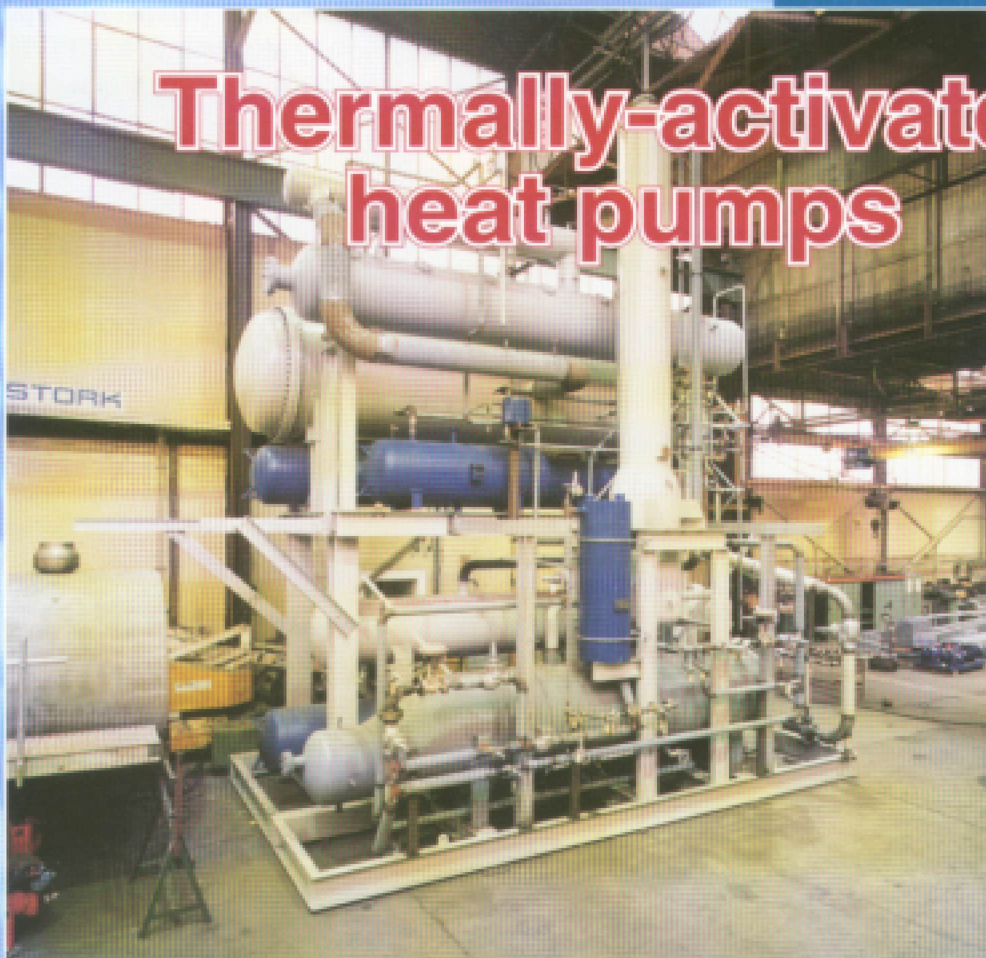
IEA Heat Pump CENTRE
NEWSLETTER
VOLUME 15
NO. 1/1997

Thermally-activated heat pumps



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Absorption heat pump for home retrofit
The absorption process - what are its prospects?
Saving energy with concrete

IEA OECD heat pump centre

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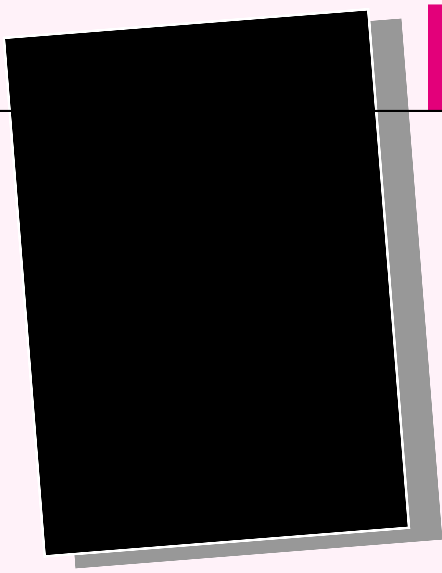

Thermally-Activated Heat Pumps

Thermally-activated heat pumps, such as absorption and engine-driven systems, offer energy efficiency, comfort and in some cases operating cost benefits over conventional heat pumps. Absorption heat pumps also offer environmentally-friendly alternatives to CFC/HCFC-based space-conditioning systems. This issue of the newsletter highlights some of these aspects.

Front cover:
A steam-driven absorption machine with a refrigeration capacity of 1400 kW, developed in the Netherlands, is used for refrigerating food. The article on page 27 explains further.

TOPICAL ARTICLES

COLOPHON

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Technical editing:
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Language editing:
Barbara Shapland
Production: Novem Support Group
Illustrations: Offermans EPS
Printer: Huntjens, Stein, The Netherlands

Frequency: quarterly
Printed March 1997

HPC Newletter subscriptions are automatically renewed unless written cancellation is received by 1 October

ISSN 0724-7028

Cherry Blossom Bloom in Spring

Many people know that the Japanese national flower is the cherry blossom (Sakura). Apparently about three hundred kinds of cherry blossom bloom in Japan throughout the spring. Sakura blooms first at the end of March in Kyushu (southern Japan), and gradually continues north according to the ambient temperature, until finally blooming in Hokkaido in the middle of May. Anyone who likes Sakura can enjoy "Sakura watching" by travelling for about 50 days in the spring, following the shape of the Japanese Island.

There are many different reasons why people enjoy Sakura. I love it most because it is the sign that spring has finally arrived, and the blooms confirm that our environment is still clean and beautiful.

We are now facing the huge problem of protecting the earth from certain environmental pollutants, especially from ozone layer depletion and global warming by CO_2, as well as other chemicals such as HCFCs and HFCs.

The Heat Pump Technology Center of Japan has been performing the important task of carrying out research and development to implement the technologies that have been developed since 1986. It has also tried to introduce these technologies overseas. Implementation of heat pumps is a very applicable solution for decreasing CO_2 emission, together with the adoption of other energy-saving technologies.

Last year, our center started the implementation of activities on ice thermal storage systems for space cooling, as well as for process cooling. An indirect contribution to a decrease in CO_2 emissions can be made by using nighttime electricity more efficiently, especially in Japan where high peak loads occur during the daytime on hot summer days.

Our objective is to implement large numbers of heat pump systems equipped with ice thermal storage, as cleaner energy technologies can help us retain our current global environment. Then we will be able to continue enjoying our lovely Sakura every year at the same time in the spring, and not in winter.

We hope that most readers recognize the beauty of nature and the fact that we should all do our very best to keep it that way.

Kunio Hamada

Director of the B oard, Heat Pump Technology Center of Japan and Executive Managing Director, Hitachi Ltd.

Heat pump news

Changes to HPC staff

The Netherlands - The IEA Heat Pump Centre (HPC) has experienced some staff changes with the departure of technologists Mike Steadman and Bert Stuij. The HPC staff now consists of Mr Jos Bouma (general manager), Ms Gerdi Breembroek and Ms Hanneke van de Ven (technologists), Ms Minie Wilpshaar (secretary) and Ms Ria Bastiaens (sales administration). Ms Rebecca Jones is the coordinator of the Technical Support Services Unit of the IEA Heat Pump Programme.

Readers should also note that the IEA has moved to a new office. The new address is:
9, rue de la Fédération
75739 Paris Cedex 15
France
The new contact numbers for the IEA's Public Information Office are:
Tel: +33-1-4057 6554
Fax: +33-1-4057 6559
E-mail: info@iea.org

Annex 21 updates its IHP screening program

Sweden - An update of the industrial heat pump (IHP) screening program developed under Annex 21 of the IEA Heat Pump Programme will be released in March. This software was originally developed under the project "Environmental Benefits of Industrial Heat Pumps" in 1995 and has attracted wide interest from industrial engineers.

This interest can be expected to increase with the availability of a demonstration version at the IEA Heat Pump Centre Internet Site in April. This will be a reduced version with fewer options for processes and heat pumps, and with limited possibilities for process definition.

The Annex 21 computer program was developed to assist in a preliminary screening of the technical and economic suitability of IHPs in industrial process applications. The program is based on pinch technology theory. It identifies IHP opportunities that are consistent with fully optimized plant heat exchange systems to provide the most economic IHP designs and the lowest possible plant-wide energy consumption. The program contains data on over 100 industrial processes in five industries: food, chemicals, petroleum refining, pulp and paper, and textiles. These data can be used directly, or modified as needed to assess site-specific IHP opportunities. The program also contains data on 50 types of IHP.

One of the improvements made in the updated version is the possibility to specify the mass flow through the compressor in calculations with the MVR-type, in addition to the existing method where heat flows of the sink and sources must be specified. A second new option is the possibility to construct a graph showing the specific installation costs versus the heat pump capacity. Also, more temperature levels will be tested in the screening procedure. Finally, some errors have been corrected and the interface has been improved.

Source: Mr Per-Åke Franck, Chalmers, Sweden.
Fax: +46-31-418 056.

Deregulation: challenge or brilliant opportunity?

USA - Power utility deregulation is now a hot issue for the heating ventilation and air conditioning (HVAC) industry. A recent issue of Koldfax - the monthly newsletter of the Air Conditioning and Refrigeration Institute - has highlighted this issue with an article by Mr Jim Bruce of the Washington DC law firm Wiley, Rein and Fiedings, who are active in this field.

According to Bruce, the first challenge for the HVAC industry is that the current basis for consumer demand for premium high efficiency HVAC units will erode. The electricity price increases that sustain demand for these products are likely to level out or decline, because of the competition in the new situation. A second challenge is that loss of their guaranteed market for electricity sales means utilities must scramble to find new business opportunities. Utility sales and repair of HVAC equipment is no novelty, but their efforts in this area are clearly intensifying.

But deregulation also offers new opportunities for the HVAC industry. With multiple electricity suppliers, each supplier will want to provide just enough electricity to the grid to meet its own customers' demand. This will necessitate a real-time communications system between the energy supplier and the customer. A two-way digital communications system could create a whole new market for "brilliant" HVAC equipment whose "smartness" is enhanced by the addition of real-time information.

Such information might include real-time electricity prices, peak load control signals, weather predictions coupled with the use of on-site heat/cold storage devices so as to permit the use of less expensive interruptible power, and central monitoring of refrigerant pressures and temperatures to schedule preventive maintenance. Electricity prices could be tailored to specific HVAC units.

The battle over deregulation of the electric utilities has begun. The resulting changes will present some challenges to the current way the HVAC industry does business. However, deregulation is likely to open the door to a new generation of "brilliant" HVAC equipment.

Source: Koldfax, November 1996.

’97 ASHRAE Winter Meeting

USA - Heat pumping technologies, both thermally-activated and compression, and working fluids were well-represented at the ASHRAE Winter Meeting in Philadelphia from January 24 to 29, 1997.

The market penetration of ground-source heat pumps in commercial/institutional buildings is developing positively in the US. Reliability, simplicity, energy saving, cost-effectiveness and comfort are the most important factors driving this. Cost-effectiveness of residential applications is not yet as good, but this market is growing too. Various case studies of commercial/institutional applications were presented including retrofitting a 40,000 m^2 multi-purpose building in the centre of Philadelphia with a ground-coupled heat pump system consisting of 28 Trane heat pumps. Sixty-six boreholes were made under a large parking lot to install the ground loop. This project demonstrated that even in high density urban locations groundcoupled heat pumps for cooling and heating can be realized successfully and that the economics of retrofit installations can be favourable, in this case five years. Other crucial conditions for success include knowledge of “installation basics” and a committed building owner.

ASHRAE has reorganized its structure for international membership. ASHRAE’s new International Committee consists of representatives from the international Chapters and geographic regions. The purpose is to improve service to unaffiliated members. The regions include Europe, Central/South America, Middle East, Africa, Far East and the Pacific Rim. Europe is divided in two sub-regions, the UK, Ireland and Scandinavia, represented by Mr Frank Mills of Frank Mills Associates, England, and the rest of Europe including Israel by Mr Jos Bouma, Novem/IEA Heat Pump Centre, the Netherlands. Each year a meeting will be organized in the regions for the unaffiliated members.

Source: Mr Jos Bouma, IEA Heat Pump Centre.
Note: More information on the case-studies is available from the HPC.

Residential heat pump project started

The Netherlands - At the end of November 1996, the building process started for 36 houses in Grootstal, which is a sustainable housing development in the city of Nijmegen.

In each house, an individual ground-source heat pump provides heat for space heating and tap water heating. By participating in this project, the energy utility NUON aims to demonstrate that heat pumps can be a very suitable way of providing heat for these purposes, now and in the future. The use of heat pumps allows better use of fossil fuels and contributes to CO_2 emissions reduction.

The heat pumps have a heating capacity of 6.6 kW. The ground heat exchanger consist of four pipes that are inserted vertically into the earth, to a depth of about 30 metres. A storage tank, filled with water, is placed under each house. By heating the water with cheap nighttime electricity, heat is available during the day for space heating using conventional hydronic radiators. A condenser in the boiler heats the tap water to a minimum temperature of 60°C. The houses are not connected to the gas grid.

The houses will be ready for use at the end of 1997. NUON is currently working on a second demonstration-project in Boven-Leeuwen. In this project, floor and wall heating systems will be used for space heating.

Source: Mr B. Casteleijn,
NUON Zuid-Gelderland.
Fax: +31-24-3719 477.

Erratum

The article in Vol.16 No.4 on page 14 and 15 discusses the third session of the IEA Conference on Heat Pumping Technologies. In the paragraphs on Geothermal Energy the figure on the total length of BHEs installed in Switzerland, should have been 2500 km, instead of 200 km.

New projects in Austria

Austria - At the end of January 1997 an Austrian National Team Meeting took place during which interesting projects and ideas on heat pump applications were presented by utilities.

