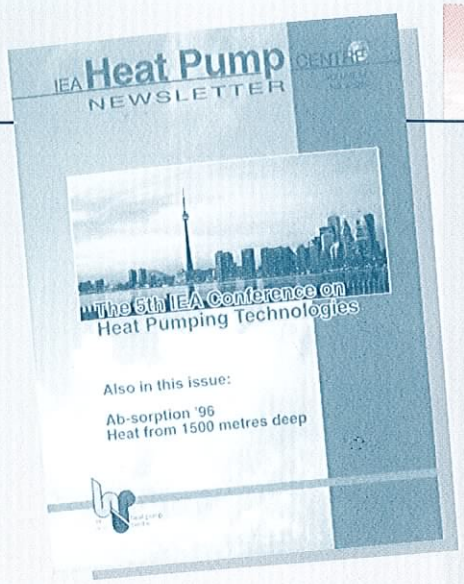
IEA Heat Pump CENTRE
NEWSLETTER
VOLUME 14
NO. 4/1996

The 5th IEA Conference on Heat Pumping Technologies

Also in this issue:

Ab-sorption '96
Heat from 1500 metres deep

IEA
OECD
heat pump
centre



In this issue

The 5th IEA Conference on Heat Pumping Technologies

Toronto, Canada was the venue for the fifth in a series of international conferences held under the IEA Heat Pump Programme. Like its predecessors, this conference highlighted key technical, marketing, policy and regulatory issues. New to this conference was the explicit widening of the field of interest to include, not only heat pumps, but other heat pumping technologies such as air conditioning and refrigeration systems. This edition of the *IEA Heat Pump Centre Newsletter* summarizes the papers presented in Toronto to give a unique flavour of the major issues concerning heat pumping technology today.

TOPICAL ARTICLES*

* *All conference sessions are summarized by Mike Steadman, IEA Heat Pump Centre*

HEAT PUMP NEWS

FEATURES

Front cover:
With the world's largest free-standing structure, Toronto city is an impressive venue for an international conference. But for those attending the 5th IEA Conference on Heat Pumping Technologies, it was the impressive programme of international presentations that offered the widest viewpoint.

COLOPHON

Publisher:
IEA Heat Pump Centre
P.O. Box 17
6130 AA Sittard
The Netherlands
Tel: +31-46-4202-236
Fax: +31-46-4510-389
E-mail: nlnovhpc@ibmmail.com
Internet: http://www.heatpumpcentre.org

Editing:
Jos Bouma / Mike Steadman / Rebecca Jones
Production: Novem Support Group
Illustrations: Offermans EPS, Willem Boijens
Printer: Huntjens, Stein, The Netherlands
Frequency: quarterly
Printed December 1996

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

ISSN 0724-7028

NON-TOPICAL ARTICLES

Vive la pompe à chaleur

Speaking in both English and French, the Canadian hosts warmly welcomed participants from around the world to the 5th International Energy Agency Conference on Heat Pumping Technologies, in Toronto from September 22 to 26, 1996.

While just the tip of an iceberg of IEA activities in this field, the triennial Conference is the most visible and major event of the IEA Heat Pump Programme (the IEA Implementing Agreement on Heat Pumping Technologies). Active for nearly twenty years, the Programme has created a tradition and a format that these conferences are built upon. And it was my privilege to play a role in the fifth event as the Chairman of the International Organizing Committee.

Some important changes were introduced for this conference. It was the first to use the term "heat pumping technologies" in order to include refrigeration and air conditioning in the conference theme. It was also the first with a pronounced global perspective, with a coordinator appointed to secure presentations from regions outside the IEA/OECD countries.

And although I might be biased, it is my sincere opinion that the 5th conference was a notable success. Some forty presentations in eight sessions, and close to sixty poster presentations matching the main sessions, gave life, intensity, breadth and depth to the conference. But even more than that, and due to the fact that all events took place within one building complex, I witnessed intense discussions and exchange of views during coffee breaks, lunches and dinners.

Many people deserve thanks for their contribution to an outstanding conference, including the members of the International Organizing Committee, the regional coordinators, the conference chairmen, the authors of papers and posters, the 250 people who attended and numerous sponsors and supporters. But above all else, I want to thank the twelve members of the National Organizing Committee of Canada and their chairman and vice chairman, Vincenza Galatone and Michel Lamanque.

Vive la pompe à chaleur and thank you for an unforgettable week in Toronto.

Per-Erling Frivik
Chairman of the International Organizing Committee
Professor/Research Director, SINTEF Energy
Trondheim, Norway

Heat pump news

IEA starts ab-sorption Annex

Sweden - The IEA Heat Pump Programme has begun a new Annex (international project) entitled *Ab-Sorption Machines for Heating and Cooling in Future Energy Systems*. Known as Annex 24, the new initiative aims to support both absorption and adsorption technology through collaborative efforts in various countries.

Annex 24 will examine the technical, economic, political, environmental and knowledge factors that affect the market for ab-sorption machines (machines using either absorption or adsorption technology). The results will be used to develop guidelines to encourage more application-oriented R&D activities that can attract the participation of industry, manufacturers, utilities and governmental bodies. Further support will be given to the setting up of case studies and demonstration projects.

Annex 24 was officially approved at the Executive Committee of the IEA Heat Pump Programme meeting held on 27-28 September 1996 in Toronto, Canada. Sweden, as represented by the Royal Institute of Technology, has been chosen as the Operating Agent of the Annex. Canada, Italy and the Netherlands have officially joined and several other countries have expressed interest in participating.

The first phase of the Annex will involve collecting and reporting information on the current state-of-the-art of absorption and adsorption technology. Manufacturers, users, utilities and governmental bodies will be invited to a workshop in 1997 to evaluate the findings.

The Annex is scheduled to run until 30 June, 1999. Those interested in participating in this Annex should contact the address below.

Sources: Prof. Frank Setterwa and IMr Magnus Gustafsson of the Royal Institute of Technology, Stockholm, Sweden. Tel: +46-8780-8235, Fax: +46-810-5228, E-mail: magu@ket.kth.se

Norwegians show renewed interest

Trondheim - SINTEF Energy has been active in 1996 with the provision of high-quality impartial information on heat pumps to a wide audience in Norway. Supported by government funds, the company has contacted home owners, regional energy conservation centres, consultants and heat pump suppliers. And the response has been good – the recent sharp rise in electricity prices has generated renewed interest in heat pumps among Norwegians.

However, political support is not so positive. Politicians appear to favour other forms of renewable energy such as wood-fired systems. The 1997 state budget will not include any specific funding for heat pumps. Despite this set- back, a new source of heat pump information will soon be available via Internet, at a site to be maintained by the Norwegian National Team.

Source: Mr Jørn Stene, Norwegian National Team.

Power utilities awarded for promotion efforts

USA - The efforts of power utilities to promote groundsource heat pumps has been highlighted by the International Ground-Source Heat Pump Association (IGSHPA) and by the Geothermal Heat Pump Consortium (GHPC).

Particularly successful has been the Associated Electric Cooperative Inc. (AECI) of Springfield, Missouri. They have won the IGSPHA's 10,000 Club award, which provides recognition for installing 10,000 ground-source heat pumps (GSHPs). Since launching its GSHP promotion programme *Marketing 2000* in 1986, AECI has made more than 8,000 GSHP rebates.

Another winner was the Red River Valley Rural Electric Association (RRVREA) of Marietta, Oklahoma who received the Marketing Penetration award. Nine percent of their customers have a GSHP installed in their homes and members have realized savings of US$ 226,000. The residential load factor (ratio of average : to maximum power load) has improved from 38.17% in the 1980s to 52.57% in 1995.

Two other power utilities have been awarded by GHPC for innovative programmes to target the commercial buildings sector. Pennsylvania Power & Lights is making videos and other material for potential customers in commercial, health care and school buildings. Jackson County is developing new marketing material such as tailor-made presentations for the school markets. All material developed will be made available to GHPC members.

Source: IGSHPA, Oklahoma State University. Fax: +1-405-744-5283. GHPC, Washington DC. Fax: +1-202-508-5222. Internet: http://www.ghpc.org

US & China agree on standards

USA - The Air Conditioning and Refrigeration Institute (ARI) and the China Refrigeration and Air Conditioning Industry Association (CRAA) have concluded a Memorandum of Understanding (MOU), which allows CRAA to use ARI standards to develop similar standards in the People's Republic of China.

This agreement is intended to encourage harmonization of US and Chinese standards for HVAC equipment. CRAA has already indicated that it will use ARI rating conditions as it develops standards for the Chinese market. Under the terms of the MOU, CRAA must acknowledge any ARI standard used to develop a Chinese standard.

Source: Air-Conditioning, Heating and Refrigeration News, 26 August 1996.

Heat from "down under"

Australia - The largest ever geothermal (ground-source) heat pump system in Australia is to be installed in the new offices of the Australian Geological Survey Organisation (AGSO) in Canberra.

The system will extract geothermal heat at around 17°C using some 350 borehole heat exchangers of 100 m depth. This heat is then distributed around the building in a water-loop system. Around 220 electric water-to-air heat pumps will be installed, each supplying heating or cooling to up to four perimeter offices, or eight interior offices.

The building will have a total floor area of about 40,000 m^2 including offices and laboratories. Conventional air conditioning will be used in the laboratories which have special needs for ventilation and heating.

The net present cost advantages of this system over a base variable-air-volume air conditioning system is calculated to be around AU$ 940,000 (US$ 740,000) over a plant life of 25 years. Further information is available from Mr John Coffey of Bassett Consulting Engineers
(Fax: +61-3-9510-1430).

Source: Australian Energy News, August 1996.

A better way to make tea

Sri Lanka - According to Mini Well Systems (Pvt) Ltd., the tea industry presents an important opportunity for the application of heat pump technology. The company has developed and applied a ground-source heat pump system for use in a process known as physical withering.

