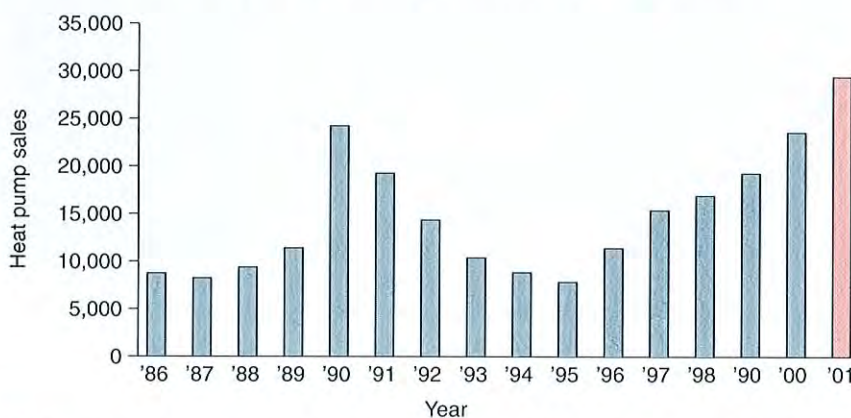
More information: Raymond Beuken,
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Certification makes Swedish heat pump market grow

Sweden - Sweden has 9 million inhabitants. The number of single-family houses is about 1.6 million, including summer residences. About 350,000 of these houses are currently heated by a heat pump.

The Swedish heat pump market has shown large fluctuations in sales over the years; see **Figure 1**. The decrease between 1991 and 1994 was caused by stagnation in the construction of new dwellings, falling oil prices, subsidies being phased out, and a number of non-professional installers in the market. As a result, sales dropped dramatically during the period 1992 - 1995. Three important factors contributed to the favourable development after 1995:

- the Swedish government subsidised the changeover from oil/electricity to other forms of individual heating;
- an increase in the construction of new dwellings and an increase in the retrofit market;
- the Swedish heat pump association (SVEP) developed a system of certification for heat pump installers to ensure that they had obtained the required level of training. Furthermore, consumer guarantees were strengthened, as SVEP developed common warranty and insurance policies as a part of a security package.



▲ **Figure 1:** Heat pumps sales in Sweden over the period 1986-2000, estimate for 2001.

The increase of sales in 2000 indicates an annual increase of approximately 20% compared to 1999. This indicates that about 30,000 heat pumps will be sold in 2001.

Source: Scanvac Newsletter, 1/2001
More information: Anders Paulsson, SVEP
E-mail: anders.paulsson@svepinfo.se

7th IEA Heat Pump Conference

Heat Pumps – Better by Nature

Second announcement with full programme and all relevant details available through the Conference Secretariat and the Heat Pump Centre, address on page 27 of this Newsletter.

Don't miss the opportunity!

Japan proposes fluorocarbon tax

Japan - The Democratic Party of Japan has unveiled a bill to levy a tax on manufacturers to promote the collection and disposal of three types of refrigerants, including some that are harmful to the ozone layer. The bill proposes a fluorocarbon tax and use of the revenue raised to run a centre to collect and destroy CFCs and HCFCs used as refrigerants in automobiles, industrial cooling equipment and home appliances. Revenues would also

be used to develop technologies to replace these ozone-depleting substances and to collect refrigerants contained in used appliances exported to developing countries.

Source: OzonAction, April 2001
More information: Mr Kono Haruhiko
Fax: +81-3-3501-6604
E-mail: kono-haruhiko@miti.go.jp

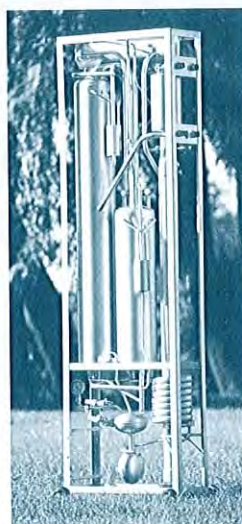
Gas-driven absorption heat pump

Germany - At the ISH (a leading international trade fair for sanitation and heating) in Frankfurt earlier this year, a new heat pump product was introduced for single and two-family houses, which will become available for consumers in the second half of 2002. Buderus Heiztechnik GmbH introduced the Loganova gas-driven diffusion absorption heat pump (figure 1).

This heat pump achieves SPF values of up to 130%. It is constructed with only a few moving parts and is therefore very durable and produces very little noise. A condensing boiler that supplies hot water is integrated into the design, while the heat pump provides space heating.

The heat pump is produced in two sizes, a 3.6 kW (max. 11 kW) for new buildings and for existing buildings or two-family houses a 3.6 kW (max. 19 kW) unit.

Source: Wärmepumpe Aktuell, September 2001



▲ Figure 1: Gas-driven diffusion absorption heat pump.

Canada adopts programme to govern ODS disposal efforts

Canada - The Canadian council of ministers of the environment (CCME) recently adopted a strategy for the disposal of ozone-depleting substances in Canada. The strategy includes enacting bans on the reuse and refilling of CFC and halon containers, mandating the development of stewardship programmes by industry and imposing 'seller take-back' rules.

The ban on CFC refills for the commercial refrigeration and chiller industries will be implemented in stages, starting on 1 January 2004. Refrigerant users will be able to begin turning in supplies for disposal at the beginning of next year through Refrigerant Management Canada.

Source: OzonAction, August 2001
More information: Laura Linza, Refrigerant Management
E-mail: llinza@hrai.ca

Water heater using CO₂ as refrigerant

Japan - Sanyo Electric Air Conditioning Co. Ltd. has launched a water heater incorporating a CO₂ compressor this autumn. Last summer, it went through the second-stage-monitoring test and was favourably accepted by users.

After starting R&D last year, Sanyo has been manufacturing the new CO₂ water heater and subjecting it to monitoring tests, which involve actually installing the heater at an employee's house. For its new product, the company applies its room air conditioner (RAC) compressor technology, which is highly reputed for reliability and durability. Sanyo is one of the very few CO₂ compressor makers in Japan.

In combination with a storage tank requiring only 460 x 650 mm space for installation (plus an outdoor unit for 4 kW class RAC), the new product realises an efficiency three times as high as that of an electric water heater. An electric water heater, which utilises low tariff electricity at night, requires electric power for additional heating of water in the daytime once stored hot water has been depleted. The Sanyo CO₂ water heating system consumes less electric power for the additional heating of water in the storage tank. Therefore, the storage tank could be made very compact.

Although electric water heaters still have a large share of the water heater market, the share of CO₂ water heaters is expected to increase. Electric power companies as well as house builders and users are expected to show interest in the new product as an environmentally friendly, highly efficient, energy-saving system.

Source: JARN July 25 2001



New on the HPC Internet site: Case studies and Newsletter

The HPC has updated its Internet site. Improvements include use of full screen width, more information about ongoing Heat Pump Programme and HPC projects, and a streamlined publications ordering procedure.

Visitors will be able to download back-issues of the Newsletter as pdf files (new section "Project results").

Also new on the site are examples of successful heat pump installations, which have been gathered within the framework of an HPC project. At the time of writing,

8 residential, 10 commercial and 7 industrial cases had been identified and described. If you have an interesting case to add, please contact the HPC.

Source: IEA Heat Pump Centre
More information:
<http://www.heatpumpcentre.org>

Refrigerant Recovery and Recycling: an International Assessment

The report "Refrigerant Recovery and Recycling - an International Assessment", will be available soon from the HPC.

This report documents refrigerant recovery, recycling, reclamation, policies, practices, and national plans in major markets in Asia, Europe, and North America. Refrigerant containment and management regulations, policies, and practices are described and analysed. The study will be continued covering additional countries and will include disposal.

The report can be ordered from the HPC, order number HPC AR-11. Availability of the report in non-HPC member countries is restricted.

Source: IEA Heat Pump Centre

CO₂ emission reduction potential UK

The HPC has completed a study into the CO₂ emission reduction potential of heat pumps in the UK for the period 2000-2020.

The study focused on use in commercial/institutional buildings. Trends in new construction, growth of the packaged air-conditioning market, penetration rates, performance of heat pumps and fuel mix for electricity generation were considered.

In a business-as-usual scenario, heat pumps will be able to reduce CO₂ emissions by 2.7% of total space heating demand in 2020.

More information: IEA Heat Pump Centre
Address: see back cover.

ASHRAE develops guidelines for geo-exchange projects

USA - The American Society of Heating, Refrigeration & Air Conditioning Engineers (ASHRAE) will pay USD 120,000 to develop guidelines that improve earth energy systems and reduce costs. ASHRAE has solicited proposals for the selection and design of pumping and piping subsystems for ground-coupled heat pumps. The goal of this programme is to find an optimum balance between capital costs and operational and maintenance costs.

Source: Earth comfort update, May/June 2001

Ongoing Annexes

Red text indicates Operating Agent.

Annex 16

IEA Heat Pump Centre

AT, JP, **NL**,
NO, UK, US

Annex 25

Year-round Residential Space
Conditioning and Comfort Control
Using Heat Pumps

FR, **NL**,
SE, US

Annex 26

Advanced Supermarket
Refrigeration/Heat Recovery Systems

CA, DK, SE, UK, **US**

Annex 27

Selected Issues on CO₂ as a
Working Fluid in Compression Systems

CH, JP, **NO**,
SE, UK, US

Annex 28

Sorption - Heat Recovery Systems
Market and Environmental Impact for
cooling and heating

NL, **NO**, ES, SE,
others to be confirmed

IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).



Adsorption and desiccant systems – an international overview

Gerdi Breembroek, IEA Heat Pump Centre

The application of adsorption and desiccant systems for air conditioning has increased in recent years. They serve market niches where inexpensive low-temperature drive energy is available or where dehumidification is required. This article gives an overview of the technologies involved, some recent technological developments, and the current state of the market and possible future developments.

Introduction

Adsorption refers to a physical process in which the molecules of one substance are 'adsorbed' or fixed on the surface of another substance. The latter substance is always a solid and is referred to as the sorber or the sorption material. An example is the adsorption of water vapour onto silica gel for air-conditioning. Desiccant systems remove water from the air or from other materials with the help of a desiccant or drying agent. The desiccant may be solid or liquid. An example of a solid desiccant is silica gel. Adsorption and desiccant systems make use of the same physical process. The essential difference between adsorption and desiccant systems as referred to in this article is that in the former the emphasis is on cooling whereas in the latter the emphasis is on dehumidification.