SAFE, the electric utility from the province of Salzburg, has started a project for supplying heat for space heating purposes. In a group of multi-family houses a ground-water heat pump and low-temperature floor heating systems have been installed by the utility instead of hydronic radiators. The heat pump is operated by the utility, and supplied the heat consumption is charged to the consumers at the same price as heat from a district heating network.

Another project is in the planning phase in the province of Burgenland. The central part of a community is supplied by heat from a small district heating network. Heat generation is achieved by a biomass boiler and a diesel power generator which runs on methyl ester biofuel made from rape seed. The electricity from the generator is used to power the heat pumps, which are installed in buildings outside the town centre. These consumers are charged the same tariff for the heat as the consumers in the centre of the community.

Source: Mr Halozan, Austrian National Team.
Fax: +43-316-873 7305.

Successful “Heat Pump Weeks”

Germany - From 5 to 20 October 1996 the first Bavarian “Heat Pump Weeks” were organized by the heat pump group Initiativkreis Wärmepumpe (IWP). Main items were an exhibition on heat pumps in Munich, a stand on heat pumps at the ÖkOBAU’96 exhibition in Erding and a seminar at SOLARTEC’96 in Erding that was dedicated to heat pumps. Furthermore, regional exhibitions and lectures were organized for architects and planning engineers at several locations. The weeks were very successful. Several companies noticed increased interest in their products as a result of these activities.

Source: Wärmepumpe, December 1996.

Drought conditions test GSHPs

USA - During the long hot spring and summer period in Texas last year, conditions for ground-source heat pumps (GSHPs) were critical, putting the existing systems to a severe test.

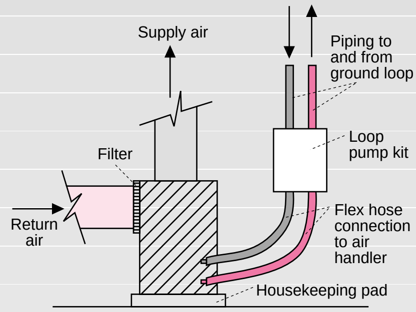
Firstly, the equipment needed to reject more heat to the ground because of the unusually high air-conditioning load in buildings. Secondly, the ground itself performed badly because there was less moisture to help conduct heat away from the ground loop: a terrific test for the technology.

The proving ground was the Austin Independent School District, in the heart of the drought-affected region. The district has installed more than 6,000 tons (21,000 kW) of ground-source heat pump systems, with loops of every size and in several types of ground. **Figure 1** shows such a system. The systems were carefully monitored.

In previous periods of drought some problems had occurred, especially for larger units serving big common areas such as cafeterias and libraries. Since then, some modifications have been made. The first modification made was that well spacing was increased from 4.5 metres (15 ft) to 6 metres (20 ft). Second, one or two extra wells were added to each large unit well field. Finally a better grouting method was required to retain the pipes: positive displacement from the bottom up, using a bentonite-based slurry. These new techniques were implemented on three new units in heavily-used areas at Brooke Elementary School. All of them performed quite well throughout the dry spell.

A fourth system, which was placed in a cafeteria, caused more difficulties. The ultimate solution here was to artificially extract some heat from the well loop. By installing a small flat-plate heat exchanger in the ground loop, heat from the well loop was used to preheat the water going into the kitchen water heater.

While this has been effective, an even more productive way to use this heat is



▲ *Figure 1: Water-source heat pump installation.*

dehumidification. An outside air unit uses a direct expansion coil to cool the outside air to 13°C (55°F) so that moisture condenses out. The air then presses over a coil, through which ground loop water circulates, to reheat it before delivering it indoors. Thus, several kW of heat are extracted from the common ground loop. Apparently the modifications made were a considerable improvement in the functioning of the ground-source heat pump systems in difficult dry weather conditions.

Source: Mr William H. Clark, Air Conditioning & Refrigeration News, December 1996.

LT systems show promise

Switzerland - The project “Low Cost Low Temperature Heat Pump Heating System” under contract from the Swiss Federal Office of Energy aims to develop a cost-effective and environmentally feasible heating system for low energy buildings. In its first phase, a feasibility study and an enhanced problem analysis have been carried out using a dynamic simulation program (TRNSYS).

It could be demonstrated that a continuous shut-off period of two hours has no negative impact on the comfort conditions within the building. However the supply temperature must be increased since the heat demand has to be covered in a shorter time. This results in a 5% lower seasonal performance factor (SPF).

The highest SPF can be achieved with earth-coupled heat pumps which can exhibit an SPF of 4.1 for heating only, and an SPF of 3 to 3.2 for space and tap water heating . This yields a primary energy ratio (PER) of 1.5 to 1.6 if electricity is generated by combined heat and power (CHP). This ratio could be higher considering the low COP of small heat pumps compared to larger units.

The yearly overall costs of a heat pump heating system with small capacity and low distribution temperature are in the same range as for a conventional oil heating system.

The results gathered in this first phase will assist in a second phase of feasibility study and problem analysis, which will then lead to the development of the heating system.

Source: Kostengünstige Niedrigtemperaturheizung mit Wärmepumpe (see Books and Software section).

Russians explore chemical cycle

Russia - In numerous industrial processes, waste heat is available at a temperature of about 80°C, which often cannot be used for subsequent applications. To raise the temperature to a useful level, a chemical heat pump offers several advantages over other solutions. This is because no mechanical compression is required to achieve a temperature increase. Only a small specific size of equipment is needed, and the system offers potential for long-term storage and long-distance transportation of thermal energy. In Siberia, Russia, a research project is planned for a specific type of a chemical heat pump.

The objective of the project is to develop a chemical heat pump system based on the endothermic dehydrogenation of 2-propanol at low temperatures, and the exothermic hydrogenation of acetone at higher temperatures. Specifically, catalysts for the dehydrogenation of 2-propanol will be improved and the application potential of chemical heat pumps will be evaluated more precisely.

Funds are still needed to cover the cost of the project, amounting to about USD 65,000. Interested parties can contact the address below.

Source: Prof. Dr Vladimir Anikeev
Head of Energy-Chemical Engineering Group
Boreskov Institute of Catalysis
Fax: +7-383-235 7687/5754.

Risk assessment study on HFC-32

USA - ARTI (Air-Conditioning & Refrigeration Technology Institute) has announced the start of two new research projects supported by the MCLR programme (Materials Compatibility and Lubricants Research).

The first project “Risk Assessment for A2 Refrigerants in a Split System Residential Heat Pump” will be conducted by Arthur D. Little, Inc. This project is a risk assessment of using R-32 and R32/134a (30/70) in a typical residential heat pump. The project will consist of small-scale flammability testing of the refrigerants with potential ignition sources, evaluation of potential damage, testing of possible leak scenarios (to include refrigerant/air concentration mapping and ignition testing) in a large-scale flammability test facility, and the preparation of a risk assessment. The project is scheduled to end by 30 September 1997.

A contract for a second project, “Effects of Temperature on Desiccant Catalysis of Refrigerant and Lubricant Decomposition”, was awarded to Spauschus Associates, Inc.

Source: Mr Steve Szymursi, Koldfax, November 1996.

Sanyo develops HFC compressors

Japan - Sanyo is planning to introduce new-type compressors using an HFC blend such as HFC-410A (R-410A) in early 1998. Although the ternary refrigerant R-407C is a promising alternative for HCFC-22, Sanyo selected R-410A as a first choice since it is efficient and the compressor can be made compact. Sanyo started with the development of rotary compressors for room air conditioners (RACs).

R-410A is a zeotropic refrigerant, a mixture of HFC-32 and HFC-125. Although it is very efficient, the design pressure is 41.5 bar (42.3 kg/cm^2) and this has been the largest bottleneck in its compressor application. The American and Canadian safety standards (UL, CSA) demand pressure resistance five times higher than the design pressure. To achieve this with R-410A, it is necessary to review the system design.

In the case of compressors for commercial packaged air conditioners (PACs), it is even more difficult to clear the high design pressure problem and the pressure resisting performance, thus there is a general trend to select an adequate refrigerant from a wider range of alternatives, including R-407C.

For low-temperature applications, although HFC-134a as an alternative for CFC has taken root, the current trend is towards R-404A (HFC-125/143/134a). Refrigeration equipment manufacturers have already finished the basic design of R-404A systems, including vehicle-mounted refrigeration units.

Source: JARN, November 1996.

NH_3 ice thermal storage system developed

Japan - Mayekwa Mfg. Co., Tokyo, and Chubu Electric Power Co., Nagoya have jointly developed Japan's first "Ammonia (NH_3) Ice Thermal Storage Heat-Pump Air Conditioning System", and are currently carrying out performance tests at Chubu Electric Power's Offices.

This system is benign to the global environment, as it uses ammonia with an ozone depletion potential (ODP) of zero. It is also designed as a unit-type ice thermal storage system which, by utilizing nighttime electricity, can shift the cooling peak and help to level out the electric power load.

A hermetically sealed motor has been included in the system. It also has a newly developed ammonia leakage prevention system which, by quickly responding to the detector, inhales gas into the ice thermal storage tank. An electronic expansion valve helps to reduce the ammonia charge and to improve the response to load variation. Using high performance lubricating oil reduces the replenishing frequency. This allows automatic operation and simplified maintenance comparable to a CFC system.

Source: JARN, December 1996.

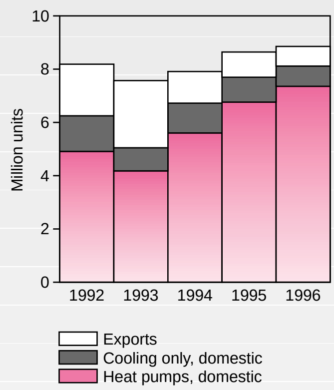
RAC shipments reach new record high

Japan - The domestic shipments of room air conditioners (RACs), i.e. the number of units delivered to Japanese sales outlets by manufacturers, amounted to more than 8 million units in the refrigeration year (RY) 96, exceeding the previous year's record. Although the export of RACs continued to decline, the total sales increased (see **Figure 1**). Shipments of packaged air conditioners (PACs) increased as well.

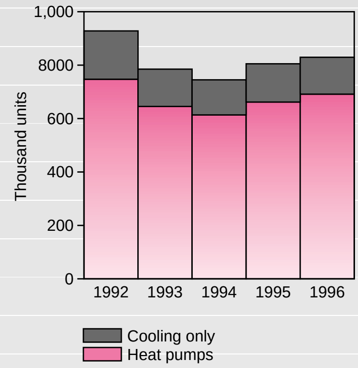
The share of heat pump RACs increased to 90% of the total, because the number of units of cooling-only RACs decreased, while the amount of heat pump RACs grew by over 8%.

Last year's trend of renewed growth in shipments of packaged air conditioners (PACs) was continued in RY 96 (see **Figure 2**) - which were up by 3%. PACs generally include equipment with a capacity of over 2.25 kW, many of which are multi-split systems with up to eight indoor units connected to one outdoor unit. Also for PACs, heat pump models are gaining over cooling-only models.

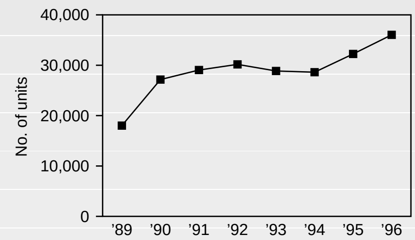
The domestic shipments of gas engine heat pumps (GHPs) in RY '96 has risen by 12% to 35,916 units. The GHPs are air-source types ranging from 1.5 kW to 22 kW. The trend is shown in **Figure 3**. This growth can be partly attributed to the sales promotion by the major town gas companies. It was also stimulated by the government energy policy for diversification of energy sources and shaving the peak electric power load, which is caused by huge demand for cooling on summer days.



▲ *Figure 1: Total RAC shipments.*



▲ *Figure 2: Domestic shipments of PACs.*



▲ *Figure 3: Trend in GHP sales.*

The number of absorption chillers, which are mainly installed in commercial buildings, slightly declined to 4,648, although the total capacity installed increased to 2,380,659 kW (754,089 RT) because of an increased average capacity per chiller.

Source: JARN.

Toshiba UK produces 100,000th AC

UK - In October, Toshiba celebrated the 100,000th air-conditioning (AC) system to roll off the production lines at its Plymouth-based European manufacturing plant. Since production began in November 1991, growth in demand has outstripped the company's planning expectations, and forced a series of rapid expansions. Growth of 40% last year stretched the factory to the limit.

Toshiba is now putting in place a more streamlined manufacturing system, adding new products around the initial core range. At the national HVAC show in London a total of 16 new packaged air-conditioning products were unveiled. The company is also expanding its R&D and sales and marketing to take the company to the next phase of development. Since much of the growth so far has come from the home UK market, which accounts for 60% of the sales, the objective is to place Toshiba's market on a wider footing across Europe.

Source: JARN, November 1996.

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Annex 23 reports on single-room market

Canada - IEA Heat Pump Programme Annex 23 on "Heat Pump Systems for Single-Room Applications" has just completed its first year of operation. The Annex addresses world markets for the use of heat pumps that can heat (and possibly cool) rooms in buildings not equipped with a ducted central system. Each of the participating countries has agreed to tabulate and share information on heat pump technologies and equipment to space-condition single rooms. To illustrate the results of this first phase, the situation in three countries is described below.

In **Sweden**, around 1.2 million houses use electric heating. Approximately half a million of these homes have electric-resistance baseboard heaters and consequently have no heat distribution systems. Heat pumps for single-room applications could provide these houses with a viable, cost-effective space-heating alternative. Such products would also prove useful for heating and cooling of commercial office buildings.

For users, room-sized heat pumps can reduce heating costs by as much as 60% and offer an environmentally superior system compared to conventional forms of space heating. An important obstacle to the growth of single-room heat pumps, however, is their limited cold-weather performance. In cold weather, the heating efficiency of an air-source heat pump is low and there are concerns about reliability. They also have little effect on the electricity peak load. In addition, electricity tariffs are still too low to make heat pump application attractive in an electric baseboard heated house. Novel, room-sized, heat pump products have been introduced in Sweden to overcome the limitations of the conventional equipment.

