IEA Heat Pump CENTRE NEWSLETTER

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Sorption Heat Pumps

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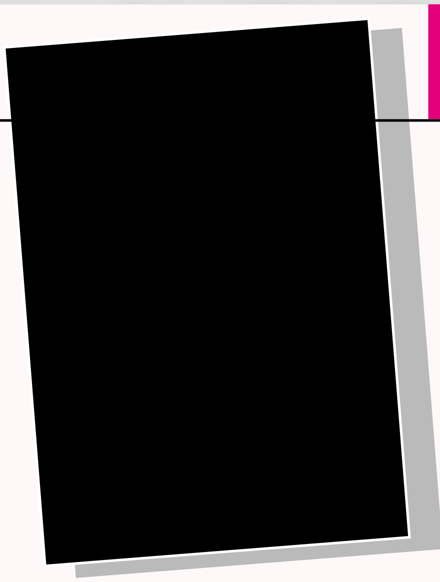
New opportunities for heat pumps in the UK

IEA
OECD
heat pump centre

In this issue



Sorption heat pumps

Sorption heat pumps are systems that use heat to drive a heat pump cycle to produce heat and/or cold. This issue of the IEA Heat Pump Newsletter discusses the market developments for this type of heat pump, as well as the technological issues that might further increase their use. Both absorption and adsorption applications are included.

Front cover:
Detail of a mass transfer unit in a reverse rectification heat pump process, the Netherlands.

TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

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The gas absorption heat pump finally enters the home

For decades, gas absorption technology has been rated among the best for heating and cooling applications, mostly in industry and commercial buildings. For these applications the technology proved to be efficient and, more importantly, very reliable. At first sight, the penetration of gas absorption technology in the residential market sector seems very limited.

However, the huge number of mini diffusion absorption systems used for cooling purposes in hotel or leasure refrigerators has gone almost unnoticed. The low profile of this application must be the reason that development of more sophisticated systems for heating applications was never really pursued.

Of course, since the 1970s, the late Dr Stierlin promoted the technology on all possible occasions, but industry appeared to be unenthusiastic about taking the initiative. This lasted until 1997 when the attractiveness of the technology for heating and hot water production in homes was fully recognised and industry finally acted.

Right now, at the end of the second millennium the first 'commercial' practical tests of diffusion absorption heat pumps have just started. In no less than 100 test installations in Dutch and German homes, this is proving to be the most promising heating technology for the next millennium; efficient, reliable and completely silent.

In cooperation with several utility companies, diffusion absorption heat pumps are being installed in conjunction with various types of heat sources, including heat recovery from exhaust ventilation air.

These practical tests give valuable information on the energy efficiency and comfort levels, both for heating and hot water production, that can be achieved with the diffusion absorption heat pump alone or in combination with a small auxiliary boiler, to be used for peak shaving. We must avoid the situation that energy savings with this new technology can only be realised by changing the heating behaviour of the customers. Too many promising energy-saving technologies have failed in the past due to this.

Dr Th.P.M. Hendriks
Managing Director Nefit Fasto BV

NON-TOPICAL ARTICLES

Heat pump news

Heat pump test centre established in Vienna

Austria - Arsenal Research in Vienna, a research centre specialising in air conditioning for stationary systems and railway carriages, thermal and fluid flow problems, is establishing a test centre for heat pumps.

Heat pump units are tested for the D-A-CH quality label. Testing of air-to-water, brine-to-water, and water-to-water heat pumps is carried out in Töss, Switzerland. Direct-evaporation (DX) ground-coupled heat pumps, which are popular in Austria will be tested at the new Austrian test centre.

The test rig for DX ground-coupled heat pumps, which will begin operating in June, uses brine to simulate the ground. Studies are currently being carried out to establish the test conditions, i.e. brine temperatures, which allow secondary loop systems to be compared with direct evaporation systems, considering different pipe materials and pipe diameters. Test conditions for exhaust-air heat recovery systems (air-to-air or air-to-water heat pumps possibly in combination with heat exchangers) also need to be established for compliance with the D-A-CH quality label.

Source: Hermann Halozan, Austrian National Team

Political agreement on new EU HCFC phase-out schedule

On 21 December 1998, the EU Environment Council reached agreement on the Commission's proposal regarding the new regulation of ozone-depleting substances. The regulation is expected to come into force during the second half of 1999. Some details have changed since the proposal was discussed in Newsletter 97/3.

Today, the use of HCFCs as working fluids has already been banned in non-confined direct-evaporation systems, domestic refrigerators and freezers, in air-conditioning systems for motor vehicles, and road and rail public transport.

The use of HCFCs will be banned:
- per 1 January 2000 for new applications in public and distribution cold stores and warehouses and for all applications of 150 kW or more shaft input;
- per 1 January 2001 for all new cooling and air-conditioning systems, except for reversible air-conditioning and heat pump systems (forbidden in new equipment per 1 January 2004), and fixed air-conditioning equipment with a cooling capacity below 100 kW (forbidden in new equipment per 1 January 2003).

Per 1 January 2010 the use of newly produced HCFCs for maintaining existing equipment will also be banned.

With regard to CFCs:
- per 1 January 2000, change of ownership is banned for all CFCs;
- per 1 January 2001, maintenance of cooling and air-conditioning equipment using CFCs is banned.

The ministers also agreed that immobile applications, which contain more than 3 kg of working fluid, should be checked for tightness every year.

Sources: http://www.europa.eu.int/comm/dg11/ozone/political_agreement.htm;
CCI Zeitung 3/99.

Japanese power producer promotes storage heating and cooling

Japan - Kyushu Electric Power would like its customers to switch to storage-type heat pump heating and cooling systems. This would ease demand by using electricity during off-peak periods and save 25% on daytime rates. The company will invest up to USD 50 million each year to provide equipment to customers at no cost, and will offer 15-year contracts.

Source: http://www.renewables.ca/t-mar.html

ARTI 21-CR website launched as focal point for industry research

US - The Air-Conditioning and Refrigeration Technology Institute(ARTI) recently launched a new website for its "HVAC&R Research for the 21st Century" (21-CR) Programme.

The new site, located at http://www.arti-21cr.org, will act as a focal point for research efforts in the heating, ventilation, air conditioning, and refrigeration (HVAC/R) industry. The site supports the mission of the 21-CR programme: to identify, prioritise, and undertake precompetitive research, focusing on reducing energy consumption, increasing the indoor environmental quality, and safeguarding the environment. The 21-CR programme was described in Newsletter 16/3.

The website provides detailed background information on the programme, its subcommittees, and related contacts. It contains links to sponsors, supporters, and endorsers of the programme, and seeks to establish links to related research sites throughout the industry. It also provides comprehensive information on the ARTI Refrigerant Database.

Source: ARI News service
More information: http://www.arti-21cr.org

Tender for Swiss Retrofit Heat Pump

Switzerland - Thirty-four percent of new residences in Switzerland use heat pumps. For retrofit situations this is only 3%. Therefore the Swiss Federal Office of Energy (SFOE) has launched a project to develop a Swiss Retrofit Heat Pump, which is suitable for the standard hydronic heat distribution systems.

The main requirements are:
1. air-to-water heat pump (located inside, outside or split);
2. water supply temperatures up to 60°C;
3. monovalent operation for space and tap water heating without a backup heater;
4. preferred use of natural working fluids (alkanes, alkenes, ammonia, CO_2, etc.);
5. modular construction;
6. complete control for heating, tap water, tariff optimisation;
7. high exergetic efficiencies (air-to-water heat pumps working at temperatures of 2/50 and 10/60°C should have efficiencies over 42% and 37% respectively)
8. low sound emissions;
9. D-A-CH quality label;
10. good cost to benefit ratio;

All heat pump manufacturers that design and produce products in Switzerland may develop a prototype fulfilling the aforementioned requirements by 30 March 2000. Development costs may be supported by SFOE. After selecting the most promising candidates by April/March 2000, the prototypes will be tested by a neutral testing organisation according to European standard EN255. After analysing the potential costs for serial production, two or three prototypes with the best cost to benefit ratio will be tested in the field. The winner will be announced in the spring of 2001.

Source:
Martin Zogg (martin.zogg@bluewin.ch)
Thomas Afjei (afjei@infel.ch)

Norwegian heat pump and refrigeration meeting

Norway - For the first time, heat pumps were included at the annual meeting of the Norwegian Refrigeration Association, March 1999: a clear signal that there is an increasing focus on heat pumps in Norway. Over 160 participants from the Norwegian refrigeration and heat pump industry participated, and one of the four technical sessions was dedicated to heat pumps.

The heat pump session started with an overview of the current energy situation in Norway. Norway has reached a peak with regard to exploitable hydro electricity, and 1998 was the third year in a row that coal-based electricity was imported from Denmark. Electric resistance heating has always been the main heating system for buildings, but the government is encouraging the transition to more flexible heat distribution systems (ducted air systems/hydronic systems) combined with renewable energy sources such as bioenergy and heat pumps.

In view of the high percentage of energy used to heat homes, the heat pump session focused mainly on residential applications. Two presentations elaborated on design and economical aspects. Despite the limited energy-saving potential of air-to-air heat pumps compared to water-to-water units, in many cases these are the most profitable option for small buildings with a low energy usage. For larger buildings, ground water or seawater as heat sources, combined with hydronic heat distribution systems, give the highest energy saving and the lowest annual energy costs. The conclusion from both presentations was that, due to the high investment costs, economic incentives (e.g. subsidies) are necessary to ensure improved market penetration of heat pumps.

Experience of operating air-to-air heat pumps over many years was discussed by one of the largest suppliers. Problems have mainly concerned defrosting the units in cold climates, in the heartland of eastern and northern Norway. For the long coastline of southern and western Norway, with its long and relatively mild winters, only minor problems have occurred.

The session ended with a look at the technology of the future, as SINTEF Energy Research presented their work and progress with CO_2 heat pumps for domestic water heating.

Source: Trude Tokle, Norwegian National Team

Heat Pump Association Student Awards 1999

UK - The fifth annual Heat Pump Association Awards Ceremony formed part of the Federation of Environmental Trade Associations Annual Luncheon held in London, on Wednesday 28 April.

The HPA Student Awards are open to both full-time and part-time students from universities and technical colleges, and are awarded to the students who, according to the panel of judges, provide the best solutions to a hypothetical, but realistic, heat pump design project.

This year's project required the entrants to produce a commercially viable heat pump solution for a large, detached family house with five bedrooms, three reception rooms, a conservatory and a large outdoor swimming pool. All necessary heating and cooling loads had to be considered, together with opportunities for heat recovery where possible. In addition, any relevant environmental issues were to be highlighted, including noise, indoor air quality, refrigerants and TEWI (total equivalent warming impact).

The HPA first prize of GBP 2,000 went to Glen Christie of Heriot-Watt University, Edinburgh, for what the judges described as a professional presentation with imaginative solutions, based on a sound understanding of the project. Glen shares the prize equally with his university department.

Second prize was awarded to Anthony Duckworth of Huddersfield University Department of Design Technology. Anthony shares GBP 1,000 with his university. Third place student Jonathan Walker of UMIST shares GBP 500 with the Department of Building Engineering in Manchester.

The success of the HPA Awards has encouraged many universities to include the project in their degree course curriculum. Success in the HPA Awards demonstrates an understanding of heat pumps and heat pump technology as well as the environmental issues associated with their use.

Source: Tony Bendall, Heat Pump Association
Tel.: +44-1491-578674

Odessy: a user-friendly tool to increase process energy efficiency

The Netherlands - As industry pays increasing attention to reducing energy costs, finding energy conservation options becomes crucial. TNO Institute of Environmental Sciences, Energy Research and Process Innovation (TNO-MEP) has developed a unique tool known as 'Odessy', which is an acronym for Optimum Design of Energy Supply Systems.

Odessy optimises the process towards a minimum energy requirement, and presents an overview of the required investments and resulting payback period. The tool simultaneously analyses the possibilities for using heat pumps, heat exchangers and combined heat and power (CHP) plants.

The program is designed as an evaluation tool, used to discover which energy-saving technologies are applicable. Industrial end-users, who are not always specialists in heat pump and pinch technology, will appreciate the following features.

- Built-in databases with heat exchanger, heat pump and CHP system specifications.
- Pinch technology incorporated in the optimisation method.
- Two optimisation levels: 'quick scan' and detailed network calculation.
- All cost parameters can be adapted to a company's individual situation.
- Graphical presentation of network diagram with saving options.
- Possibility to define existing or prohibited matches of streams with heat exchangers / heat pumps.
- Standard Windows 95/98 environment.
- Output includes estimated payback period.

See page 26 for ordering information.

More information :
H. Boot, TNO Institute of Environmental Sciences, Energy Research and Process Innovation
E-mail: h.boot@mep.tno.nl
Internet: http://www.mep.tno.nl/prod&serv/sheets/001e.htm

Heat pumps in greenhouses take major step forward

The Netherlands - Greenhouses are a major economic and energy-intensive sector in the Netherlands, constituting around 5% of the gross national product, and around 7% of total energy consumption. Over 80% of this energy is used for heating purposes, using gas-fired boilers or heat from cogeneration plants.