Another type of chiller analogous to the adsorption chiller is the absorption chiller. Both are commonly referred to as 'sorption systems'. However, in an absorption chiller, the molecules of the one substance penetrate the other substance fully and a homogeneous mixture is reached. At present, absorption chillers have a much higher global market share than adsorption chillers.

Technologies involved

Adsorption chillers

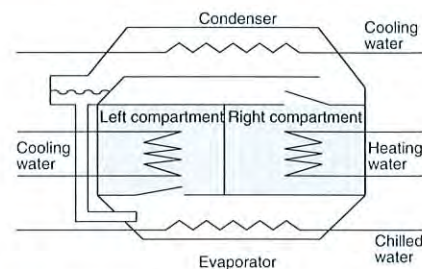
An adsorption chiller consists of two adsorbers, each filled with the refrigerant/solid sorption material, an evaporator and a condenser (See **Figure 1**). All commercially available equipment uses water/silica gel as the

working pair, and cooling capacities range from 70-350 kW. The system depicted in **Figure 1** operates as follows:

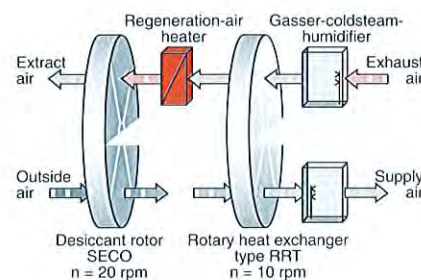
1. The refrigerant adsorbed to the sorber is driven off through the use of hot water (right compartment);
2. The refrigerant condenses in the condenser and heat of condensation is removed by cooling water;
3. The condensate is sprayed in the evaporator, and evaporates under low partial pressure. This step produces the useful cooling effect;
4. The refrigerant vapour is adsorbed onto the sorber (left compartment). Heat is removed by cooling water.

When the sorber is fully charged, the functions of the left and right compartments are interchanged. The process is therefore cyclic, which is its main disadvantage. Switching functions between the compartments, i.e. changing cycles, takes time and means that the process is not continuous. This decreases the efficiency of the process. The main advantages of the adsorption chiller are that it has no moving parts, can operate with low driving temperatures (60-80°C for water/silica gel, 70-130°C for water/zeolite), and generates little noise.

To create a more uniform and continuous cooling effect, two or more cycles can be connected to each other. There is then always a sorber available to absorb the vapour from the evaporator and provide cooling. The use of multiple sorber units also makes it possible for different units to exchange heat with one another, reducing the



▲ **Figure 1: Adsorption chiller.**



▲ **Figure 2: Desiccant evaporative cooling.**

auxiliary heat needed to heat the sorbers and improving the efficiency of the overall cycle.

Solid-desiccant systems

Figure 2 shows a desiccant evaporative cooling (DEC) process. Hot humid air passes a sorber, which extracts humidity directly from the air. As a result, the temperature of the airflow rises. After cooling down the airflow to the exhaust air temperature with a heat recovery wheel, water is sprayed into the airflow, cooling it down further. After the sorption process, the desiccant wheel is regenerated by heating the desiccant, e.g. by hot air, steam, flue gas or solar heat. Desiccant rotors typically treat 2,000-40,000 m³/h of air.



Commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, titanium silicate, lithium chloride, synthetic polymers, glass or ceramic fibre matrices or cellulose. New desiccant materials such as titanium silicate have much higher affinities for water than previously used desiccants such as silica gel. The wheel is designed to minimise pressure losses and maximise effective area. ASHRAE and ARI issue standards for desiccant wheel certification, and an ASHRAE testing method for packaged desiccant systems is being developed.

The main advantage of the DEC cooling system is that it enables users to separate humidity control from temperature control. This is a major advantage compared to vapour-compression cycles, which have to rely on overcooling and reheating to handle high humidity loads. The disadvantage of the DEC system as the only source of cooling is that the air cannot be cooled under 18°C and that the ventilation system has to be well balanced. There are, however, different system configurations possible, which alleviate the latter problem.

Another disadvantage of the desiccant air-(pre)conditioning system is that its energy efficiency is low in hot and humid climates, such as in Japan. The article on page 18 discusses work on an advanced cycle with two-stage dehumidification, intended to deal with this problem.

Liquid-desiccant systems

Applications where solid-desiccant systems are successfully competing can also be served by liquid-desiccant systems. Liquid-desiccant systems include those using lithium chloride, lithium bromide, calcium chloride and triethylene glycol solutions. Carryover of the, usually corrosive, desiccant is the most important potential problem.

An Israeli company markets liquid-desiccant systems for air-conditioning applications. A diagram of the system is shown in **Figure 3**. It consists of a

dehumidification section, a heat pump section and a regeneration section. The lithium chloride (LiCl) flows over cellulose honeycomb media and the process air stream goes through it. As the desiccant solution is cooled by the heat pump, the supply air is cooled and dried at the same time. The heat pump supplies the waste heat to the regeneration section. The system is very efficient and has been successfully applied in schools, hospitals, restaurants, industry, agriculture etc. In addition to dehumidification and cooling, the system also removes 77% of air-borne particles larger than 5 µm and the LiCl helps destroy bacteria.

Market segments

An important traditional market for desiccant systems is drying for industrial applications. This ranges from product preservation in the pharmaceutical, food and chemical industries, to rust protection, dehumidification after floods, and speeding up building processes through drying of concrete. Another application is in supermarkets to reduce frost build-up, provide safer working conditions and extend product shelf life.

In the air-conditioning sector, desiccant systems are ideally suited for applications requiring low humidity levels, or where ventilation rates are high, such as in supermarkets, health spas, hotels, offices, hospitals and medical facilities. They also provide

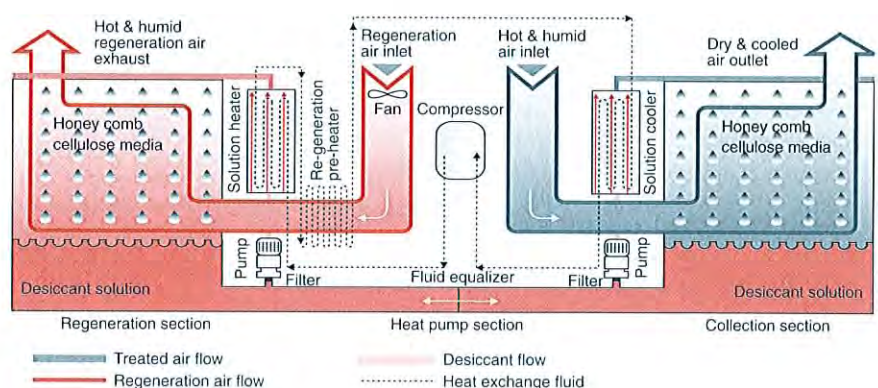
precise control of humidity where that is essential to the manufacturing process.

In the USA, dehumidification of outdoor air used for air-conditioning purposes will become increasingly important, as ASHRAE standard 62-99 requires the intake of more outside air to improve indoor air quality. This is especially relevant for buildings with high occupancy loads, such as schools, theatres, and office buildings.

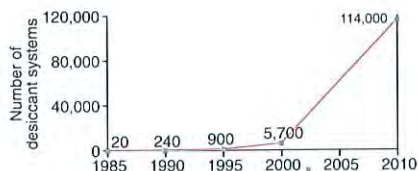
In contrast to desiccant dehumidification systems, which are applied in a broad range of drying applications, adsorption chillers are used primarily where waste heat is available. This is because such systems are well suited for using low-temperature waste heat and solar heat as a driving energy source. Examples are air conditioning in factories and industrial process cooling. A potential market for heat-driven systems exists in locations where electricity is not easily available, such as in developing countries.

Markets

The market for adsorption chillers is less than 0.5% of the overall world market for sorption equipment but is seeing rapid growth. During the last ten years, over one hundred adsorption systems have been installed in Japan. They are supplied by two pioneer Japanese manufacturers.



▲ **Figure 3:** Diagram of a liquid-desiccant system.



▲ Figure 4: Market status and projection of desiccant systems in US commercial buildings (Wurm, 1999).

The market for desiccant systems for air conditioning in Japan is also estimated at around one hundred systems per year. However, the market for industrial applications is much larger.

In the USA, annual production of desiccant systems and components for air conditioning in 1997 was worth nearly 100 million USD, representing about 1% of all US HVAC&R market shipments (Wurm 1999). It is expected that this will more than triple by the year 2003. The number of manufacturers of solid-desiccant dehumidifiers has increased from two in 1980 to more than ten in 2001. Figure 4 shows the expected and recorded market growth of desiccant systems in commercial buildings.

In 1995, the US Department of Energy (DOE) launched a programme to increase the application of desiccant cooling systems in the commercial/institutional building sector. The aim of the programme was to reduce energy consumption by 106 PJ annually by 2005 and 420 PJ annually by 2010, and to realise corresponding CO₂ emission reductions. Also, desiccant systems are targeted to capture 20% of total air-conditioning sales in 2005 and 35% in 2010. The US DOE is working with an industry consortium to develop the next generation of desiccant systems for broader commercial applications. Long-term goals also target the residential market.

Conditions for future success

Though solid-sorption and desiccant systems have secured market niches, they are not being used to their full potential. Developments to improve the

price/performance ratio, equipment versatility and system integration will improve market prospects. Further engineering is needed to develop a second generation of products, specifically designed to address dehumidification loads and indoor environmental quality issues in modern buildings. Marketing is needed to gain commercial acceptance of these products. The article on page 13 of this Newsletter reports on initiatives taken by the US DOE. There is also a need for educating architects and engineers with regards to designing and applying the systems.

In order to gain greater market acceptance of adsorption systems in Japan, R&D for higher efficiencies, reduced cost and more compact systems is ongoing. Developing machines that operate with lower driving temperatures is another area of R&D. In HPC Newsletter 17/2, 1999, current R&D activities on adsorption systems in Japan are described.