In general, single-room heat pumps only have a good chance in situations where no hydronic heat distribution systems are installed or planned. In **Switzerland**, this is currently limited to the retrofitting of buildings with decentral electric heating systems (direct or storage heaters), and to those with single furnaces that are heated with wood or coal.

Approximately 1.4 million electric room heaters under 5 kW are in use. As a part of the active government policy on efficient use of energy and the promotion of renewable energies, a license obligation was introduced for fixed resistance heaters. Together with higher tariffs, this has led to a considerable drop in sales of electric resistance heaters. Replacing them with central hydronic heating systems is expensive. Consequently, this represents a major opportunity for single-room heat pumps to gain ground.

The driving forces behind the heat pump market in **Canada** are the environmental and financial benefits. The present low cost of heating residential homes with conventional natural gas systems makes most heat pump systems difficult to justify in gas-heated areas. However, space cooling often justifies the initial cost of a reversible heat pump. The need for mechanical ventilation in new buildings could create a market for exhaust-air (heating only) heat pumps as it has in Sweden.

One potential market for single-room heat pumps is in hotels, motels and apartments. In Canada and the US, many motels and hotels have wall units that need to heat and cool. Direct electric-resistance heating often results in the lowest initial cost. However, there are many attractive heat recovery and hot water opportunities and single-room heat pump development should focus on the needs of hotel and motel owners.

A workshop is being scheduled in 1998 to discuss and present the Annex results. The participants of Annex 23 have also linked with ASHRAE to help organize a forum titled "New Ideas for Non-Ducted Heat Pumps / Air-Conditioners for Single Zones". The forum is scheduled for the Boston ASHRAE Annual Meeting in June.

Source: Mr Frank Lenarduzzi, Operating Agent Annex 23, Ontario Hydro Technologies.
Fax: +1-416-207 6565.

Annex 22 workshop announced

USA - The Oak Ridge National Laboratory will host the second Annex 22 workshop on Compression Systems with natural Working Fluids. This workshop will focus on the results of the research/development and prototype/demonstration projects conducted under the Annex. It will take place on 2 and 3 October 1997 in Gatlinburg, Tennessee, USA, in conjunction with the ASHRAE/ NIST Conference "Refrigerants for the 21st Century" which will be held on 6 and 7 October 1997. The 1997 working meeting will take place on 4 October 1997 on the same location.

Source: Mr Jørn Stene, SINTEF Energy.
Fax: +47-73-593 950.

Thermally-activated heat pumps

An international overview

Mike Steadman and Gerdi Breembroek, IEA Heat Pump Centre

Most of the world's heat pumping systems are electrically driven. Millions of refrigerators, air conditioners and heat pumps meet the needs of their users with good reliability. So why should anyone want to use a thermally-activated system? Focusing on absorption and gas engine equipment, this article highlights attempts to answer this question by highlighting the benefits of the thermally-activated option. In addition, reports from various IEA Heat Pump Centre member countries and an overview of the international market give insight to today's market status and the type of equipment being applied.

The term "thermally-activated heat pumping equipment" describes systems which use thermal energy to drive a heat pump cycle for producing cold and/or heat. It includes thermal compression systems, such as absorption equipment, and mechanical compression systems driven by an engine. It excludes electric heat pumps even though the electricity may be generated thermally. Thermal compression systems include absorption and adsorption heat pumping systems and certain types of chemical heat pump. Other thermally-activated heat pumping technologies are the Stirling-cycle and the desiccant cooling system. This article focuses on absorption and engine-driven systems - the technologies that are most widely-applied at present.

The world market for absorption and gas engine systems currently stands at over 40,000 units per year. While this is very small compared to the market for electric air conditioners, heat pumps and refrigeration systems, the market is nonetheless of significant commercial interest. So what is the motivation for purchasers of thermally-activated equipment?

Low running costs

The answer, for many users of absorption and engine-driven equipment, is running costs. The ratio between the price of electricity and gas varies considerably, but electricity typically costs between two and four times more for a unit of energy. A typical gas cooling unit will require about three times as much gas energy as equivalent electrical energy to meet the same cooling demand. So in some situations it can cost less to run a gas-driven system.

Energy costs tend to favour gas-driven equipment in the summer. In regions with a large cooling demand, power utilities set higher electricity tariffs during the summer in order to reduce the peak demand. Conversely, gas utilities may reduce their prices in summer to reflect the low demand for gas-fired heating and to encourage gas-driven cooling.

In some countries, such as Japan, the government regards the need to reduce peak electricity demand in summer as one of national importance and is therefore prepared to support the use and development of thermally-activated heat pumping systems, as well as cold storage systems.

Harmless working fluids

In addition to running costs, there are other reasons for choosing a thermally-activated system. For absorption systems, the fact that they do not use CFCs or HCFCs has been a key factor in widening their appeal. The phase-out of these refrigerants, and the uncertainty over their replacement has encouraged equipment buyers to choose an absorption system with water or ammonia as the refrigerant instead of conventional HCFC vapour compression systems.

Better for heating

Particularly in central Europe, many houses have hydronic (wet) central heating systems operating at up to 80°C. Such systems are unsuitable for electric heat pumps which cannot reach the high temperatures needed for the coldest days unless an electric resistance or fossil-fuel backup system is also installed - adding to the costs. Gas-driven heat pumps, however, can be designed to supply heat at the temperature needed to meet the peak demand without an auxiliary heater.

Using waste heat

A unique feature of absorption heat pumps is that they can be driven by waste heat. This opens up a range of applications such as using waste heat from industry or heat from refuse incineration. A recent trend is to drive absorption chillers with heat from district heating networks and cogeneration systems. In the summer months district heating systems are under-used, and therefore expensive to run. At the same time, there is an increased need for cooling, especially in commercial and institutional buildings. Using this heat to drive an absorption chiller can be an economically-beneficial option.

Good reliability

Another reason for choosing absorption technology is that it is intrinsically reliable. Because compression is achieved thermally instead of mechanically, absorption heat pumps suffer less mechanical stress than electric or engine-driven equipment. The only moving parts are liquid pumps. Indeed, the diffusion-absorption heat pump **(see page 26)** has no moving parts at all.

Gas-engine heat pumps, however, are more difficult to design with a comparable level of reliability. Like car engines, the gas engines must undergo regular service checks and changes of oil and components.

How many are there?

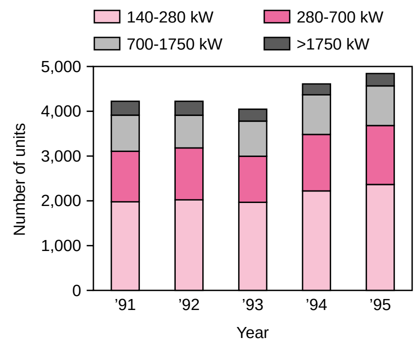
The most widely applied thermally-activated system is the absorption chiller, which is a cooling-only system used for air conditioning in large commercial buildings and for refrigeration in the food industry. The market is dominated by Japanese and US manufacturers. Over 6000 absorption chillers are produced annually in Japan and a further 2000 in the USA. Many of them are imported. The market for gas engine heat pumping equipment is concentrated in Japan, where more than 30,000 units are sold annually. China is a rapidly developing market, too.

Absorption systems

Figures 1 and 2 show the domestic sales of absorption chillers in Japan and the US. The US models range in size from 350 kW to 7 MW. The Japanese systems are typically smaller, with almost half having a cooling capacity of between 140 kW and 280 kW.

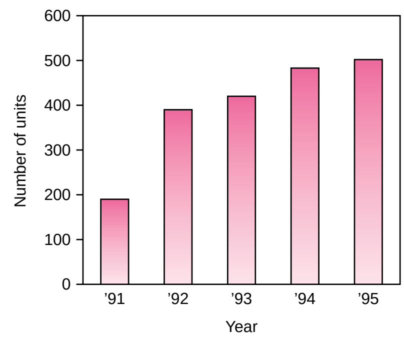
Figure 3 shows that around half of the absorption chillers in Japan are gas driven, and around one third are oil driven. The rest are driven by heat sources such as in the form of steam or hot water.

The market in Europe is much smaller. Germany is reported to have 634 absorption machines with a total refrigerating capacity of 679 MW. This market



▲ *Figure 1: Annual sales of absorption chillers in Japan.*

▼ *Figure 2: Annual sales of absorption chillers in USA.*



is growing, mainly due to the promotion of this technique by the gas industry.

The French gas utility Gaz de France is also actively promoting absorption chillers. In 1992 it launched a programme to promote gas-operated air-conditioning systems with the objective of gaining 10% of the air-conditioning market by the year 2000. Five absorption chiller-heaters were installed in 1993 and four more in 1994.

In Switzerland, some 50 installations are currently in service with a refrigerating capacity of approximately 50 MW.

Another country with a significant market for absorption chillers is the Republic of Korea. Sales of 1,500 absorption chillers are reported for 1994.

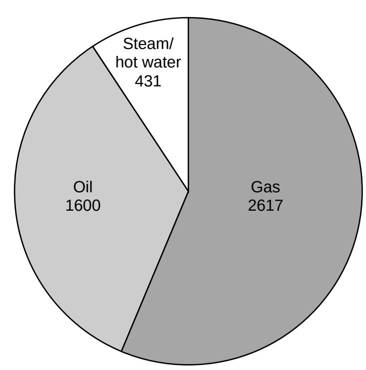
In China, the absorption chiller market is developing fast. An example of a popular unit is a directly-fired absorption unit with a capacity of 400 kW, supplying chilled and hot water. They do not suffer from insufficient electricity supplies, like the electric heat pumping units. A total production of 1,500 absorption units over 1995 was estimated.

Absorption cycles

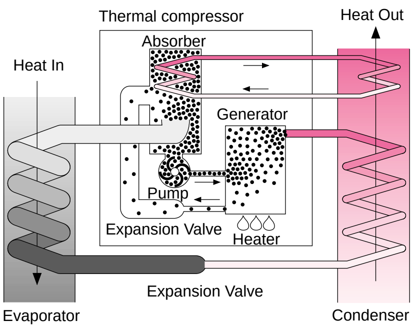
The early absorption chillers were single-effect systems operating with a single evaporator, condenser, absorber and generator, as illustrated in **Figure 4**. A higher efficiency can be achieved by adding a second generator/condenser combination. Such cycles are known as double-effect. A system using a double-effect cycle can exhibit a cooling PER (primary energy ratio) of up to 1.2, whilst a typical single-effect system has a cooling PER of 0.7. A number of US and Japanese manufacturers are now producing double-effect chillers.

Cooling PERs of up to 1.6 are possible with triple-effect systems. Currently, there are no triple-effect absorption chillers sold commercially. However, much work is ongoing in the development of such systems.

Another concept, which has been developed to improve energy efficiency, is the GAX (generator-absorber heat exchange) cycle, whereby heat is recovered from the absorber and used in the generator. The GAX cycle is especially beneficial for heating purposes, for which PERs of up to 1.5 can be reached.



▲ *Figure 3: Japanese sales breakdown for 1996 according to drive energy.*



▲ *Figure 4: Illustration of absorption heat pump operation. In the thermal compressor, working fluid vapour from the evaporator is absorbed in a solution and heat is given off. The weakened solution is pumped to the generator at a higher pressure. Here, heat is applied to release the working fluid gas at a high temperature and pressure.*

Absorption heating

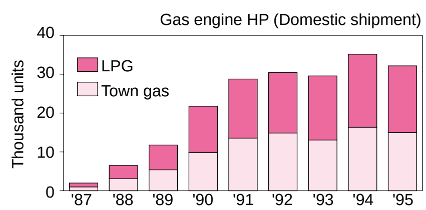
Very few absorption chillers provide heating. If they do supply heating then this heat is taken from the driving heat source. Very few systems operate in heat pump mode. It is reported that some 100 heat pump absorption systems have been installed in Japan since 1971. Sanyo, for example, had produced 55 double-effect units up until the end of 1995. There appears to be more interest in heat pump absorption systems in Europe. Sweden has nine large absorption heat pumps providing district heating. In Germany, it is reported that 100 absorption heat pumps have been installed in homes, 75 in commercial buildings and 110 in industry, as well as a few industrial heat transformers.

Absorption heat pumps for the home have been developed in Austria and Switzerland (see articles on **pages 20 and 26).** These are designed to meet the heating needs of the typical home in central Europe which currently uses a gas or oil-fired boiler with a high-temperature hydronic (wet) heat distribution system. In the US and Japan, residential units for cooling and heating are under development.

Larger systems, using the GAX cycle, have been developed in the US and the Netherlands and are now on the market. The GAX heat pump developed by the Dutch company Colibri has proven its potential with its first application in a local government building in Maastricht in the Netherlands. Using heat from the river Maas, the system has registered PERs of over 1.5 during the heating season (see also **page 27**).

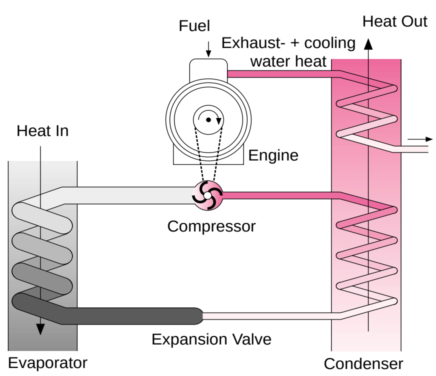
Gas engine systems

The use of gas engines to drive medium to large size compression heat pump systems was significant in the 1980s in Europe, mainly in countries with a gas infrastructure. Due to dropping energy prices, many installations were dismantled. As shown in **Figure 5**, sales in Japan rose sharply at the beginning of the 1990s. These are air-source systems, most of which have a cooling capacity of between 1.5 kW and 22 kW. They are installed in medium-sized buildings such as offices, factories, restaurants, schools and hospitals. Their strong market growth owes much to the support of the gas utilities.



▲ *Figure 5: Gas engine heat pump sales in Japan.*

▼ *Figure 6: Illustration of gas engine heat pump operation.*



Gas engine systems have been less successful in the US. In 1992 it was reported that just 10 to 50 units were installed in the commercial buildings sector and 100 to 200 in the residential sector. This situation has changed significantly with the introduction of the York Triathlon heat pump in August 1994. Over 2000 units were sold in the first two years.