In the early 1980s, over 40 (mostly gas-fired) heat pumps were installed in Dutch greenhouses. No breakthrough was achieved because of falling energy prices, teething problems and the increased focus on cogeneration. Growing attention for renewable energy, a different situation on the Dutch electricity market (overcapacity) and a strong and focused heat pump policy has renewed attention for heat pumps.

A recent detailed study into the economic feasibility of various heat pumps (ground-source, waste-heat-source electric, gas-fired, and absorption) for different crops (roses, freesias, tomatoes) was described in Newsletter 15/4.

Two major projects were started in 1998, both closely monitored by Novem, which will advance the reintroduction of heat pumps in the greenhouse sector.

- Installation of cogeneration and seven electric heat pumps covering and combining the heat and electricity demand of seven horticulturalists, over a total area of 30 ha. The total installed heat pump capacity will be 14 MW, while the CHP plant has a thermal capacity of 4.5 MW.
- Installation of a 3 MW absorption heat pump, based on water/LiBr, for tomato-growing greenhouses covering 6 ha. The heat source will be an underground aquifer.

It looks as though these developments will proceed. Together with a selected group of commercial partners, Novem is working on the development of a 'closed greenhouse concept', where absorption heat pumps will play a major role.

Source: Onno Kleefkens
Dutch National Team.

Absorption heat pump to heat Amsterdam-West

The Netherlands - The Amsterdam waste incineration plant plans to install two large heat transformers to supply 48% of the heat for the Amsterdam-West district heating network. Using absorption heat pumps for heat recovery from waste incineration plants has never been realised in the Netherlands, though the principle has been applied in large-scale applications in Gothenburg and Exjö, Sweden.

A technical and economic feasibility test has been performed for the Amsterdam waste incineration plant. Heat transformers (water/LiBr and water/glycol) and electric heat pumps were considered for upgrading the waste heat to a temperature suitable for district heating. The flue gases contain 14 MW_{th} waste heat at 62°C. Thermodynamic and economic design parameters were calculated using a MAX simulation program.

A water/LiBr heat transformer system, the best of the studied options, will be installed at the site. The system, consisting of two units, will utilise the 14 MW waste heat at 62°C, and produce 6.7 MW at 75-80°C (PER=0.48). This amounts to 48% of the heating power required by the Amsterdam-West district heating network. This project is partially financed by the Dutch CO_2 reduction fund.

Source: Dutch National Team
More information: R.E. Conradie, HoSt
Tel.: +31-74-2401801

Ice slurry centre established in Denmark

Denmark - An international ice slurry centre has been established to further develop components and study the thermodynamic properties of various ice slurry mixtures. The centre is a collaboration between government, university and eight industrial partners and will operate for four years to mid-2002.

Ice slurry is a mixture of small ice particles (0.01-0.1 mm), water and an agent such as ethanol, salt or glycol, which lowers the freezing point. It is environmentally friendly and has high energy density capacities.

The initial activities of the centre will focus on ice slurry generators, centrifugal pumps, heat exchangers (shell and tube, tube and fin, and plate), corrosion inhibitors and additives, plastic pipes and measuring instruments. The centre collaborates with a users group (supermarket chain, food industry), a group of observers for technological support (e.g. manufacturers of pipes and additives), and an international scientific network.

More information:
Dr Michael Kauffeld, Danish Technological Institute, Tel.: +45-89438552
Internet: http://www.coolsite.dk

Proposed Dutch governmental policy on HFCs and PFCs

The Netherlands - The Dutch government has published a concept text proposing a policy for mitigating global warming. The Kyoto protocol requires that greenhouse gas emissions in the Netherlands be reduced by 6%. This concerns CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. HFC emissions from fixed and mobile heat pumping equipment are included in the proposal.

HFCs entered the market as replacement working fluid for CFCs and HCFCs, which have been or will be phased out under the requirements of the Montreal protocol. Policies to reduce emissions of HFCs and PFCs should not hinder the phase-out of ozone-depleting substances, so the policy will be aimed at reducing HFC/PFC emissions. An agreement between government, industry, installers, research and consumer organisations is proposed, to implement a package of measures. This includes:

- HFC alternatives to be considered in the design phase of heating, air-conditioning and cooling equipment, as long as compliant with other standards and regulations;
- promoting domestic appliances (refrigerators, air conditioners) with working fluids that do not deplete the ozone layer and have little greenhouse effect;
- if no suitable alternatives are available, HFCs/PFCs may be used;
- enhancing heat pumping equipment efficiency through RD&D;
- The ‘Reducing other greenhouse gases’ fund, similar to the existing CO_2 reduction fund, will be established in 2001. Projects will be judged on the CO_2 equivalent emissions reduction versus costs.

Source: RCC Koude & luchtbehandeling, April 1999

Phase-out of CFCs starts in developing countries

The phase-out of CFCs in developing countries is scheduled to start on 1 July this year with a freeze of Annex A CFCs (R-11, 12, 113, 114 and 115) at 1995-97 average levels (calculated production of 0.3 kg/capita can also be used, if lower). Total phase-out will be in 2010, after reducing to 50% (2005) and 85% (2010).

More information: http://www.unepie.org/ozat/protocol/countdow.html

Successful CO_2 technology workshop

Germany - The final meeting of the EU Joule COHEPS project *Energy-efficient and environment-friendly heat pumping systems using CO_2 as working fluid* took place in Mainz, Germany, on 18 March 1999. It was combined with the IEA/IZWe.V./IIR workshop *CO_2 Technology in Refrigeration, Heat Pump and Air Conditioning Systems*. More information on COHEPS can be found in HPC Newsletter 16/3.

At the morning session project partners (Austria, Belgium, Germany, and Norway) presented their findings on CO_2 as a refrigerant for various applications: heat pump water heaters, heat pumps in combination with existing high-temperature hydronic distribution systems, dehumidification and drying, and car air conditioning. Transport, thermodynamic and safety aspects were also discussed. The afternoon session was devoted to presentations from companies working in this field, mainly concentrating on compressors. More than 60 participants attended the workshop.

The findings of this project are promising, so the partners decided to tender for the follow-up project, in which the scientific results would be transferred to industry, allowing production and market introduction of this technology.

The workshop proceedings can be ordered from IZW e.V. at a cost of DM 120 (EUR 61.36).

Source: Hermann Halozan, Austrian National Team

Another record for Swiss heat pump sales

Switzerland - Heat pump sales met expectations in 1998. With a total of 6,155 heat pumps sold for heating and heat recovery, a new record has been set. This figure includes 270 single-room heat pumps (double 1997 sales). Total heat pump sales increased by 18% compared to 1997 (**Figure 1**). The heat pump market for water heating increased by 30% to a total of 552 units sold over 1998. This market success is also due to the joint efforts of all the branches that are united in the Promotion Association. It also demonstrates the effectiveness of the federal *Energie 2000* programme; one of its aims is to increase the use of ambient heat using heat pumps.

The bulk of the models sold in 1998 (4,047 units) was used in new buildings, with heating powers up to 20 kW. This represents a market share of 34% for new construction, assuming that 12,000 detached and terraced houses were built in 1998 (as in 1997). An upturn could also be seen in renovations. Some 1,105 units were used to replace existing installations. There was no significant change regarding the distribution of models, as shown in **Figure 2**.

All in all, a generally satisfactory outlook, that points to further successes. Last but not least, the international D-A-CH heat pump quality label should result in an additional increase in confidence in 1999. The heat pump is no longer regarded as a possible alternative to conventional heating systems. It is one of the heating systems with a real future in Switzerland.

Source: Swiss National Team

Figure 1: Heat pump sales in Switzerland.

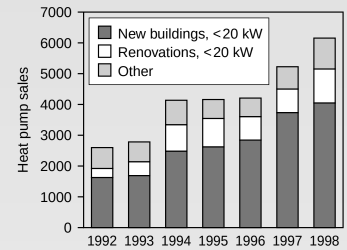
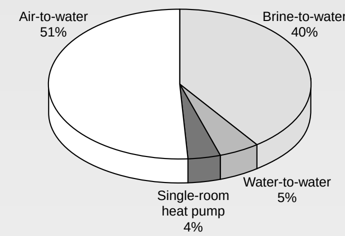


Figure 2: Breakdown of Swiss sales 1999.



French air conditioning and heat pump market

France - Market data from the French air conditioning promotional body GIE Climatisation et Devellloppement, which represents 80% of the market, have been published in the journal *RPF*. For 1997, the market for fixed and mobile room units fell by 10% to reach a total 164,200 units. Window air conditioners have stabilised, registering sales of 11,000 units per year from 1995-97.

Sales of multi-splits continue to rise and installations are becoming larger, as shown by the rise in the average number of internal units for each external package from 2.2 in 1996 to 2.5 in 1997. Heat pump versions are also becoming more common. Mono-splits nevertheless take the largest share of sales with 61% of the market in 1997 but the trend is moving downwards.

Source: JARN, 25 February 1999

Canadian strategy for GSHPs

A 'Ground Source Heat Pump (GSHP) Market Development Strategy' has recently been developed that provides a blueprint for the development and implementation of collaborative actions designed to establish a viable GSHP industry in Canada. More information can be obtained from the Earth Energy Society of Canada website (http://www.earthenergy.ca).

Austrian space heating heat pump market grows

Austria - In 1998, 4,900 heat pumps were installed in Austria, totalling 39 MW of heating capacity. Space heating systems increased by 15% from 1997, while installations of heat pump water heaters dropped by 19%. **Figure 1** shows the market development for heat pump water heaters, space heating heat pumps and (swimming pool) dehumidifiers from 1995-98.

The most popular 1998 space heating heat pump systems were ground-source (78.3%, mostly DX), followed by water-to-water (14.9%) and air-to-water (6.8%) heat pumps (**Figure 2**).

The choice of working fluids is moving towards the use of chlorine-free and natural substances. A rough estimation is that more than 55% of the current heat pump stock (including water heaters) use chlorine-free working fluids, with R-134a and R-407C being the most popular (both around 25%). NH_3 is applied in large installations with heat recovery and cooling. The Austrian heat pump stock reduced CO_2 emissions by an estimated 456,000 tons in 1998.

Source: G. Faninger, Wärmepumpenmarkt in Österreich 1998, Fax: +43-222-5050928

Figure 1: Heat pump sales in Austria.

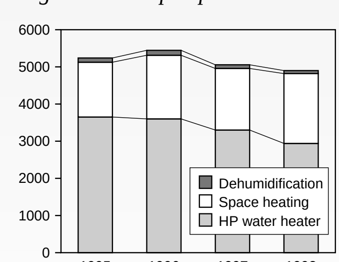
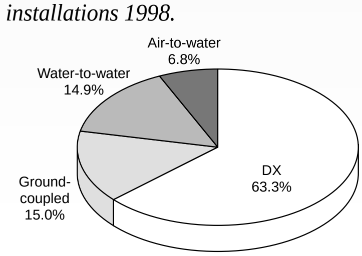


Figure 2: Space heating heat pump installations 1998.



Results from Annex 23, now available

Distributed heating and cooling systems have a tremendous potential to save energy and improve comfort in residential and commercial buildings. This is the message conveyed by the Workshop Proceedings and the Final Report of the International Energy Agency (IEA) project entitled *Heat Pump Systems for Single-Room Applications.*

The Annex 23 ***Workshop Proceedings*** focus on the energy savings contribution from single-room or single-zone heating applications. Experts from around the world gathered to present state-of-the-art heat pump solutions that can help reduce our dependency on non-renewable energy. The proceedings document heat pumps as capable of reducing global warming and providing an excellent long-term return on investment.

The Annex 23 ***Final Report*** gives an analysis of the market for single-room heat pump applications, including market size, market difficulties, potential markets and climate conditions in each of the five participating countries: Canada (Operating Agent), France, Switzerland, Sweden and the USA. Regional and economic considerations, such as cost aspects, building factors and emissions, as well as current and future R&D are included. The report concludes that heat pumps for single-room applications can provide an energy-saving and cost-saving alternative to built-in or portable electric resistance heating in the residential market and for commercial buildings (e.g. offices, hotels/motels). They could be an effective retrofit solution for homes or offices where no ductwork for air distribution exists. Space-heating costs could be reduced by at least 50% compared to existing single-room electric heating equipment.

Both these publications can be ordered from the IEA Heat Pump Centre, see page 27 for further details.

Source: IEA Heat Pump Centre

New HPC member country

UK - The UK joined the IEA Heat Pump Centre at the beginning of 1999. Mr Jeremy Tait is the UK contact until a National Team has been established. Parties collaborating in the UK include the Department of Trade and Industry (DTI), the Department of the Environment, Transport and Regions (DETR) and the Heat Pump Association. The UK introduction can be found on page 24. The IEA HPC are pleased to welcome the UK to its network, and feel sure this will be mutually beneficial to all concerned.

Source: IEA Heat Pump Centre

IEA HPP 1998 annual report now available

The IEA Heat Pump Programme 1998 promotional annual report, is now available from the IEA Heat Pump Centre.