Solar-powered systems

Both adsorption and desiccant systems allow solar energy to be used for powering and/or regenerating air-conditioning equipment. Adsorption equipment and solar collectors have improved since the 1980s, when the first efforts in solar-assisted air-conditioning systems were undertaken. The number of installations has been increasing in the last few years.

Within the IEA Solar Heating and Cooling (SHC) programme, an international project *Solar assisted air conditioning of buildings* aims to improve market conditions for the introduction of solar assisted cooling systems (see picture front cover). Deliverables of the project will be a design handbook, a design tool, and a book of solar assisted air-conditioning example projects. More information can be obtained from <http://www.iea-shc.org>

Conclusion

Adsorption and desiccant systems serve market niches that may expand in future. Adsorption systems are notable for the possibility of utilising low-temperature waste heat. They can be part of solar assisted air-conditioning systems. The same is true for desiccant systems. In addition, desiccant systems allow the separation of latent and sensible cooling loads, which helps reduce peak loads and increase efficiency. They are being increasingly applied in air-conditioning systems, and the market for such systems is growing favourably. However, to realise the full potential of adsorption and desiccant systems for air conditioning, a second generation of products will need to be developed specifically designed to address dehumidification loads and indoor environmental quality issues.

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Investing in the future of desiccant-based systems for indoor air conditioning

James R. Sand, USA

The U.S. Department of Energy has selected three industry teams to design, build and test desiccant-based air-conditioning systems. Goal of the programme is to assist the industry in accelerating the penetration of second-generation, desiccant-based technology into the broader market for air-conditioning systems.

Introduction

Desiccant-based dehumidification technology is an alternative to traditional comfort conditioning and indoor air quality (IAQ) control systems in commercial and residential buildings. Desiccant systems can reduce energy consumption, reduce peak electricity demand and improve indoor air quality. One estimate indicates that the annual potential for energy savings in U.S. buildings would be 88 TWh, which would lead to a reduction of more than 13,000 tons of CO₂ emissions each year. The energy savings and economic pay-back would depend on the performance of the desiccant system and the efficiency of the conventional system being replaced, the rate of market penetration, and the source of thermal energy used to power the desiccant system.

Over the last twenty years, R&D efforts and technological improvements have advanced desiccant ventilation air pre-treatment technology and improved the performance of desiccant-based ventilating and air-conditioning (VAC) equipment. These advances have improved the performance and reliability of desiccant systems while reducing their cost. However, further cost reduction and performance improvements are needed for these systems to compete successfully in the broader building market. At present, the technology has penetrated niche markets (such as supermarket and skating rink dehumidification applications), but has not yet achieved

widespread acceptance for dehumidification, comfort conditioning, and IAQ systems within the broader commercial and institutional buildings market. To achieve such acceptance, manufacturers of desiccant-based systems need to focus on:

- lower initial costs;
- its ability to satisfy several building functions (integration);
- improved convenience or efficiency by combining novel techniques;
- its ability to utilise waste heat from other building operations.

Industry involvement

Field tests and market/cost evaluations of first-generation desiccant products by leading U.S. HVAC (heating, ventilating and air conditioning) and desiccant equipment manufacturers, utilities, manufacturer trade organisations, professional engineering associations, and government agencies have shown that it is possible to achieve reduced unit costs, improved equipment versatility and better system integration with the help of commercially available technologies. Further engineering and marketing efforts are needed to develop a second generation of products, specifically designed to address dehumidification loads and indoor environmental quality issues in modern buildings, and to gain commercial acceptance of these products. For such efforts to succeed, it is important to secure the active involvement of major building equipment manufacturers.

These established partners can provide:

- a practical understanding of current markets and system engineering practices;

- objective appraisals of cost/benefit features in building subsystem components;
- a reliable and knowledgeable network of service agencies capable of system repairs;
- experience with and ability to provide in-house hardware for control systems and regulation strategies;
- an established base of commercially available equipment into which desiccant system components can be integrated;
- engineering expertise to specify modular desiccant components compatible with conventional system components;
- existing customer and service agency training programmes, through which new technologies can be readily communicated and transferred to field operations;
- established industry reputations for quality, as well as existing customer bases;
- well-developed computerised marketing and system design simulation tools, which can be applied to desiccant component modules.

However, it would entail an unacceptably high risk for any one manufacturer or corporation to attempt to develop and market the second generation of desiccant technology by itself.

Government involvement

Projected benefits from the use of second-generation, desiccant-based technology for IAQ systems – in terms of national energy savings, improved



IAQ, and enhanced occupant health and productivity – qualify such technology as a research effort that merits support by the U.S. government. The aim of such support is to assist industry in accelerating penetration of desiccant technology into broader markets of comfort conditioning in commercial and residential buildings. The near-term objective focuses on lower cost and more efficient applications in broad public and commercial markets. The long-term objective focuses on expansion of this technology into public and commercial building markets that incorporate a distributed power and BCHP (building, cooling, heating and power) aspect in their design.

Request for Proposals

Within the framework of its commitment to initiate industry-led, cost-shared research projects promoting new product development, hardware deployment and demonstration, and market penetration, the U.S. Department of Energy (DOE), in February 2001, issued a request for proposals (RFP) from industry players for advanced desiccant-based systems. The goal of these systems is higher efficiency, lower first cost, increased reliability, greater versatility and better systems integration – as compared to state-of-the-art, first-generation products previously tested and benchmarked. For example, combining ‘total-energy-recovery’ systems and thermally regenerated (passive and active) desiccant-based technologies to produce hybrid systems, has been shown to provide energy and operating savings as well as comfort and IAQ benefits. Under the RFP, concepts using active desiccant components and subsystems could be proposed for developing new second-generation, high-efficiency, combined systems. Such proposals could also serve to get major HVAC and desiccant equipment manufacturers involved.

Winning Proposals

The three winning proposals were from:

- Kathabar/AIL Research/University of Illinois Chicago,
- SEMCO/University of Illinois Chicago/C&M Engineering,
- University of Central Florida/Trane Company/Air Exchange.

The total cost of research proposed by the three winning teams was USD 1.9 million, with 25% cost sharing, and USD 1.4 million from the DOE. Work on all three projects began in July 2001. Oak Ridge National Laboratory is overseeing these projects for the DOE. All of this government sponsored or partially government-sponsored research is contingent on the availability of program funds that vary from fiscal year to fiscal year, and these projects fall into that qualification. They are currently scheduled to last from 2 to 2½ years, and we anticipate that they will be completed in that period of time. All teams associated with winning proposals started work in August or September 2001.

Kathabar Incorporated/ AIL Research/University of Illinois Chicago: a rooftop liquid desiccant air conditioner

Kathabar will design and build a liquid desiccant air conditioner (LDAC) and cooling tower that replaces and performs the sensible and latent cooling work normally done with a conventional, vapour-compression rooftop air conditioner. The proposal points out that a liquid desiccant system offers the best opportunity for increased COP of the desiccant dehumidification process as compared to a solid-desiccant, wheel system. A 52.5 kW cooling system is proposed, which dehumidifies and cools the ventilation and building return air. The work builds heavily on the zero-carryover, plastic heat exchanger work that is being conducted at the National Renewable Energy Laboratory in Colorado. Lower equipment costs and operating costs are the most salient features of the system.

More complicated plumbing and working material characteristics are potential drawbacks.

SEMCO Incorporated/ University of Illinois Chicago/C&M Engineering: a cost-effective and high efficiency active desiccant – total energy hybrid outdoor air preconditioning system for BCHP and non-BCHP facilities

SEMCO will design, model, and build a combined total-energy-recovery and active desiccant hybrid outdoor air preconditioning system that will function in parallel to, and complement, a sensible temperature air conditioning system in HVAC building designs. The University of Illinois Chicago (UIC) will work with SEMCO to optimise their active desiccant wheel component regarding size (first cost), moisture depression (required process dew point), and pressure drop (fan power) for the selected design. The product concept is an energy recovery wheel/ active desiccant wheel combined system, which has the same cost-effective, energy-efficient appeal as a custom system used for a dormitory installation at Berry College in Rome, Georgia, USA. A redesigned desiccant wheel and tighter air handler modules will improve overall system performance, and the redesigned product will fit a broader range of market applications.

University of Central Florida– Florida Solar Energy Center, the Trane Company, and AirXchange Incorporated: Trane Active Cromer Cycle

This proposal will result in the design, construction, and testing of two prototype “Trane Active Cromer Cycle” modular air handlers for light commercial applications: a 1.9 m³/s, 35 kW unit and an 3.8 m³/s, 70 kW unit. This cycle uses a desiccant wheel to transfer moisture between the supply and return air stream of a conventionally designed, ducted air-conditioning system. The desiccant picks up moisture from the cool, highly humid air leaving an evaporator or cooling coil, and transfers it to air

returning from the space that has been heated with condenser waste heat or an auxiliary heating source. The moisture taken from the supply air by the desiccant is the same moisture that is re-evaporated for pre-cooling into the return air prior to it reaching the cooling coil. In this Trane Active Cromer cycle, moisture that is captured by the desiccant and not expunged from the building is presented again to the cooling coil – for another opportunity at condensing it down the drain as evaporator condensate. Advantages claimed by the cycle are:

- dry ducts leading to improved IAQ;
- no need for stand-alone dehumidifiers;
- lower sensible heat ratio HVAC performance (better latent load capability);
- energy savings;

- simplified equipment and maintenance.

Conclusion

With financial support from the US government, three separate projects are now being carried out that focus on developing new second-generation, desiccant-based systems for use in comfort conditioning and IAQ applications. The development of these systems and the active involvement of industry players should help realise the promise of this alternative technology and accelerate its acceptance by the broader markets involved. Wider application of such technology can also lead to significant environmental benefits with regard to reducing energy consumption and CO₂ emissions.

The current research proposals result in a laboratory-tested and rated prototype piece of equipment. Previous desiccant product technology research work funded by DOE through Oak Ridge National Laboratory resulted in pilot field demonstrations of equipment concepts developed as part of the research. It is anticipated that similar field trials and field demonstrations will result from the active desiccant equipment designs developed as a result of the current effort.