In tea production green leaves are picked and allowed to wither. They are then subjected to physical withering whereby moisture is removed by passing a current of air through the wet leaves. The rate of moisture removal is governed by the relative humidity of the air, the volume of air used and its velocity.

Using a heat pump, the temperature and humidity of the air can be precisely controlled for the best results. And by using the ground as a heat source, the system is highly efficient. Mini Well Systems calculate that if the technology were applied to the entire tea industry, assuming a production of 250,000 tonnes of tea per year, the consumption of wood fuel, used in existing processes, would be reduced by 222,000 tonnes per year – equivalent to around 6 km^2 of forest. The simple payback period is estimated to be 4.3 years.

Source: Mr Vythilingam Tharumaratnam, Mini Well Systems (pvt) Ltd., Nugegoda, Sri Lanka.
Tel/Fax: +94-825965.

Adsorption system enters Europe

Belgium - An adsorption refrigerator has recently been introduced to the European market by Japanese manufacturer Mycom. The system is typically used to provide chilled water at 9°C using waste heat at 75°C as drive energy. Under these conditions, the system can supply 0.6 kW cooling for every kW of waste heat. Water and silicagel are used as working pair in a "batch process" operation.

Available in cooling capacities ranging from 70 to 350 kW, the adsorption refrigerator is already used in a number of applications in Japan. Now, the search is on to find more customers in the European market.

Source: Mr Michel Distelmans, NV Mycom Europe SA, Zaventum, Belgium.
Fax: + 32-2757-9023.

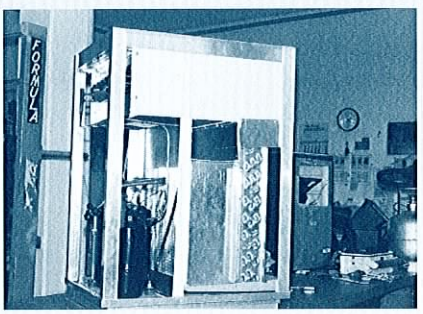
More efficient laundry drying

Switzerland - Conventional tumble dryers are large consumers of electricity, typically requiring around 4 kWh to dry 10 kg of wet laundry. They operate by blowing hot air over the laundry in a rotating drum, and expelling the warm moist air outdoors. All the energy used to evaporate moisture from the laundry – including the latent heat of vaporization – is lost.

Heat pump technology can be used to recover and re-use this energy. The latent heat is recovered by condensing out the water vapour from the moist air expelled from the dryer at the heat pump's evaporator. The dried air is used again to dry the laundry after being reheated by the heat pump - reusing the latent heat.

The problem with this process is that, as the laundry becomes dryer, less water vapour is available as a heat source. This increases the drying time to around twice that of conventional equipment.

Thermodul Consulting claims to have overcome this problem in its newly developed heat pump tumble dryer (**see photo**) which performs laundry drying using half as much electricity but in the same time as conventional equipment. The new technique employs the company's Thermodul Consulting's HED (high efficiency dehumidification) heat exchange technology which the company also employs in air conditioning equipment for tropical climates, and for industrial drying applications.



▲ *Prototype heat pump tumble dryer.*

Source: Mr Ernst Schwarzwald, Thermodul Consulting, CH-6985 Curio, Switzerland. Fax: +41-91-606-8716.

Heat pumps go to press

Netherlands - Printing processes require both heating and cooling. This is normally met using gas-fired boilers and large amounts of groundwater. Gastec NV is looking at the potential of using heat pumps instead.

Three electric heat pumps have been installed at the printers NIMAX Etiketten in Elst. Two are used to provide cooling for the company's two parallel production lines. The condenser heat is added to the inlet of the process so as to reduce gas consumption by the air heater. The third heat pump is used in the distillation of solvents for re-use.

The aim of the study is to investigate whether heat pumps can meet the needs of printing processes whilst saving energy, reducing groundwater use, and equalling or lowering the current costs. The study will be completed in April 1997.

Source: Podium Warmtepompen from the Dutch Heat Pump Programme.

Introducing the quick test method

Switzerland - A new test method will enable the performance of an installed residential electric heat pump system to be tested in as little as one month. The technique works by detecting deviations between the planned performance and that of the installed system and extrapolating the results to predict the energy consumption rate for a full reference year.

The quick test method is based on "parameter identification techniques". Measurements taken during the test period are used to identify the parameters of a mathematical model of the heat pump system under test. Using this approach, it is possible to forecast the behaviour for a reference year and to detect errors by computer simulation.

The method is being developed in a project for the Swiss Federal Office of Energy with the aim of providing better quality assurance for heat pump systems. Partners in the project are Sulzer Friotherm Ltd., the Measurement and Control Laboratory of the Swiss Federal Institute of Technology in Zurich, Gabathuler Ltd., and the heat pump manufacturer Saurer Thermotechnik.

The first phase of the project will investigate the applicability of this technique for a simple heat pump system. Experience gained in this project will serve to help develop the necessary software and hardware to enable heat pumps to be fitted with a built-in diagnostics system.

Source: Mr Günther Reiner, Sulzer Friotherm AG. Fax: +41-41-462-5061, E-mail: guenther.reiner@sulzer.ch

New RACs control humidity

Japan - One problem with currently available room air conditioners (RACs) is that they tend to dry the air when operating in heat pump mode. And conventional moisture replenishment techniques can cause bacteria proliferation.

A new range of RACs extract water moisture from the air before it is expelled outside and then return it to the incoming ventilation air. So no additional water is supplied.

They use a humidifying rotor containing a specially developed zeolite absorbent which is heated by a ceramic heater to return the moisture to the air. The new RACs can thus control temperature, ventilation and humidity.

Source: JARN, Japan, 26 October 1996.

Passenger trains to use air-cycle

Germany/UK - Together with its German partner Hagenuk Faively, UK-based company, Normalair-Garrett claim to have devised the first ever system to use air-cycle technology for air conditioning in passenger trains.

Air-cycle systems are already used in passenger aircraft, making use of compressed air from the jet engines. In the passenger train system, compressed air is produced by a specially developed compressor.

Although the price of the new system is comparable to conventional equipment, lower maintenance costs could mean that running expenses are 15% less than with conventional air conditioning. The company claims the savings could amount to "tens of millions of dollars".

Interest in this new system is growing rapidly amongst rail operators. The German rail operator, Deutsche Bahn, has already ordered the first production units of the system in a contract worth US$ 15.5 million and interest has been expressed in France, the United States and the United Kingdom.

Source: OzonAction from UNEP IE, Paris, France, October 1996.

New mixture for car ACs

USA - Refrigerant-Gases Inc. has obtained a license to distribute its Freezone refrigerant – a mixture described as 19% HCFC-142b, 79% HFC-134a and 2% lubricant – for use in mobile and stationary air conditioning (AC).

The refrigerant, which is considered to be a potential replacement for car ACs, has been accepted in the US SNAP (Significant New Alternatives Policy) programme, for non drop-in use subject to requirements on fittings and labelling.

Source: OzonAction from UNEP IE, Paris, France, October 1996.

Naturals congress attracts 280

Denmark - The attendance of some 280 people, including strong participation from Japan and the US, at the International Conference on *Applications for Natural Refrigerants* shows that interest in the "naturals" remains high.

Many presentations discussed the replacement of HCFC-22 with hydrocarbons. Others discussed the use of ammonia in commercial buildings applications, and in particular the choice of heat transport media for such systems. The use of ice-slurry was described for cooling at between -8°C and 0°C. At lower temperatures, down to -20°C, CO_2 can be beneficial in large systems. Examples of the use of CO_2 as a secondary transport medium were reported in supermarkets and cold storage depots.

Held in Aarhus on 3-6 September 1996, the conference was co-sponsored by the IIR (International Institute of Refrigeration). The proceedings are available from the IIR (Fax: +31-1-4763-1798).

Source: Mr Jan Bosma, Novem, the Netherlands. Tel: +31-30-2393-581.

Water-based system awarded

Denmark - The world's first industrial refrigeration plant using water as a refrigerant has won the 1996 *European Better Environment Awards for Industry*. The Danish Technological Institute (DTI), LEGO System A/S and Sabroe Refrigeration A/S shared the award for the 2 MW cooling plant at LEGO System A/S in Billund.

The project started at the DTI at the end of 1991. In 1994 a 1.9 MW cooling plant was built and has been in operation since August 1995.

Using water as both the primary and secondary refrigerant, the plant supplies cooling water at 9°C for some 600 injection moulding machines which make bricks for construction toys. The system uses a specially-developed compressor, built by Sabroe Refrigeration, and is claimed to exhibit a 20 to 50% better COP than conventional cooling plants.

Another water-based refrigeration unit for dairy products is expected to be in operation in 1997.

Source: OzonAction from UNEP IE, Paris, France, October 1996 and Annex 22 report HPP-AN22-1 from the HPC.

Hydrocarbons lack industrial support

Germany - A symposium held on *Hydrocarbons in European Refrigeration Systems* revealed a lack of widespread European industry support for using hydrocarbons other than in their present applications which are domestic refrigerators, some heat pumps and certain commercial refrigeration systems. The symposium was organized by the European compressor manufacturers association, ASERCOM, on 9 October 1996 in Nuremburg, immediately prior to the annual IKK air-conditioning and refrigeration exhibition.

The meeting was attended by more than 300 industry representatives from Europe and beyond. Calls were made for further investigation of flammability concerns, better training of service technicians and improved product labelling to ensure safe use of hydrocarbons. At the exhibition, hydrocarbon systems were notably absent, while many exhibitors displayed ammonia equipment.

Source: Minuteman Bulletin from ARI, USA. Fax: +1-703-528-3816.