1998 marked the 20th anniversary of the IEA Heat Pump Programme. The highlights of 1998 included the evaluation and revision of the strategy and identification of a new stronger mission statement, the re-structuring of the IEA Heat Pump Centre and the new Annexes 25, 26 and 27.

Source: IEA Heat Pump Centre

European HPN and HPC to collaborate

The European Heat Pump Network (HPN) and the IEA Heat Pump Centre (HPC) are looking forward to enhanced collaboration. A joint workshop will be organised and collaboration on the Newsletters of both organisations is proposed.

The European Heat Pump Network will organise two workshops in conjunction with Interklima in Paris, 8-9 November 1999 entitled *Heat pump training programmes* and *Natural refrigerants for heat pump applications.* The IEA Heat Pump Centre is co-organising the latter workshop.

The first Newsletter of the European Network became available on the Internet in May (access through http://www.fiz-karlsruhe.de/hpn/hpn.html). A printed version is also planned later this year, to be published by the HPC.

Source: IEA Heat Pump Centre

Ongoing Annexes

Red text indicates Operating Agent.

Annex	Participants
Annex 16 IEA Heat Pump Centre	AT, JP, NL, NO, CH, UK, US
Annex 24 Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	CA, IT, JP, NL, SE, UK, US
Annex 25 Development of Practical Concepts for Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	CA, FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	SE, US*
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	NO, UK, US*

IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), 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).

* to be confirmed June 1999.

Sorption heat pump systems - an international overview

Hanneke van de Ven, IEA Heat Pump Centre

Sorption systems for heating and cooling are still nowhere near as widely applied as compression systems. However, there are several characteristics of this technology that can make it an attractive option under certain conditions. This article discusses the pros and cons, and provides an update of the most recent developments for both absorption and adsorption systems.

Sorption systems are systems that use heat to drive a heat pump cycle to produce either heating and/or cooling, in contrast to compression systems where mechanical energy is used to achieve this. Absorption heat pumps for space conditioning are often gas-fired, while industrial installations are usually driven by high-pressure steam or waste heat.

Absorption systems utilise the ability of liquids or salts to absorb the vapour of the working fluid. In absorption systems, compression of the working fluid is achieved thermally in a solution circuit which consists of an absorber, a solution pump, a generator and an expansion valve as shown in **Figure 1**. Low-pressure vapour from the evaporator is absorbed in the absorbent. This process generates heat. The solution is pumped to high pressure and then enters the generator, where the working fluid is boiled off with an external heat supply at a high temperature. The working fluid (vapour) is condensed in the condenser while the weah solution is returned to the absorber via the expansion valve. The most common working pairs are NH_3/water and water /LiBr. Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature in the condenser and in the absorber. In the generator high-temperature heat is supplied to run the process. A small amount of electricity may be needed to operate the solution pump.

Heat transformers are a special type of absorption heat pumps, which through the same absorption processes can upgrade waste heat without requiring an external heat source.

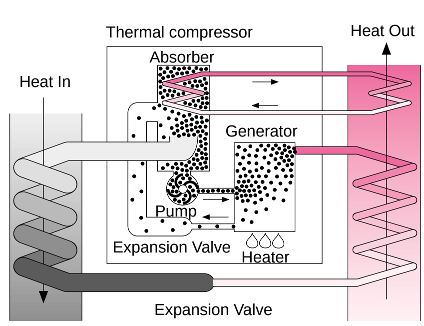
The *adsorption* process is different. Instead of circulating a liquid absorbent medium, solid adsorbent materials are employed in components that switch function with time. First, they adsorb refrigerant from an evaporator and reject heat to the environment until filled to capacity. In a second step they are heated to drive off the refrigerant, which goes to a condenser for reuse, until fully regenerated. In these systems, the solution pump is replaced by a set of switching valves which alternately connect the sorber vessels to the evaporator and the condenser. The article on page 13 gives more detailed information on the development of this technology in Japan.

The term sorption is a general expression encompassing both processes. Engine-driven systems, which also use thermal energy but work by means of mechanical compression, are not included in this article.

Benefits

Sorption heat pumps and refrigeration machines have gained increased interest in recent years.

▼ *Figure 1: The absorption process.*



Heat-driven systems are viewed as an environmentally friendly alternative to compression systems that use HCFCs or HFCs, as they do not deplete the ozone layer and reduce global warming. Thermally activated systems can utilise almost any source of heat, including a wide variety of fuels and solar energy, as well as waste heat from incineration plants, industrial processes and cogeneration systems.

In some countries the air-conditioning demand contributes considerably to the electricity peak demand in summer. Thermally driven air-conditioning systems can contribute to load levelling, since instead of electricity heat is used as the driving energy. Other advantages of heat-driven technology include less vibration and noise, due to the limited amount of moving parts, longer lifetime expectancy and easier operation and maintenance.

The market status varies significantly per region and country. The article by Mr Gustafsson (page 20) provides the current market data for the different regions. The following paragraphs discuss the main technological and market developments in each of the regions.

The most important drawback is still the investment cost. The decision to choose either sorption or compression technology is often determined by economic circumstances. However, energy policy and the energy infrastructure in a region also play an important role. Furthermore, due to the low market penetration in some countries, there is a lack of knowledge, information and experience about the design and operation of these systems.

Applications

The most widespread applications of absorption technology are absorption chillers. These are used to cool mainly large commercial buildings and in industry. Applications for heating purposes are far less common. Large installations are mainly found in Japan and Sweden, where they are sometimes used to provide district heating. For residential heating applications Switzerland and the Netherlands are the leading countries (see below). However, also in Italy, Japan and the US projects for residential or small commercial reversible air conditioners are ongoing.

Absorption chillers are mainly large capacity double-effect sytems. This means that an extra generator/condenser pair has been added to the system to increase the efficiency of the cycle. Thanks to microelectronic control systems and more efficient heat exchangers, the average primary energy ratio (PER) is about 1.20. To further increase the COP, another 'effect' is added to the thermodynamic cycle (see below).

Developments in the US

In the US absorption heat pump systems have found successful niches. Utilisation of waste heat, peak demand shaving and local steam generation have driven applications of absorption systems. But in most cases economics based on life cycle costs dictate the use of competing systems, primarily electric-driven vapour compression.

Three advanced technology projects in the US are worth mentioning, all supported by the Department of Energy (DOE). Firstly, in the residential absorption heat pump programme, a GAX (generator absorber heat exchange) heat pump is being developed with Robur Corp. This technology, which will be available in a few years, has a heating performance that is 50% better than the best gas furnace, and cooling performance equal to an electric air conditioner with a seasonal performance factor of 2.9.

DOE is also working on an advanced "high-cool" absorption heat pump with a cooling performance 30% better than the GAX. This will capture markets in southern USA where cooling is the dominant form of energy use. An 8-ton ammonia/water prototype laboratory heat pump is expected to be ready for testing in mid-1999.

Working with York International, the DOE is developing a triple-effect absorption chiller, using double-condenser-coupled (DCC) technology. A 400-ton (1.4 MW) water/LiBr chiller is undergoing testing at the laboratory in York, Pennsylvania. This chiller is powered by an indirect-fired heater built by Advanced Mechanical Technology, Inc., and has a cycle thermal PER of over 1.6. When the direct-fired burner is incorporated and the packaging complete, the chiller PER should be close to 1.4. A field test prototype unit will be built in 1999 that will incorporate all the latest developments.

Japan

In Japan the power load factor has seriously declined over the past few years due to the increasing demand for air conditioning in summer. Air conditioning currently accounts for nearly 40% of the summer peak electricity demand. Sorption machines, and more specifically absorption chillers using town gas or oil as the main driving energy, have been promoted by the government and gas utilities. Avoiding further depletion of the ozone layer has also motivated wider use of sorption machines.

Table 1 shows the product range of sorption machines available in Japan. Since the first commercialisation of a double-effect water/LiBr absorption chiller about 35 years ago, active developments over the years have ensured a steady improvement in energy efficiency. Sales of absorption chillers have steadily increased, although there has been a small downturn in the last couple of years due to the stagnant economy.

An absorption heating and cooling system similar to multisplit electric heat pumps, has been developed and put on the market. Another newly developed type is the air-cooled absorption chiller with water and LiBr as the working pair, which emerged on the market for small commercial applications. Absorption chillers with NH_3/H_2O as working pair are also gaining a market position for small commercial and industrial low-temperature applications. Small residential absorption heat pumps are also being developed, but are not yet available on the market.

On the other hand, adsorption chillers have also attracted attention because of their potential to be driven by low-temperature waste heat (see page 13). Since their first introduction to the market nearly 10 years ago, adsorption chillers with water/silica-gel have been used successfully, mainly in niche markets such as industrial process cooling and air conditioning in factories using various sources of waste heat.

Table 1: Sorption machines available in Japan.

Type	Working fluids	Heat source / sink	Driving energy	Cooling/heating capacity
Absorption chiller	H_2O/LiBr	Water-cooled	Gas, oil, steam, hot water	26-8,800 kW
Absorption chiller	H_2O/LiBr	Air-cooled	Gas, oil	35 kW
Absorption heat pump	H_2O/LiBr	Water-source	Gas, oil, steam	400-9,000 kW
Heat transformer	H_2O/LiBr	Water-source, steam-source	Hot water, steam	600-5,000 kW
Absorption chiller	NH_3/H_2O	Water-cooled	Gas, oil, steam	176 –1,760 kW
Absorption chiller	NH_3/H_2O	Air-cooled	Gas	10-53 kW
Adsorption chiller	Water/Silica-gel	Water-cooled	Hot water	70-350 kW

Europe

The market for sorption heat pumps in Europe is diverse. Electric compression systems dominate the market in all sectors. Large sorption installations are mainly found in Sweden, Germany and the Netherlands. Also in Italy and Spain there is a considerable market for sorption heat pumps. In France gas utilities are actively promoting and developing absorption heat pumps. In countries where the share of fossil fuels in end-use consumption is relatively high compared to electricity and where there is a high availability of natural gas, the chances for successful market penetration of sorption heat pumps increase. Also the discussion on refrigerants used for compression chillers favours the use of absorption technology.

In *Switzerland*, *Austria*, and *Norway* sorption heat pumps do not play a significant role, mainly because of cost considerations. Gas-driven absorption chillers are mainly used for large demands. Only a few large absorption heat pumps are operated in commercial buildings. For residential use, a concept known as a Diffusion Absorption Heat Pump has been developed by Swiss Creatherm. About 100 units are being field tested in the Netherlands and Germany and will be produced by Nefit Fasto in the Netherlands. In a demonstration project, they are aiming at a heating efficiency of 140%, thus realising a 30% energy saving compared to a state-of-the-art condensing boiler. The demonstration period will be two years. Further developments towards a mature product have already started.

The Austrian company Heliotherm has developed a small gas-fired absorption unit suitable for both heating and cooling. This type combines absorption with a gas-fired boiler which makes it suitable for the retrofit market. Since oil still dominates the Austrian heating market, an oil-fired unit is now being developed. Furthermore Austrian gas utilities have shown interest in gas-driven air conditioning equipment for cooling-only applications. The best chance for absorption cooling is the combination of a gas engine-driven CHP unit with an absorption unit, where the generator is heated by waste heat of the engine.

In *Norway* several district heating systems use waste heat. In summer, the surplus heat from these systems may be used to drive sorption cycles for district cooling, and the available cooling capacity has been estimated at approximately 150 GWh/year. However, because of low electricity prices, these sorption systems cannot compete with electrically driven chillers installed in individual buildings or district cooling systems.

In the *United Kingdom* absorption machines are only used for cooling. No absorption heat pumps or heat transformers are in use.

At Warwick University a small sorption system has been developed for residences or small commercial applications. A laboratory demonstration based on the adsorption principle using ammonia refrigerant and active carbon adsorbent has been successful. The next step in taking this concept to a commercial product involves reconfiguring the components to achieve a 10 kW chiller/heat pump with low manufacturing costs (USD 2,280), compact size and improved PER (0.95 for cooling, 1.8 for heating based on gas input). A consortium of industrial and academic partners is now looking for further collaborators to complete the work. Also the development of Rotex technology (see page 15) was started in the UK.

In *the Netherlands* absorption heat pumps have a higher penetration grade than in most other European countries, with 1.5% in the commercial/institutional sector. Over the last two years, when an initiative was started for a Dutch Platform for Sorption Technology (Internet site: http://www.gastec.nl/annex24), there has been increasing attention for sorption heat pumps. The success of the platform reflects the number of sorption projects currently under development in the Netherlands.

Two developments that are close to market introduction are domestic sorption heat pumps and the application of absorption heat pumps in greenhouses. Studies have shown that sorption heat pumps would be a very attractive technology to achieve targets set by the Dutch government for saving energy in this sector. The first demonstration installations will be built this year (see news item on page 7).