In Europe, the biggest numbers for gas engine systems is for Germany where it is reported that 870 units were installed in 1992 - 120 in homes, 365 in commercial buildings, and 373 in industry. Relatively few gas engine heat pumps were installed in the Netherlands in the early 1980s, as well as in the UK and France.

Heat recovery

Figure 6 illustrates the operation of a gas engine heat pump. As shown, heat from the engine's exhaust and cooling water is added to the heat output from the condenser. This heat amounts to approximately 45% of the energy content of the fuel, 30% carried by the cooling water and 15% by the exhaust gases. This heat allows a gas engine air-to-air heat pump to supply indoor air at a higher temperature. Alternatively, the heat may be recovered to supply hot tap-water.

Two methods are used for the recovery of engine heat. In the "two-pipe" method, the refrigerant is the only medium that transfers heat between the indoor and the outdoor unit. The heat from the engine's cooling system is transferred to the refrigerant by a heat exchanger. This is shown in the figure on page 13. With the "four-pipe" method, the engine's cooling system forms a separate loop that can transfer its heat directly to the room or to the outside. Japanese gas-engine heat pumps use the two-pipe method, while the York Triathlon is a four-pipe system.

A key factor in the design of gas engine systems is the durability of the engine. Research in this field has improved engine reliability such that they can run for up to 4,000 hours without maintenance.

Intense development work has also been carried out to minimize the emission levels from gas engines through the use of catalytic converters and special combustion techniques.

Efficiency

An important advantage of an engine-driven compressor is its inherent ability for variable-speed operation and therefore energy-efficient performance under part-load conditions. In field tests, the York Triathlon gas engine system registered seasonal cooling PERs of between 0.8 and 1.3 and seasonal heating PERs of up to 1.7. Such efficient use of primary energy is hard to achieve with electric heat pumps used in combination with conventional power generation equipment.

Thermal or electric?

At the IEA Heat Pump Centre we try to encourage the inclusion of heat pumps in national and regional policies for reducing energy consumption and environmental emissions. This brings the question - should the policy be for absorption, gas-engine or electric systems, or for a combination of these?

Until recently, the electric heat pump was the obvious choice. There was little experience in using absorption systems and the availability of efficient products on the market was poor. Although gas-engine systems were used in Europe in the 1980s, some of the installations were poorly designed and they did not meet the expectations. Now this situation is changing, at least for medium to large-sized applications.

If natural gas is the available energy source there is little to choose between them. The combination of a gas-fired

Austria

Thermally-activated heat pumps are not very common in Austria, even though an absorption unit had ran for many years in the Amalienbad, a public indoor swimming facility in Vienna.

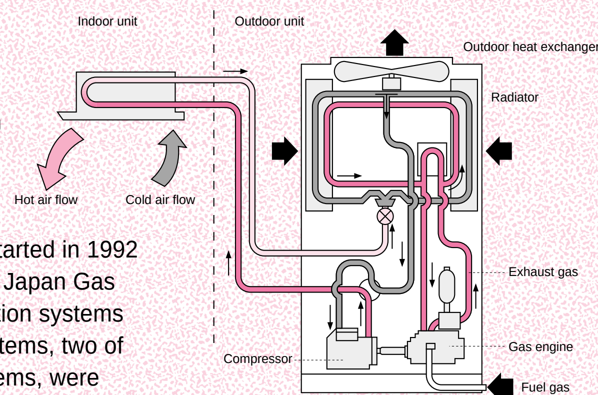
In the 1980s, several small engine-driven units for heating of residential buildings were developed but the market penetration of these systems failed. Nowadays, an increasing number of absorption systems are in operation in industrial applications, mainly for cooling purposes. In hospitals, such as the Allgemeines Krankenhaus in Vienna, large absorption systems are used to provide both heating and cooling. For residential and small commercial applications the Heliotherm Company in Tyrol has developed a small gas-fired absorption unit suitable for both heating and cooling. The unit is also suitable for the retrofit market, as it can operate in combination with an auxiliary boiler for peak load, and higher water temperatures.

The spread of thermally-activated heat pumps is expected to grow for two reasons. Gas utilities are now interested in gas-driven air-conditioning equipment, and district heating companies consider selling cold during the summer time for air-conditioning purposes. The combination of gas engine-driven combined heat and power plants and absorption units, where the generator is heated by waste heat from the engine, is also being studied.

Source: Mr Hermann Halozan, Austrian National Team.

Japan

Of the various types of thermally-activated heat pumps, the gas engine heat pump is the most significant item on the market at this moment. Sales have now surpassed 30,000 units a year with the total installation stock amounting to about 200,000. Most of these units are multi-split type, with multiple indoor units coupled to an outdoor engine-driven unit with refrigerant piping, similar to the electric heat pumps popularly used in small commercial buildings. The figure illustrates a typical system. They are installed mainly in offices, restaurants, supermarkets, hospitals, schools and factories.



Three national R&D projects on small thermally-activated heat pumps were conducted in Japan, of which two were completed in the 1980s. The third project, on residential heat pumps, started in 1992 and was managed by the Japan Gas Association. Four absorption systems and five compression systems, two of which are Vuillemier systems, were developed. The specifications of the three systems that have been selected for field testing are given in the **table**. The developers aim for a PER of at least 0.7 for cooling and 0.75 for heating, and for a service requirement of just once in every three to five years.

Source: Mr Yoshio Igarashi and Mr Takeshi Yoshii of the Japanese National Team.

Manufacturer	Takagi	Honda-Sanyo	Yanmar
Type of heat pump	absorption	gas engine	gas engine
Working fluid	water-LiBr	HCFC	HCFC
No. of rooms	1	2	3
Cooling/heating capacity (kW)	2.2/3.5	5.0/6.0	6.7/8.7

combined heat and power generator with an electric heat pump can be expected to supply heat with a PER of around 1.5. A similar performance is achievable with absorption and gas engine systems. However, there are a number of points that could give thermally-activated heat pumps the edge over the electric system.

Firstly, they can reach the high temperatures needed in retrofit situations with traditional heat distribution systems. In contrast, electric heat pumps cannot easily operate with high-temperature heat distribution systems and therefore their use tends to be confined to new buildings. For this reason a policy to encourage the application of thermally-activated heat pumps in the, much larger, retrofit market could have a considerable impact on energy consumption.

Secondly, a policy to support thermally-activated heat pumps is simpler to implement than an electric heat pump policy. With electric heat pumps, policies should also take account of how to generate the excess power needed to drive the heat pumps. In Switzerland, for example, the electric heat pump policy is coupled with policies to encourage the use of combined heat and power (CHP) plant.

A particular advantage for absorption systems is that it is relatively simple to design them so as to provide back-up heating in the form of a gas burner. For electric heat pumps, this is often done with resistance heating which is far less efficient.

Finally, absorption systems have an inherently high reliability due to their lack of moving parts, and they do not use HCFCs.

Norway

There are currently no absorption, adsorption or engine driven heat pumps installed in Norway. This is because electricity generation is almost entirely based on hydropower. Due to a surplus of hydropower, electricity prices have been low for many years. In 1996 the average price to the consumer, including taxes and transmission charges, was US$ 0.075/kWh (firm power - 100% availability). Industrial users pay even less for occasional power (availability < 90%), which has an average price of US$ 0.023/kWh. Gas-driven heat pumps cannot compete with such low prices. Furthermore, a heat pump driven by electricity from hydropower has an overall energy efficiency (PER) of 3 to 4, whereas gas engine-driven systems and absorption systems attain PERs of 0.8-2.0 and 1.0-1.6 respectively.

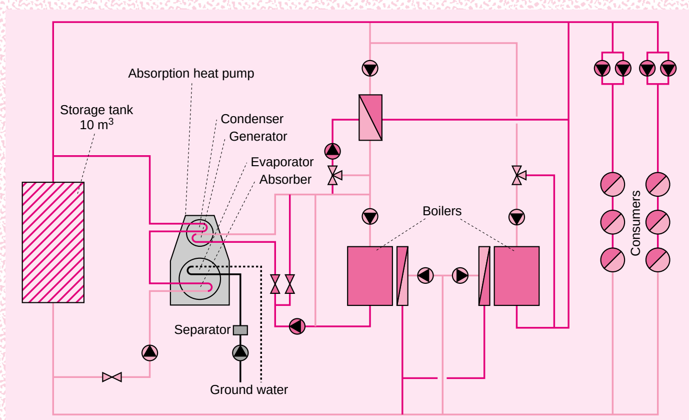
In Norway, a number of waste incineration plants is connected to a district heating system for space and hot water heating in residential and commercial buildings. The surplus heat of these systems in summer may be used to drive absorption cycles for district cooling. This would lead to a cooling capacity of 140 GWh/year. However, with current electricity prices, these systems cannot compete with electric chillers or with district cooling systems with electric heat pumps.

Mr Jørn Stene, Norwegian National Team.

Switzerland

A recent study which highlights the benefits of absorption heat pumps could lead to more widespread application of this technology. It showed that the reliability and service life of absorption machines is as good as or better than that of compression machines. Furthermore, the profitability is higher when low-cost heat energy is available from natural gas or as waste heat, such as from combined heat and power stations, or refuse incinerators. The study also found that the energy efficiency of a gas-fired absorption heat pump approximates that of an electric heat pump driven by combined heat and power.

A good example of an absorption heat pump is the installation in a major building development. The water-lithium bromide heat pump uses ground water as a heat source and is driven by hot water (115/109°C) from a low-NO_x gas boiler (see **Figure**). It covers some 40% of the total heat requirement for space heating and hot water production. Electric heat pumps are used to increase the temperature for hot water supply.



The heating PER is between 1.42 and 1.45 in summer and 1.30 and 1.45 in winter operation. If the electricity consumption is included, the annual heating PER works out at around 1.35.

Source: Mr Thomas Afjei, Swiss National Team.

The Netherlands

In 1993 it was reported that a total of 54 thermally-activated heat pumps had been installed in the Netherlands. Thirty gas-engine systems were installed in commercial buildings and a further 12 in industry. GAX absorption heat pumps have been installed in institutional buildings in Maastricht and Heerlen. A larger, 1.4 MW cooling capacity, system is being installed for the food industry (see article on **page 27**).

Interest is growing in gas-fired heating systems. A market study is being conducted by GASTEC and several thermally-activated systems are being tested to determine their suitability for the Dutch market. The **photo** shows the York Triathlon heat pump from the US in test laboratories at GASTEC. Also under serious consideration is the absorption diffusion heat pump.

Source: Mr Ad van Maaren, GASTEC. Fax: +31-555-393-494.

USA

Thermally-driven heat pumping systems are seeing significant growth in the US, with the primary focus on absorption chillers and natural gas engine-driven heating and cooling equipment for commercial applications. The Trane Company, with support from the Gas Research Institute (GRI) and the American Gas Cooling Center (AGCC), has introduced the Horizon line of absorption chillers for commercial buildings (see article on **page 16**), and McQuay and Tecogen are having success with their respective lines of gas engine chillers.

Perhaps the most significant market development is the introduction of the York Triathlon Heating and Cooling System. Triathlon was developed with support from GRI, AGCC, and gas utilities. Driven by a single-cylinder, four-stroke, 4 kW (5 hp) natural gas engine, this 11 kW (3 ton) heat pump has been on the market for over two years and is selling well in the American South-east, with significant market penetration in the American South-west as well. The heat pump can yield a heating SPF of 4.1 (HSPF of 14) and a cooling SPF of 4.5 (SEER of 15.5), and yields strong peak load and cost saving benefits during the summer months. In a demonstration project for the Federal Energy Management Program, the Triathlon was installed at several military installations in single-family housing, and yielded cost savings of 32.9 percent over electric heating and cooling systems.

In partnership with gas industry partners, the US DOE is proceeding with final development activities to bring the GAX (generator-absorber heat exchange) heat pump to the market. With a prototype heating COP of 1.6 to 1.8 and a cooling COP of 0.7 to 0.9, the GAX concept holds tremendous potential for energy savings and energy demand levelling. The DOE is also working with private industry on triple-effect absorption chillers, even higher-efficiency absorption heat pumps, and working fluids and computer design tools for thermally-activated systems.

Source: Sandy Smith of Oak Ridge National Laboratory, Gary Bedard of York International, and Bob DeVault of Oak Ridge National Laboratory.

A drawback of thermally-activated heat pumps is that their initial cost is higher than that of electric systems. Engine-driven systems also require noise protection.

While thermally-activated heat pumps have only a minor market impact at present, in comparison to their electric cousins, the signs are that this will change as awareness of their benefits grows.

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References:
Sweetser, R.S. "Fundamentals of Natural Gas Cooling", The Fairmont Press, Lilburn, 1996.

HPC-Analysis study AR-3 "International heat pump status and policy review" 1993.

Nowakowski, G.A., "An introductory and Status update on unitary engine-driven heat pumps", ASHRAE Journal 38 (1996/12) 42-47.

Absorption chillers

Expanding the options for commercial buildings HVAC systems

Jennifer Hok, USA

Owners today are faced with many issues when selecting appropriate equipment for their buildings, including energy efficiency, air quality, CFC replacement and deregulation. Because of these issues, gas technologies, particularly direct-fired absorption chillers and engine-driven chillers, are becoming increasingly popular with many owners and engineers. This article discusses direct-fired absorption chillers, how they work and some of the features that are critical in meeting today's building requirements.

In order to understand the increasing popularity of absorption chillers, it helps to examine the market and how direct-fired absorption technology evolved in the United States. In the 1960s, the absorption business was booming and gas was extremely inexpensive. Single-effect absorption cooling was the mainstay for building chiller plants. The first indirect-fired, two-stage steam absorption chiller was introduced in the 1970s.

A year later the oil crisis hit and, because of the lack of stability with energy resources, absorption all but disappeared. In the 1980s, demand for efficient gas-fired absorption machines reemerged due, once again, to the ready availability of natural gas as a cost-efficient primary fuel. Gas-fired machines were popular in other markets such as Japan and as a result, most US manufacturers joined Japanese manufacturers to bring gas-fired machines to the US market in a timely fashion.