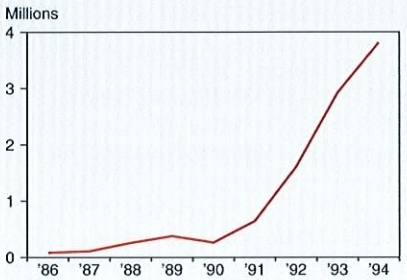
Erratum

A news item in Vol.14 No.3, on page 7, described the installation of an air-cycle system at the Winter Olympics bobsled run in Japan. The system developers, Kajima, have informed us that this information is incorrect and that the bobsled run uses a conventional ammonia chiller system. The IEA Heat Pump Centre apologizes for this error.

AC boom led by Russia

In America, Asia and Europe, there is an upward trend in sales of all types of air conditioner (AC). The fastest growing market appears to be Russia. Sales of room air conditioners are reported to have risen from 10,000 units in 1994, to 40,000 in 1995. And sales are expected to grow further to reach 100,000 units in 1996 and 250,000 units in 1997.

Japan continues to have the largest volume of air conditioner sales. It has been predicted that the year to October 1996 will be a new record, with total sales reaching almost nine million units. But Japan's market volume will soon be surpassed by China. Chinese production of air conditioners is reported to have reached 5 million units in 1995. **Figure 1** shows the production trend for the years 1986 to 1995.



▲ *Figure 1: Air conditioner production in China.*

AC sales are also booming in the US, where shipments of unitary air conditioners reached 3.2 million units for the first half of 1996, 15% higher than for the same period in 1995. Some 18% of these were reversible heat pumps.

Another strong market is the United Kingdom. According to BSRIA, sales of packaged air conditioners in the UK are expected to have risen by 31% in 1996 to reach 170,000 units, with further growth to 217,000 units predicted for 1997. These systems are used mainly for commercial buildings, although there is speculation that a residential market is now taking root. The market for central air conditioning plants is also growing. The total sales value for central and terminal units is expected to have grown by 4% to reach GB£ 390 million (US$ 650,000) in 1996.

Source: JARN, Japan, October 25 1996; Koldfax from ARI, USA, August 1996, Mr Igarashi, Japanese National Team.

Market success for prize winner

Sweden - One of the winning companies from the Finnish-Scandinavian heat pump competition is already making a healthy profit from its prize-winning product. IVT Energy, who were awarded a prize for their Puls-Greenline residential heat pump in 1995, reports a multiple increase in sales value from 1995 to 1996.

Heat Pump sales in June 1996, for example, were worth SEK 7 million (US$ 1 million), compared with SEK 1.2 million (US$ 180,000) in June 1995. Furthermore, IVT Energy has added 24 more people to its workforce – a rise of 42%.

The Puls-Greenline is a compact electrical brine-to-water unit with very low noise and high efficiency. Interest in this unit is spreading throughout Europe. In Switzerland, the energy corporation Durena has placed an order for 2000 units. And IVT Energy is negotiating with the French power utility Electricité de France, and with the Dutch energy distributor AGPO.

Source: Mr Håkan Persson, IVT Energy, Tranås, Sweden. Fax: +46-140-17890.

HPC addresses deregulated energy markets

Canada - In many countries, the traditional operation of power and gas utilities has been, or will soon be, swept away by the introduction of deregulation. This can have a profound impact on the role of utilities in supporting heat pumping technologies.

At the IEA Heat Pump Centre's (HPC's) 1996 National Teams Working Meeting, held in Toronto on 22 September, this issue emerged as one of great importance to HPC member countries. Consequently, a new analysis study will be conducted on *The Role of Heat Pumping Technologies in a Deregulated Energy Market*.

In addition, an analysis study entitled *The Environmental Benefits of Heat Pumps* will be carried out to follow up on an earlier study *The Impact of Heat Pumps on the Greenhouse Effect*. Furthermore, work will continue on the *Monitoring of Natural Working Fluid Developments in Europe* and to update the study *International Heat Pump Status and Policy Review of 1992*.

Also agreed at the meeting were the topics for forthcoming Newsletter issues. These are listed in **Table 1**.

A major event for the HPC in 1997 will be the organization of a workshop on *Building HVAC Equipment Regulations and Standards*. This will be held in Madrid, Spain on 27 February in conjunction with the international trade fair "Climatización '97". More details are given on page 30. Also, in spring 1997, an experts meeting will be held in Paris, France, on *Practical System Concepts for Year-Round Residential Space Conditioning and Comfort Control Using Heat Pumps*. Turn to page 31 for other forthcoming events under the IEA Heat Pump Programme.

Source: IEA Heat Pump Centre

▼ *Table 1: Forthcoming Newsletter topics.*

Vol. 15/1 Thermally-Activated Heat Pumps
Vol. 15/2 Systems and Controls
Vol. 15/3 Residential Heat Pumps
Vol. 15/4 Space Conditioning with Heat Recovery
Vol. 16/1 Large Energy Systems

Promoting the results of Annex 21

Canada/UK - Events held in Canada and the United Kingdom have highlighted the work of Annex 21: *Global Environmental Benefits of Industrial Heat Pumps*.

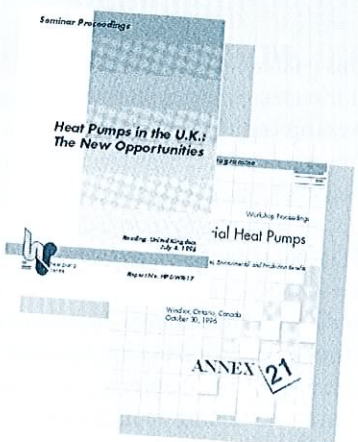
Held near the US border in Windsor, Canada, on 30 October 1996, the Canadian workshop provided an opportunity to review North American operating experiences with industrial heat pumps in the light of the Annex 21 work. Those at the workshop were also given a demonstration of the Annex 21 Screening Program – a major achievement of the Annex.

In Reading, UK, the Annex 21 results were discussed within a wider seminar entitled *Heat Pumps in the UK: the New Opportunities*. Presentations were given on heat pump markets, technology status and energy and environmental benefits, and parallel sessions were held on residential, commercial and industrial heat pumps.

Proceedings of these two events can now be ordered from the HPC using the attached response card. The Canadian workshop proceedings (Order No. HPP-AN21-4) cost NLG 120, or NLG 60 for people living in HPC member countries or Canada, France, Sweden or the UK. The UK seminar proceedings (Order No. HPC-WR-17) cost NLG 120, or NLG 60 for people living in HPC member countries and the UK.

Another workshop to follow up Annex 21 was held in Norway on 26 November 1996. The proceedings of this workshop will be published in Norwegian and will be available from the Norwegian National Team (see back cover for address).

Source: IEA Heat Pump Centre.



Ongoing Annexes

Red text indicates Operating Agent. Japan is the Co-operating Agent of Annex 18.

Annex 16 IEA Heat Pump Centre	AT, ES, JP, NL, NO, CH, US
Annex 18 Thermophysical Properties of Environmentally Acceptable Refrigerants	CA, DE, JP, NO, SE, UK, US
Annex 22 Compression Systems with Natural Working Fluids	CA, DK, JP, NL, NO, CH, UK, US
Annex 23 Heat Pump Systems for Single-Room Applications	CA, FR, CH, US, SE
Annex 24 Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	CA, IT, NL, SE

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

Opening and closing sessions

Heat pumping technologies towards the next century

Beginning on 22 September 1996, some 250 participants, from 25 countries, gathered at the Sheraton Centre hotel in the heart of Toronto city, for the "5th International Energy Agency Conference on Heat Pumping Technologies". Eight oral sessions were held over a four-day period under the conference theme: "Heat Pumping Towards the Next Century: Applications and Markets".

Some 40 oral papers were presented and are summarized further in this issue of the *IEA Heat Pump Centre Newsletter*. In addition, a large number of poster papers were presented, many of which are compiled in the conference proceedings. This article summarizes the keynote addresses of the opening session and the concluding discussions of the closing session.

This conference was the 5th in a series of triennial conferences organized under the auspices of the IEA Heat Pump Programme. But it was the first to use the term "heat pumping".

Heat pumping has come to mean all technologies, regardless of the application, for pumping heat from a source at one temperature, to a sink at a higher temperature. It thus encompasses all air conditioning applications including space heating, space cooling and dehumidification. It also includes heat pump water heaters and industrial heat pumps, plus all types of refrigeration equipment.

The organizers of this conference were thus able to select papers on a broader range of technologies than their predecessors. Nonetheless, many of the papers focused on heat pumps – equipment for the provision of heating by means of the refrigeration cycle. This includes heating-only equipment, and equipment that provides both heating and cooling.

Energy and environment

After a welcoming address from Ms Jean McClaskey, the Deputy Minister of Natural Resources Canada, the conference was set underway with a keynote address from **Mr Hans Jørgen Koch**, director of the IEA's Office of Energy Technology and R&D. Under the title "Energy and Environment", Mr Koch outlined the IEA's view on the important link between energy and the environment. He emphasized how the nature of the IEA's mandate has evolved to reflect the increasing sensitivity of governments and the public to environmental problems.

Mr Koch summed up the IEA's objectives as the "three Es":

- Energy security
- Economic growth
- Environmental sustainability.

Governments are pursuing more environmentally sensitive energy policies. And the projected growth in energy consumption gives further impetus: "The latest version of the IEA's "World Energy Outlook" projects total primary energy demand in 2010 to be between 34 and 46% higher than it was in 1993, with the share of non-OECD countries increasing substantially."

Major changes are needed in the way we produce and consume energy: "In the long run we will need to depend far more on renewable energy technologies and we will need to use all forms of energy in ways that involve smaller environmental impacts. These are clearly objectives of great interest to people who work on heat pump technologies."