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Sorption systems in district-heating networks

Richard Krottil, Hermann Halozan, Austria

One of the problems with district heating is summer operation, during which the facility either has to be shut down (and consequently cannot provide hot water) or remains in operation, with over-capacity and energy losses as a result. An investigation of a district-heating network in Graz shows that heat-driven sorption systems may be used in district-heating networks to provide consumers with an additional product - cooling - and at the same time to increase the efficiency of the network as a whole.

Introduction

District heating, whereby the heating needs of larger residential blocks are supplied from a central unit via a system of pipes, is very common in Central and Northern Europe. When CHP (combined heat and power) plants and/or individual heat pumps are used for space heating and hot water production, district heating is an efficient way of utilising energy resources. Additionally, air quality can be improved by avoiding flue gases in the city. One problem of district-heating systems is the operation during summer. Due to the reduced demand for heat delivery, the system is under-utilised

and works less efficiently. New systems using plastic pipes are often shut down. Systems using steel pipes have to remain in operation, and water has to remain circulating at a temperature level of about 60°C in order to avoid corrosion.

The demand for space cooling in Central and Northern Europe has increased in recent years due to better insulation, new architecture using glassed facades, and increased internal heat loads caused by computer equipment etc. Electrically driven chillers generally supply air conditioning. A new approach is to use hot-water-driven sorption systems, with

low-temperature heat from district-heating networks as energy source.

This article discusses the possibility of integrating sorption-based coolers into district-size heating networks, and is based on a study of the district-heating network of Graz, Austria, which supplies 3,600 customers with a total of 430 MW heat. The heat is provided by two steam cycle power stations with heat extraction and one CHP plant with a gas turbine.

History of sorption systems

Sorption systems are based on an old technology. It was Ferdinand Carré

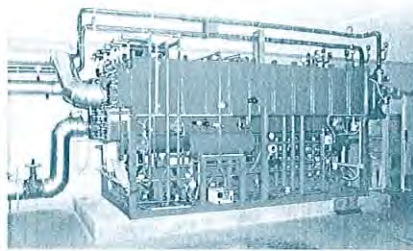


who, in 1860, probably invented the absorption cycle by replacing the mechanical compressor by a so-called thermal compressor. This thermal compressor consisted of an 'absorber' solution (a refrigerant dissolved in a solvent), a pump to transport the solution to a higher pressure and temperature level, and a 'desorber' or generator, which separated solvent and refrigerant by adding high-grade heat. He used the working pair ammonia/water, where ammonia was the refrigerant and water was the solvent. With this cycle, it was possible to produce cold with only a small amount of mechanical energy. The main source of energy was heat, and the production of heat was at that time much easier and safer than the production of mechanical energy. At first, the new technology was used mainly for refrigeration, but it was soon adapted for air-conditioning purposes as well, especially for large systems. For the latter application, the working pair water/lithium bromide became common.

At the beginning of the 20th century, much research work was carried out. New working pairs were tested, and advanced systems such as those using multi-lift multi-effect cycles and the generator-absorber heat exchanger (GAX) cycle were developed. However, heat-exchange technology was not yet advanced enough to achieve economically competitive sorption solutions. Compression-based systems gained wider acceptance, and the market share of sorption systems decreased.

Recent developments

With the Montreal Protocol (1987), a revival of absorption technologies began, as sorption systems cause no ozone depletion. The most commonly used absorption systems for air conditioning are direct gas-fired units with the working pair water/lithium bromide. Such units have a remarkably high market share in Japan and China, where they are primarily used as a demand-side measure for reducing



▲ Figure 1: $H_2O/LiBr$ single effect/single lift-double lift absorption unit.

peaks in the electrical grid. From an energetic perspective, they are less efficient than compression systems, as gas is used only for providing low-temperature heat in the generator.

However, in recent decades hot-water-driven sorption systems have also been developed that can be operated effectively in conjunction with CHP systems, i.e. at hot-water temperatures of about 90°C. In this case the driving energy is 'waste' heat from an engine, a gas turbine, a steam power plant or a combined cycle steam power plant. The fact that the primary fuel has already been used to produce mechanical energy and/or electricity and only waste heat is being used to power the sorption system means that the overall energy efficiency of such systems is very high. For district heating networks, special units have been developed that

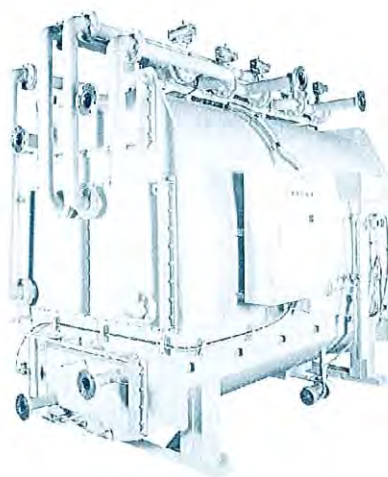
maximise the difference between the hot water supply temperature and return temperature (Figure 1).

A relatively new approach is the use of adsorption systems with water/silica gel as working pair. These machines can be designed as closed systems (Figure 2) or as open systems as in the desiccant evaporative cooling (DEC) system (see the article on page 21). The main advantage of such systems is that they can be powered by low-temperature heat sources such as solar heat or waste heat from engine-based CHP systems etc.

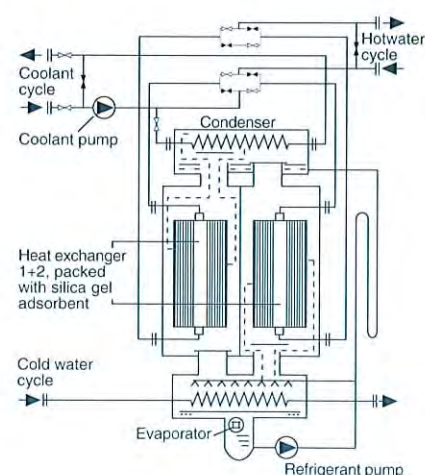
DEC systems provide reliable solutions for cooling. However, they can only provide a limited cooling capacity – depending on the outdoor temperature and humidity. An interesting solution to this problem is the use of hybrid systems, i.e. a DEC system combined with a compression system, where the condenser heat from the compression system is used to power the DEC system.

Integration into district-heating system

A technical and economic market analysis was carried out on the possibility of integrating sorption chillers into a hot water network. In



▲ Figure 2: Water/Silicagel Adsorption Unit (Nishiyodo).



particular, sorption systems using water/silica gel as working pair were evaluated as to their ability to effectively utilise the low-temperature heat energy available from district-heating systems in summertime. Depending on the coefficient of performance (COP), the capacity of the cooling system has to be up to four times the capacity for a compression system – an aspect that has to be included in an economic evaluation of the different systems. In addition, thermal storage capacity is often required. Analysis showed that the COP depends mainly on the cold-water temperature, the cooling-water temperature and the hot-water temperature. The cold-water temperature should be as high as possible, the cooling-water temperature as low as possible, and the hot-water temperature again as high as possible. The cold-water temperature cannot be varied due to the demands of dehumidification. However, it can be increased if ceiling-mounted cooling units are used. The cooling-water temperature depends on the site and the cooling system used.

The only one of the above three temperatures that can, to a certain extent, be controlled is the hot-water temperature, which should be as high as possible. In this regard, an analysis was carried out of the district-heating system of Graz and the components: combined heat and power plants, main transport lines, and urban distribution network. The analysis considered current summer operation and whether it would be possible to raise the network temperature in order to facilitate the integration of sorption systems for air conditioning. The analysis showed that an increase of the supply temperature from 60 to 90°C is possible without increasing energy consumption, as increased heat losses

are compensated by a reduction of the power requirement for pumping.

The investigation led to the conclusion that introducing sorption systems for cooling would lead to a higher rate of utilisation in summer for the district-heating system of Graz as well as for the CHP plants supplying the energy. In addition, a new product could be offered to the district-heating network customers – ‘cooling’. It also became clear from the investigation that an economical use of sorption systems for air conditioning in conjunction with a hot water network is only possible if the technical aspects (especially the hot-water, the cold-water and cooling-water temperatures) as well as the economic aspects are analysed for the individual location concerned.

Summary

At present, the costs of electrical and thermal energy are such that sorption systems are superior, from an economic perspective, to compression systems for air conditioning in only a limited number of cases. One such case is the integration of sorption systems into district-heating networks powered by CHP plants and/or related facilities. The sorption systems can then be powered by low-temperature waste heat that is available, especially in summer when the facility would otherwise be under-utilised. A more efficient utilisation of the energy sources being used would, of course, have environmental benefits as well. Finally, the district-heating network can offer an additional product to its customers: cooling.

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Solar-powered adsorptive desiccant-based air-conditioning systems for the hot and humid climate of Japan

Akio Kodama and Tsutomu Hirose, Japan

A typical single-stage adsorptive desiccant-based air-conditioning system, powered by hot water from commercial solar collectors, was tested in the Japanese climate. At lower ambient humidity, cooling efficiency and cooling power were sufficient to provide a comfortable indoor climate even at an ambient temperature of 33°C. At higher ambient humidity, cooling efficiency and power decreased sharply and were not adequate. A new two-stage system is proposed for use in hot and humid climates. Model calculations indicate that the two-stage system would perform better at higher humidity.

Introduction

Adsorptive desiccant-based cooling is an environmentally friendly technology that can be used to replace traditional air-conditioning systems for climate control in buildings. Whereas conventional air-conditioning systems rely on 'high-grade' electrical energy, desiccant-based systems can be powered by 'low-grade' energy sources such as waste heat or solar heat. By eliminating the need for traditional refrigerants and reducing the consumption of fossil fuel and associated emission of CO₂, such alternative systems can be beneficial to the environment. From an economic perspective, economic growth in Asia requires an increased utilisation of energy resources and makes the development of technologies that use alternative energy sources all the more

urgent. The research described in this paper focuses on the development of a solar-powered adsorptive desiccant-based air-conditioning system for use in a hot and humid climate such as in Japan. It was carried out in cooperation with the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

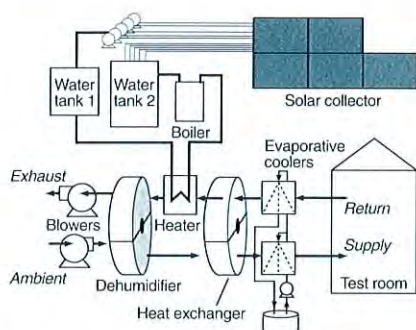
Design of single-stage system

The design of the single-stage unit is shown in **Figure 1**. The system consists of a rotary dehumidifier equipped with a honeycomb adsorbent wheel, a fin coil heater, a rotary heat exchanger and two evaporative coolers. It is installed in Kumamoto, located at 32° 48' north latitude and 130° 43' east longitude.