Conclusions

Sorption heat pumps enjoy a growing interest in various countries. This is caused by the increasingly important problem of peak loads in summer, the international agreements on reduction of global warming and ozone depletion and a more pro-active attitude of gas utilities aiming at a larger market share. In addition, absorption systems are, especially in countries with a well developed gas infrastructure, very suitable for retrofit applications in buildings with a hydronic distribution system requiring relatively large temperature lifts. Considerable efficiency improvements have been made, and sorption heat pumps have proven to be a very reliable technology. However the higher efficiencies usually mean higher costs.

Will these developments increase the market share of sorption heat pumps that have to compete with compression systems? This is a difficult question to answer since, while efficiency and reliability improvements in absorption equipment have been achieved, compression refrigerating and heating equipment has also achieved higher COPs etc. Under certain economic, fiscal and policy conditions absorption equipment can be used successfully. However, without these conditions applications may be limited to successful niche markets only.

Hanneke van de Ven
IEA Heat Pump Centre (see back cover)

References:
Proceedings of the International Sorption Heat Pump Conference, Munich, Germany (see page 26).

R&D on adsorption cooling systems in Japan

Hideharu Yanagi, Japan

In Japan, the R&D of adsorption heat pumps conducted in research laboratories, at universities and companies has focused on cooling applications. Most projects look at waste heat recovery at low temperatures of 60-80°C. Two companies have commercialised adsorption refrigerators using water/silica-gel pairs with cooling capacities of 70-350 kW. Research is currently concentrating on developing machines using new advanced cycles that can be operated at lower heat source temperatures (40-50°C). Another topic that is being studied is the use of an ethanol/activated-carbon pair.

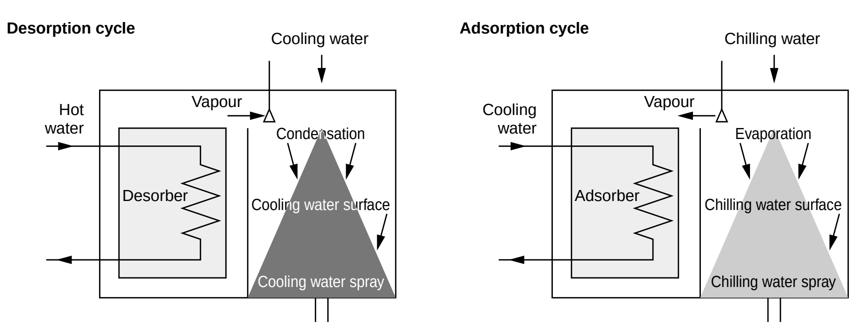
From an environmental point of view, using waste heat at low temperatures is a big challenge. A clear advantage of adsorption cycles over other systems is their ability to produce cooling by using low temperature waste heat at 60-80°C without harming the environment. However, adsorption chillers currently available are heavier and larger than electric chillers. Improving the compactness, reducing costs and increasing efficiency are important points in achieving a higher market penetration of adsorption refrigeration machines.

Direct contact

Conventional adsorption chillers consist of two adsorption heat exchangers housed in vacuum chambers that are connected to an outer evaporator and a condenser, via four separate and larger diameter vapour valves, which are used to reduce the pressure drop. Horizontal copper fin shell-and-tube type heat exchangers are used as evaporator and condenser. To obtain a lower pressure drop, a falling-film heat exchanger is used for the evaporator. The heat transfer coefficients do not exceed 3,500 W/m^{2}K. However, direct condensation and evaporation results in much higher coefficients of heat and mass transfer. In addition, the temperature drop across the separation wall is eliminated so that the thermodynamic efficiency of the refrigerator can be improved. Furthermore, the vapour valves installed in-between the adsorber housing and evaporator/ condenser, can be removed.

MYCOM has developed a machine utilising direct contact condensation and evaporation (see **Figure 1)**. The main components are two sets of an adsorber bed neighbouring on a spray nozzle working for a condenser or evaporator housing in a same vacuum shell, which is connected to an outer receiver for condensed or evaporated liquid. As shown in the figure, the water vapour evaporating directly from the surface of the sprayed water jet is adsorbed by the adsorption reactor in the adsorption cycle, while the desorbed water vapour from the adsorption reactor in the desorption cycle is condensed on to the sprayed water so that no vapour valve is required.

▼ *Figure 1: Diagram of the adsorption refrigerator using a direct contact condenser and evaporator.*



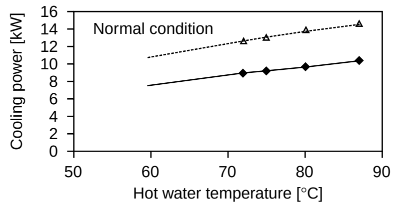
The thermodynamic efficiency of the refrigerator using the direct contact condenser and evaporator can be greatly enhanced due to the high heat transfer coefficients, i.e. the reduced cycle time and pressure drop. An additional advantage is that the refrigerator itself could be made simple and compact. To verify the aforementioned features, a prototype producing 11.5 kW with 0.58 PER has been tested with inlet temperatures of hot/cooling/chilled water 70/29/14°C, supply chilled water of 9°C, and a cycle time of 10 minutes.

Figure 2 demonstrates the dependency of the cooling capacity on the inlet hot water temperature. The inlet temperature was varied between 70°C and 90°C. The solid line shows the test results using an inlet cooling water temperature of 20°C and an outlet chilled water temperature of 5°C. When the inlet temperature of the hot water drops from 75°C to 60°C, the cooling capacity reduces by only 20%. For conventional adsorption machines the decrease in capacity resulting from this temperature change is 40%. These features result in a higher heat transfer coefficient and a lower pressure drop. The overall heat transfer coefficient resulted in a higher value of 58 kW/ m^{2}K on evaporation.

Solar heating

Another adsorption system currently being studied in Japan is a system for cold storage using solar heat as the drive energy, for application on the Okinawa islands where electric power infrastructures are not available. To

▼ *Figure 2: Cooling capacity, depending on the inlet temperature of the hot water.*



obtain efficient refrigeration a new adsorption cooling cycle has been proposed, where a depressurising process was added to the conventional heat regeneration. The thermodynamic efficiency of the cycle can be greatly enhanced by a larger driving mass.

Notice that the cold storage energy density is quite large: 357 kJ per kg silica gel under a solar regeneration temperature of 60°C, a condensing temperature of 30°C, an adsorption temperature of 30°C and an evaporating temperature of 10°C. The cooling COP is expected to be 3.0. This cycle is applicable for the short cycle time of adsorption-desorption, which allows a lower temperature driving heat source from 40-50°C with a rather high COP.

Three-stage adsorption

Another application of a new cycle is the three-stage adsorption 1.2 kW chiller shown in **Figure 3** (Tokyo University of Agriculture and Technology). It consists of eight heat exchangers: a condenser, an evaporator, and three pairs of adsorber/desorber heat exchangers. The system has eight refrigerant valves and one expansion valve. The figure illustrates an adsorption-desorption process operating in four cycles, where refrigerant valves 1, 3, 6 and 8 are open to allow refrigerant flow between heat exchangers. The heat exchangers 1, 3 and 5 work as desorbers heated by hot water, and heat exchangers 2, 4 and 6 work as adsorbers that are cooled by cooling water. The test resulted in a cooling capacity of 1.2 kW and a cooling PER of 0.15, using a hot water temperature of 50°C, a cooling water temperature of 30°C and an inlet chilled water temperature of 12°C.

Another noteworthy study has been conducted by Osaka Gas on the development of a low-temperature output adsorption chiller (3°C) using ethanol/activated-carbon. A special mesoporous carbon (so-called ‘super activated’ carbon) is used to achieve an estimated cooling PER of 0.62 with an inlet hot water temperature of 88°C and a cooling water temperature of 31°C, using a newly developed adsorption heat exchanger.

Conclusion

Japan has put a lot of effort into obtaining higher efficiency, reduced costs and higher compactness of adsorption systems, in order to penetrate the wider market. So far, the solutions have been applied to cogeneration systems and chemical process plants. The greatest barrier is the cost. Adsorption systems using direct contact condensers/evaporators are promising to improve this important factor. A new cycle, adding a depressurising step, is quite attractive for enhancing the amount of driving refrigerant at a lower inlet heat source with a temperature of 40-50°C, which will extend the application possibilities.

International cooperation, such as Annex 24 of the IEA Heat Pump Programme, can help in recognising the worldwide opportunities for using new adsorption heat pumps.

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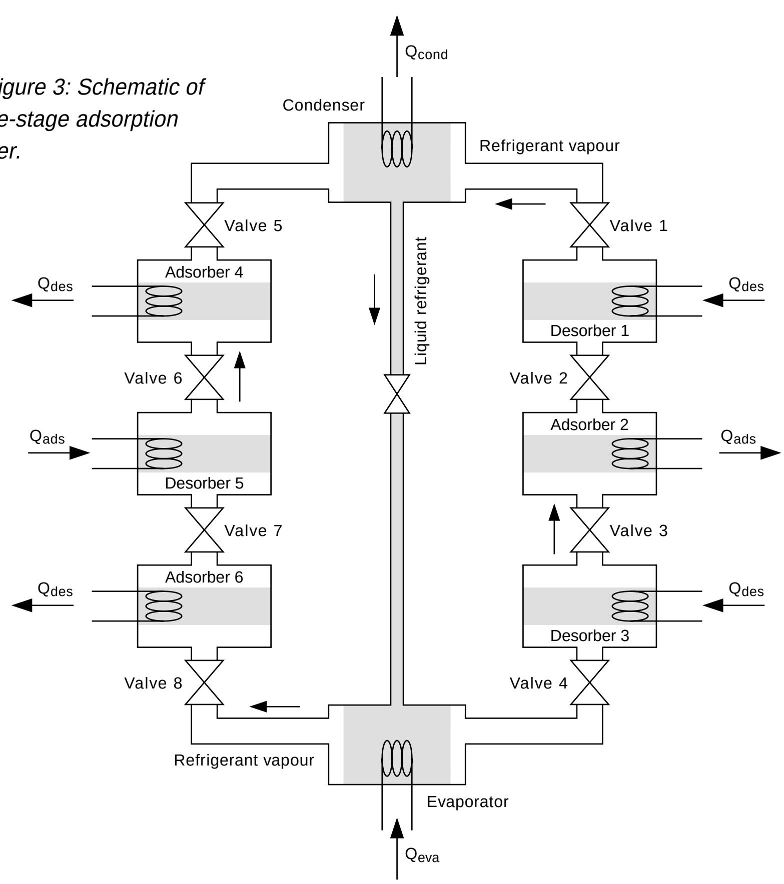
▼ *Figure 3: Schematic of three-stage adsorption chiller.*



Interotex absorption heat pump development

Robert Uselton, USA

In the US small-capacity air-conditioning appliances, i.e. for the residential and light commercial sectors, are almost all powered by electricity. The demand for air conditioning peaks on the hottest summer days, so the widespread use of air conditioning results in a peak demand for electricity. In several countries this peak demand is growing faster than the base load demand for electricity. Peak demand then becomes particularly expensive to supply and users of electrical air-conditioning appliances may be confronted with higher operating costs. Large-capacity air-conditioning equipment powered by natural gas or liquefied petroleum gas (LPG) helps to overcome the costs and problems associated with the growth in air conditioning demand. This article describes the development of an improved absorption type heat pump.

Operating cost savings of gas-fired air conditioning may increase as gas and electricity supplies are deregulated. In addition, many of the gas-fired technologies offer the environmental advantage of not using the refrigerants associated with ozone depletion and global warming. For the user this eliminates the uncertainty regarding the future supply and use of these refrigerants. As well as eliminating these refrigerants, using gas as a fuel in high-efficiency cooling and heating appliances can reduce carbon dioxide emissions, compared with electrically powered air conditioning and heating. For all these reasons gas-fired air conditioning is increasing in popularity for large-scale air-conditioning loads.

However, despite these benefits gas-fired air conditioning has very little impact in the residential and small-commercial air-conditioning sectors where small-capacity equipment is required. The barriers to greater penetration of small-capacity gas-fired appliances have been their relatively high initial cost, their large size and weight, poor efficiency and, for some types of equipment, the maintenance required. The Rotex technology described in this article represents a change in the technology used for small-capacity gas-fired cooling and heating. It overcomes the traditional barriers and enables the benefits of gas-fired air conditioning to be applied to the residential and small-commercial sectors. In the US the trend towards more expensive peak electricity for air conditioning will further enhance the operating cost advantages of efficient gas-fired air conditioners.