The IEA sees "market restructuring" as an important policy option, whereby energy prices are increased to include the full environmental costs of energy production and use. But this is a long-term option. Today, government and private efforts should be continued to foster the development and deployment of energy efficient and renewable technologies. Mr Koch reiterated the role of the IEA: "the IEA is highly committed to international collaboration in the advancing of energy technologies."

▲ *Some of the 250 people who attended the conference.*

Heat pumping next century

Following the theme of the conference, **Prof. Eric Granryd**, of the Royal Institute of Technology, Sweden, looked to the future in his address: "Heat Pumping Technologies".

He expects some improvements in energy efficiency to be made through the optimization of compressors and motors. These components will also become quieter and more reliable, and oil management will be improved.

Further efficiency gains will be made through advanced techniques for heat exchange. On the air side, more efficient air moving devices can be envisaged. Other advances will be made in heat distribution systems, such as the use of ice slurry or CO_2 as transfer medium. For low temperatures, such as below -30°C, an ideal solution is still being sought.

Another way to distribute heat is to use a "neutral loop" to act as a heat source or sink for various heating and cooling equipment. Such an approach can be applied not only within one building but also to small or large networks, and can be an interesting alternative to conventional district heating and cooling systems.

Prof. Granryd predicts that while natural refrigerants will have a large-scale market impact for certain niche applications, the most common replacement refrigerants are likely to be the HFC mixtures R-410A and R-407C. And because some of the new refrigerants will operate at higher pressures, we can expect heat pumping equipment to become more compact.

Other developments will focus on new cycles such as the air-cycle, stirling cycle, absorption cycle and the supercritical cycle.

Another important development will be in microprocessor controls for performing energy or cost optimization and to allow more efficient servicing and maintenance, and user-friendly operation.

Overall, developments in heat pumping technologies will aim at improving energy efficiency, reliability, servicing, maintenance and environmental impact, whilst still maintaining a low first cost.

Within the heat pump range

Dr Katsuhiko Narita of Tokyo Electric Power Co., Japan, took a fundamental look at the need for heating and cooling in his address "Application of Heat Pumping Technology": "The energy demand for air conditioning occurs to adjust a little difference in temperature between the rooms and the natural environment." At the same time, a large amount of waste and environmental heat is available. To utilize these energy sources, three "mismatches" should be resolved.

The first is that the waste and environmental heat is at the wrong temperature. This can be resolved with heat pumping technology.

The second is that waste and environmental heat is scattered extensively and is costly to collect. This can be resolved by heat recovery and delivery technologies.

The third "mismatch" is that waste and environmental heat often vary in temperature. This can be overcome by combining heat recovery and delivery technologies with thermal storage technology.

Dr Narita: "What is essential to stimulate the spreading use of heat pumping technology is to develop and popularize not only heat pumping technology itself, but associated technologies as well."

Policies to widen the application of heat pumping technology should focus on "the heat pump range" – the range of temperatures for favourable heat pumping. Efforts should be made to ensure that heat streams come within this range. For example, a sewage network may be used as a heat source network for heat pumps. Likewise, waste heat from subways, underground shopping malls, energy supply facilities, and waste incineration facilities, should be utilized as heat sources. This would lead to "tremendous progress" in the application of heat pumps.

Closing session

At the final session of the conference, the chairmen of Sessions 2 to 7 looked back on the main themes of the four-day meeting. One of the highlights was certainly the evidence presented on the staggering growth in the Chinese market for air conditioners, which will soon be larger than that of Japan. In Japan, new markets are being sought in the colder regions by introducing specially adapted equipment.

The refrigerants issue was a major theme, as it was in the previous conference of 1993. Today, though, there is more clarity on the available options to HCFC-22. HFC-134a, R-407C and R-410A are emerging as the primary candidates, with some competition from ammonia and propane in regions and applications where safety issues can be resolved.

Another key message emerging from the conference was that the ongoing restructuring of the power utility industry in many countries will have a profound impact on the heat pumping equipment industry.

In his concluding remarks, **Prof. Per-Erling Frivik**, chairman of the conference's International Organizing Committee, returned to the phrase "heat pumping" which evoked much comment from participants during the final session. He emphasized that heat pumps, cooling air conditioners and refrigeration equipment have so much in common that a combined approach is needed. The IEA Heat Pump Programme will continue to act as a vehicle for international cooperation on all these technologies.

Prof. Frivik declared the conference "another success" and looked forward to the 6th IEA Conference on Heat Pumping Technologies in 1999.

Shortly after the conference, it was announced that Germany would be the venue, subject to the approval of the German authorities.

Session 2: Markets for Heat Pumping Technology

Market experiences from around the world

Present Situation and Market Trends in East Asia
Role of the European Union Concerted Action Group
Heat Pump Markets in Australia
Market Assessment and Economics in North America
Electric Utility Perspective on Heat Pumps
Will the Gas Heat Pump Achieve Success?

Yoshio Igarashi, Japan
Hans Jürgen Laue, Germany
Bill Charters, Australia
Mark Pearson and Jim Clark, Canada
Mike Bell, Canada
John Brogan, USA

"We have the technology ... but do we have the market?" That was the question posed by Mr Jean-Pierre Galloin, of Danfoss, France, who chaired this session. And after the presentation on the Asian market, where, in China and Japan, heat pumps are counted in millions, the answer is clearly yes. But the other presentations served as a harsh reminder that the market situation in other parts of the world is much more difficult.

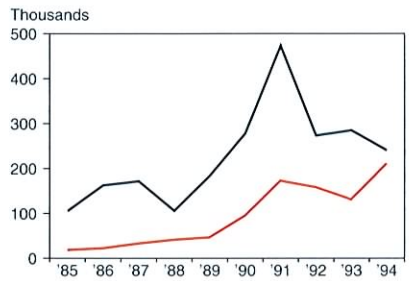
East Asia

Mr Yoshio Igarashi of the Heat Pump Technology Center of Japan compared the heat pump potential in various countries in East Asia.

It is estimated that the number of air conditioners installed in China surpassed eight million at the end of 1995, and that they will number over 20 million by 2005. Around 5.2 million air conditioners were sold in 1995, mostly split systems, with around 1.5 million providing a heat pump (heating) function. The manufacturing base is significant with around five million air conditioners made in China in 1995.

In the Republic of Korea (ROK), the heat pump market is much less significant. Most homes use underfloor heating, known as "Ondol" systems, which use fossil-fuel burners or boilers and transfer heat with hot water piping or by warm air or even flue gases. One way for heat pumps to penetrate the ROK market would be with equipment compatible with the "Ondol" system. Another route, is to penetrate the market for cooling-only room air conditioners, which currently stands at around 200,000 units per annum (see **Figure 1**). Only 2% of these have reversible operation.

In Japan, more than 75% of households have at least one room air conditioner (RAC) (see **Figure 2**) and 90% of those now sold are heat pump types. In contrast, the diffusion of oil stoves, the alternative heating system, has dropped to 70% and is falling.



▲ *Figure 1: Domestic shipments of air conditioners in the Republic of Korea.*

Europe

Prof. Hans Jürgen Laue of the German information centre FIZ, presented a report on the European Union Heat Pump Concerted Action Group (HPCAG). European markets are small in comparison with the USA and Japan. The major barriers are low energy prices, the lack of stimuli to invest in environmentally-friendly systems and low awareness.

The HPCAG was set up in 1992 to try and overcome these barriers, but has now ceased to exist. Among the "deliverables" produced by this group of heat pump experts was a heat pump handbook, software to aid heat pump selection, and a market study.
The market study concludes that heat pumps are best marketed as a "concept" rather than a piece of equipment. The idea of the heat pump "concept" is to market not only the equipment, but all the services associated with marketing, installing and maintaining the heat pump.

By bringing about closer coordination of heat pump activities in Europe, the HPCAG made important strides to narrow the gap between R&D and the market. New cooperation is now envisaged for the future.

Australia

Prof. Bill Charters from the University of Melbourne, Australia, described the Australian heat pump market as small, although a number of manufacturers, both local and overseas, market reversible air conditioners. Around 65% of homes have small window-type air conditioners, with most homes using gas-fired heating systems with ducted air heat distribution during the mild winters – temperatures rarely fall below 0°C in most regions.

Many of the reversible air conditioners installed in Australia do not perform well in cold weather and this has hampered the market penetration of heat pumps. Prof. Charters urges the heat pump industry to design and install heat pumps to meet the heating load.

To promote heat pumps in Australia, an overall heat pump industry strategy needs to be developed, based on market research. Furthermore, power utilities and government can support the heat pump market through special electricity prices and incentive schemes.

In addition, education and training programmes should be set up for maintenance personnel, and the general public should be better informed. One idea is to set up an "interest group" on heat pumps comprising various parties such as manufacturers, installers, energy suppliers, end-use groups, academics and educators and related industry associations.

Canada

The joint presentation of **Mr Jim Clark**, a standards officer, and **Mr Mark Pearson**, an economist, both of Natural Resources Canada (NRC), looked at how the market in Canada can be persuaded to use more energy-efficient heat pumping technology.

Jim Clark looked at voluntary programmes. In cooperation with the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI), NRC has set up the EnerGuide HVAC Energy Efficiency Rating Program to inform consumers of the availability of more efficient air conditioners and heat pumps. A slide-rule and software program have been made available to help contractors and consumers decide on the most economic option for a particular application.

Another way to "move the market" towards more efficient technologies is to increase the minimum requirements for energy efficiency. Mark Pearson described an economic analysis of the effects of changing the already existing minimum efficiency regulations for various types of heat pump. This analysis has been conducted in response to proposals for increasing the existing Canadian federal regulations on minimum energy efficiencies.

The results showed that most of the proposed changes were economically attractive. Only the proposals for open-loop ground-source heat pumps were found to be unattractive. For split-system heat pumps, the analysis also showed that it would be economically attractive to impose minimum levels which are 18% more efficient than those proposed for federal regulation.