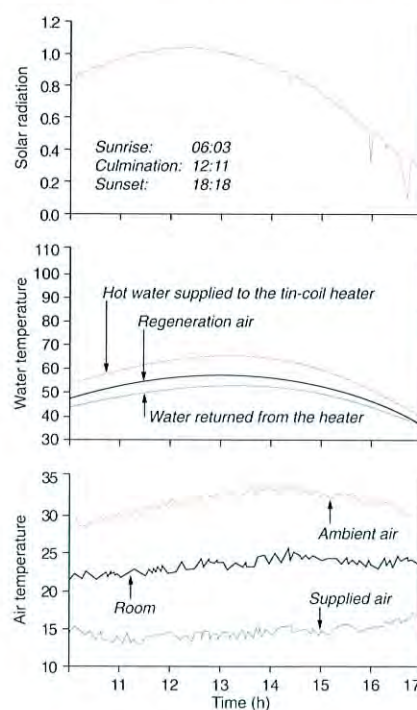
As the wheel is regenerated at the relatively low temperatures supplied by the solar collectors, a symmetrical dehumidifier with equal area and balanced flow was chosen in order to ensure a good match between the supplied and ventilated airflow rates [1]. A honeycomb rotor with a thin layer of adsorbent is used in the dehumidifier, as it provides a large specific surface area for heat and mass transfer. The dehumidifier, with an adsorbent rotor 1.2 m in diameter and 0.2 m in width, was manufactured to have a channel pitch of 3.4 x 1.9 mm and a 0.2 mm thick coating of silica-based sheet adsorbent. The honeycomb wheel used

in this test contains about 50-60% of silica gel in the voids of the glass fibre sheet of the wheel matrix and has been designed especially for lower temperature regeneration.

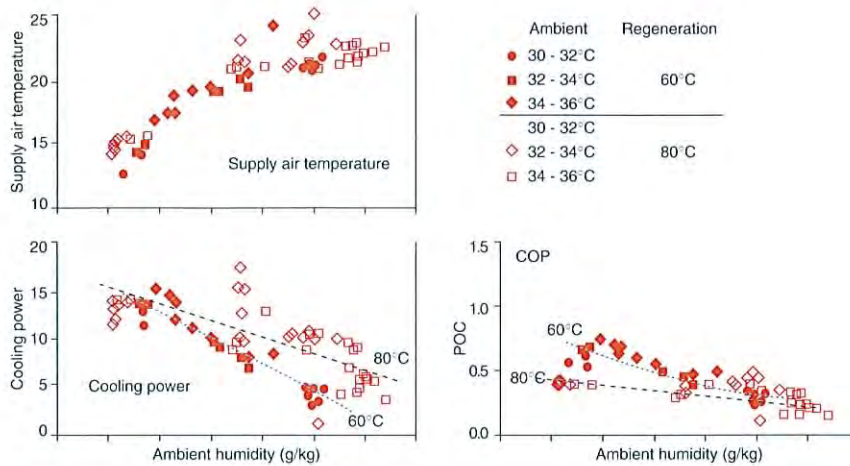
The hot-water supply unit consists of thirty solar collector modules, two heat



▲ Figure 1: Schematic diagram of the solar-powered adsorptive desiccant-based cooling system



▲ Figure 2: Variation over time of solar radiation, water temperatures in heat supply system, and air temperatures relevant to the cooling process; measured on Sep. 19, 2000 (ambient humidity $H_1 = 8.8$ to 10.1 g/kg).



▲ Figure 3: Influence of ambient air humidity on performance of typical single-stage cooling system operated in ventilation mode (supply and return air velocities 2 m/s).

storage water tanks and an auxiliary boiler. The total aperture area of the solar collectors is 60 m², and they are trimmed to the south at an angle of 30 degrees elevation. Approximately 0.5 m³ of water is used in the heat supply unit as a heat transfer medium. The volume of the test room is 144 m³.

Results with single-stage system

Figure 2 presents data on solar radiation and various relevant water and air temperatures measured during a field trial on September 19, 2000, a rather sunny day. During the daytime, ambient temperature varied between 28.4°C and 33.4°C. Ambient humidity varied between 8.8 g/kg and 10.1 g/kg. Maximum radiation of 1.05 kW/m² was observed at midday, and maximum water temperature at the inlet of the fin-coil heater was 66°C at 13:00 hours. Maximum cooling power occurred around 14:00 hours, at which time thermal COP was 0.62.

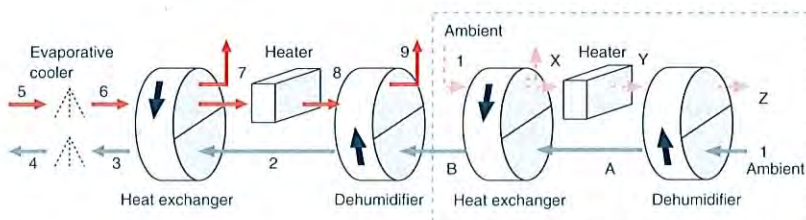
Despite the variation in the hot-water temperature supplied to the system, the temperature of the air supplied to the test room was maintained at 14°C from the beginning of the measurement until 15:00 hours, after which there was a gradual and limited rise in temperature. Test room air temperature was maintained within the comfortable range of 21.3°C to 24.4°C all day long. Test room humidity was the same as ambient humidity. This stability in the parameters measured can be explained by the fact that the heat load in the test room was mainly sensible heat due to solar radiation. As the cooling power of the system is also a function of solar radiation, both heating and cooling forces are in phase and tend to stabilise the system. Ambient temperature remained quite high even in the late afternoon towards evening, when solar radiation had already decreased quite markedly. The temperature of the hot water supplied to the system, and thus of the regeneration air, also remained quite high later in the day. This is due to

the large heat storage capacity of the working fluid. This may be another reason for the rather constant room temperature.

Problems with high ambient humidity

The experimental results presented in Figure 3 demonstrate the effect of higher ambient humidity on the performance of the single-stage system. Results are given for regeneration temperatures of 60°C and 80°C and for three different ranges of ambient temperature.

The results make it clear that, within the range of experimental conditions examined, ambient humidity had a much greater influence than ambient temperature. At ambient humidities under 15 g/kg, COP is over 0.5, cooling power remains relatively high and supply air temperatures remain relatively low. Under these conditions, a regeneration temperature of 60°C is preferable, as COP is considerably higher at 60°C than at 80°C, and the effect of a higher regeneration temperature on cooling power and supply temperature is relatively small. In contrast, at ambient humidities over 15 g/kg, a higher regeneration temperature of 80°C is required to maintain significant cooling power. However, it is also clear that at higher humidities, the single-stage desiccant-based wheel system has difficulties in delivering sufficient cooling power to lower the supply air temperature to an adequate level. As a result, a design was proposed for a desiccant-based cooling system based on a two-stage dehumidification cycle for use in very humid weather.



▲ Figure 4: Schematic diagram of desiccant-based cooling system with two-stage dehumidification cycle.

Two-stage system

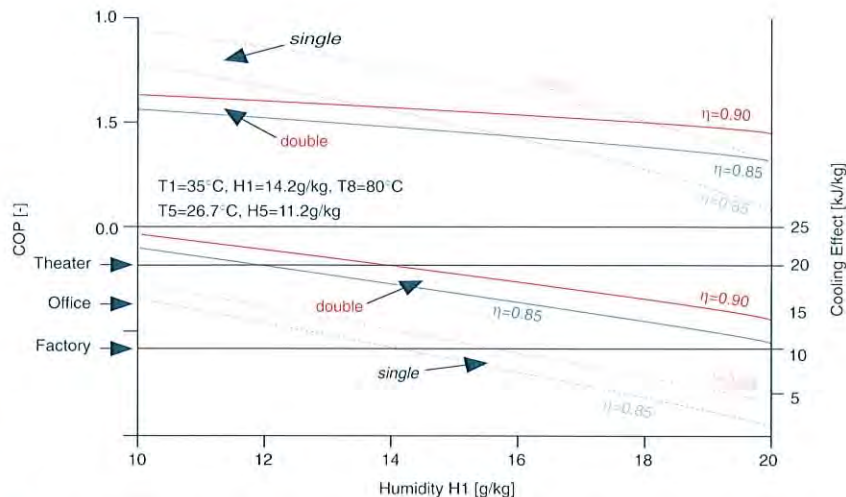
The proposed two-stage design is presented in Figure 4.

The first stage pre-dries the air being used. After passing through the first dehumidifier, the dehumidified and slightly heated air (A) is cooled down in

a heat exchanger making use of counter-current ambient air. The pre-dried air (B), of which the temperature - depending on the efficiency of the sensible heat exchanger used - is nearly equal to ambient temperature, is used as input air for the second stage. The second stage produces cool air for air-conditioning purposes.

The performance of the proposed two-stage system was investigated with the help of a model [2]. **Figure 5** shows the calculated results for the two-stage cycle in comparison to the single-stage cycle. Temperatures (T_i) and humidities (H_i) in Figure 5 refer to points i ($i=1-9$) in Figure 4.