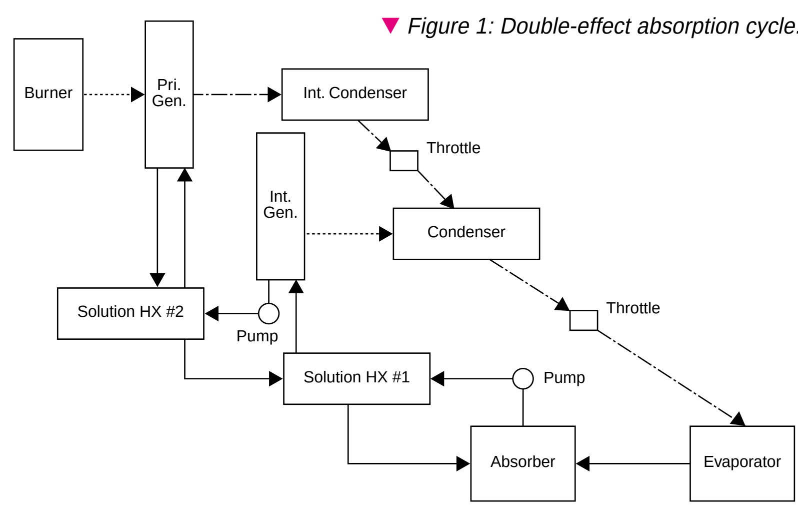
History

In the early 1980s, scientists in the chemical industry searched for ways to reduce the size of chemical processing equipment and thus improve the plant's capital efficiency. Chemical processes involving the simultaneous requirement for heat and mass transfer relied on "falling film" technology, where a liquid was directed down a continuously cooled heat exchanger surface. The heat exchanger was located inside a vessel containing the vapour to be absorbed by the liquid. The effectiveness of the process was determined by the thinness and speed of the film, while gravity and the heat exchanger height set the limits of this effectiveness.

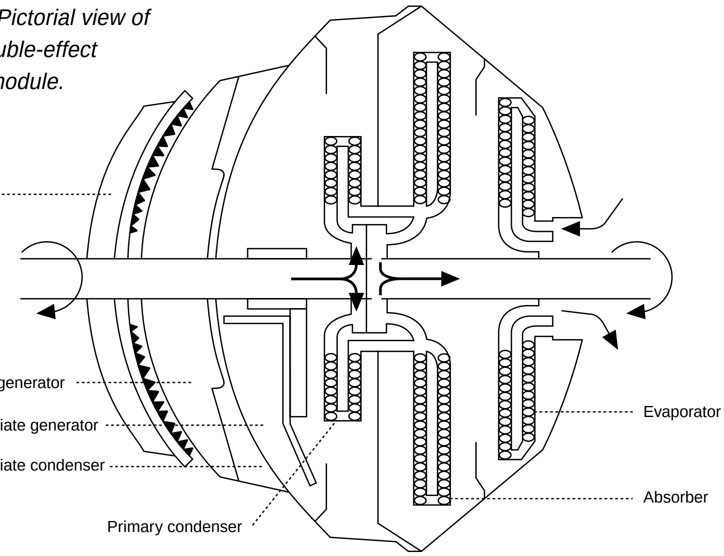
Scientists at ICI developed a rotating heat exchanger and successfully applied it to a laboratory-sized chemical process. The concept behind this innovation was the use of a spinning heat exchanger to artificially induce an acceleration field of arbitrary magnitude. The liquid applied near the centre of the spinning heat exchanger is rapidly accelerated and thinned as it travels towards the periphery. A 1-metre disk spinning at 550 rpm produces more than 100 Gs of acceleration on the liquid. This allows much thinner and faster moving films than when relying on gravity.

Commercial absorption air-conditioning systems rely on "falling film" absorption of refrigerant vapour. The effectiveness of this process determines the size and weight of absorption air-conditioning equipment. However, one of the major disadvantages is that the

▼ *Figure 1: Double-effect absorption cycle.*



▼ *Figure 2: Pictorial view of Interotex double-effect absorption module.*



- gas-fired double-effect absorption cycle with net cooling PER of 0.90;
- dry heat rejection system (no cooling tower required);
- compact, unitary physical arrangement;
- lightest air-cooled double-effect absorption machine;
- mild climate heat pump capability with heating PER of 1.6;
- improved dynamic response (compared to other absorption systems);
- environmentally benign fluids and materials;
- hermetic construction (maintenance-free absorption module);
- projected 15-year product life.

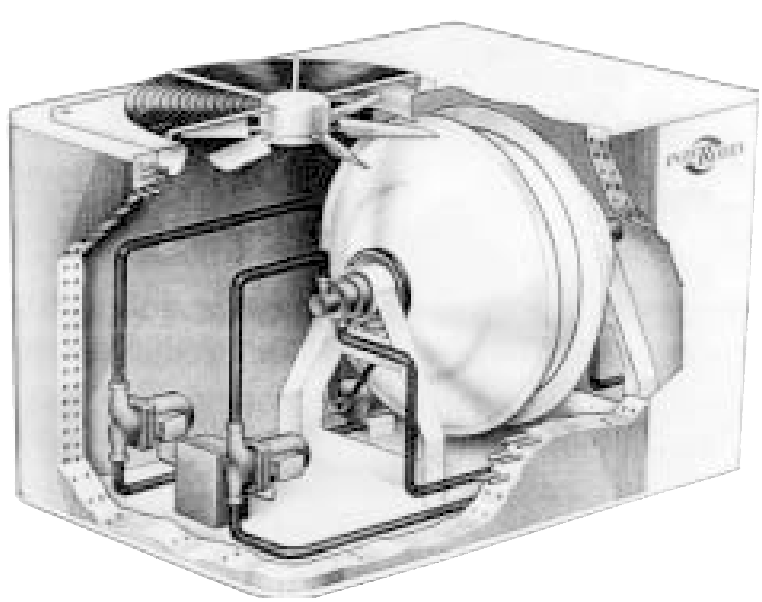
system is larger, heavier and more expensive than electric vapour compression air-conditioning equipment.

In 1983 a project sponsored by two UK companies, British Gas and Caradon, set out to prove the applicability of rotationally enhanced heat and mass transfer in a single-effect absorption heat pump. The success of the Rotex proof-of-concept system was reported in a 1988 technical paper by Ramshaw et al [1].

Technology development

In 1993 several companies from the natural gas and the appliance manufacturing industries joined forces to develop a heat pump utilising Rotex technology. This R&D venture took the name "Interotex". The investors were Lennox Industries Inc. (US), BG plc (UK), Fagor Electrodomesticos S. A. (Spain) and Gas Natural S. A. (Spain). Their goal was to demonstrate a 10.6 kW (3 ton) cooling heat pump with the following characteristics:

▼ *Figure 3: Sample Interotex packaging arrangement.*



Double-effect cycle

The double-effect absorption cycle adopted for this development is entirely conventional (see **Figure 1)**. However, the hardware implementation of the double-effect cycle and the absorption solution chemistry is very unconventional.

The Interotex heat pump is a water-to-water system housed inside a welded drum that rotates on a horizontal axis. All heat exchange components, except the solution heat exchangers, utilise high gravity-force heat transfer intensification. A proprietary absorption fluid with a wide operating temperature range is used. The solution, an aqueous metal hydroxide mixture, is too viscous for practical use in conventional static absorption machines. In a high-gravity environment, the solution viscosity is not a problem and the properties are such that higher heat rejection temperatures are tolerable (compared to water/lithium bromide, the usual double-effect absorption pair). Higher heat rejection temperatures allow a dry heat rejection system in cooling operation and hotter water delivery when heat pumping. The physical arrangement of the main heat exchange components is depicted in Figure 2.

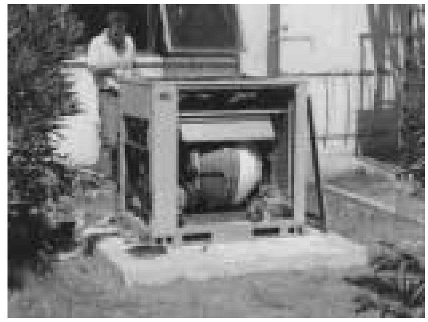
The rotating absorption module is divided into three chambers. The leftmost chamber in **Figure 2** is the upper generator stage, fired by natural gas. The partition labelled “intermediate condenser/intermediate generator” separates the upper and lower stages. Heat for the second, lower effect, passes through this thin metal partition. The water-cooled, tube-format condenser is in the lower stage chamber. A second partition separates the lower stage from the low-pressure chamber containing the absorber and evaporator. The absorber uses the same cooling water as the condenser. The evaporator uses a tube format but has its own chilled water loop. The two water circuits use automotive-type rotating seals.

The need to rotate the drum, or module, is one drawback to this technology. An electric motor and a drive belt are required, as are the rotating water unions mentioned above. However, the benefits of rotating the module are numerous. As mentioned earlier, most heat exchangers are more compact, thus reducing size and weight. Another benefit is that pumping the solution around the cycle becomes simple and worry-free. Solution pumps ordinarily represent a significant cost and complexity in a double-effect machine. In Rotex machines, the pumps are simply Pitot tubes (scoops), which dangle from the central shaft and use a bobweight to prevent their rotation with the rest of the machine. The cost of introducing pumps into the design is very low, so it becomes practical to add pumps to accomplish auxiliary functions such as active concentration control and evaporator recirculation. These extra functions provide improved system efficiency but are typically found only on very large absorption machines due to their added cost [2]. One of the conclusions from over five years of Interotex development is that rotating the absorption module affords subtle, but important, new capabilities.

Current status

In May 1993 representatives of the Interotex investors met to agree the specifications for the proof-of-concept machine. The first double-effect

▼ *Figure 4: Installation of a heat pump in Zaragoza, Spain.*



rotating absorption air conditioner came to life in March 1995, and the first machine to operate outside a laboratory was commissioned at the BG plc test house in Didcot, UK in October 1997. A second unit was installed to provide air conditioning at Ikerlan’s new research facility near Vitoria, Spain in 1998. The first heat pump unit was installed at a Gas Natural facility in Zaragoza, Spain in 1998.

The cooling PER of these machines is 85% of the target specification. These field demonstration units were deployed at an early stage to generate real-world operating experience earlier in the design cycle. New machines with an improved absorber are yielding performance approaching the target PER specification.

Market opportunities

This appliance will predominantly be sold in the southern half of the United States. The high cooling PER will make it a preferred gas technology for cooling-dominated climates and applications. Since water is the refrigerant, the system cannot operate as a heat pump when the outdoor temperature is near freezing. When the temperature falls below 7ºC, an auxiliary gas burner is used to provide 80% efficient gas heating. This new heat pump will serve as a complement to GAX absorption heat pump technology (which has a performance bias toward heating operation). The best applications will be light commercial air conditioning and larger residential buildings. The ability to deliver chilled water to multiple indoor air coils will provide comfort and application advantages over direct-expansion air-conditioning systems.

Southern US operating costs, with conventional utility gas and electricity tariff structures, will be similar to costs for running an electric air conditioner with a cooling COP of 3.5, or with a furnace with an annual fuel utilisation efficiency (AFUE) of 80%. Most areas of the country have optional “Time of Use” (TOU) electricity rates available for light commercial and residential customers. There is a trend toward mandatory TOU electrical rates as a proxy for “real-time pricing”. For example, the Maryland Public Utility Commission now requires a TOU rate for all new single-family residences. It is also becoming more common for gas utilities to offer discounted natural gas prices to light commercial and residential customers who have gas-fired cooling equipment. Customers who take advantage of these tariff structures can realise up to 25% further reduction in their HVAC operating costs. Switching to an efficient gas-fired heat pump can provide benefits to owners, utilities and the environment.

The Rotex technology currently under development is offered for licensing to interested manufacturing companies.

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New applications of sorption technology

Hans van der Stoel, the Netherlands

Sorption technology is back. After a long period in which compression heat pump and refrigeration systems dominated the market, sorption technology is now receiving renewed attention in the Netherlands. As a result of some clear advantages, such as a low noise level, low maintenance and the possibility to use waste heat as the driving energy, a number of new markets are emerging.

The Department of Refrigeration and Heat Pump Technology at the Institute of Environmental Sciences, Energy Research and Process Innovation (TNO-MEP) is working on the development of new (ab)sorption systems to achieve a breakthrough in the application of sorption technology. TNO also participates in the Dutch Platform on Sorption Technology which is linked to Annex 24 of the IEA Heat Pump Programme. The platform is a forum for exchanging knowledge and initiating various types of cooperation.

Transport refrigeration

One of the current ongoing activities at the aforementioned department is a project on transport refrigeration. A feasibility study has been performed, together with engineering firm Colibri and a manufacturer of transport refrigeration units. The study included the selection of a product-market combination, design of a refrigeration unit, a risk analysis, assessment of the energy saving potential and a technical and economic feasibility.

The decisive criteria for the product-market combination proved to be the available space and the quality of waste heat from the exhaust gases, which drive the absorption unit. These criteria led to a lorry with trailer, transporting frozen goods between distribution centres.

With respect to energy savings, a comparison was made between conventional units and the newly designed absorption unit. Annually, absorption refrigeration saves about 15% on primary energy consumption. This relates to the Dutch climate and the practice of loading the lorry at the end of the day. If the trucks are loaded early in the morning instead of the evening before, savings on primary energy consumption would increase to 80%. Savings of 75% can be accomplished in international transport of frozen goods. The weight and investment costs are comparable to conventional units.