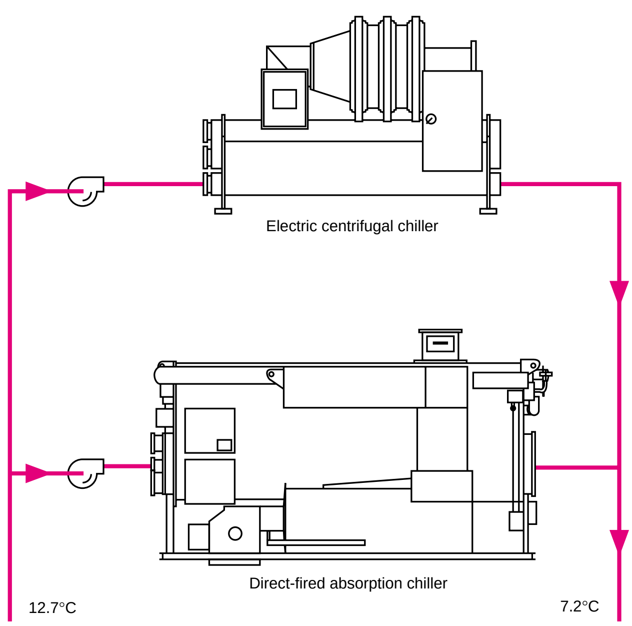
New opportunities

In the early 1990s, new opportunities were presented by changes within the building construction market and owner expectations. The construction market moved away from new building work to a retrofit market. At that time, microprocessor control systems were also becoming more common and were expected to be provided on all new equipment coming onto the market. It was at this point that The Trane Company, assisted by the Gas Research Institute, started to design its "Horizon™" absorption chiller line.

The application of absorption chillers should be considered when looking at replacing an existing HVAC system or when a new chiller plant is to be built. They could be the most cost-effective system for a building. Consider the following three cases where an absorption cycle might make sense.

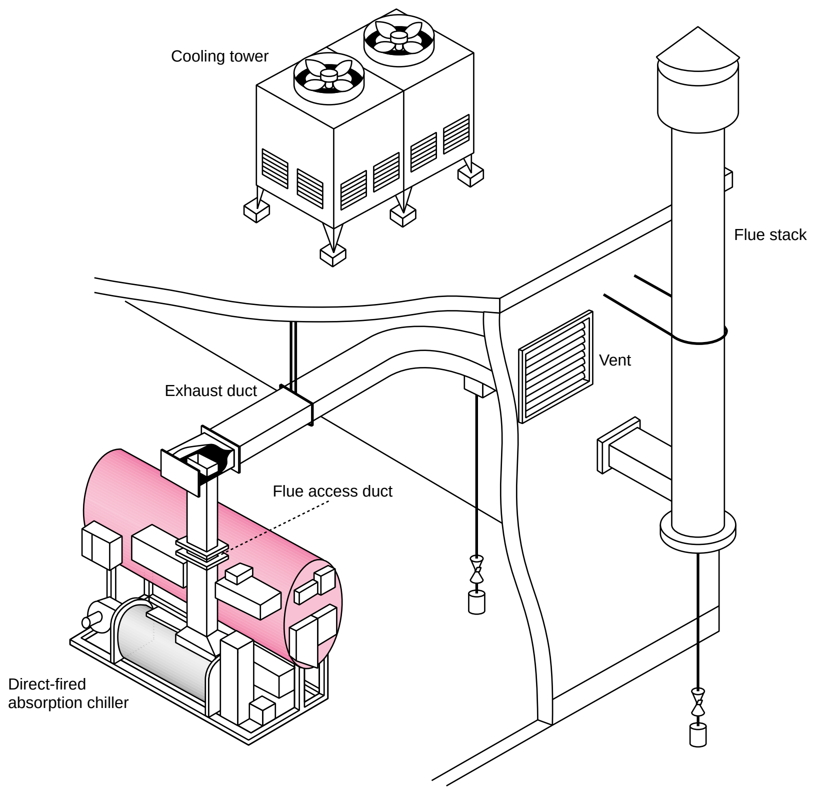
First, cases where electrical demand rates are very high, driving costs up with even the most efficient compressor chillers. An absorption alternative can reduce the total cost of cooling where the owner has access to favourably-priced natural gas.

Figure 1: A hybrid gas/electric system.



Another ideal application for absorption equipment is in combined energy source systems. These hybrid gas/electric systems (see **Figure 1**), allow the operator to make energy choices based on building energy demand patterns and variable pricing for alternative energy sources.

A third case is the replacement of an old electric chiller and boiler with a single piece of machinery. The direct-fired absorption chiller is capable of producing hot water temperatures up to 82°C with a primary energy ratio (PER) for cooling of 1.0. Benefits an owner receives from this type of system include the reduced volume of equipment to maintain and potentially lower initial cost. The Trane "Horizon" machine is designed for lower cooling tower water flows of 0.23 m^3/kWh (3.6 gpm/ton) versus the Air-Conditioning and Refrigerating Institute (ARI) standard of 0.29 m^3/kWh (4.5 gpm/ton), making it an attractive replacement for an electric chiller since existing towers or pumps may not have to be replaced. This approach is illustrated in **Figure 2**.



▲ *Figure 2: Layout of a situation where a direct-fired absorption chiller is used.*

Environmental benefits

The 1980s saw significant changes in air quality requirements that not only applied to the inside of a building, but also to the outside environment. CFCs were found to be harming the environment by depleting the ozone layer. As a result, specific areas of the country placed restrictions on other types of emissions. Because of these restrictions, many building owners are looking for alternative refrigerants that meet all requirements. The direct-fired chiller which uses water/lithium bromide as the working fluid is therefore an attractive option. Direct-fired chillers are also available with low-NO_x burners, meeting the strict emissions requirements of southern California and other areas. By using a direct-fired chiller, a building owner can have reduced environmental concerns.

Controls

Today, microprocessor controls are an industry standard. With these advanced controls, many of the problems inherent to absorption chillers have all but disappeared. Crystallization, the precipitation of salt crystals when the solution gets too strong, is now mainly a problem of the past. Microprocessor controls are able to monitor conditions in the absorption machine and take corrective action before crystallization can occur. Ultimately, microprocessor controls allow a chiller to operate safely and reliably at full load and partial load conditions.

Triple-Effect

Current absorption technology has reached its maximum effectiveness and thermal dynamic efficiencies. Triple-effect absorption is the next evolutionary step in the advancement of higher efficiency absorption technology. With PERs for cooling in the range of 1.4 to 1.5, gas-fired, triple-effect absorption chillers can compete directly with mechanical compression systems on an energy consumption basis.

The triple-effect can be achieved by simply stacking another high-temperature generator on a conventional double-effect water/lithium bromide cycle. However, numerous challenges must be addressed, including engineering, chemistry and regulatory concerns. These challenges will have to be overcome to make a triple-effect cycle acceptable to the public. This “stacked” triple-effect cycle is under development by a number of absorption manufacturers around the world.

Over the past eight years, Trane has overcome many of the engineering and chemistry challenges related to this triple-effect cycle. In the first quarter of 1997, Trane will test a prototype triple-effect chiller that will yield a cooling PER in the range of 1.4 to 1.5.

The Future of Gas Technology

Considering the ever-changing market and improvements made so far, absorption technology is definitely an alternative that should be considered when designing a system. The results obtained from an economic study might come as a surprise, especially where gas rates are favourable.

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The absorption process - what are its prospects ?

Pierre Renaud and Martin Kernen, Switzerland

Absorption machines represent a valuable alternative to compression machines for cooling. The absorption process has been demonstrating its qualities – reliability, long life, low maintenance, profitability – for several decades in the USA and Japan, where it is widely used. In Switzerland, absorption is still not well known in professional circles, which hinders its application. A targeted promotion action would enable the enormous potential of this technology to be exploited. Besides machines for cooling, this potential also includes absorption machines that are used as heat pumps for heating at low temperature. These can have a very interesting coefficient of performance (COP) compared to the COP of gas furnaces.

The absorption principle is shown schematically in **Figure 1**. The essential difference between the absorption and compression cycles is the way in which the transformation of the gaseous refrigerant from low to high pressure takes place.

In absorption machines, the refrigerant is first absorbed in a liquid solution before being “compressed” in liquid form. The compression of a liquid requires much less energy than for a gas. Absorption machines therefore consume very little electrical energy to drive the liquid pump. The main energy requirement is for thermal energy from fuel, waste heat or solar heat, for separating the liquid refrigerant from the solution by boiling.

Where is it used?

The applications for this process are many:

- industrial cooling for large-scale cold storage depots
- cooling for preservation purposes throughout the food industry
- general air conditioning (hospitals, administrative buildings etc.)
- building heating, in heat pump operation.

It is worth noting that the Swiss Confederation is currently supporting the development of an absorption heat pump combined with a boiler. Such a module enables the coefficients of performance achieved by condensing boilers to be extensively surpassed. The aim of this absorption heat pump in combination with a boiler is to yield an annual primary energy ratio of 1.5 (a heating efficiency of 150%).

The absorption cycle can be powered by different energy sources:

- flue gas, used directly in the generator
- waste heat from combined heat and power (CHP) stations
- waste heat from industry
- heat from district heating systems (including those supplied by domestic waste incineration plants)
- solar energy.

How is it applied?

The engineering of a system is relatively simple. However, it is imperative that certain criteria need to be satisfied to guarantee the proper operation and reliability of the installation.

The *hydronic system* must be planned with care. The levels of temperature and output must be carefully observed, taking into account the large heat losses of the heat exchangers.

The *cooling tower* must be correctly sized to ensure the proper functioning of the absorption installation.

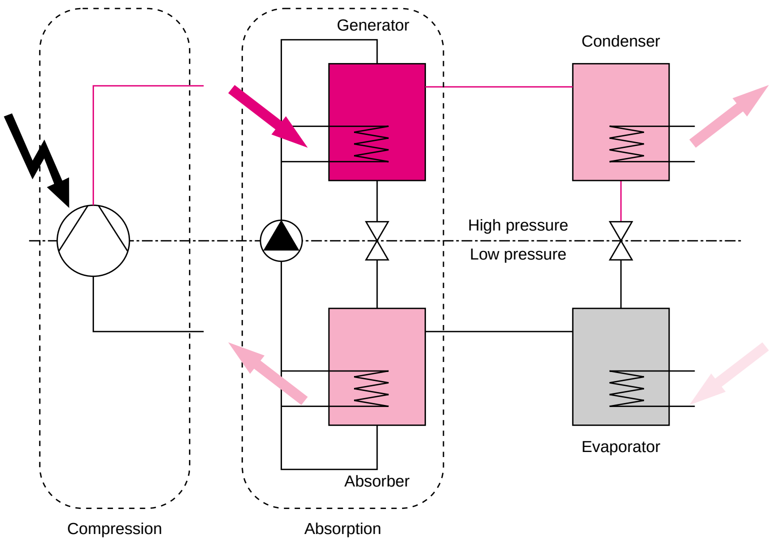
It is important to note that the behaviour of absorption machines under *part load conditions* is different to that of compression-type refrigeration systems. As shown in **Figure 2**, the efficiency of an absorption machine can be higher under part load conditions.

Absorption equipment has a good record for *service life and maintenance*. An installation which is properly planned and executed is subject to very little wear because the machines have very few moving parts (no motor or compressor). Around the world, large numbers of machines have been in operation for many years. Some, such as in American university campuses, have been operating for more than 30 years.

Because absorption machines do not use refrigerants which destroy the ozone layer and produce a greenhouse effect they are not subject to the *regulations* such as those concerning the use of CFCs, HCFCs or HFCs. However, many machines contain ammonia and must meet the necessary safety requirements. It would be beneficial to have more flexible legislation with respect to ammonia for machines containing very small amounts of this substance.

What is the market?

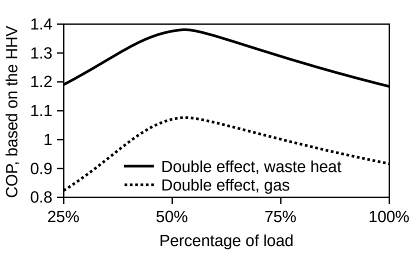
The largest market for absorption machines is in Japan where 4,648 machines were shipped to wholesalers in the year to September 1996, with a total refrigerating capacity of 2.65 GW. The US market is also large and is growing steadily, with shipments of absorption chillers rising to 502 units in 1995.



▲ *Figure 1: Schematic representation of difference between absorption and compression principle.*

In Germany, 634 machines have been installed, with a total refrigerating capacity of 679 MW. This market is growing, mainly due to the promotion of this technology by the gas industry. The market is also growing in France where Gaz de France have been running a programme to promote gas-operated air-conditioning systems since 1992. The objective is to gain 10% of the airconditioning market by the year 2000.

▼ *Figure 2: Efficiency of an absorption machine depending on the load. (HHV: Higher Heating Value)*



In Switzerland, approximately 50 installations are currently in service with a refrigerating capacity of around 50 MW. The majority of these installations operate on district heating systems supplied by domestic waste incineration plants or with the heat from CHP. There are also a few gas-operated installations. Two projects in French-speaking Switzerland are described below.

At the SIG administrative building in Le Lignon, Geneva, a single-stage absorption machine, with a refrigerating capacity of 1,234 kW, provides air conditioning by recycling heat from a gas-fired CHP plant. This installation improves the profitability of the CHP plant by increasing it's annual operating time.

Another absorption machine is installed at the printing works of Heliographia in Cheseaux-sur-Lausanne, to supply cooling for the rotary printing machines and for air conditioning. This 650 kW (cooling capacity) installation is supplied solely with thermal energy recycled from the rotary printing machines. The extra cost of the absorption installation, compared to a compression installation, was paid back in approximately three years.

In need of promotion

Absorption technology represents an advantageous alternative to compression systems for the production of cooling. The benefits include:

- good reliability
- long service life
- low maintenance requirements
- no noise or vibration

It is also very beneficial with respect to energy conservation, especially when used in combination with waste heat or when using heat from domestic waste incineration.