The top half of the figure shows COP as a function of ambient humidity. The lower half shows cooling effect (CE) of the ventilation cycle as a function of ambient humidity. CE is the difference in enthalpy between the air supplied to the room (4) and the air returning from the room (5). According to the air-conditioning handbook, minimum values of CE for factory/laboratory, office and theatre/restaurant locations are respectively 10, 15 and 20 kJ/kg, taking into account maximum ventilation flow rate. Results are calculated for both the single and the two-stage system assuming a temperature efficiency of the sensible heat exchanger $\eta=0.85$ and 0.90. Regeneration airflow rate (8) and rotation speed of the desiccant wheel are kept at optimum values. Other operating conditions, with the exception of ambient humidity (1), are constant as indicated in the figure. Model calculations were done for a range of ambient humidity from 10 g/kg to 20 g/kg. Humidity greater than 20 g/kg is not rare during Japan's rainy season. The figure makes it clear that the conventional single-stage cycle can not produce sufficient cooling power at higher humidities even if a sensible heat exchanger with an efficiency of $\eta=0.9$ is used. On the other hand, the two-stage cycle will deliver sufficient cooling for factory/laboratory conditions at higher ambient humidities



▲ Figure 5: Model calculations on the performance characteristics of the two-stage cycle compared to the conventional single-stage cycle.

even when equipped with a lower-efficiency heat exchanger. Unfortunately, the COP for the two-stage cycle is lower than that of the single-stage cycle at lower humidities. However, controlling the flow rate and/or temperature of regeneration air in the first stage as a function of ambient humidity can help improve the system's overall performance.

Future prospects

The field results obtained with a single-stage adsorptive desiccant-based system for air conditioning indicate that such technology can work effectively at regeneration temperatures as low as 50°C, which is much lower than we had expected. When combined with solar heat collectors and an adequate heat storage buffer, this technology could be attractive for further development. However, under conditions of higher humidity, cooling effect and COP fall off markedly, making such a system less attractive. Model calculations indicate that at higher humidities a two-stage system, using pre-dried air, will perform better. Such a system can also be powered by low-grade heat supplied by solar energy, and there is still much room for further improvements that have not yet been incorporated into the model. For example, a purge zone could be introduced in the dehumidifier to

minimise heat leakage. Among other possibilities are pre-cooling by an indirect spray-flash-evaporator, or improved airflow configuration, cascaded use of heat in the cycle.

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A computer model for dimensioning solar-powered desiccant evaporative cooling systems

D.J. Naron, G.J.H.A. Verhoeven, the Netherlands

The market for cooling in buildings is growing worldwide. Although electrically driven chillers have reached a high standard of energy efficiency, they still consume large amounts of energy and cause significant peak loads in electricity grids. Desiccant evaporative cooling, or DEC, is an alternative technology for indoor cooling, which is driven by thermal energy and uses no refrigerants. The use of solar thermal energy as the driving force for DEC is relatively new and promising. This article describes a computer model that can be used to dimension and measure the effectiveness of solar-powered DEC indoor cooling systems.

Introduction

Desiccant Evaporative Cooling (DEC) technology uses thermal energy to provide indoor cooling. The relatively low working temperature (i.e. the required regeneration temperature) of such systems allows the use of solar energy as a heat source. The use of solar-powered DEC systems for indoor cooling is a relatively new and a promising technology. However, detailed information on how to dimension and evaluate such systems is hardly available. In order to bridge this gap, TNO Building and Construction Research and Econosto have developed a design and evaluation tool, named DEC-Sol, for solar-powered DEC systems. In this paper, the tool is used to analyse the influence of various parameters on system performance and the influence of different climate conditions. This analysis was used in the European project ASODECO (advanced solar driven desiccant cooling systems for Central European and Mediterranean climates).

Working principles of a typical solar powered DEC system

The principle of desiccant evaporative cooling is illustrated in **Figure 1**.

Warm moist ambient air (condition 1) is drawn through the sorption-desiccant wheel, where it is dehumidified. In the process, the air not only becomes drier

but also warmer (condition 2). The thermal wheel using cold humidified return air (condition 3) then cools this dry warm air. During this process, no moisture is exchanged. The 'pre-cooled' dry air can be and will be cooled more deeply by humidification in an adiabatic cooler (condition 4). This is the conditioned air being supplied to the building. In the building, the temperature of the (ventilation) air increases due to internal heat and moisture load. The return air (condition 5) passes through the humidifier, resulting in a temperature drop (condition 6). This cold humid return air is then used for cooling purposes in the thermal wheel, during which process it is itself warmed up (condition 7). The regeneration heater further raises the temperature of this return air (condition 8), after which it enters the desiccant wheel and reactivates the adsorbent before being vented off (condition 9).

System components

The sorption/desiccant wheel is used to exchange moisture between the

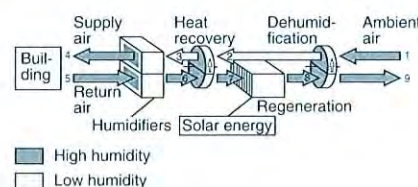
incoming ambient air and the return air. In summer, the wheel dehumidifies the incoming ambient air. In winter, it is used as an enthalpy wheel to recover latent and sensible heat from the return air. High latent heat recovery efficiencies of up to 80% can be achieved in this way.

The regeneration heater heats the return air to the required regeneration temperature before it enters the desiccant wheel, where it reactivates the sorption/desiccant wheel. The regeneration heater can be powered by solar energy, delivered in the form of hot water from a storage tank connected to solar collectors. A supplementary heater may be necessary to further heat the water to the required temperature. See **Figure 2**.

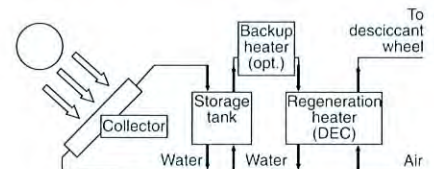
Model calculations

The DEC-Sol design tool is meant to:

- calculate the energetic performance of a specific solar-powered DEC;
- dimension the various components of a solar-powered DEC.



▲ **Figure 1:** Flow scheme of typical DEC system.



▲ **Figure 2:** Solar energy in DEC.



A study was carried out, using the DEC-Sol design tool, to investigate the influence of various parameters on system performance. The regeneration energy required by the system is taken as a measure of the energetic performance of the system. The situation studied was a typical office building in which the cooling load is covered by a solar-powered DEC system. For the calculations, the following default values were assumed to apply (Table 1):

The temperature setpoint for regeneration of the regeneration heater will directly influence the degree of regeneration of the desiccant wheel, and therefore eventually the supply air temperature. Figure 3 shows the influence of setpoint temperature on the solar fraction and the number of exceeding hours. Solar fraction is the fraction of the total regeneration energy, that is covered by solar energy. Exceeding hours are those hours during which the maximum air supply temperature to the building is exceeded, and the indoor temperature therefore rises to an uncomfortable level.

It can be seen from Figure 3 that a lower regeneration setpoint results in a higher number of exceeding hours.

▼ Table 1: Defaults values for parameters to calculate the influence on the yearly energetic performance of the Solar DEC system¹.

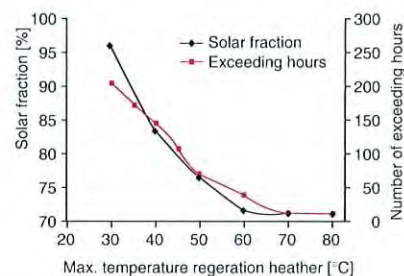
Parameter	Default value
Ventilation requirement for the building	2500 m ³ /h
Required supply air temperature (summer)	15.7°C
Required supply air temperature (winter)	21.0°C
Allowable return air temperature (summer)	26.0°C
Allowable return air temperature (winter)	22.0°C
Maximum humidity of the supply air (summer)	95% (or 95 g/kg)
Maximum humidity of the supply air (winter)	30%
Collector area	35 m ²
Collector curve	$h_0 = 0.8$ $C_1 = 3.5 \text{ W/m}^2\text{K}$ $C_2 = 0.008 \text{ W/m}^2\text{K}^2$
Tilt angle	45°
Azimuth	South
Store volume	4.0 m ³
Maximum regeneration temperature	80°C
Heat recovery efficiency	80%
Climate (reference)	De Bilt

Lowering the setpoint temperature causes a decrease in the delivered regeneration energy. The (average) temperature of this regeneration energy decrease causes an increase in solar fraction.

From setpoint temperatures above 60°C the solar fraction is fairly stable; increasing the setpoint temperature will not result in a considerable change in solar fraction.

Figure 4 shows the influence of thermal wheel efficiency on the solar component of the solar-powered DEC system.

The solar performance (i.e. the delivered solar energy to the DEC system) decreases with increasing thermal wheel efficiency. This is because the regeneration load decreases with increasing thermal wheel efficiency. The solar fraction increases with increasing efficiency of the thermal wheel, because the solar collectors are more able to cover the decreasing regeneration load. The influence of humidifier efficiency on solar fraction and performance is similar to the influence of thermal wheel efficiency.



▲ Figure 3: Influence of setpoint of regeneration heater on solar fraction and number of exceeding hours.

Figure 5 shows the influence of several different European climates on solar performance and solar fraction.

Table 2 shows the resulting number of exceeding hours in these climates.

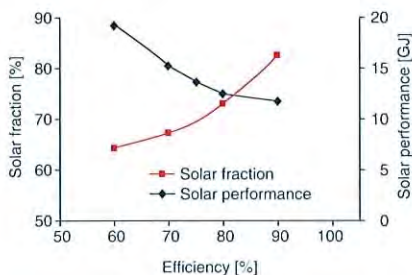
▼ Table 2: The number of exceeding hours of a solar-powered DEC in several European climates.

Climate	Exceeding Hours
Davos (CH)	0
Eskdalemuir (UK)	0
Copenhagen (DK)	1
De Bilt (NL)	3
Carpentras (FR)	69
Trapani (IT)	498

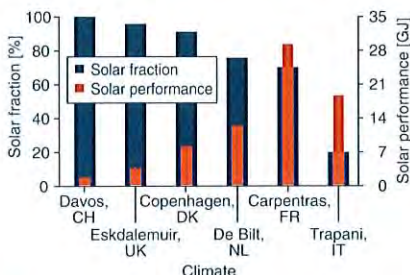
Davos (CH), Eskdalemuir (UK) and Copenhagen (DK) are climates with a low regeneration load, where ambient air temperatures and humidities are reasonable low. De Bilt has a regeneration load that is considerably higher; although the number of exceeding hours is still low. Carpentras (FR) has a dry hot climate, resulting in a high regeneration load. The solar fraction can be high because of low ambient air humidities. Trapani (IT) has a very hot and humid climate. This results in an extremely high regeneration load. The solar fraction is relatively low due to the relatively high extent of diffuse radiation, which also results in a lower solar performance.