Residential appliances

Various parties, both in the Netherlands and abroad, are working on developing a residential absorption heat pump. Each team focuses on a specific area of absorption technology, for example on diffusion absorption or reverse rectification technology. As a knowledge centre, and with 20 years of experience in sorption related research, TNO has now started its own development, sponsored by EnergieNed. For reasons of efficiency, TNO hopes to cooperate with the Delft University of Technology on the concept of reverse rectification. This university is involved in a similar development under a different consortium. With the excellent Dutch gas infrastructure, the residential absorption heat pump could be a fierce competitor for a compression heat pump. However, to be commercially successful the cooperation will have to be extended with a manufacturer.

District heating

Energy distribution companies are looking for ways to expand their services to include the supply of heating and cooling. District heating combined with absorption cooling is an option used by several companies. TNO was involved in evaluating the system performance of these projects. Although the performance of the absorption machine itself was often good, an incorrect system design sometimes led to a moderate system performance.

Zeolite

With respect to zeolites, TNO concentrates its activities on industrial drying processes. Based on a thorough knowledge of zeolites, simulation models are used to predict the behaviour of zeolites and food during the drying process. Together with a set of design tools developed at TNO, this has already resulted in 100 kW demonstration projects.

In addition to the developments mentioned above, TNO is also involved in many other sorption technology activities. Several projects combine the use of waste heat with cooling, freezing or dehumidification. Sorption can be regarded an energy-efficient technology with promising market opportunities for the Netherlands and other countries. The list of new applications is long!

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Fireworks for the future of absorption heat pump technology - the potential of $LiClO_3$ as an absorbent salt

Carel van Lange, the Netherlands

GASTEC, a gas research centre, is currently studying the properties and market opportunities of lithium-chlorate as an absorbent for absorption heat pumps using water as a refrigerant. This new absorbent salt has the potential to create a breakthrough for absorption heat pump technology. The work is funded by Energie-Ned, the association of Dutch utilities and Novem.

Currently the most widely applied absorption heat pump systems are based on the working pair water and lithium-bromide (LiBr). Cooling below 0˚C is not possible, and a typical heat rejection temperature for a water-LiBr chiller is 40˚C. This temperature cannot be much higher, as the lithium bromide would crystallise, causing system failure. This means that the heating system has to be designed for this low temperature.

Why $LiClO_3$?

Lithium-chlorate is a salt used in the fireworks industry. Dry crystalline $LiClO_3$ is a good rocket fuel. However, the solution of $LiClO_3$ and water is perfectly safe. The salt is extremely hygroscopic and will dissolve when about 10% water is added.

As previously mentioned, the LiBr heat pump has two restrictions, no cooling below 0˚C and no heating above 40°C. $LiClO_3$ cannot take away the first restriction: 0˚C will always be the lower limit for water as a refrigerant. However, heating temperatures up to 65˚C can be used without crystallisation problems (see **Figure**). This will make it easier to apply the system, not only in new buildings, but also in existing buildings or homes, e.g. to replace gas condensing boilers. Under the same working conditions $LiClO_3$ will also result in a higher heating efficiency than lithium bromide. These advantages could mean an important step forward. Of course these restrictions could also be removed by using heat pumps based on ammonia and water, but the main disadvantages would be higher costs and lower efficiency.

Market prospects

For Europe gas-fired heat pumps have very good prospects. Nowadays a large proportion of space heating is based on gas-fuelled boilers. Fuel taxes and restrictions on the energy use of buildings will increase interest in new efficient technologies. Heat pump systems that can provide year-round space conditioning will become increasingly important.

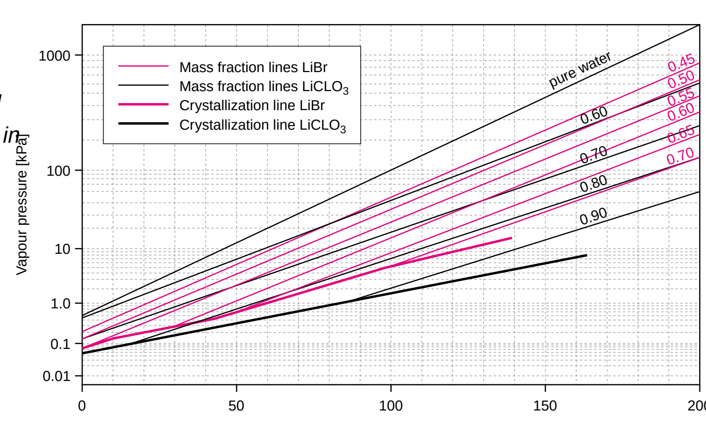
The energy consumption reduction measures for space heating in the Netherlands are typical. For new buildings the government has placed an upper limit on energy use. This limit will gradually be reduced, so that in a few years heat pumps, solar-assisted boilers or other types of efficient equipment will become part of the building design. Simultaneously, the Dutch government is working on legislative frameworks for energy use in existing buildings.

Results

Research into the properties of lithium-chlorate as an absorbent for heat pumps has only just started. In this first phase all attention has been given to thermo-dynamics, the efficiency of the working pair, crystallisation behaviour and corrosion. The main advantages were identified as higher efficiency under equal working conditions and the possibility to select higher heat rejection temperatures. Crystallisation is expected to be far less of a problem than with LiBr. The first corrosion tests have been performed at a temperature of 85˚C and no problems were encountered.

Further to these successes, the next step will be to test $LiClO_3$ under actual heat pump conditions. We are confident that at the end of this phase we will be able to confirm that there will be fireworks for absorption heat pump technology in the future.

Figure: Chart of LiBr and $LiClO_3$ dissolved in water.



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IEA Annex 24 - Absorption technology

Magnus Gustafsson, Sweden

Sustainable development is increasingly important to ensure a more efficient use of energy and provide environmental protection. Absorption machines can use almost any source of heat, including a wide variety of fuel energy, solar energy, waste heat, etc. This article gives an overview of the market penetration in various regions as well as ongoing projects, based on information gathered within the context of Annex 24 of the IEA Heat Pump Programme (Ab-Sorption Machines for Heating and Cooling in Future Energy Systems).

Market status

Within the context of Annex 24, the participating countries have compiled country reports that include the market status of absorption heat pump technology.

Europe

The European market for refrigerators, chillers and heat pumps is dominated by electric- and engine-driven vapour compression systems, for industry as well as residential applications. However, absorption systems are used in specific applications, e.g. when there is a high energy-saving potential, plenty of waste heat and when the government or utilities are actively promoting this technology. This makes the European absorption heat pump market rather specialised, which in turn makes series production less attractive. Absorption technology can contribute to environmental protection and reduce the greenhouse effect.

Applications of absorption equipment in Europe can roughly be divided into five categories (see **Table 1).**

Large heating installations are mainly found in Sweden, Germany (heat transformers) and the Netherlands (heat transformer) and outside Europe in Japan. Some have been realised to recover heat from refuse incineration plants, notably in Sweden and Denmark. Current systems with water/ lithium bromide as working pair achieve an output temperature of 100°C and a temperature lift of 55°C. The PER typically ranges from 1.2 to 1.4. The new generation of advanced absorption heat pump systems will have higher output temperatures (up to 260°C) and higher temperature lifts.

The European market for comfort cooling in public and commercial buildings is dominated by H_2O/LiBr systems that are mainly imported from USA and Japan. Some of these systems are driven by heat from combined heat and power units. Direct-fired systems using natural gas are often installed in cases where electrical compression cooling is economically not attractive. Absorption chillers using hot water from district heating schemes have also been gaining interest lately. Successful applications exist mainly in Sweden and Germany. Furthermore, small direct gas-fired NH_3/H_2O systems for comfort cooling have entered the market over the past few years.

For industrial refrigeration, absorption cooling is an attractive, cost-saving technology for low-temperature applications (evaporating temperatures down to -60°C) compared to compression cooling. Using absorption technology (NH_3/H_2O), it is easier to overcome the pressure difference necessary to operate the system at these large temperature differences.

Asia

In Asia, absorption systems for space air conditioning have been on the increase for 10-20 years. This includes various types of machines, normally utilising steam or natural gas heat sources. Both chiller and chiller-heaters are used as single-purpose systems and double-purpose systems. Both single-effect and double-effect machines are used and the trend is that the more efficient (internal heat recovery) double-effect chillers will replace single-effect systems.

Worldwide, Japan is the market leader with numerous manufacturers of absorption systems. Domestic shipments reached 4,712 units in 1995,

▼ *Table 1: European applications of absorption equipment.*

Domestic refrigeration	Small gas-fired or electric-heated, air cooled NH_3/H_2O refrigerators.
Small commercial applications	Gas-fired, air-cooled NH_3/H_2O systems up to 80 kW for brine cooling and chilling as well as combined heating module.
Air-conditioning	Gas-fired, air-cooled NH_3/H_2O systems. Water-cooled H_2O/LiBr chillers with cooling capacities in the range of 200 kW - 5 MW. These chillers are direct-fired, steam-fired or hot water-heated.
Industrial refrigeration	NH_3/H_2O absorption refrigeration plants ranging from 200 kW up to several MW with evaporating temperatures down to –60°C. All heat sources and air- or water-cooled machines.
Industrial heat pumps	H_2O/LiBr absorption heat pumps normally with a heating output of several MW. Both heat transformers and heat pumps are used.

from a total of 6,500. Of the total number of units sold, 92% were direct-fired absorption chiller/heaters, which represent 84% of the total refrigeration capacity. A new chiller/heater, consisting of a double-effect absorption unit for cooling, and a single-effect absorption heat pump for heating, recently became available. Absorption machines have mainly been supplied to large office buildings, health centres, hospitals, schools, etc. However, under an initiative by the three major gas utilities in Japan, marketing activities have been carried out to expand outlets to small- and medium-sized buildings and homes.

With regard to NH_3/H_2O systems, over 400 units with a capacity of 10.5 and 17.5 kW have been installed for air-conditioning, and 13 units (capacity between 58 and 1,930 kW) have been installed for industrial refrigeration.

China has recently begun to gain attention as a huge market next to Japan. Production of H_2O/LiBr chillers in China has increased from 700 units in 1992 to 3,500 units in 1997. In Korea, the demand for absorption chillers is also increasing rapidly. In 1995, the residential air-conditioning sector was growing by 500,000 units per year. Chillers are usually installed, with only about 1% heat pumps. In the commercial sector, absorption technology is widely used due to the fact that non-electric cooling is recommended in the summer. In 1994 there were 1,500 units sold.

USA

In the USA, sales of large capacity absorption (H_2O/LiBr > 350 kW) chillers are rising. Sales in 1996 totalled 579 units, compared to only 160 units in 1990. These units are typically used for air-conditioning applications in commercial/retail, education, government and health sectors.

Current market penetration in the USA for residential/light commercial air conditioners (NH_3/H_2O systems) is rather low. However, commercialisation of the GAX (generator absorber heat exchange) heat pump, which provides both high-efficiency heating and cooling, will open a new market (see page 11).

Annex 24 activities

In addition to compiling information on market developments in country reports, Annex 24 member countries have been conducting case studies and assessments for various applications. Some of the projects running on a national basis under Annex 24 are summarised below.

In Norway a project was started to develop a hybrid heat transformer for high-temperature applications. A related research field is process integration of heat pumps and heat transformers in industrial processes. A UK project aims at demonstration of the cost savings that can be achieved by connecting an absorption chiller to a combined heat and power (CHP) system in a pharmaceutical plant. In Sweden, a study compares different chiller technologies, economics, environmental aspects as well as overall system aspects for district cooling applications.

Many Dutch projects focus on the greenhouse sector and include application of gas engine-driven and absorption heat pumps, particularly in greenhouses without assimilation lighting. Other projects are ‘thermal solar systems for greenhouses and bulb growing’ and ‘absorption technology for heating and cooling for mushroom-growing facilities’.

The potential for commercial rooftop GAX heat pumps is studied in Canada. The evaluation includes economic and technical potential of the GAX heat pump compared to current technologies as well as the constraints and practical problems related to its use. The study focuses on 10-70 kW (3-20 ton) commercial rooftop GAX units which are typical in Canada.

In Japan three projects are ongoing on high-efficiency low/high-temperature heat production technology. The first project aims to develop a high-efficiency absorption type heat pump system (dual-loop double-effect cycle) capable of efficiently recovering heat from low-temperature heat sources (e.g. river water, seawater, etc.). A second project aims to develop a high-efficiency absorption type heat pump system which, using high-temperature steam from a waste incineration plant, can produce chilled/hot water by using low-temperature heat available from sources such as a sewage water treatment plant. The third project aims to develop an absorption type refrigeration machine which, by adopting a double-lift cycle, can deliver chilled water (7°C) for air conditioning by using hot water at low temperatures (60°C).

A summary report on adsorption technology is being prepared with input from the participating countries. The objective is to collect and summarise information on R&D, demonstration/pilot plants, establish the merits of these systems, market potential in specific applications and recommendations for follow-up work in terms of RD&D etc. The Operating Agent (Sweden) will also cover some of the findings in Europe, particularly Germany and France.

Internet

More information about the activities of the Annex, R&D, manufacturer details, newsletters, conferences and related issues can be found on the Annex 24 Internet site currently being developed (http://www.ket.kth.se/Avdelningar/ts/Annex24/).