In Switzerland, however, absorption technology is not widely used because of a lack of information. By contrast, in France, and especially in Germany, absorption technology is well-known in the building industry. This is because the gas industry has been on the offensive for some years to promote cooling with natural gas. Information is provided through seminars and brochures, consultancy services are available to advise customers, and training is given to engineers. In some cases, the gas utilities offer special tariff structures for absorption equipment.

In Switzerland, a targeted promotion campaign is needed to bring about a substantial increase in the number of absorption installations.

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Absorption heat pump for home retrofit

Uli Spindler, Austria

The Austrian heat pump and solar technology company Heliotherm Wärmepumpen- und Solartechnik has developed an absorption heat pump (AHP) specially designed for the retrofitting of gas and oil boilers in one and two family houses. The AHP is driven by a gas or oil burner and offers a maximum heat supply temperature of 70°C and a capacity of 20 kW in boiler mode. In heat pump operation (15 kW heating capacity) it reaches a primary energy ratio (PER) of up to 1.43 and a maximum temperature of 50°C. In December 1996 the first prototype was set up in a nursery school in Amaliendorf, Austria. Heliotherm is now looking for a partner to complete the development and to start mass production.

In central Europe, about one third of the primary energy consumption is used for space heating, most of which is for residential housing.

Currently available electric compression heat pumps suffer from an unsatisfactory coefficient of performance (COP) when used in the conventional hydronic heating systems installed in existing residential buildings. This is not a problem for new houses. However, the annual construction rate in Austria is only 2 to 4% of the total housing stock. So, even with a 100% market share in new buildings, the impact of heat pumps on the energy consumption would not be significant before the year 2020. But reality is even worse - the best heat pump market in Austria, Upper Austria, has just reached a 10% share.

The only way heat pumps can bring about a faster effect is with a system that can replace the oil and gas boilers that are commonly used in hydronic heating systems in residential houses. In most cases, these operate at a maximum water supply temperature of 70°C or higher - out of reach for monovalent electric heat pumps to operate with a reasonable COP. Moreover, the capacity of a compression heat pump drops with increasing temperature lift, just the opposite of what is required for residential heating.

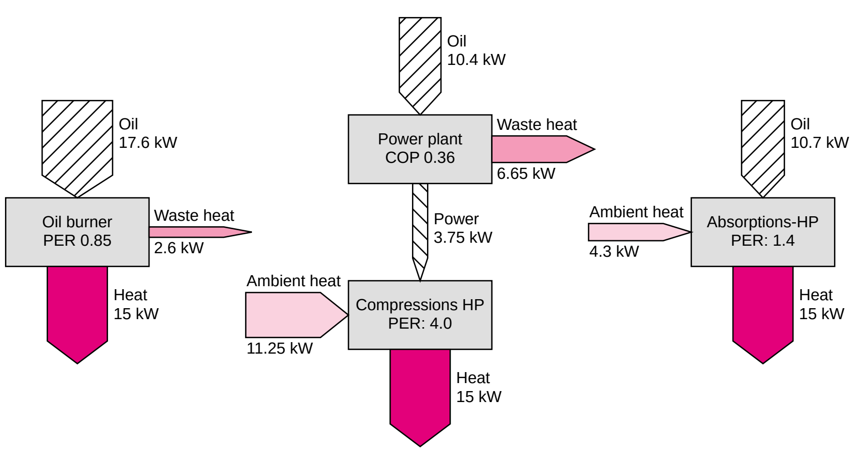
Many advantages

AHPs have some major advantages over electric heat pumps. Firstly, their energy efficiency is much less influenced by higher temperature lifts. Also, a heat source, such as an oil or gas burner, is already integrated and can be used in boiler mode if the operation conditions exceed the heat pump working limits.

Another big advantage is that AHPs need only about half the ambient energy of an electric heat pump of the same capacity. This aspect should not be underestimated: it is quite an impediment to heat pumps if the whole nicely-planted garden needs to be dug up to install a ground collector. The reason for this difference is that the power plant driving an electric heat pump delivers waste heat to the environment, while an AHP keeps all the heat inside the process and delivers it directly to the heating system (see **Figure 1**).

Last, but not least, AHPs have the advantage that, apart from the solution pump, they have no moving parts and can therefore be expected to have a long lifetime - the many absorption chillers with over 30 years service prove this point.

▼ *Figure 1: The oil consumption of a 15 kW absorption heat pump is much less than that of an oil boiler, and equivalent to that of an electric heat pump with a COP of 4.*



Developed for the market

The lack of possibilities for electric heat pumps to enter the market for retrofitting oil and gas boilers made Heliotherm think about the development of an AHP. It was clear that it had to be a system specially designed for this market.

Heliotherm found that the German Aerospace Research Establishment (DLR) had developed just the technology they needed - a direct-fired ammonia/water system made for heating residential houses. Heliotherm bought the rights and in 1995 started the development needed for mass production.

Two major changes were made to the original machine. The air-source evaporator was replaced by a brine system. Switching to brine gives some important advantages. Since brine temperatures down to -10°C can be used, different ambient energy sources, even air, can be used with one type of machine. In all cases, the AHP will be delivered to the installer as a completely assembled apparatus with no need for on-site work on the refrigerant cycle. This is particularly important with ammonia as a refrigerant. Also, apart from the connection of the brine circuit, the AHP is connected as a boiler. A design that resembles the traditional boilers is important to bring down the fear of most installers in selling and installing new technology.

The more difficult step was to switch all heat exchangers from shell-and-tube design to plate heat exchangers, to provide a more compact system. Since little knowledge existed about the typical processes in AHPs that use plate heat exchangers, in particular for absorption and rectification, considerable experience had to be gained before the system operated properly. Even evaporation caused problems in the beginning.

The results were worth the efforts. The current prototype measures only 70 x 95 x 140 cm, hardly larger than an oil boiler (see **photo**). And there is still room for further improvement.

Patented control system

For financial and design reasons, the maximum working pressure of the machine is limited to 25 bar. This limits the maximum temperature to about 50°C. As stated before, a monovalent heat pump for retrofit must supply higher temperatures. With the Heliotherm AHP, this is achieved with a patented control system that switches to boiler mode when the heating system demands higher temperatures. Switching is controlled by solenoid valves.

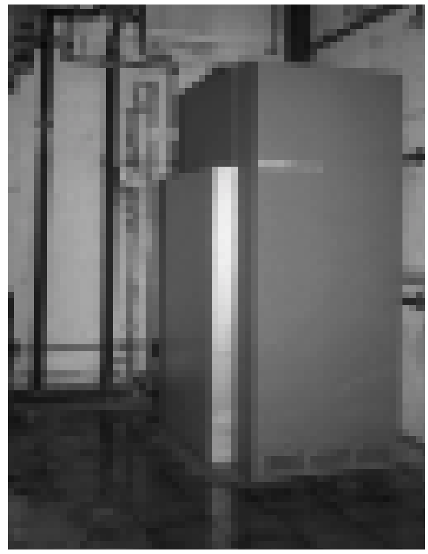
In heat pump operation refrigerant vapour from the rectifier flows to the condenser, and thereafter liquid refrigerant flows to the subcooler and the evaporator (see **Figure 2**). Useful heat is produced in the condenser and ambient heat is extracted in the evaporator. As soon as the condensing pressure exceeds the operation pressure, valve V1 is closed and valve V3 is opened. This clears a direct line for the vapour from the rectifier to the absorber. Since in boiler mode no evaporation is required, the low pressure can be increased and the absorption temperature rises respectively. Thus, temperatures of up to 70°C are achieved. In the laboratory, temperatures as high as 85°C were reached without any problems, but the limit is currently set at 70°C to ensure smooth switching.

The solenoid valves also have another task. Since controllable oil burners in the 10 kW range are not yet available, capacity control is achieved by on-off switching. Unfortunately, this causes considerable cycling losses due to pressure equalization. To prevent this, valves V1, V2 and V3 are all closed during the off-cycle, to disconnect all lines between the high- and low-pressure side. This is a very efficient way of suppressing cycling losses. The energy efficiency during cycling reaches 95% of the steady-state value.

The control process described above for mode switching and on-off cycling has been patented by DLR. The rights for the patents are held by Heliotherm.

Energy efficiency

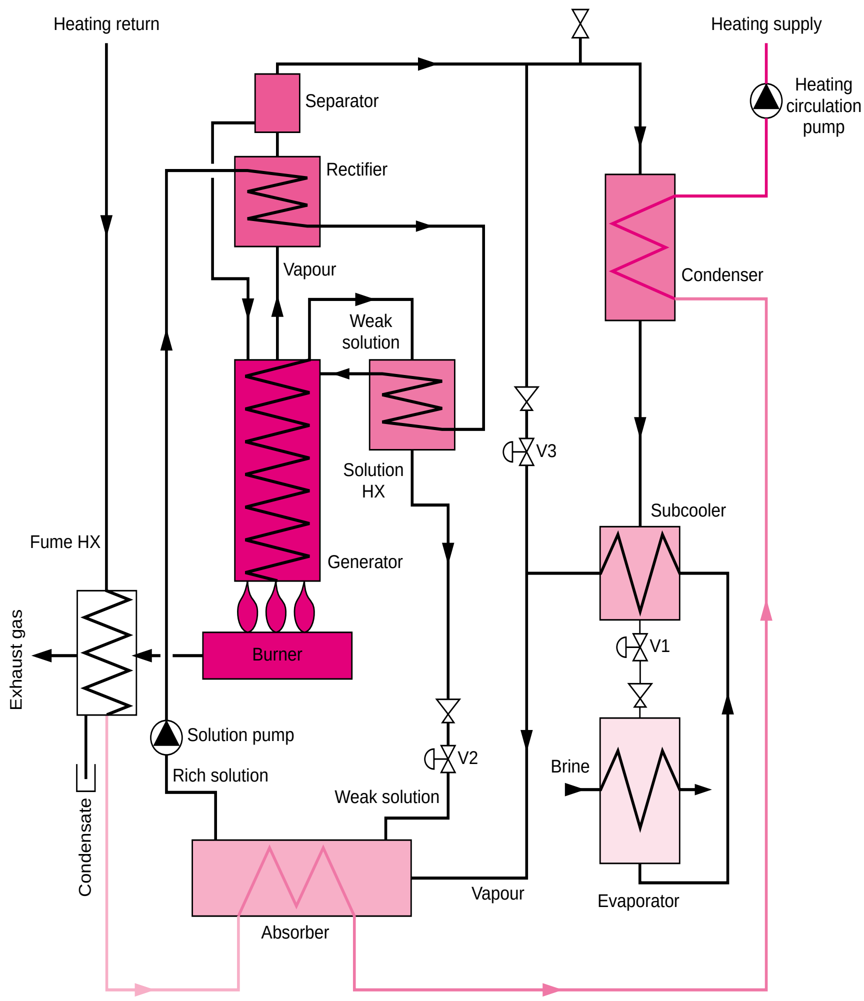
Switching the modes changes the PER (primary energy ratio). In the heat pump mode the PER varies between 1.14 and



1.43 depending on the temperature conditions. In boiler mode the efficiency is the same as for a condensing boiler and has a value of 0.91.

The burner capacity in the heat pump mode is 10 kW. This results in a heating capacity of about 15 kW. Switching to the boiler mode would reduce the heating capacity to 9.5 kW at high heat demand. Instead, a two-stage burner is used, which provides an additional 20 kW heating capacity for peak demand in boiler mode. The AHP can thus not only reach higher temperatures but also provide additional heating capacity at little extra cost.

Operating in boiler mode is not such a drawback on the PER as may be expected. For example, a one-family house built in the early seventies is typically equipped with a hydronic heating system designed for a maximum temperature of 70/50°C and a yearly heat demand of about 30,000 kWh. In central Europe, the number of cold days when the temperature of the heating system needs to be higher than 50°C accounts for only 2 to 5% of the yearly heat demand. The remainder can be covered in heat pump mode. Thus boiler operation lowers the yearly mean PER by only 0.01 to 0.04.



▲ *Figure 2: Schematic diagram of Heliotherm's absorption heat pump.*

The energy efficiency of an AHP compares well with an electric heat pump. Assuming an average power generation efficiency of 35%, the AHP operating in boiler mode is equivalent to an electric heat pump with a COP of 2.6, but with a heat output at 70 °C. Operation in heat pump mode with a PER of 1.43 is equivalent to an electric heat pump with a COP of 4.09.

Emissions reduction

Replacing an old oil boiler in the house described above by a new oil-boiler with a yearly mean PER of 0.81 would reduce CO_2 emissions by about 30% to 9,900 kg per year. However, an oil-fired AHP with a yearly average PER of 1.35 would emit only 5,940 kg of CO_2 per annum. This is 40% less than the new boiler. The boiler replacement rate in Austria is about 10%, which amounts to 25,000 new oil boilers a year and the same number for gas boilers. Considering a market share of 10% for the AHP, this would lead to a yearly CO_2 emissions reduction of 99,000 tonnes in Austria within 10 years. [Ed: IEA statistics report the annual energy-related CO_2 emissions in Austria to be 58 million tonnes in 1994]. This shows that the AHP can influence the energy consumption and CO_2 reduction considerably.

Costs

However, the cost of such a system is crucial for its market penetration. Considering production in large series, Heliotherm aims at a consumer price of US$ 8,000. Since Heliotherm has no capabilities for such mass production, the company is looking for partners or licensees for the AHP. Production in small numbers is scheduled for 1998.

Installations

At the end of 1996, the first AHP prototype was installed at a nursery school in Amaliendorf in Lower Austria. Two more prototypes have been installed for field testing next winter.

The gas-fired heat pump in Amaliendorf replaces an electric heating system equipped with floor heating with a maximum supply temperature of 50°C. The AHP is fired by gas. The AHP system works satisfactorily.

A unique chance

The AHP developed by Heliotherm has a good chance of penetrating the retrofit market replacing boilers in residential houses. Because AHP systems are specifically designed for use with high supply temperatures, they offer a unique chance for heat pumps to bring about energy savings and CO_2 emissions reductions on a large scale.