Conclusion

A design tool, named DEC_Sol, has been developed to help dimension solar-powered DEC indoor cooling systems.



▲ Figure 4: Influence of thermal wheel efficiency on solar fraction and solar performance.



▲ Figure 5: Influence of climate on solar fraction and solar performance.

The computer model allows the user to vary a range of design parameters and to calculate their effect on the system's energy performance. Some model predictions are:

- increasing solar collector area results in an increasing solar fraction and decreasing collector performance;
- optimum position for the solar collectors is facing south at an angle of 30° to 45°;
- optimum volume of heat storage tank can be calculated;
- decreasing set point temperature of regeneration heater increases the number of exceeding hours;
- an increase in thermal wheel efficiency and/or humidifier efficiency results in a decrease in solar performance (GJ) and an increase in solar fraction (%);
- relative performance of a solar-powered DEC system subjected to different European climates: system will perform best in relatively dry northern climates and worst in relatively humid and hot southern climates.

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“Hands-on experience with heat pumps in buildings”

Gerdi Breebroek, IEA Heat Pump Centre

The international workshop “Hands-on experience with heat pumps in buildings” was held in Arnhem, the Netherlands, 10 - 12 October 2001. This was the second workshop organised by the Heat Pump Centre together with the International Power Utility Heat Pump Committee. The workshop registered more than 100 participants from 13 countries with representation from industry, utilities and the research community. NUON (the Netherlands) and EdF (France) were the main sponsors of this event.

EU Policy

Mr Horrocks, from the Directorate General Environment of the European Commission sketched the background for heat pumps in Europe. On the one hand, the energy market is being deregulated and utilities will have to compete in the marketplace. Energy will become cheaper, so the economic benefit of reducing energy consumption will also reduce. At the same time, the European Commission has

environmental goals, and acts to meet its Kyoto targets. The new EU Directive, “Energy performance in buildings”, requires that consideration be given to energy planning in building design. Heat pumps are one of the renewable solutions that need to be considered. It is an important step in the right direction that the EU (Directorate of the Environment) has recognised heat pumps as a renewable energy technology.

Market developments

First an overview of the markets in Europe, Asia and North America was presented. Mr Rivoalen of EdF presented market data for Europe (see also HPC Newsletter 19/2, 2001), where the main application is for heating. He pointed out that the retrofit market is weak except in Sweden. In his words, “It probably takes 10 years to develop a heat pump market and another 10 years to develop the retrofit



market as well.” Besides the retrofit market, there is a market for heat pumps for apartment blocks.

The Japanese and US markets are much larger than the European market and are traditionally driven by a demand for cooling. Mr Narita, of TEPCO, described the evolution of the Japanese heat pump market from 1926 until the present. Heat pumps have become a popular product and their efficiency has increased considerably over time. Mr Groff pointed out that the US heat pump industry has built up an important market with reliable and efficient products, with important benefits for society. He noted that, due to deregulation, there has been a drop in support from utilities in the US. Governments should step forward to further support heat pumps. Mr Schutte of Stiebel Eltron, a German heat pump manufacturer, took a broad perspective and argued that the market in Europe has no future without government and utility support. Stiebel Eltron is now active in Northern Japan with heating-only products.

Mr Bergsjø, of Thermia Värme, discussed the Swedish market, which is a mature market. More than 50% of the homes renovated this year will convert to (or continue using) heat pumps. To avoid complaints from end-users, manufacturers coach and train installers. Also, a so-called Heat Pump Jury has been established. It consists of representatives of the manufacturers and consumer organisations and decides in case of conflicts.

Panagro, a building project developer, provided insight into the heat pump market in the Netherlands. A priority is shifting from quantity to quality of systems, and government regulations with respect to the energy demand of new houses and commercial buildings are an important stimulus for heat pumps. Panagro aims to market buildings with high comfort standards.

Ms Breembroek, of the IEA Heat Pump Centre, presented results of an IEA HPC

study on heat pumps for retrofit. More dedicated products are coming to market and monitoring results are good, so that this market merits targeted action.

Deregulation and heat pumps

Mr Bell presented the paper “Heat pump policy of utilities in a deregulating market”. Utilities face two challenges: emissions reduction and market competition. Green power, renewable energy sources and emissions trading can help to meet the first challenge. Emissions trading allow utilities to get the credits for reductions they have somehow realised. If heat pumps could be included in emissions trading schemes, it would increase market opportunities for the technology. However, first authorities need to be convinced that heat pumps do reduce carbon dioxide emissions.

The second challenge, market competition, will go through four stages: consolidation, competition on price, extreme cost reductions, and moving away from a commodities-based approach. Just as telephone companies have expanded their services with many features, utilities should also search for value-added energy products. Heat pumps can offer the following advantages: enlarging the market share of electricity for heating (especially when the companies involved do not market gas and oil as well), space cooling, and a relatively stable demand (no summer peak). Factors responsible for the limited success until now are equipment failures, lack of maintenance infrastructure and higher profit margins on fossil fuel-fired boilers.

Mr de Ronde and Mr Juffermans, of utility NUON, explained NUON’s strategy regarding heat pumps. In the Netherlands, the EPN energy performance standard for buildings, which is calculated from the quality of the building and its installations, is tightened regularly. This creates opportunities for heat pumps. NUON works together with housing

associations, project developers and municipalities to realise new houses and commercial buildings with low energy demand. NUON may invest in installations and sell heat and/or cold to the user. They aim to be the one-stop-shop for energy-efficient installations.

Training installers

The importance of trained installers was underlined in several presentations. The following initiatives were reported:

- Arsenal Research in Austria has started a 12-day course for installers in Austria: 9 days theoretical, 3 days practical work, and a one-day examination. At present, 25 installers have taken the course, and 50 are expected to do so next year. There is an increasing demand for certified installers.
- Electrabel, a Belgian utility, has recognised that installers play a key role in their market-transformation efforts. They offer a course with a 32-hour programme plus examination. The Belgian grant system for heat pumps requires installation by a certified installer. The market has doubled each year since 1998 when 50 heat pumps were sold.
- In Sweden, heat pump association VET certifies installers after a 2.5-day course. They focus on insulation, heat loss calculations etc. Before attending this course, installers must learn about the equipment at courses organised by manufacturers.
- Two Canadian utilities have developed a checklist for installers and a user manual for homeowners to ensure good installation and rational use. A similar approach was reported by Mr Fresquet of EdF, who developed a checklist and decision-making procedure to help consumers make the right choices.
- Perhaps the most consistent training efforts have been made by Alabama Power Company in the USA, which has been promoting heat pumps since 1950. Their training programme has contributed to higher



consumer satisfaction. See further Newsletter 19/1, 2001.

Two speakers discussed strategies to inform end-users. Mr Eklund, of Vattenfall, explained how his company informs end-users about the principles of thermal comfort. Mr de Wolff, of KEMA, reported on a communication checklist, used to inform new residents about their new heating system. This is particularly important in the Netherlands, where a new house is typically built and sold by a project developer.

Improved heat pump design

A number of papers presented possibilities for improved designs:

- Mr Sakamoto explained the background behind the significant improvements in COP of Japanese heat pumps from 1992 (COP=3) up to now (COP=6). One of the improvements, the variable speed compressor, is now installed in 88% of residential heat pumps sold in Japan. Since 20% of residential electricity demand is for driving heat pumps, energy-saving models are in high demand.
- Mr Aarlien presented Norwegian research on a residential heat pump system with CO₂ as the working fluid. A prototype 6.5 kW plant is now being constructed. It will be a ground-coupled system for space heating and domestic hot water, with a floor-based heating system and a 300 l storage tank for domestic hot water.
- Ms van Hemel presented the residential diffusion absorption heat pump (see page 8), developed and marketed by Nefit Buderus. This heat pump will be the successor of the gas-fired condensing boiler, with a 20% higher efficiency. For next year, a sales target of 500 units has been set. This design was reported on in HPC Newsletter 18/4, 2000.
- Mr Lundqvist of the Royal Institute of Technology gave an overview of cycles and refrigerants for various applications. He stated that high COPs are not linked to high Carnot

efficiencies. The highest COPs can be obtained at the lowest temperature difference between source and sink, where the Carnot efficiency is relatively low.

Mr Van Wolferen, of TNO, discussed Legionnaires disease in relation to heat pump system design, especially heat pump water heaters. It is important to realise that this problem can be solved, but should not be neglected!

Systems-based approach

Three papers discussed the possibilities of cost reductions and maintaining quality through a systems approach:

- Mr Armstrong, of CIAT, presented a manufacturer's view of the European heat pump market. His main message was that packaged systems, including source, distribution, storage, and domestic hot water functions are of great value. There are local differences within Europe, with people in some areas not being prepared to pay much for a heating system, whereas in other parts they consider environmental benefits a justification for higher cost.
- Mr Afjei, of Eutacon, is developing a planning tool for selecting a suitable hydronic circuit for residential heat pump systems that supplies space heating and domestic hot water. The tool will provide potential circuits for a number of standard applications. The goal is to promote cost-effective and reliable systems.
- ITHO's sustainable heat pump system for houses is a new product, which is available in two varieties: a) an air-based system with balanced ventilation, heat recovery and heat pump, and b) a ground-coupled heat pump system combined with a solar collector. In the Netherlands, the heat extraction from and heat supply to the ground must balance over a year. The 'free' cooling that the system offers is highly valued by building occupants.

Mr Buitenhuis, of DWA, gave a presentation on integrated systems for

commercial or institutional buildings. He described a number of innovative projects in the Netherlands, consisting of year-round thermal storage in aquifers and heat pumps. A combination of heating and cooling turns out to be profitable for commercial buildings. Finally, Mr Bangheri, of Heliotherm, discussed developments in Austria. The CO₂ ground probe that has been developed and tested works without circulation pump and is of particular interest for heating-only systems.

Testing and monitoring

Mr Roth of NOK presented test and monitoring results collected over eight years (1993-2000) by the heat pump test centre in Töss, Switzerland.

Surprisingly and in contradiction to earlier evidence, no COP improvements and no noise level improvements were found. This is discouraging. However, manufacturers have been giving priority to other issues such as reliability, documentation, cost reduction and environmentally friendly refrigerants. The overall competitiveness of heat pumps has certainly increased since 1993.