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A combined geothermal heat pump system - the results after two years

Bernard Matthey, Sonia Freiburghaus and Sylvain Langel, Switzerland

An installation consisting of an electric heat pump coupled to an underground thermal storage system and a combined heat and power (CHP) unit has made spectacular energy savings possible for a secondary school complex. The storage system is recharged by 306 m^2 of selective, unglazed solar collectors. Financial balance would be attained if the fuel (natural gas) were to cost USD 0.046 per kWh, which is slightly higher than current prices. This article describes the system and evaluates the technical and financial results after two years of operation.

System description

The Les Coteaux secondary school complex at Peseux-Neuchâtel, Switzerland, was modified and expanded between 1995 and 1996. The heating system was completely modernised and the building equipped with an electric heat pump coupled to a gas-fired CHP unit. An oil-fired condensing boiler meets peak demands and acts as backup in the event of a breakdown. The system is shown in **Figure 1**. The underground thermal storage system is formed by 30 vertical double-U boreholes drilled in unsaturated rock (hauterivian limestone and marls). The top of the store, which is buried under the school playground, is not insulated.

The store is recharged by 306 m^2 of selective, unglazed solar collectors facing south east. Hot water production is ensured mainly by 24 m^2 of glazed solar collectors, in combination with the heat pump desuperheater and the heat pump itself.

The combination of the electric heat pump, the desuperheater, the gas-fired combined heat and power unit and its exhaust gas condenser is referred to as the ‘combined heat pump system’.

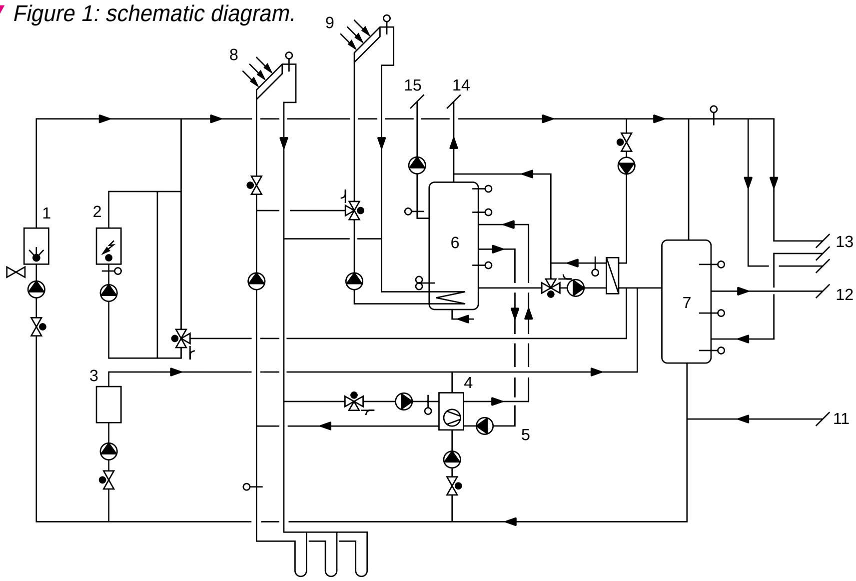
The power group and the heat pump system are connected through the electrical circuitry in the building. Surplus electricity produced by the CHP unit (3-4 kW) is used to supply the pumps for the heating system. If the CHP unit fails, electricity for the heat pump can be supplied through the grid. The CHP unit can also function independently and supply electricity to the school grid. Heat is distributed through the buildings by radiators with supply/return temperatures of 60/40°C at outside temperatures of -7°C.

Assessments and results

The system’s energy requirements were measured over a period of two years (see **Table 1**). This was financed by the Swiss Federal Office of Energy. Seventy-nine percent of the heat is supplied by the combined heat pump system, the rest comes from the oil-fired boiler.

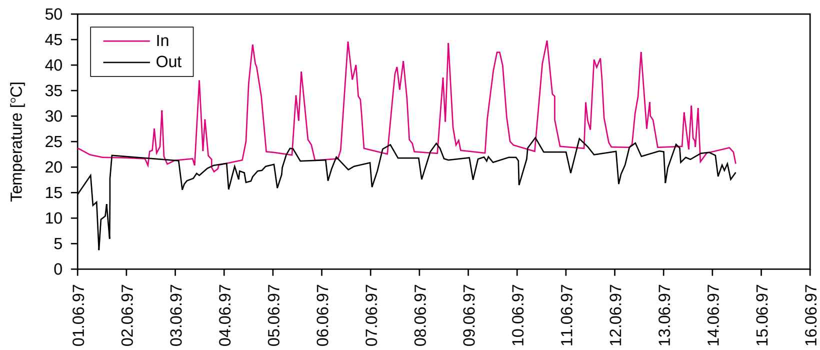
It was originally hoped that the unglazed solar collectors would produce 600 kWh/m^2 per year, but they actually produced over 800 kWh/m^2 per year during the second year. Together with the fact that heating requirements for the building were slightly lower than

▼ *Figure 1: schematic diagram.*

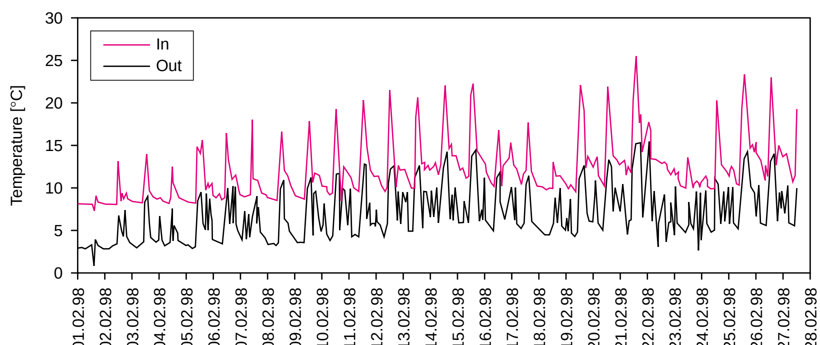


1. Oil-fired boiler (300 kW)
2. CHP group (th: 61 kW, el: 24 kW)
3. Condenser of CHP (10 kW)
4. Electric heat pump (62 kW)
5. Desuperheater (3 kW)
6. Hot water tank
7. Heat accumulator (2 m^3)
8. Unglazed solar collectors (306 m^2)
9. Solar collectors (24 m^2)
10. Earth store
11. Space heating circuit (return)
12. Low temperature circuit (45°C)
13. High temperature circuit (65°C)
14. Hot water
15. Hot water circuit (return)

▼ *Figure 2: Input/output temperature of the store in June 1997.*



▼ *Figure 3: Input/output temperature of the store in February 1998.*



expected, this explains why only 50% of the heat that was injected in the store was extracted for heating purposes. This caused a slow increase in the average temperature of the store, observed during the second year: the minimum temperature increased from 5.7°C to 8.2°C.

▼ *Table 1 : Energy assessment of the system (3/10/96 to 2/10/97).*

Final energy consumption (gas + oil)	384 MWh
Supplementary network electricity	10 MWh
Heat supplied to the building	521 MWh
Energy supplied by the electric heat pump	
- condenser	207 MWh
- desuperheater	6 MWh
Energy supplied by the CHP group	
- heat from cooling the motor	170 MWh
- condenser	28 MWh
- electricity	53 MWh
Energy supplied by the condensation boiler	103 MWh
Energy supplied by CHP + heat pump	411 MWh
Solar collectors for hot water supply production	7 MWh
Unglazed solar collectors	
- to the store	213 MWh
- to the heat pump	31 MWh
Total	244 MWh
Extraction from the store to the heat pump	107 MWh

The coefficient of performance (COP) of the electric heat pump is 3.35, while the primary energy ratio of the combined heat pump system equals 1.5. The electric efficiency of the motor is no more than adequate (0.24). Solar energy contributes over 30% to the thermal requirements of the building.

One point is worth noting which is linked to the solar installations, as well as to other measures such as renewing the regulation and ventilation systems. The building's specific primary energy consumption decreased drastically from 794 MJ/m^2 per year before the modifications, to 176 MJ/m^2 per year (1996-97) and 145 MJ/m^2 per year (1997-98).

The difference between the first and second year results from a breakdown of the power group during the second year, when the heat pump ran for 1,500 hours on electricity from the network.

Financial aspects

The total additional cost of the improvements was USD 423,000. Investments can be roughly given as one third for the solar installation, one third for the store and one third for the gas heat pump and CHP group.

The financial assessment shows that to make the overall improvements pay, the cost of fuel would need to be USD 0.046/kWh, despite spectacular energy savings. The average cost of fuel (gas and oil) is USD 0.036/kWh, which leads to the conclusion that the breakeven point is almost attained.

Final remarks

The system has been functioning since the autumn of 1996 without any particular problems.
Measures to make the system more profitable would be:

- a more efficient electric heat pump;
- floor heating instead of radiators;
- a more efficient power group;
- on a new building, solar collectors should be used as a roof.

On the other hand, the results show that the system is coherent, the capacities of the components are correctly sized, the productivity of the unglazed solar collectors is extremely high, the condensers and desuperheaters are justified and the store system with double-U tubes can be recommended.

The size of the store was calculated using mathematical models from the University of Lund, and this proved to be very efficient, even if the calculations were more pessimistic than in reality.

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New opportunities for heat pumps in the UK

Jeremy Tait, UK

The UK is proud to announce its membership of the Heat Pump Centre. We have worked hard to build interest and momentum, and that has now paid off with our full participation in the Heat Pump Programme from March 1999.

With support from industry and government, we are currently developing a National Team and an information network to ensure maximum benefit from UK membership. Information services and coordinating collaborative project work will be key activities. UK network objectives are to:

- inform the government on energy, environmental and trade issues affecting heat pumps;
- encourage greater UK participation in international R&D and market development projects;
- develop balanced information about heat pump technology and energy efficiency;
- transfer innovation and best practice from abroad into the UK;
- improve understanding of heat pump technology and markets.

Activities per sector

The UK has an increasingly positive attitude towards heat pump technology. Our strong R&D activities and well-developed market for commercial heat pumps are well known. Costs and environmental pressures have brought growing interest from the process industries, while some initiatives in the domestic sector are also showing good results. The UK is now in a strong position to exploit heat pump opportunities, driven by the need for energy efficiency, environmental protection and increasing UK competitiveness.

The Heat Pump Association (HPA) are assisting with the formation of a UK National Team. The HPA represents manufacturers of heat pumps and associated equipment, and aims to ensure that heat pump systems are appropriate to their applications and installed with professionalism.

Commercial buildings form the most prolific area of heat pump application, with most systems capable of providing heating and cooling. With growth in air conditioning around 5% per annum, it is this that drives the heat pump market. The overall penetration of air conditioning in offices, hotels and retail outlets is approaching 25%, with central London at 50%. In 1996 annual heat pump sales to this sector totalled over 50,000 units. Interestingly, the amount of heat provided by reversible heat pumps in commercial buildings remains relatively small, less than 0.2% of the heating demand, emphasising the importance of the cooling duty. Absorption machines are making inroads into the buildings market for cooling; gas suppliers are promoting absorption, with government promotion focusing on use with CHP and waste heat. Interest in ground-source heat pumps is also growing.

For residences, gas-fired hydronic central heating systems are generally used, with condensing boilers being the current technology for improving energy efficiency. The market is dominated by heating applications and the high cost of heat pump equipment inhibits penetration. Forecast growth in domestic air conditioning may provide a more rapid route to acceptance of heat pumps. Since 1992 approximately 3,000 heat pumps have been installed in single-family homes in the UK with 40% believed to be air-to-water heat pumps for residential swimming pools. Conservatories could be a significant domestic market for heat pumps in the UK, allowing summer cooling and heating at other times.

It is suggested that there are 1,500 potential sites for 'large' industrial heat pumps in the UK, out of an EU total of around 8,000. The average unit size would be 800 kW, with the chemicals sector seeing the greatest potential. Annual industrial sales have been around 100 units for several years, mostly small heat pump dehumidifiers/ dryers, with less than 10% being mechanical vapour recompression units. The potential envisaged is nowhere near being realised, hindered by low energy prices. However, the UK Chemical Industries Association agreement with the government on energy efficiency is stimulating renewed interest, and government initiatives are promoting the use of heat pumps.

R&D

This is a strong area in the UK, particularly:

- innovative R&D on heat exchangers;
- process intensification;
- double-effect absorption for residential heat pumps;
- improving sorption cycles ;
- air-cycle systems for simultaneous heating and cooling;
- integration with renewable energy sources;
- solar-assisted absorption units;
- HFC mixtures exploiting temperature glide;
- compressor and lubricant behaviour;
- hydrocarbon working fluids.

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Efficient test method for building heat pump systems

Martin Zogg, Switzerland

Heat pump heating systems can only utilise their great energy savings potential when the operation of the overall system (heat pump, heat distribution, heat delivery and building) is optimised. In order to obtain high energetic efficiency and long heat pump lifetime, special emphasis should be placed on operating with minimum flow temperatures and a maximum continuous running time of the heat pump. An important aspect of the optimisation process is registering the actual operating conditions. This article describes a new method to reduce the time needed and the costs involved.