The power utility view

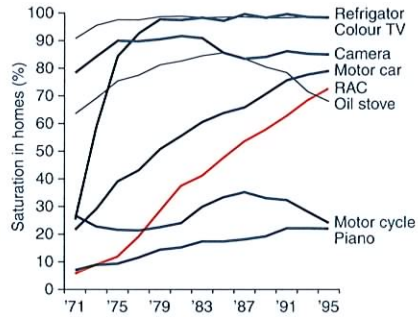
In the power utility world, a new factor is entering the equation: competition. And this will influence the way power utilities behave in relation to heat pumps. According to **Mr Mike Bell** of Ontario Hydro, Canada, electric heat pumps will continue to offer many advantages to power utilities. For example, by providing a better and cheaper service for heating and cooling, electric heat pumps can help utilities build a closer relationship with their customers and thereby encourage customer loyalty.

But, as the level of competition increases, electricity prices will be driven down and it is probable that subsidy programmes will no longer be possible. Instead, the focus will be on education, advice and special rates and contracts.

Speaking on behalf of the International Power Utility Heat Pump Committee, Mike Bell highlighted some of the major issues concerning power utilities.

In Japan the issue is thermal storage, with night-time power consumption at just 40% of the day-time level in summer. While in Germany utilities are faced with political barriers with some politicians opposed to the further use of electricity.

Power utilities expect the heat pump market to develop on two fronts: firstly as reversible units in growing markets for summer cooling, such as in southern Europe. And secondly in the heating-driven markets of northern USA, Canada and northern Europe.



▲ *Figure 2 : Diffusion of household equipment in Japan.*

Marketing the gas engine

The final paper in this session discussed the marketing of advanced gas engine heat pumping units for space conditioning. Developed with the support of a consortium of companies and organizations, the York "Triathlon" gas engine heat pump was launched in August 1994.

Mr John Brogan of the Gas Research Institute (GRI), USA, reported that initial sales were poor, with only 800 units installed by the end of 1995. In 1996 though, sales have surged, with some 1,250 units ordered in the first eight months and a further 1100 units requested at the time of this conference.

Despite this recent progress, the consortium has gone ahead with the introduction of a new range of units in an attempt to attract still larger sales. Mr Brogan announced that a range of "two-pipe gas heat pump / gas furnace" units are to be introduced in October 1996.

These air conditioners will use a conventional furnace for heating and not the heat pump cycle. They will cost between US$ 1,000 and US$ 1,500 less than the Triathlon and will offer lower maintenance costs and longer product life. Even more important, perhaps, is that they increase the incentives for support from the gas industry.

Session 3: Heat Pumping Applications I

Meeting requirements in buildings

Lessons Learned from Residential Heat Pumping Experiences in Canada	Doug Cane, Canada
Commercial Heat Pump Applications in Japan	Hireo Sakai, Japan
Commercial Heat Pump Applications in North America	Ellen Trick, USA
Heat Pump Technologies and Applications in China	Yuan-Wei Wu, China
Practical Experiences in Europe of the Combination of Geothermal Energy and Heat Pumps	Burkhard Sanner, Germany
Overview of the Earth Comfort Program in the US	Paul Liepe, USA

To develop a heat pump market, customer satisfaction is the key. A market survey in Canada shows that residential heat pump users see financial savings as an important benefit of heat pumps. In commercial buildings in Japan and the US, customers are also demanding improved comfort, with multi-zone systems and better air quality control.

In the rapidly growing Chinese market, a wide range of technologies are being tried out. One option is to take heat from the ground. In Europe, a great variety of geothermal systems have been tried. And a US programme is aiming for a ten-fold increase in sales.

Canadian homes

While much smaller than in Japan and the US, the Canadian market for residential heat pumps for space heating is the third largest in the world. Approximately 275,000 units are installed, 90% of which are air-source, the remaining 10% being ground-source systems.

Mr Doug Cane, of Caneta Research Inc., Canada, described how the heat pump market has fluctuated over the past 20 years. Many utility and government sponsored programmes have been introduced over the years to support the heat pump market by offering grants and other incentives. These programmes have caused the heat pump market to grow at an artificially increased rate, only to collapse rapidly at the end of the scheme, leaving the manufacturers with large inventories of unsold equipment. Longer-term strategies are called for, including better management at the end of programmes.

The good news for the industry is that most heat pump users are pleased with their equipment. Market surveys have found that 80% of users say they would buy another heat pump. They also found that "saving money" was the main reason for buying a heat pump. Such savings are not so difficult to achieve in Canada, where heat pumps compete with electric resistance heating.

Studies on heat pump performance reveal that air-source systems achieve heating seasonal performance factors (SPFs) of 1.6 to 1.7, saving 35 to 40% of energy costs compared with those for resistance heating. Ground-source heat pumps reach heating SPFs of around 2.5, yielding energy-cost savings of 60%.

New trends in Japan

In a country where even children are familiar with the word "heat pump", there are still many possibilities for the introduction of new equipment types. **Mr Hireo Sakai**, of Hitachi Ltd, Japan, described some of the latest trends.

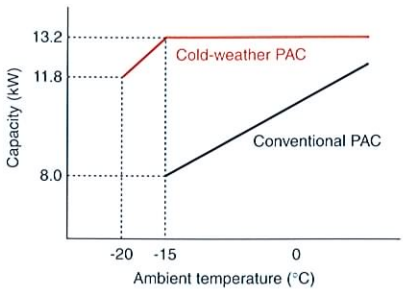
Commercial buildings are increasingly opting for multi-split systems whereby one outdoor unit serves up to ten indoor units. Multi-split systems now account for 7% of shipments of packaged air conditioners or PACs – reversible air-to-air equipment with over 2.25 kW cooling capacity. Another trend is the use of ice thermal storage for peak shifting.

Another important development has been the introduction of a new type of PAC in the Spring of 1996 to meet the heating requirements for the northern parts of Japan. As shown in **Figure 1**, conventional PACs do not perform well under sub-zero conditions. Using a newly designed scroll compressor, with high compression ratio, together with a sophisticated refrigeration cycle, the new PAC exhibits constant heating capacity at temperatures down to -15°C, thus eliminating the need for either a back-up resistance heater or a refrigerant heating burner.

Innovations in water loops

Fresh air management is an increasingly important issue, not least because of new requirements for air quality in the USA. Water-loop heat pump (WLHP) systems have been accused of offering poor ventilation management. In her presentation, **Ms Ellen Trick** of the Trane Company highlighted how industry advancement and innovation now mean that this is no longer true.

With a dedicated fresh air system, the entire air quality needs of a building can be handled from a single unit by distributing air at the required temperature and humidity via a ductwork system to various building zones. At each zone, a WLHP conditions the indoor and fresh air according to the needs of the zone. Such a system reduces the capacity requirements of the WLHPs and also makes it easier to perform heat recovery. Water-to-water heat pumps and energy recovery wheels now offer advanced techniques for heat recovery.



▲ *Figure 1: Heating mode characteristic of conventional and cold weather Japanese packaged air conditioners (PACs).*

Other recent advances in WLHP technology are two-speed compressors, hot gas re-heating and the use of direct digital controls (DDCs).

Chinese experiences

With new buildings being built at a rate of 1,150 million m^2 per annum, the potential need and market for space conditioning equipment is enormous in China. And in many regions, the climate is well suited to heat pump air conditioners.

Mr Yuan-Wei Wu, of the Institute of Air Conditioning from the China Academy of Building Research, presented an overview of the heat pumping technologies now being used in residential and commercial buildings, and in industry. This ranges from window and split-system air conditioners, to an 11 MW system now providing heating and cooling for Qingdao City, using the Yellow sea as a heat source and sink.

Heat pumps are also widely used in industry, especially for drying, such as for wood, tea and fruit processing. For example, about 400 wood dehumidifiers are installed. New refrigerants and lubricants are being developed to enable drying at higher temperatures – up to 140°C.

Mr Wu highlighted the vast extent of Chinese R&D on heat pumping technologies by citing some 20 institutes and universities that are currently active in this field. Much work is done on absorption technology, with a focus on the utilization of waste heat and on reaching high temperatures. Working pairs being explored include water-glycerine and water-ethylene glycol.

Geothermal Energy

Geothermal energy has been defined as heat from anywhere beneath the "surface of the solid earth".
Mr Burkhard Sanner, of Justus Liebig University, Germany, discussed European experiences with the different methods for the direct use of geothermal energy at various depths.

At just 1 to 1.5 meters down, horizontal coils can provide sufficient heat for heat pumps to reach SPFs as high as 4.5. Austria has many good examples. At 15 to 200 m below ground, borehole heat exchangers (BHEs) most commonly use a water/antifreeze circuit in a double-U polyethylene pipe to extract heat. BHEs are popular in Switzerland, where a total length of 200 km has been installed, mainly for houses.

Going deeper into the ground, temperatures rise at a rate of 3°C per 100 m. Abandoned boreholes, such as from gas or oil exploration, which go to depths of 800 to 5000 m, can offer much higher temperature heat sources, which can be utilized with BHEs and heat pumps.

A different way to exploit geothermal energy is from water sources. Easily accessible heat sources are thermal springs, abandoned mines and water from road and rail tunnels.

In Prenzlau, Germany, an abandoned borehole from attempted hydrogeothermal exploitation has been fitted with a BHE. With an exit temperature of up to 60°C, the BHE delivers 300 to 350 kW of heat to an ammonia heat pump evaporator and serves a district heating system.

More difficult to exploit are the warm geothermal fluids in deep aquifers. These hydrogeothermal energy sources are found in various regions of Europe including the northern and southern Alpine forelands, the north German/ Polish basin and the Aquitaine and Paris basins of France. Some are so hot that heat pumps are not required.