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Thermally-activated heat pump systems in Japan

Seiichiro Fujimaki, Japan

With 17% of the cooling capacity of Japanese air-conditioning systems now met by either absorption or gas-engine equipment, the market for thermally-activated heat pumping systems is now very significant. This article discusses the current market situation and gives several examples of commercially available equipment. Furthermore, development projects on systems for use in the 21st century are also described.

Thermally-activated heat pumping systems in Japan are primarily air-conditioning systems using town gas. Absorption equipment, used widely for some time, has recently been joined by the gas engine driven heat pumping systems (GEHP). At the end of March 1996, the cumulative cooling capacity of GEHPs accounted for 10% of all gas air-conditioning systems in Japan.

Recently, the usefulness of natural working fluids has been reviewed as a result of fluorocarbons control, and this has prompted renewed interest in gas-fired absorption machines using ammonia as a working fluid.

State of the market

By the end of March 1996, the stock of gas air-conditioning systems had grown to 21.1 GW of cooling capacity. This is 17% of the installed cooling capacity of building air-conditioning systems throughout Japan (124.2 GW). In large cities, electric packaged air conditioners and electric heat pump chillers account for most of the rest. The development of the market since 1989 is shown in **Figure 1**. This highlights the remarkable growth in GEHPs which now represent around 10% of all gas air-conditioning systems in the country.

The installed capacity of gas air-conditioning systems of all types has grown by 77% (65% growth for absorption systems and 386% growth for GEHPs) over the five-year period from 1991 to 1996.

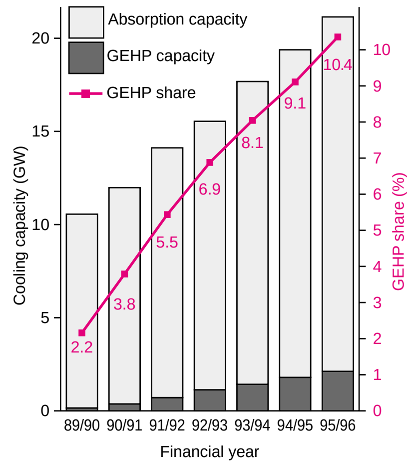
Both absorption and GEHPs are used in many office buildings. Some 23% of absorption machines are used in public agencies, reflecting the environmental concerns that fluorocarbons and other substances have posed in recent years. GEHPs are mostly used in schools, shops, department stores and amusement and assembly halls. Most GEHPs are medium sized, with 35.8% of those installed being classified in the 10 to 20 horsepower (28.1 to 58.3 kW) category for cooling capacity.

Equipment examples

Some examples of technologies implemented in commercial systems are described below.

■ A consortium made up of Tokyo Gas, Osaka Gas, Toho Gas and Yazaki Corporation have developed an absorption chiller/heater system using HFC-134a as the heat transfer medium. A two-phase thermo-siphon loop eliminates the need for pumping the HFC-134a during cooling mode and results in a high energy-saving efficiency. A pump is used during heating mode. The stock capacity of this system in combination with a water-cooled absorption chiller/heater has currently reached about 7 MW. Furthermore, an air-cooled absorption chiller/heater using the working fluids LiBr, LiI, LiCl and $LiNO_3$ was developed to be used in combination with this system.

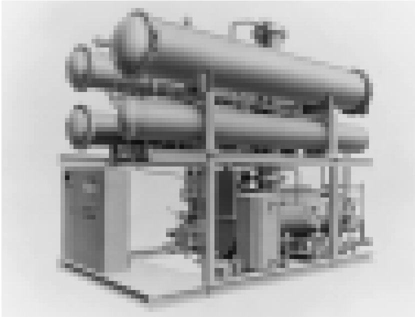
■ Recently, cogeneration systems have become widely used in Japan. Responding to this trend, Tokyo Gas has developed a gas-fired absorption chiller/heater with an auxiliary waste heat recovery system for utilizing waste heat from engines. In the system, a heat exchanger to recover heat from a



▲ *Figure 1: Growth in the installed capacity of gas air-conditioning systems in Japan, showing the share of GEHP.*

cogeneration unit is placed between the high-temperature and the low-temperature solution heat exchangers on the weak solution line. The system, which features low equipment costs and easy installation, functions as a conventional single/double-effect absorption machine. Equipment with a cooling capacity of 350 to 1,760 kW has been commercialized by Hitachi, Sanyo Electric and Yazaki Corporation.

■ Daikin Industries have achieved the highest cooling efficiency in the industry for gas-fired absorption chiller/heaters. With the adoption of a double-stage cycle, this double-effect absorption chiller/heater can supply chilled water at 7°C with a primary energy ratio (PER) of 1.2. The systems use water/LiBr as a working fluid and are available with cooling capacities ranging from 281 kW to 2,110 kW. A feature of Daikin's absorption cycle is that the concentration range of the LiBr aqueous solution is not restricted when



▲ *Figure 2: Commercial ammonia absorption refrigeration system with 176 kW cooling capacity.*

the evaporation temperature decreases. Consequently, the systems can supply cooling at temperatures as low as 5°C.

■ Since April 1991, Tokyo Gas has been running a district heating system with an absorption heat pump using heat from river water. The system serves residential complexes in the "Okawabata-River City 21" district in Tokyo. More recently the company introduced a GEHP system using heat from river water from the Sumida River in "Riverside Sumida", which became operational in June 1996. In winter, the system works in heat pump mode, supplying hot water at 45°C. In summer, the system supplies chilled water of 7°C by utilizing river water as the heat sink, and using the engine waste heat for supplying space heating and hot water. This machine is equipped with a screw compressor and uses HFC-134a as the working fluid. The cooling capacity is 350 kW.

■ In 1995, Yamaha Motor developed a water-cooled four-cylinder engine, specifically for multiple indoor unit GEHPs with cooling capacities of 28 to 56 kW. With a design lifetime of 30,000 hours, the engine boasts a maintenance interval of 6,000 hours. The company is working to achieve improved reliability and maintainability.

■ Tokyo Gas, in a joint development with Daikin Industries, have commercialized an ammonia absorption refrigeration system, achieving remarkably lower initial and running costs and allowing easy installation. The system can provide cooling at temperatures as low as -60°C. Variants of the system can simultaneously operate at two or more different evaporation temperature levels. Six models of this system have been designed, ranging in cooling capacity from 176 kW to 1,760 kW. The company plans to start commercial operation of four units at the beginning of 1997.

Power consumption is one-tenth that of an ordinary engine-driven compressor refrigerating machine, and refrigeration and cooling can be realized at lower cost by using gas, oil, steam or waste heat. The system is shown in **Figure 2**.

Ammonia absorption chillers with cooling capacities of 10.5 and 17.6 kW are imported from Robur Corporation of Italy. It is estimated that in the period from 1992, when they were first marketed, until the end of 1996, about 400 units were installed in total. Since the deregulation of the "High Pressure Gas Control Law" in 1994, installation of alarm devices and equipment for detecting leakage has become unnecessary for absorption machines with an ammonia charge of less than 25 kg. This has resulted in wider use of ammonia absorption equipment.

Development projects

There are two government supported programmes that have contributed to the development of thermally-activated heat pumping equipment in Japan:

- "Development of Direct-Fired Gas Air Conditioners for Residential Use"
- "Development of Heating/Cooling Technology for Load Levelling by Advanced Utilization of Unused Energy".

These programmes are described below.

Gas ACs for the home

With a subsidy from the Ministry of International Trade and Industry (MITI), the Japan Gas Association carried out the first programme aimed at the development of practical gas-driven heat pumping technology for residential use. This programme ran from 1992 to 1995.

In 1995, the Association conducted field tests on 63 units throughout Japan to verify the performance of these air conditioners, and the ease of installation and maintenance. The field tests were conducted on three types:

- a single-room absorption air conditioner using water/LiBr developed by Takagi Industrial
- a GEHP for two rooms developed by Honda R&D and Sanyo Electric
- a GEHP for three rooms developed by Yanmar Diesel Engine.

For all three types the capacity, the energy efficiency and weight targets were achieved. Further work for improvement was identified in the field tests.

Meanwhile, development is being continued on two other types: an absorption heat pump chiller using ammonia/water developed by Matsushita Electric Industrial, and a Vuilleumier cycle heat pump chiller developed by Sanyo Electric. Endurance tests are now being conducted by the city gas companies Tokyo Gas, Osaka Gas and Toho Gas.

Two more projects aim at the development of thermally-activated chiller/heaters for residential use. One is a direct oil-fired ammonia absorption chiller/heater that is currently being developed jointly by Petroleum Energy Center and Mitsubishi Electric. This is a GAX (generator/absorber heat exchange) system featuring a plate type heat exchanger to provide a highly miniaturized construction.

The second project concerns the development of absorption systems by the LPG Promotion Center. This organisation has been working with Katsura Seiki Seisakusho since 1993 to develop an ammonia system, and with Hitachi to develop a water/LiBr system.

Using unused energy

For the purpose of realizing electric power load levelling, a national project is being carried out entitled "Development of Heating/Cooling Technology for Load Levelling by Advanced Utilization of Unused Energy". With the support of the Agency of Natural Resources and Energy and MITI, this national project is being promoted jointly by the New Energy and Industrial Technology Development Organization (NEDO), the Heat Pump Technology Center of Japan and related companies.

Table 1 shows the absorption technologies that are being developed under this project. In the fiscal year '93 to '94, development of basic technologies was completed and the achievable target values were identified at laboratory test level. In the fiscal year '94 to '95, demonstration systems were designed, constructed and installed at test sites. Testing of these systems with actual loads will be completed in April '97. More details of these systems are given below.

■ A high-performance absorption heat pump is being developed, capable of effectively recovering heat from low-temperature heat sources such as river and sea water, even during the winter. For the double-effect absorption cycle, a combination of the working pairs TFE-NMP and water/LiBr is used. Demonstration tests are being conducted at the Ariake Minami Plant of the Tokyo Water Front District Heating & Cooling Corporation from March 1996 to March 1998.

■ A high-performance absorption heat pump is being developed using high-temperature steam from waste incinerators as the driving heat source. Heat from sewage treatment plants will be used as the heat source. A high-performance triple-effect absorption heat pump has been adopted consisting of three loops using a nitrate/water aqueous solution for the high-temperature cycle and LiBr/water for the medium-temperature and low-temperature cycles. Demonstration tests are being conducted at the Tarumi Sewage Treatment Plant of the Kobe Sewerage Bureau from February 1996 to March 1998.

■ An absorption-type chiller is being developed which is capable of supplying chilled water at 7°C for air conditioning using hot water at just 60°C as driving energy. A double-lift absorption cycle has been adopted using water/LiBr as the working pair. Demonstration and testing is being conducted at the Ariake Minami Plant of the Tokyo Water Front District Heating & Cooling Corporation from March 1996 to March 1998.

Many advantages

There are many advantages to the wider use of gas-driven air conditioning systems. They not only reduce the dependence on oil and contribute to the reduction of environmental pollution, they also provide improved capabilities for levelling demand and supply of gas and electricity. Wider use of gas air-conditioning is therefore promoted by the town gas and electricity companies, and as a result, a significant share in the market for commercial use has been gained. In the future, technical progress can be expected to result in a more widespread application in the residential market and greater utilization of waste energy.

▼ *Table 1: Absorption technologies investigated under the "Unused Energy Utilization Programme". Source: Pamphlet (NEDO - Results of Research and Development).*

Technology	Goals of research and development				
		PER	Heat source; Heat sink temperature (°C)	Inlet/ Outlet temperature (°C)	Driving heat temperature (°C)
Absorption heat pump using natural heat source	Heating Cooling	1.4 1.3	7 25	42/47 12/7	155 158
Absorption heat pump using urban waste energy	Heating Cooling	1.8 1.5	15 25	42/47 12/7	- -
Waste heat driven absorption chiller	Cooling	0.53	25	7	60

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The diffusion-absorption heat pump

An excellent prospect for gas-fired residential heating

Carl Wassermann, Switzerland

Many attempts have been made to produce reliable absorption heat pumps for efficient residential heating. Classical refrigeration machines often formed the basic concept and mechanical solution pumps were used to overcome the pressure difference between evaporator and generator. For residential applications (5 to 10 kW heating capacity) these systems experience considerable difficulties, largely associated with the mechanical solution pump. A process known as diffusion-absorption overcomes the need for a mechanical pump and can be used to provide a heat pump with no moving parts. This article describes the progress made by the Swiss company, DAWP Creatherm Ltd, in introducing the diffusion-absorption heat pump in the market.

The diffusion-absorption concept is used worldwide in gas-operated refrigerators for camping and caravans, as well as in hotel minibars. The Swiss company SIBIR and its licensees have produced more than six million diffusion-absorption refrigerators since 1944. This experience formed the basis for DAWP Creatherm to begin the development of a diffusion-absorption heat pump (DAHP) in the late 1980s.

Equal pressure

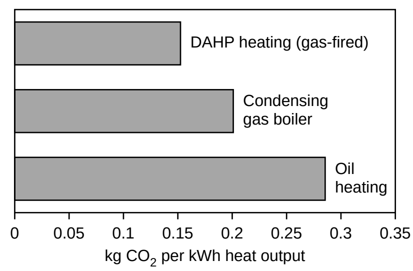
A special feature of a DAHP is that it has the same absolute pressure in all components. This is achieved by using an inert gas in the evaporator which allows the refrigerant to evaporate in a process known as diffusion rather than by boiling, as in conventional evaporators. In the diffusion process, refrigerant evaporates in the inert gas in the same way that water evaporates in air in natural processes. The DAHP developed by DAWP Creatherm uses ammonia as refrigerant and helium as the inert gas.

By operating at equal pressures, the DAHP does not require a mechanical solution pump, as is used in a conventional absorption system, to obtain the required pressure difference. The DAHP therefore contains no moving parts and has many advantages compared with conventional absorption heat pumps for house heating (up to 5 or 10 kW heat output). It produces less noise, has a longer lifetime, lower production costs and a higher efficiency. Since the DAHP is silent, it can be installed inside the living area. The DAHP is also maintenance free, and can thus be installed easily in private houses to operate unattended.