Mr Groff discussed developments in heat pump efficiency over a rather longer period. It is clear that the minimum efficiency standards set by the US government have stimulated improvements. More on this can be found in HPC Newsletter 19/1, 2001.

Other papers discussed results of monitoring projects. Mr Geelen, of TNO, monitored three commercial buildings in the Netherlands and concluded that an efficient system typically consists of a high-quality heat pump, variable speed pumps to reduce parasitic losses, and good control strategies and equipment. NUON's findings also showed that minimising losses is very important. They monitored several residential projects, many of them with collective systems. The control strategy was a critical factor. A collective system that operated during summer, for water heating, had



high losses due to this factor. Dutch utility REMU showed that communication with inhabitants is also a critical success factor. Ms Escarnot of EdF presented the results of demonstration projects that have been monitored within Annex 25 of the IEA Heat Pump Programme, "Year-round residential space conditioning with heat pumps". As a general conclusion, the feasibility of these heat pump systems has been proven. The systems have a high heating performance and provide comfort.

On the issue of monitoring, it is interesting to note that monitoring was ongoing at Dubotechniek, one of the locations visited on the last day of the workshop. Besides an exhibition and testing room for heat pumps and other sustainable options, Mr van Rijsewijk was able to monitor temperature and other relevant parameters for all projects installed.

Discussion and technical visits

The second day of the workshop concluded with a group discussion

session, in which the following issues were discussed:

- integrated systems, supplying space heating and domestic hot water;
- heat pumps for retrofit;
- the role of utilities in a deregulated energy market;
- residential space cooling in heating-focused markets;
- international heat pump R&D (several interesting topics were identified in this regard).

During the discussion, it became apparent that the strategies of utilities differ considerably. Some utilities are convinced that there is a potential market for supplying renewable energy, including contracts with the government to provide specific services. In other countries, the focus is on selling electricity, while the government is not considered a potential client.

The general opinion was that consumer demand would shape the market for heat pumps. Consumers will prefer a compact and simple integrated system, including space cooling at low additional cost. One of the main

conclusions was that the systems surrounding the heat pump are critical for success. A good heat source, a well-designed heat distribution system and high quality of the installation work are essential to ensure that consumers will recommend heat pumps to their friends and relatives.

The third and last day was devoted to visiting technical facilities and projects. One group visited information centre Dubotechniek and the residential heat pump project Waluwe and the second group visited TNO's test facilities and the Wasco information centre.

Proceedings

Proceedings of this workshop will be produced by the IEA Heat Pump Centre, order number HPC-WR23. The price is EUR 90 in HPC non-member countries and EUR 30 in Austria, Japan, Norway, Netherlands, UK and USA.

*Gerdi Breembroek
IEA Heat Pump Centre
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Final Proceedings of the 4th IIR-Gustav Lorentzen Conference on Natural Working Fluids at Purdue

Issued by Dr Eckhard Groll of the Ray W. Herrick Laboratories, 1077 Ray W. Herrick Laboratories, West Lafayette, IN 47906-1077, US. Tel.: +1-765-494-2132, Fax: +1-765-494-0787, E-mail: herlconf@ecn.purdue.edu

The 4th IIR-Gustav Lorentzen Conference on Natural Working Fluids was sponsored by the IIR through its Commissions B1, B2, E1 and E2. The organising committee received 96 paper proposals, indicating that there is a great research activity related to natural working fluids. After the review by the scientific committee, 68 papers were published in the final proceedings. Every effort was made to include papers of current engineering and scientific interest.

The proceedings are divided into 14 main sections: (1) CO₂-Studies on various applications; (2) CO₂-Heat pump water heater applications; (3) Military applications of CO₂ heat pumps; (4) Hydrocarbons I: System performance; (5) CO₂-Automobile AC and safety; (6) Hydrocarbons II: Compressors and heat exchangers; (7) CO₂-Heat transfer; (8) CO₂-Compressors I; (9) Hydrocarbons III: Policy, retrofit and safety; (10) CO₂-Compressors II: Lubrication, and expansion devices; (11) Gas cycles; (12) Sorption systems; (13) Secondary loop refrigeration; (14) Ammonia and water as the refrigerant.

DACES 2050 - Database Clean Energy Supply 2050, Final Report September 2001

Project for the Netherlands Ministry of Housing, Spatial Planning and the Environment Utrecht Centre for Energy Research, Utrecht University, Padualaan 14, 3584 CH Utrecht, The Netherlands. Contact: Mr E.H. Lysen, Tel.: +31-30-253-7614, E-mail: e.lysen@chem.uu.nl or Ms Hester Pruiksma, Tel.: +31-30-253-7641, E-mail: h.pruiksma@chem.uu.nl. Fax: +31-30-253-7601.

The joint efforts to create DACES 2050 has resulted in a versatile tool for quick explorations of complete future energy systems and the possibilities and interactions of a wide diversity of energy demand and supply options including required energy infrastructure. It is a fairly unique tool in the world of energy policy and systems planning.

The heart of the work for the database consisted of a series of sector studies, reported in chapter 2 of the report, including energy demand, energy supply and energy infrastructure. In most cases data from publicly available literature have been used and common tools have been applied to generate data for 2050. International experts have reviewed the report.



Available from the HPC

**PLEASE USE THE ATTACHED
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NEW: Retrofit heat pumps in buildings

HPC Survey report, July 2001

Order no. HPC-AR9, NLG 80. Only available in AT, JP, NL, NO, UK, US (from 1 July 2003 available without restriction).

Considerations in the design and selection of Domestic heating and cooling distribution and ventilation systems and their use with residential heat pumps

HPC Survey report, December 2000

Order no. HPC-AR8, NLG 80. Only available in AT, JP, NL, NO, UK, US (from 1 June 2003 available without restriction).

Selected issues on CO₂ as working fluid in compression systems

Workshop proceedings, January 2001

Order no. HPP-AN27-1, NLG 180 or NLG 60 in JP, NO, SE, UK and US.

Ab-sorption machines for heating and cooling in future energy systems

Annex 24 final report, November 2000

Order no. HPP-AN24-4, NLG 100. Only available in CA, IT, JP, NL, NO, SE, UK and US (from 1 December 2002 available without restriction).

Ab-sorption machines for heating and cooling in future energy systems – San Francisco and Turin workshops

Workshop reports, March 2001

Order no. HPP-AN24-3, NLG 180 or NLG 60 in CA, IT, JP, NL, NO, SE, UK and US.

Guidelines for Design and Operation of Compression Heat Pump, Air-Conditioning and Refrigerating Systems with Natural Working Fluids

Final Report, December 1998

Order No. HPP-AN22-4, NLG 300 or NLG 100 in CA, CH, DK, JP, NL, NO, UK and US.

For further publications and events, visit the HPC Internet site at <http://www.heatpumpcentre.org>

2002

ASHRAE Winter meeting

- Absorption/sorption heat pumps and refrigeration systems (symposium)
- Commercial ground-source heat pump system challenges (symposium)
- Site characterisation for ground-source heat pumps (seminar)

12-16 January 2002 / Atlantic City, USA

More information: <http://www.ashrae.org>

Tel.: +1-404-636-8400, Fax: +1-404-321-5478

International Compressor Engineering Conference at Purdue

International Refrigeration and Air Conditioning Conference at Purdue

16-19 July 2002 / West Lafayette, US

Short courses: 14-15 July 2002

Contact: Reena L. Fleischhauer, coordinator

Conference Division, Purdue University

1586 Stewart Center

West Lafayette, IN 47907-1586, US

Tel.: +1-765-494-9499, Fax: +1-765-494-0567

E-mail: rlfleischhauer@purdue.edu

Internet: <http://www.ecn.purdue.edu/Herrick/event/>

15th International Congress of Chemical and Process Engineering

25-29 August 2002 / Praha, Czech Republic

Contact: Organising Committee

CHISA 2002

Novotného Lávká 5

116 68 Praha 1, Czech Republic

Tel.: +420-2-2108-2333

Fax: +420-2-2108-2366

E-mail: org@chisa.cz

Internet: www.chisa.cz/2002

Zero Leakage - Minimum Charge

26-29 August 2002 / Stockholm, Sweden

Contact: Per Lundqvist

IIR conference

Royal Institute of Technology

Fax: +46-8-20-30-07

E-mail: elksne@egi.kth.se

Internet: <http://www.egi.kth.se/zero/>

International Sorption Conference 2002

24-27 September 2002 / Shanghai, China

Contact: Dr Wang Wen

Institute of Refrigeration & Cryogenics

Shanghai Jiao Tong University

1954 Huashan Road

Shanghai 200030, China

Fax: +86-21-62933250

E-mail: ISHPC@sjtu.edu.cn

Internet: <http://www.sorption.sjtu.edu.cn>

5th Gustav Lorentzen Conference on Natural Working Fluids

5-8 October 2002 / Guangzhou, China

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E-mail: gdra@gdra.org.cn

2003

Cold Climate HVAC 2003, The 4th international Conference on Cold Climate Heating, Ventilation and Air-Conditioning

15-18 June 2003 / Trondheim, Norway

Contact: Conference Secretariat

SINTEF Energy Research Refrigeration and

Air Conditioning

N-7465 Trondheim, Norway

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21st IIR International Congress of Refrigeration

17-22 August 2003 / Washington DC, US

Contact: ICR 2003 Conference Manager,

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7th IEA Heat Pump Conference

19-22 May 2002 / Beijing, China

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Next Issue

Alternative refrigerants in practice / refrigerant conservation

Volume 20 - No. 1/2002



International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

The Programme is the foremost world-wide source of independent information & expertise on heat pump, refrigeration and air-conditioning systems for buildings, commerce and industry. Its international collaborative activities to improve energy efficiency and minimise adverse environmental impact are highly valued by stakeholders.

Mission

The Programme serves the needs of policy makers, national and international energy & environmental agencies, utilities, manufacturers, designers & researchers. It also works through national agencies to influence installers and end-users.

The Programme develops and disseminates factual, balanced information to achieve environmental and energy efficiency benefit through deployment of appropriate high quality heat pump, refrigeration & air-conditioning technologies.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC). The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on heat pumps and the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by



Netherlands agency for energy and the environment



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