This method has been developed on behalf of the Swiss Federal Office of Energy (SFOE) at the Swiss Federal Institute of Technology. Several aspects were defined, which are determined by as few measurements as possible.

The new method should serve as the basis for the long-term goal of a new, model-based control strategy for heat pumps. This could lead to a higher seasonal performance factor, possibly without extra buffer storage, and an optimum exploitation of low-tariff periods.

The first three phases of this ambitious project are now completed. Results were obtained by taking the following steps: physical modelling, parameter identification, testing of a reference installation, simulation and fault diagnosis.

Results

The overall system (including the heat pump, heat storage, heat delivery and the building) was physically modelled. A graphical representation is given in **Figure 1**. The simplest way to represent the system and still guarantee correct reproduction of the dynamic subsystems was to simulate the building with a ‘one-zone model’. However, the heat pump needed to be modelled in more detail (see **Figure 2**). The model for the heat consumers (heat delivery and building) contains six physical parameters, the heat pump model has 11 parameters. The serially installed buffer storage in the heat distribution system was modelled to deal with the thermal stratification in six zones of similar temperatures.

The model parameters of all subsystems are determined by taking measurements under normal operating conditions, followed by computer evaluation.

The actual energy curve (curve of daily space heating demand) can be calculated by measuring the following parameters: inlet/outlet temperatures of the heat pump, supply/return temperatures of the heating system, outdoor temperature, room temperature and the pressure loss over the circulation pump. One week of measurements is sufficient, provided the heat pump operates long enough. The actual energy curve lies considerably below the design curve. This means that, according to the design, the heat pump would work at condenser temperatures that are too high for the actual situation. It would thus attain a lower COP than if controlled via the actual energy curve.

Essential parameters for a simplified stationary model of the subsystem heat pump were also identified. During the next phase, these studies will be extended to the dynamic operation of the heat pump, by identifying the dynamic parameters. The fundamentals of the corresponding models are given in detail in the final report [1].

In order to test and validate the modelling and parameter identification, measurements were conducted during the heating season on a frequently used heat pump heating system. The reference system was installed in a large single-family house close to Schaffhausen, with an annual heat demand of 234 MJ/m^2. Measurements were made at intervals ranging from 10 seconds to 5 minutes.

The heat pump uses ambient air as the heat source. The system is equipped with a storage tank, serially installed in the supply line, and a backup electric heater. The heat delivery system consists of floor heating with a few additional radiators, room thermostats and a bypass for maintaining a minimum flow rate through the heat pump condenser. The heat pump is controlled by an on/off switch, using the return flow temperature as a function of the outdoor temperature, and a timer.

Figure 1: Signal flow diagram of the overall system [1].

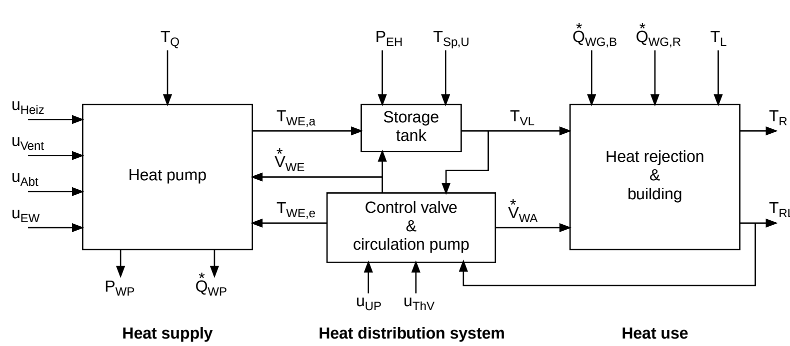
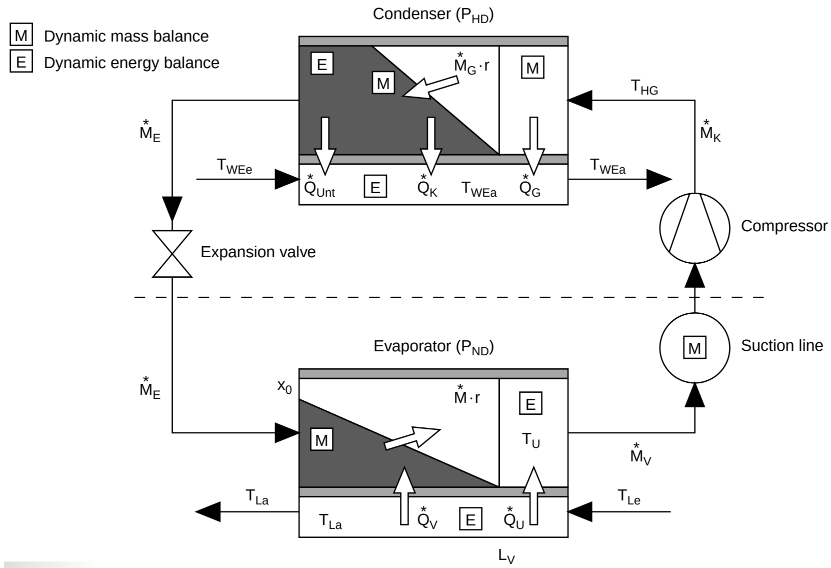


Figure 2: Modelling of the heat pump.



Simulation and fault diagnosis

The methods developed to date have been validated by computer simulations. Based on the parameter measurements made over one week, the annual results of the heat pump heating system were calculated with the help of these simulations. The extrapolation to annual results enables the effects of any faults to be assessed and allows optimisation measures to be initiated.

Fault diagnosis for a completed installation is first carried out for the entire heat pump system using generic models. If serious deviations from the target values occur, diagnosis is made in more detail using a refined model for the heat pump. The final report contains numerous error analysis schedules for systematic fault finding.

Future work

A detailed diagnosis of the heat pump will begin in phase 4 of the project. In phase 5, the identification of the overall system will be tested and extended through monitoring of existing installations. This phase will also cover aspects of integrating the heat pump control system (as a kit) and temporarily coupling an external computer as a diagnostic kit.

Since the energy curve also includes the effects of solar radiation and internal heat gains from the occupants and electric appliances, evaluation of a number of measurements during the 1997-98 heating season resulted in a wide variation in the heating curve. This means that the actual energy curve for optimum operation of the heat pump should be continuously acquired. It would be even better to predict it for the next operating hour based on the situation during the previous few hours. The work already completed is an important milestone in this direction.

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[1] The report (no. 9657407) may be ordered from ENET, Administration und Versand, PO Box 130, CH-3000 Berne 16, Switzerland
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Price changes of HPC publications for non-member countries

From 1 May 1999 prices of most HPC products have changed for people living in non-member countries. Also a postage charge has been added. A new pricelist can be obtained from the IEA Heat Pump Centre (hpc@heatpumpcentre.org) or from our Internet site (http://www.heatpumpcentre.org).

Proceedings of the International Sorption Heat Pump Conference
Available from: ZAE Bayern, Walther-Meissner Strasse 6, D-85748 Garching, Germany. ISBN No. 3-7846-1220-2. 700 pages, published March 1999. Price: DM 100 plus postage , Fax: +49-893294-4212.
The proceedings of this conference, held in Munich in March 1999, contain more than 80 papers. They are organised according to the sessions: Keynote speeches; Applications, Open Cycles; Operation and control; Working pairs; Heat and mass transfer, Thermodynamics, Thermodynamic models; Compression/absorption hybrids; Novel sorption cycles; Special cycles; Experiments: solid sorption; and Improved components and cycles.

Proceedings of the 6th IEA Heat Pump Conference
Available from: Verlags- und Wirtschaftsgesellschaft der Elektrizitätswerke m.b.H. - VWEW
Rebstöcker Straße 59, D-60326 Frankfurt, Germany. Tel.: +49-69-6304460
Fax: +49-69-6304359 E-mail: sl@vwew.f.uunet.de
Published May 1999, Price DM 395,- plus VAT
These proceedings contain the presentations and poster papers of the 6th IEA Heat Pump Conference. The theme of the conference was: Heat Pumps - A Benefit for the Environment. The sessions covered markets, technology, heat pump systems, applications and market strategies. The first volume contains the presentations, the second volume the poster papers.

Odessy: Optimum Design of Energy Supply Systems
Available from: TNO Institute of Environmental Sciences, Energy Research and Process Innovation. Fax: +31-55-5419837
E-mail: h.boot@mep.tno.nl
Price: EUR 1,350, or EUR 2,700 for an extended version for engineering or consulting agencies.
This computer program is described on page 5.

Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

Please note that prices have changed from 1 May 1999.

Environmental Benefits of Heat Pumping Technologies
Analysis Study, April 1999
Order No. HPC-AR-6, NLG 240 or NLG 80 in HPC member countries.

Ab-Sorption Machines for Heating and Cooling in Future Energy Systems
Workshop Proceedings, April 1999
Order No. HPP-AN24-2, NLG 180 or NLG 60 in HPC member countries.

IEA HPP Annual Report 1998
Order No. HPP-1998. Free-of-charge.

The Role of Heat Pumps in a Deregulated Energy Market
Analysis Study, October 1998
Order No. HPC-AR-5, NLG 240 or NLG 80 in HPC member countries.

Heat Pump Systems for Single-Room Applications
Workshop proceedings, December 1998
Order No. HPP-AN23-1
Price NLG 180, or NLG 60 in HPC member countries and Ca, Fr and Se.

Heat Pump Systems for Single-Room Applications
Final report, January 1999
Order No. HPP-AN23-2
Price NLG 300, or NLG 100 for HPC member countries and Ca, Fr and Se.

Deployment Activities for Heat Pumping Technologies
Workshop Proceedings, August 1998
Order No. HPC-WR-20
NLG 180 or NLG 60 in HPC member countries.

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

ASHRAE Annual Meeting
19-23 June 1999/ Seattle, Washington, USA
Contact: American Society for Heating Refrigeration and Air Conditioning Engineers
Tel.: +1-800-5274723
Internet: http://www.ashrae.org

'99 Air Conditioning & Heating Ventilation China
Environment Friendly Refrigeration
22-25 September 1999
Contact: Chinese Association of Refrigeration
Mr Zhong Wei Qin
Bldg 11 South No. 1 Lane
2nd Section of Sanlihe
Xi Chent Dist., Beijing 100045, P.R. China
Fax: +86-10-68536259
E-mail: wqzhong@263.net

20th IIR International Congress of Refrigeration
Refrigeration into the 21st century
19-24 September 1999 / Sydney, Australia
Contact: ICR99 Secretariat, 52 Rosslyn Street, West Melbourne, Vic 3003, Australia
Tel.: +61-3-93282399
Fax: +61-3-93284116
E-mail: icr99@airah.org.au
Internet: http://www.airah.org.au/icr99

European Geothermal Conference Basel '99
28-30 September 1999 / Basel, Switzerland
Contact: OC Secretary EGC Basel '99, Bureau Inter-Prax, Dufourstrasse 87, CH-2502 Biel/Bienne, Switzerland
Fax: +41-32-3414565
E-mail: interprax@bluewin.ch

1999 Annual GeoExchange Industry Conference and Expo
26-29 September 1999 / Sacramento, California
Contact: International Ground-Source Heat Pump Association (IGSHPA)
Tel.: +1-800-6264747 Fax: +1-405-7445283
Internet: http://www.igshpa.okstate.edu

Geothermal Heat Pump Consortium 1999 Annual Meeting and Conference
20-22 October 1999 / Atlanta, Georgia
Contact: GHPC,
Tel: +1-202-5085500
Internet: http://www.ghpc.org

Heat pump training programmes
8 November 1999 / Paris, France
Workshop in conjunction with Interclima
Contact: European Heat Pump Network, Mr Bahm
Tel.: +49-72-47808351
E-mail: wba@fiz-karlsruhe.de

IIR Gustav Lorentzen Conference
25-28 July 2000 / West Lafayette, Indiana, USA
Contact: IIR, 177 Boulevard Malesherbes, 75017 Paris, France
Fax: +33-1-47631798
E-mail: iifiir@ibm.net

Heat pipes, heat pumps and refrigerators
September 2000 / Minsk, Belarus
Contact: CIS Countries Association Heat Pipes
Luikov Heat and Mass Transfer Institute, 220072, P.Brovka 15, ITMO, Minsk, Belarus
Fax: +375-172322513
E-mail: allusr@avtlab.itmo.by

ACHRB 2000 - Air conditioning in high-rise buildings
October 2000 / Shanghai, China
Contact: IIR, 177 Boulevard Malesherbes, 75017 Paris, France
Fax: +33-1-47631798
E-mail: iifiir@ibm.net

IEA Heat Pump Programme Events

Natural Refrigerants for Heat Pumps Applications
9 November 1999 / Paris, France
Joint Workshop by the EU Heat Pump Network and the IEA Heat Pump Centre.
In conjunction with Interclima.
Contact: European Heat Pump Network, Mr Bahm
Tel.: +49-72-47808351
E-mail: wba@fiz-karlsruhe.de or the HPC or contact Mr Kleefkens (see back cover)

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National Team Contacts

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 cooperation 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

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. 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 the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by

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