Earth Comfort

Mr Paul Liepe of the US Geothermal Heat Pump Consortium (GHPC) described how a recent US initiative aims to bring about a substantial increase in the market for geothermal or ground-source heat pumps. The "National Earth Comfort Program" was set up in 1995 with the support of government funding and is operated by the GHPC. Two thirds of the programme funds come from GHPC members which currently amount to some 244 utilities and 300 manufacturers trade allies (associations).

The aim of the programme is to "jump start" the market for ground-source heat pumps to bring about a ten-fold increase in annual sales by the year 2001. Currently, around 40,000 units are sold per annum.

The GHPC carries out a range of activities to support the geothermal heat pump market. Information on design tools has been collected and disseminated. And a curriculum for installation courses has been prepared.

A key activity is to increase public awareness of the technology. An article in a widely-read television magazine has been a recent success. But the technology appears to have an image problem. Market surveys indicate that both "geothermal" and "ground-source" heat pump are terms that conjure up the wrong ideas about the technology amongst the general public. Therefore the GHPC is planning to relaunch the technology under a new name.

Session 4: Heat Pumping Applications II

IHPs, new refrigerants, thermal storage and absorption

Environmental Benefits of Industrial Heat Pumps	Paul Shesky, USA
Drying Applications of Heat Pumps	Peter Rowles, Canada
Performance of Systems and Equipment with New HFC Refrigerant Blends	Jeff Linton, Canada
European Experiences with Conversion Projects to Environmentally Benign Working Fluids	Per Lundqvist, Sweden
Experiences in Heat Pumps Combined with Thermal Storage for Buildings in Japan	Tashiyuki Hino, Japan
Experiences with Gas-fired Absorption Heat Pumps in France	Constant Maton, France

To many potential customers in buildings and industry, the heat pump is considered to be a new technology. It is therefore important to convey information on experiences with heat pumps to a wide audience. This session highlighted experiences with a range of heat pumping technologies – industrial drying equipment, ice thermal storage, and absorption equipment for office buildings. Furthermore, two papers on new refrigerants discussed laboratory measurements and practical experiences with refrigerant replacements for CFCs and HCFCs.

IHP experiences

Mr Paul Shesky of Oak Ridge National Laboratory (ORNL), USA, presented an overview of the work of the IEA Heat Pump Programme Annex 21 project "Global Environmental Benefits of Industrial Heat Pumps". An important task was to count up the number of industrial heat pumps (IHPs) being used in the member countries of Annex 21. Around 4,600 IHPs were estimated to be operating in Canada, France, Japan, The Netherlands, Norway, Sweden, UK and USA. The most common application sector is the lumber industry, followed by food, chemicals, petrochemicals and petroleum refining, pulp and paper, and textiles.

While penetration of IHPs is good in some countries, especially in Norway, there is a large potential for more widespread usage. By highlighting the environmental benefits, Annex 21 has helped gain wider recognition for the benefits of IHPs. Furthermore, the IHP Screening Program, developed under this Annex, is an important tool for helping industries to assess the benefits and feasibility of installing IHPs.

While the operation of Annex 21 officially ended in 1995, with the successful completion of a report, a brochure and the software, work is still ongoing. With the support of the IEA Heat Pump Centre, workshops have been organized in various countries and continued efforts are made to promote the Annex 21 products.

Drying

The most common application of IHPs is for drying. **Mr Peter Rowles**, of Enerbest Associates, Canada, described examples of the use of heat pumps in various drying processes in the lumber, food, brewing and paper industries.

In a typical standard lumber drying steam kiln, 75% of the heat supplied leaves through the vents. By recycling the latent heat from the rejected steam, a dehumidification heat pump can drastically reduce energy consumption. For some applications, a heat pump dehumidification system can offer other benefits as well. For example, in the fixation and treatment of pressure treated lumber, a heat pump system provides better handling of the necessary toxic chemicals, and increases product turnover.

A recent study by Quebec Hydro and the Canadian government have highlighted an application in the paper industry. By upgrading heat at 50°C, an electric heat pump could be used to supply hot water at 63°C and hot air at 70°C with a COP of five, and with a payback period of about three years.

Another interesting heat pump application is in the storage of liquid food products such as corn syrup or fructose, which must be kept at warm temperatures, typically at about 30°C. Heat pump dehumidifiers have proven an effective means of controlling the humidity in the head space at the top of the storage tank, necessary to avoid bacteria contamination.

Testing refrigerants

Mr Jeff Linton of the National Research Council (NRC), Canada, reported on the results of performance tests that aimed to find out the practical consequences of retrofitting heat pumping equipment with new working fluids. The tests were conducted at facilities at NRC and the Thermal Technology Centre, Canada.

For low-temperature applications, three replacements for the conventional CFC/HCFC mixture R-502 were

Test refrigerant	Evaporating temp. (°C)	System capacity (kW)	COP
R-502	-33.4	31.2	1.00
R-507	-35.8	31.2	0.92
R-404A	-36.8	28.9	0.90
R-407A	-43.0	18.5	0.80

▲ *Table 1: System capacity and COP for a refrigerant plant operating to cool R-11 brine to -30°C.*

considered: R-407A, R-404A and R-507 – all of them HFC blends. Test equipment was set up to examine the effect of retrofitting existing refrigeration equipment with the alternative working fluids.

In the test apparatus, the COP and available system capacity for cooling a brine circuit to -30°C was compared for the different refrigerants. As shown in **Table 1**, none of the HFC blends could match the performance of R-502.

For residential space conditioning applications, a 10.5 kW residential heat pump charged with HCFC-22 was retrofitted with the HFC blends R-407C and R-410A, and the performance compared in a calorimetric test facility. With R-407C the relative cooling and heating capacities ranged from 0.92 to 1.01, and the relative heating and cooling COPs dropped to between 0.91 and 0.99. With R-410A, capacity dropped by 0 to 8% while the relative COPs ranged from 0.95 to 1.07.

Replacing refrigerants

According to **Mr Per Lundqvist** of the Royal Institute of Technology, Sweden, the need to replace CFCs in existing equipment in Sweden is driven not only by environmental concern and legislation, but also by economics and a lack of refrigerants. This is because the import ban of 1 January 1995 has led to a CFC shortage and high prices.

In Sweden, 50% of the country's original CFC-12 charge has already been retrofitted, mostly with HFC-134a. The rest must be retrofitted or switched off by 1 January 2000. The impact on equipment performance is generally good. The COP is often increased, partly due to better heat transfer, but also because the equipment gets a thorough service as part of the retrofit process. In addition, much more attention is paid to leakage prevention, and this has improved reliability.

Another way to reduce the use of CFCs and HCFCs is to seek alternative cooling methods. District heating and cooling systems using large heat pumps can meet cooling demand with less refrigerant per unit capacity than smaller systems. Another option is to use absorption chillers driven by district heating.

Elsewhere in Europe, retrofit activities are moving at a slower pace. For new equipment, the general trend is to use natural refrigerants such as ammonia and propane. There are large variations between the different countries due to differences in legislation, the organization of the heat pumping industries and local conditions such as the availability of free cooling sources.

Ice thermal storage

Since the first ice thermal storage system was introduced in Japan in 1981, a great variety of equipment has been developed, and nearly 50 products are currently available. According to **Mr Tashiyuki Hino**, of the Kajima Technical Research Institute, Japan, the best systems are those using the traditional direct-expansion static-ice storage method, by which ice is simply grown around evaporator tubes submerged in water.

More complex systems are less efficient. Some use a variety of mechanisms to periodically or continuously remove ice from the evaporator surface. While this avoids the build up of thermal resistance between the evaporator and the water, the extra "parasitic" energy needed to remove the ice is a waste of energy.

Other systems use a brine circuit to make ice, but these consume even more energy as the refrigeration equipment must reach a lower evaporating temperature and power is consumed by the brine pump.

A new approach avoids the need for an ice generating heat exchanger and makes ice through direct contact with the refrigerant. A system known as "flash freeze" has been tested using either hydrocarbon pentane (which is flammable) or perfluoro-pentane (which is ozone depleting).

It operates by mixing refrigerant and water upstream from a nozzle, and spraying this mixture onto a water/ice surface in a tank. In this expansion process, pressure and temperature drop rapidly and "sherbet-like" ice particles are made. COPs of between 3 and 4 have been measured with off-the-shelf oil-free compressors and other components.

Gas-fired absorption

With the low cost of natural gas, and by offering a year-round service of heating and cooling, gas-fired absorption machines can offer overall cost savings in France. According to **Mr Constant Maton**, of Gaz de France, there are about 32 units operating in France with a total cooling capacity of 10,000 kW.

Most are in commercial buildings such as large offices, hotels and large retail stores. The gas utility Gaz de France plays a central role in ensuring that installations have a high quality, and often reduce the customers initial costs by charging the customer for the heating and cooling delivered.

Most systems only operate in cooling mode. A good example of one providing both heating and cooling is installed at a business complex in the coastal town of Le Havre.

A direct-fired Carrier machine supplies chilled water at 7°C or hot water at 60°C. The cooling capacity is 315 kW. The chilled water serves fan-coil units in shops, offices and conference rooms as well as a central air-treatment bank. In cooling mode, 580 kW of heating capacity is available from the condenser, enabling simultaneous production of 7°C chilled water and 37°C hot water for underfloor heating.