In the field

Field tests were started in late 1992 in two houses in Switzerland. Each house was fitted with a single DAHP unit using outside air as the heat source. The existing hydronic central heating system is used for heat distribution and a standard gas heater provides peak-load heating. The DAHP units installed for these tests have a nominal performance of up to 3.6 kW and a PER of 1.5. Both the DAHP and the peak-load heater are controlled by computer, and are monitored by a data-recording system.

Compared to a typical European gas heating system, annual savings of up to 6000 kWh primary energy and around 1200 kg CO_2 per year were achieved with the DAHP (see **Figure 1**). The potential daily energy savings of a unit amount to 29 kWh. Since the DAHP satisfies the base-heating demand only, it switches on/off a few times only. This reduces losses and results in an average yearly COP of 1.42. Based on improvements made with laboratory DAHP units, an average COP of over 1.45 can be expected.



▲ *Figure 1: DAHPs produce far less CO_2 than conventional heating systems.*

In production

A leading European manufacturer of heating equipment is now producing the DAHP under licence from DAWP Creatherm Ltd. For additional production in Asia, North America and Mexico new partners are being sought.

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Bringing GAX absorption technology to the market

Jürgen Langreck, The Netherlands

In the Netherlands, absorption machines for heating and cooling over a wide capacity range have been introduced in the market. The Dutch engineering company Colibri has developed absorption machines working with ammonia and water, for use as heat pumps or refrigeration machines. This article describes the progress made in bringing them to the market.

▲ *Photo1: The Colibri AWP250 in Heerlen.*

In 1993 Colibri's first heat pump (type AWP 250) was installed in a government building in Maastricht, the Netherlands, using water from the nearby river Maas as the heat source. It operates with a high primary energy ratio (PER) and is characterized by good reliability.

The heat pump is driven with natural gas and uses a GAX (generator absorber heat exchange) cycle. By using different types of welded compact plate-fin heat exchangers, the heat pump achieves a very high efficiency and compactness. The system is controlled by a microprocessor and operates completely automatically. The process can be monitored remotely.

In summer 1996 an absorption heat pump with a heating capacity of 250 kW and a cooling capacity of 100 kW was installed in Heerlen, the Netherlands (see **photo 1**). The heat pump links the heating and cooling demand of two adjacent office buildings. In winter the evaporator of the heat pump cools a large computer room and the condenser and absorber heat are used to heat the other building. For both cooling and heating, the heat pump delivers the base load, with the remaining demand met by conventional back-up equipment.

Another heat pump of the same type will go into operation in summer 1997 in a German university building. In this case, the evaporator supplies chilled water for the air-conditioning system and the absorber and condenser heat are used to heat the building.

▼ *Photo 2: A steam-driven absorption refrigeration system.*

Large capacity systems

For the production of absorption systems with larger capacities Colibri cooperates with Stork Ketels, a Dutch manufacturer of energy systems such as large scale cogeneration plants.

In March 1997 an absorption chiller with a refrigeration capacity of 1400 kW starts operation (see **photo 2**). It is a steam driven machine which produces cold at -28°C for refrigerating food. The evaporator of the absorption machine condenses the refrigerant vapour of the clients cooling system. The absorption system was delivered in prefabricated modules which were connected on site. Just as the smaller AWP 250, the refrigeration machine is controlled by microprocessor and runs completely automatically.

In summer 1997, another absorption refrigeration machine for the food industry will go into operation in Spain. The plant will have a refrigeration capacity of 1000 kW and cool a new type of brine to -12°C. It is driven by steam from a cogeneration plant.

With these projects Colibri has demonstrated the market potential for advanced absorption technology for both medium and large-scale applications for heating, cooling and combination thereof.

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Saving energy with concrete

Heating and cooling using energy from ground-contact concrete parts

Reinhard Preg, Austria

Concrete parts used in building construction can be used for other purposes in addition to their traditional load-bearing and architectural functions. Since 1981, the Nägelebau company of Röthis, Austria, has been fitting them with plastic pipes so that heat can be extracted from the ground or air and upgraded, with the assistance of a heat pump, for the provision of space heating. This article discusses the technique and describes a number of example projects.

Concrete has two properties which make it an ideal medium for energy absorption, namely good thermal conductivity and storage capacity. Just as a concrete wall absorbs and quickly transports body heat from a hand placed on it, concrete is also capable of absorbing ambient energy and storing it.

Ambient energy comprises heat from the circulating air or precipitation, solar irradiation from cloudy or clear skies, and also energy released when condensation forms on the absorber surfaces. In order to utilize energy stored in the concrete for heating purposes, it is necessary to incorporate a loop and a brine-to-water heat pump.

In 1981 Nägelebau, which has many years of experience in the manufacture of precast concrete parts, took out a licence for a heat generation system based on concrete parts as heat absorbers. Since then a large number of detached houses, condominiums, and commercial and industrial properties have been fitted with this eco-friendly heating system.

In many new detached houses in the Alpine region, the outer skin of the double wall takes the form of an 8 cm thick concrete slab, which can serve as a good source of heat. For existing houses, a garden wall, retaining wall or prefabricated garage can serve the same purpose. With detached houses and condominiums, additional pilaster strips (square projections) can be incorporated to obtain an additional source of energy.

In all cases concrete parts are employed that also make sense in structural terms.

Concrete piles

Where pile foundations are required for a building, the piles can be designed to serve for heating and cooling purposes at relatively little extra cost.

The potential supply of geothermal energy is impressive, as the following case of a detached house shows. Given a ground plan of 100 m^2 and a pile depth of 12 metres, an effective total volume of 1200 m3 of earth is available for geothermal exploitation, corresponding to a mass weighing 2000 tonnes. Cooling this mass by only 1°C will release more than 1000 kWh of geothermal energy.

An heat absorbing pile is constructed by laying PE (polyethylene) pipes in the reinforcement cages of the reinforced concrete ram piles (see **photo below**). About 50 cm below the pile cap, an opening is made for the flow and return pipes. The length of the pile available for heat transfer and storage depends on the data supplied by the geologist. The minimum length for a cost-effective system is 6 metres, and the maximum is about 14 metres, varying according to the cross-sectional area of the pile. Where longer piles are employed, the lower sections are not used for heating and cooling.

For the best results, the PE pipes should be carefully monitored until concreting is complete, and care should be taken to control compaction. It is therefore advantageous to use prefabricated reinforced concrete ram piles.

▼ *Reinforcement cage with integrated piping system.*

Pile placement

The absorber piles are not more expensive to place than conventional piles. It is merely necessary to ensure that the piles placed at the perimeter of the building are located with the opening for the supply and return pipes facing inwards. This ensures that the lines to the header duct are protected by the foundation slab.

A number of piles are connected together to form a circuit. The order of connection depends on the position of the piles as well as on such factors as the location of the header, the total length of the circuits, the position of the feeder lines and the heating and cooling loads. The required capacity of the circulation pump depends on the number and length of the circuits. Valves on the header can be used to regulate the flow rates in the absorber piles individually.

Utilizing reinforced concrete ram piles as heat absorbers permits buildings of all types to be heated entirely with the heat pump system. In addition, the absorber pile heat pump system is used more frequently for cooling purposes. The electricity use for circulating the liquid in the loops is limited.

With predominant temperatures of between 12 and 14°C in the piles, the building can be cooled directly either via the floor heating system or via separate ceiling cooling circuits without incorporating a refrigerator unit. About 1 kWh of electricity is needed to dissipate up to 100 kWh of thermal energy. This system can be used not only with prefabricated piles but also with hollow piles, bore piles, cavity walls or even via the foundation slab itself.

Applications

Nägelebau’s heat pump system is applied in a number of installations in the Alpine region. The **photo** below shows the offices of the Pago labelling factory in Grabs, Switzerland where the energy requirements for the building have been met with an absorber system since the summer of 1995. This system comprises 2,400 m^3 of concrete and a total length of 95,000 metres of PE pipes. The absorber piles are designed for a total heating and cooling capacity of 600kW.

▲ *Offices of the Pago Labelling Factory, Grabs, Switzerland.*

Another example is the new Werdenberg Cinema and Cultural Centre in Buchs, Switzerland, which employs a pile system combining the conventional load-bearing function with an absorber function for heating and cooling. Out of a total of 277 piles, varying in length between 8 and 20 metres, 180 are heat absorbing piles. In winter the ground serves as a source of heat for the heat pump, and in the summer it provides a highly economical cooling medium for the auditoriums in the cinema. The ground thus provides seasonal storage within a highly cost-effective and environmentally friendly system.

In a primary school in Triesenberg, a heating capacity of 320 kW is achieved with the help of elements that are in ground-contact concrete. The absorber surfaces are incorporated in the floor structure of the basement carpark, the gymnasium, the auditorium and various retaining walls, which are partly clad in natural stone. The system incorporates a total length of 30,000 metres of PE pipes.

With building land becoming increasingly scarce and expensive in the urban environment, an increasing number of buildings are being constructed today with multi-level basements. In such cases massive concrete cavity walls are built to stabilize the construction pit. In the Bregenz Art Centre an integrated system of pipes permits internal heat gains produced by solar radiation, the lighting system, large audiences, etc. to be discharged. A network of pipes integrated in the concrete walls and floors ensures that the room temperature does not exceed 25°C in the summer months.

Successful technology

From the examples mentioned above, it can be concluded that the use of the concrete construction as absorbers can be successfully applied as a cost-effective energy-saving technology, improving human comfort by providing cooling or heating in an environmentally-friendly way.

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Applications for Natural Refrigerants
Proceedings of the International Institute of Refrigeration (IIR) conference held in Aarhus, Denmark, 1996.
Available from: IIR, 177 Boulevard Malesherbes, F-75017 Paris, France. Fax: +33-1-4763 1798. Price: US$78, 740 pages.
The report contains 85 papers. The most recent advances in technologies based on naturally occurring refrigerants such as NH_3*,* H_2O*,* CO_2*, hydrocarbons and air are presented, as well as applications of these technologies.*

Research, Design and Construction of Refrigeration and Air-Conditioning Equipment in Eastern European Countries
Proceedings of the conference held in Bucarest, Romania. Available from: IIR, 177 Boulevard Malesherbes, F-75017 Paris, France. Fax: +33-1-4763 1798. Price; US$40, 350 pages, 1996.
The report contains 40 papers and covers CFC substitutes including HCFCs, hydrocarbon blends, as well as air cycles, Stirling cycles and sorption systems. The papers deal with heat transfer and leaks, energy analysis and modelling.

Proceedings of the 1996 Refrigeration Conference at Purdue
Available from: IIR, 177 Boulevard Malesherbes, F-75017 Paris, France. Fax: +33-1-4763 1798. Price; US$80, 547 pages, 1996.
These proceedings contain 83 papers. Subjects covered include: R22 substitution, R-502-R503 substitution, capillary tubes, industrial aspects of the use of zeotropic refrigerants and alternative refrigerating techniques.

Handboek Warmtepompen voor de Gebouwde Omgeving
Available from Intechnium, PO Box 484, 2440 AL Woerden, the Netherlands. Fax: +31-34843 2013, January 1996, 125 pages, NLG 159. Dutch language.
This handbook was produced by ISSO (Institute for Study and Stimulation of Research on Building Equipment). It summarizes the knowledge available in the Netherlands on implementation of heat pumps in buildings. A distinction is made between electrical and thermal -driven heat pumps. The target groups for this publication are installers, advisors and architects. It covers different topics including terms of reference, design, realization, use and demolition.

Industrial Heat Pumps; MVR/TVR-Systems in Chemical Industry
Available from MHP, PO Box 127, 3950 AC, Maarn, the Netherlands, Fax: +31-343-441 936, November 1996, 37 pages.
The report is compiled by Stork Comprimo B.V. and is intended for process-engineers working in the chemical process industry. It gives a summary of the available heat pump systems, discussing their advantages, disadvantages and application potential. It also shows application criteria for heat pump systems in general and for mechanical vapour recompression (MVR) systems in particular.

INTERNET SITE

For a list of all publications and events, visit the HPC Internet Site at

http://www.heatpumpcentre.org

Chinese Air Conditioning Study 1996
For information and orders: Contact JARN Ltd. 1-1-16, Akasaka, Minato-ku, Tokyo 107, Japan. Fax: +81-3-3584 4704. Price: US$ 3,200 for two parts and US$ 2,400 for one part.
A comprehensive market research has been carried out by local specialists as well as BSRIA's in depth-interviews to provide further insight into this unfamiliar market.
The report consist of two parts:
- *Packaged Air conditioning and Close Control (75 pages)*
- *Central Plant Air Conditioning (40 pages)*

A Chinese Company Profile section will be included when this report is purchased.

Kostengünstige Niedrigtemperaturheizung mit Wärmepumpe
Available from: ENET, Administration und Versand, Thunstrasse 9, Postfach 142, 3000 Bern 6, Switzerland. Fax: +41-31-352 7756, ENET No. 9655701, December 1996, 117 pages. German language.
This is the final report from phase 1 of the project "Low Cost Low Temperature Heat Pump Heating System" under contract from the Swiss Federal Office of Energy. The first phase involved a feasibility study and an enhanced problem analysis carried out using a dynamic simulation program (TRNSYS).

Calculation Model for Analysis of Waste Heat
Available from: Novem BV. For further information contact HPC (see back cover).
This calculation model was developed by HoST and can be used to analyze potential technologyies for using industrial waste heat. The type of heat pump and size are indicated, as well as an estimation of investments cost.

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Fax: +32-2-511 7597

Heat Pipes, Heat Pumps, Refrigerators
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3. Symposium Erdgekoppelte Wärmepumpen
20-22 Nov '97 / Giessen, Germany
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Natural Working Fluids '98
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Deadline for abstracts: 1 Sep '97
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Contact: Mr Jørn Stene, Sintef Energy, Trondheim (see back cover).

IIR - Linz 97 Heat Pump Systems, Energy Efficiency and Global Warming
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Contact: Mr Jørn Stene, SINTEF Energy, Trondheim (see back cover).

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Volume 15 - No.2/1997