Session 5: Heat Pumping Technologies I

Alternative options to CFCs and HCFCs

Trends and Advances in Working Fluids	Earl Muir, USA
Experiences in Air Conditioning Heat Pumps with Mixed Refrigerants	Kokichi Furuhama, Japan
European Heat Pump Research with Advanced Refrigerants	Horst Kruse, Germany
Compression Systems with Natural Working Fluids	Rune Aarlien, Norway
Practical Experiences of Heat Pumps with Hydrocarbons as Working Fluids	Hans Jürgen Laue, Germany
Technology Alternatives to CFC/HCFC Vapor Compression	Steve Fischer, USA

The options to replace CFCs and HCFCs are becoming clearer. Most applications are covered by six pure or blended HFCs. In addition, propane or ammonia can be used when the problems of using flammable or toxic substances can be overcome. In the longer-term, other alternatives may become significant, including the use of air, CO_2 or water as working fluids, or the use of alternative technologies such as sorption systems or thermoelectric cooling.

The six HFC alternatives

Mr Earl Muir of Copeland Corporation, USA, highlighted the main candidates for the replacement of CFCs and HCFCs in air conditioners and refrigeration equipment. **Table 1** shows the main non-flammable candidates. Flammable options, such as propane, are considered to be unacceptable by US companies because of liability laws. Except in Europe, manufacturers in other countries appear to be following suit.

ASHRAE No.	Blend of HFCs	Percent composition by weight
HCFC-22 replacements for air conditioning		
HFC-134a	-	-
R-407C	R-32/125/134a	23/25/52
R-410A	R-32/125	50/50
R-502 and HCFC-22 replacements for refrigeration		
R-404A	R-125/143a/134a	44/52/4
R-407A	R-32/125/134a	20/40/40
R-507	R-125/143a	50/50

▲ *Table 1: The choice of non-chlorinated, non-flammable refrigerants for air conditioning and refrigeration.*

Of the pure and blended HFCs, none of the candidates offer benefits for equipment manufacturers. An important factor is the requirement to switch to polyolester (POE) oils, which require extra care to avoid problems from moisture and contaminants. However, such difficulties can be overcome and 50% of low-temperature refrigeration equipment is now made using R-404A, R-407A or R-507 with the remainder using HCFC-22.

Air-conditioning systems are less easy to convert. For R-407C, the changes are minimal, but the performance is likely to be poor due to difficulties in coping with temperature glide and fractionation (changes in the refrigerant blend). Both HFC-134a, which operates at low pressure, and R-410A, which requires a high pressure, involve substantial equipment redesign. However, conversion to R-410A will bring either performance improvement or cost benefits which is not the case with HFC-134a. Therefore, Mr Muir predicts that R-410A will be the "long-term winner" for most applications.

Mixtures for Japan

Japanese consumers expect their heat pump air conditioners to be highly efficient, compact, and to operate reliably for at least ten years with only minor maintenance. **Mr Kokichi Furuhama** of Toshiba Corporation, Japan, described some of the work that Toshiba is doing to determine how these demands can be met without using HCFC-22. Like their counterparts in North America, Japanese manufacturers also see R-407C and R-410A as the two main refrigerant candidates.

Using R-407C without modifying equipment design, would cause a drop in efficiency, especially in the cooling cycle (COP drops by 6%). This can be overcome by modifying the indoor heat exchanger for partial counter-flow operation and by increasing size.

The use of R-410A as a drop-in replacement results in a sharp drop in cooling efficiency. Optimization of the compressor, including a reduction in displacement volume by 30%, brings the efficiency up to 98% of an HCFC-22 system. And modifying the heat exchangers from a two-path to a one-path arrangement increases the efficiency by a further 4 to 5%.

Reliability questions seem to be much harder to answer. More time is needed to determine the full impact of operation under higher pressure with R-410A. The eventual choice of refrigerant will be difficult as either one will require major changes to production facilities. Mr Furuhama sees R-410A as the most likely choice even though the initial investment costs will be much higher.

Going natural

Despite their flammability, hydrocarbons are being increasingly used in heat pumping equipment in Europe. According to **Prof. Horst Kruse** of the Institute of Refrigeration at the University of Hannover,

Germany, the desire for environmental protection is not the only reason for this trend. With several European countries, including Denmark, Germany, and Sweden, banning the use of HCFC-22 in new equipment from the year 2000, there is insufficient time to make the more difficult switch to HFC blends. And for Austrian heat pump manufacturers, for example, the use of soluble HCFCs and HFCs causes difficulty in obtaining licenses for direct-expansion ground-source heat pumps.

Interest in ammonia is also growing. Developments in compressors, lubricants and materials are expanding the possibilities for ammonia. For example, techniques to allow the use of aluminium piping instead of steel will lower the cost of ammonia installations.

Carbon dioxide is also under consideration, firstly for use in car air conditioners. In 1996, a European Union funded project began to examine the development of new CO_2 heat pump concepts such as for residential space conditioning, water heating and district heating.

Annex 22

Speaking on behalf of his colleague Mr Jørn Stene, **Mr Rune Aarlien** of SINTEF Energy, Norway, updated the audience on the progress of the IEA Heat Pump Programme's Annex 22 project "Compression Systems with Natural Working Fluids". Focusing on non-conventional systems, Annex 22 is compiling information on the application of the use of ammonia, hydrocarbons, CO_2, water and air as working fluids in the member countries and beyond.

The main product will be the report "Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigeration Systems with Natural Working Fluids". This will be completed in 1997 and will be published and distributed by the IEA Heat Pump Centre.

A report on the international status of natural working fluids has already been published. One finding is that the most promising "new" applications for ammonia are in space conditioning systems for commercial buildings, refrigeration systems for supermarkets, district heating and cooling systems and industrial heat pumps. Experience with hydrocarbons is reported as positive. No serious accidents or reliability problems have been recorded and efficiency is 3 to 5% higher than with conventional equipment.

A more long-term option is CO_2, which is considered to be well-suited for applications, such as district heating, where there is a considerable temperature glide at the heat distribution side. For water refrigerant, the main problem is to find reasonably priced and efficient compressors able to handle large volumetric flows in combination with high pressure ratios and high discharge temperatures. Air-cycle systems suffer from very low efficiency. Nonetheless they have good potential for blast freezing of food, industrial drying and transport.

Opting for propane

Propane is low in price, available in large quantities and can be used with conventional equipment. What's more, it could result in a longer life for compressors and lubricating oils. **Prof. Hans Jürgen Laue** of the German information centre, FIZ, presented a paper which had been prepared by two other German authors: Artur Rodecker of the heat pump manufacturer, KKW GmbH, and Peter Göricke of the power utility, RWE Energy AG.

Prof. Laue highlighted the dominant role of hydrocarbons in European refrigerators and pointed out that all German heat pump manufacturers are using propane.

KKW GmbH currently has about 400 propane-charged air-to-water heat pumps in operation with nominal heating capacity ratings of between 9 and 25 kW. After some initial difficulties in selecting the right type of oil and the corresponding viscosity, the systems now work perfectly, with seasonal performance factors of more than three.

Alternative technologies

Another approach to the refrigerant issue is to use alternative technologies to the reverse Rankine cycle of traditional systems. Absorption technology is already widely used. Other, less mature, technologies are now also being considered.

Mr Steve Fischer of Oak Ridge National Laboratory, USA, reported that research efforts in adsorption cycle heat pumps are targeted at automobile applications using a water-zeolite working pair and at residential air conditioning using ammonia-activated charcoal and ammoniated salts.

A completely different technology is thermo-electric cooling based on the Peltier effect. While the efficiency is low, thermo-electric coolers have achieved success in niche markets such as for portable coolers for recreational use, for the transport of pharmaceuticals and the cooling of electronic equipment.

More widespread applications are envisaged for air-cycle (or Brayton) systems. They are already used extensively in aircraft and will soon be introduced in European passenger trains.

Thermoacoustic refrigeration is interesting for the cooling of electric equipment. It has been used on the Space Shuttle and is being considered for use in vehicle refrigeration.

At the end of his paper, Mr Fisher pointed out that many alternative technologies could exacerbate global warming unless they offer comparable energy efficiency. In most applications, the global warming impact of emissions from power generation far outweigh the impact of refrigerant leakage.

Session 6: Heat Pumping Technologies II

An international review of technology trends

The Relation between Heat Pumps and New Energy Infrastructures	Mr Peter van der Ploeg, Netherlands
Comfort Control for Space Conditioning	Moriyoshi Sakamoto, Japan
Vapour Compression Refrigeration Technology	Dave Didion, USA
Trends of Absorption Heat Pumps in Japan	Shigeru Sakata, Japan
Technology Trends in Gas Heat Pumps in North America	Robert Devault, USA

What is the future for heat pumping technology? In the Netherlands it has never looked brighter. The need for entirely new housing areas is creating new opportunities for heat pumps – especially electric units. Papers from Japan and the US highlight some of the technologies that are and will be available for future applications.

Much development in recent years has focused on improving comfort control, with technologies such as variable speed compressors and microprocessor control. Some of the latest R&D programmes in the USA will focus on improving efficiency, noise levels and size by improving compressor technology.

Much smaller market technologies exist for absorption technology. The latest trend is to use absorption chillers in combination with cogeneration equipment. But while heat pumping technology will continue to develop, there is some evidence that the core of the market will not deviate far from the technology that has already been used successfully for over half a century.

The final frontier

Quoting from the television series Star Trek, **Mr Peter van der Ploeg** of the Dutch power utility organization, Sep, outlined why the expression "Space... the Final Frontier" has relevance for current Earth dwellers as well as for future space travellers. No more so than in the Netherlands, where space for a growing, and more dispersed, population must be found in an already densely-packed land area.

To meet this demand, some 1.2 million homes will be built between now and 2015. Most will be in new "green field" sites, known as VINEX locations, where new infrastructures such as roads, sewers and energy services will have to be provided. This presents an opportunity for new techniques to be considered, including heat pumps.

An important factor in designing these infrastructures is that the new houses will need about one third of the gas required for older houses (see **Figure 1**). This makes it difficult to justify the installation cost of a gas network and opens the door for electric heat pumps. Mr van de Ploeg estimates that current heat pump installation costs need to be just 7% lower than at present in order to compete economically on equal terms with gas technologies.

The energy saved by using heat pumps is significant. Combined with a low-temperature heat distribution system and modern power generation equipment, a heat pump can achieve a primary energy ratio (PER) of at least 1.65. Even higher PERs can be expected with improvements in heat pump and power generator technologies. And the associated environmentally harmful emissions will lessen as power generators strive to meet the Dutch government's target of producing 20% of electricity from renewable resources by 2020.

The new building programme in the Netherlands has led to a rethink of the relationship between heat pumps and the energy infrastructure. There now appears to be a good chance of heat pumps becoming a "big hit" in the Netherlands. And if heat pumps can be successful in the Netherlands then they have the potential of doing so anywhere.

Comfort control

Many Japanese consumers have complained that their air conditioners do not meet their requirements for comfort. Manufacturers have responded by introducing a range of new innovations to improve comfort control. **Mr Moriyoshi Sakamoto** of the Tokyo Metropolitan University outlined three of the most significant technologies: variable speed motors, microprocessors and control algorithms.

Using the latest pulse width modulated (PWM) inverter electronics, compressor motor speeds can be varied between 480 and 7,500 RPM. By allowing operation at slower speeds, inverter control improves heat pumping efficiency at the expense of motor and compressor losses. These losses can be minimized by using a DC brushless motor, a rotary compressor and fast-switching power transistors.

Around one third of Japanese microprocessors for home appliances are used in air conditioners. The typical microprocessor uses 8-bit logic and has a built in read-only memory (ROM) of 24K. This memory contains sophisticated program algorithms for controlling components such as the compressor, fans and expansion valves in response to signals from various sensors.

Using concepts such as the "Neural Network Approach" and "Fuzzy Logic", the program algorithms work to achieve a good level of thermal comfort. Comfort is measured by the so-called "PMV Index" – a factor defined by the International Organization for Standardization (ISO) in its 7730 standard. Taking account of variations in outdoor temperature, indoor air humidity and draughts, the advanced control systems ensure that people are not subjected to large variations in their perceived comfort.

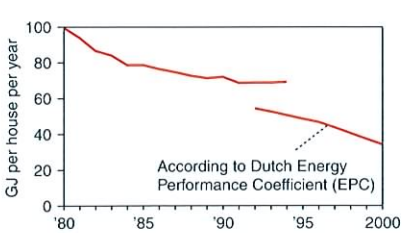
Vapour compression

Mr Dave Didion, presenting the paper of Mr James Hill of the National Institute of Standards and Technology (NIST), USA, outlined NIST's Advanced Technology Programme (ATP). Under this programme, government funds are allocated to support the development of "high-risk but powerful" new technologies. All projects are funded on a cost-shared basis, with half the funding coming from industry.

ATP has recently agreed to fund seven projects in the field of vapour compression refrigeration technology, with a total funding of US$ 13 million. The overall technical goals are for improvements in system efficiency, noise levels and size, and to avoid refrigerant leakage.

Three projects relate to the development of advanced cooling systems, for application in small commercial and residential buildings. Technologies to be developed include a high-speed centrifugal compressor with refrigerant-lubricated bearings, a high-speed screw compressor without an oil separator, and a co-rotating scroll compressor.

Another project will develop condenser coil technology for residential engineering using microchannel heat exchangers and a tangential fan. Other technologies to be developed include an optical-acoustical laser refrigerant leak detector and a photocatalytic indoor-air purifier.



▲ *Figure 1: Energy use for residential heating in the Netherlands.*

Japanese absorption

Mr Shigeru Sakata of Sanyo Electric Co. Ltd, Japan, highlighted how the Japanese market for absorption chillers has grown since the introduction of the first steam-driven unit in 1959. In the year to September 1995, some 4,700 units were installed, of which 92% are driven by gas or oil. Most of these fuel-driven units are known as chiller/heaters, whereby heating is obtained directly from the burner and not by heat pumping. For cooling, typical coefficients of performance (COPs) are 1.0 for smaller units (140 to 280 kW cooling capacity) or 1.1 for larger units (over 280 kW cooling capacity).

Absorption heat pumps, which provide both heating and cooling by the heat pump cycle, have a much smaller market. Mr Sakata estimates that a total of around 100 units have been installed in Japan. Typical heating COPs are reported to range from 1.4 for a single-effect, fuel-driven system producing heat at up to 95°C, to 2.0 for a double-effect, steam-driven system producing heat at up to 40°C.

A trend is to use absorption chillers in combination with cogeneration equipment. Waste heat from a gas-engine power generator is transferred to the weak solution in the absorption cycle so that it is pre-heated prior to the generator. Gas consumption at the generator is thus reduced.

American absorption

Mr Robert Devault of Oak Ridge National Laboratory (ORNL) reviewed US projects on gas-activated absorption technology. A major focus is on GAX (Generator-Absorber heat eXchange) absorption technology for residential and small commercial buildings applications.

As demonstrated by Phillips Engineering in 1984, GAX technology can achieve a heating COP of up to 1.8 and a cooling COP of up to 0.9 (excluding electric parasitics). Mr Devault listed seven companies and organizations who are working on GAX technology today. Carrier Corporation, for example, are working on improving the "manufacturability" of the original Phillips Engineering design.

Another key activity is on large triple-effect chillers which can improve cooling efficiency by 30 to 50% compared with the double-effect systems. The challenge is to overcome the corrosion and decomposition difficulties associated with high-temperature operation. Two triple-effect cycles have been patented by ORNL. The "dual-loop" concept was patented in 1988 and has been licensed to the Trane Company. The double-condenser coupling (DCC) concept was patented in 1993 and is now being investigated by York International.

Work is also ongoing to find improved working fluids. ORNL has identified a promising new ammonia quaternary mixture known as Q2. Q2 enhances performance at temperatures above 200°C and appears to have favourable corrosion characteristics. Tests are now being conducted on a GAX system.

ORNL is encouraging further developments in absorption systems by conducting a competitive procurement programme under the name Hi-Cool. Six companies are taking part and have completed the analysis and selection of cycles. The next stage is the development of critical components.

Session 7: Markets (Influences/Regulatory)

Expanding the market for heat pumping technologies

Building Equipment Energy Efficiency Regulations	Jos Bouma, IEA Heat Pump Centre
Impact of Emerging Building-Equipment Technologies on Markets	Bill Noel, USA
Inter-Regional Impact of the Swiss Heat Pump Promotion Programme in Switzerland, Germany and Austria	Gabbi Brugger-Mariani, Switzerland
National Projects Related to Heat Pump R&D and its Relation to Markets	Takashi Imanaga, Japan
A New Generation of Small Electric Driven Heat Pumps - New Market Opportunities	Arne Lögdberg, Sweden
Trends and Experiences in Residential Gas Heat Pumps in Japan	Shoji Yoshida, Japan

What are the influencing factors on the heat pump market? Regulations and standards can determine the performance of the available equipment. And government-backed promotion programmes can help to create a large market. But the biggest impact on market penetration is surely the technology itself. A competition in Scandinavia has led to the development of two very-suitable products for that region's market. And demonstration projects in Japan are proving the market possibilities of both "super heat pumps" and gas-driven heat pumps.

Regulations and standards

One way to influence the market for efficient heating and cooling equipment is through regulations and standards. Minimum efficiency standards, for example, can influence the performance of the equipment on sale. **Mr Jos Bouma** of the IEA Heat Pump Centre, presented the results of the HPC's recently completed study "Heat Pump Energy Efficiency Regulations and Standards".

This study found that the most comprehensive minimum efficiency standards are in Canada and the USA, while Austria, France and Mexico have more limited standards. Japanese regulations set minimum standards for cooling efficiency which will be extended to include heating efficiency from October 1997. South Korea has an efficiency classification scheme but no minimum limits.

In general, efficiency standards have not been in place long enough to discern their effect on markets from other factors such as energy prices. However, the experience of the US indicates that the introduction of minimum energy efficiency standards has made a significant change in the product efficiency mix and in the shipment weighted average efficiency of products available.

Labels are another way to tilt the market in favour of more efficient equipment. Labels with energy efficiency or cost information are prescribed in Australia, Canada, Mexico, South Korea and USA.

Both labelling and efficiency standards can also have an adverse market effect by "freezing" product technology at the minimum standard and inhibiting the market introduction of new products.

Overcoming market barriers

Many market barriers stand in the way of efficient emerging building-equipment technologies. According to **Mr Bill Noel** of the US Department of Energy (DoE), the key market defining factors are costs, information, infrastructure and technical constraints.

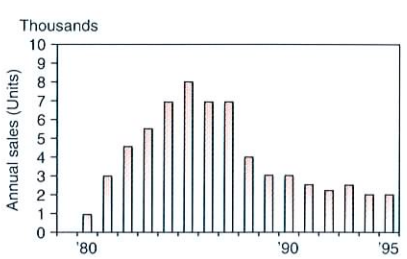
The DoE conducts several programmes which aim at breaking down these barriers. With its "Volume Purchase Program", for example, the purchase of 50,000 super-efficient refrigerators has been facilitated, for public housing apartments in New York City.

Another programme aims at promoting heat pump water heaters (HPWHs). As depicted in **Figure 1**, HPWH sales have been in decline in recent years. But even in their best year, sales were insignificant in comparison to the eight million conventional water heaters sold at that time, of which almost half were electric resistance heaters. A recent market study indicates that the potential market for HPWHs is about 300,000 per annum.

The DoE is currently working with stakeholders in the development of a market transformation strategy for HPWHs. Specific measures may include working with manufacturers on co-funded product development and field demonstration, making commitments for volume purchases, supporting the development of financing options, providing contractor training programmes and educating customers of the benefits of HPWHs.

Promotion programmes

In Austria, Germany and Switzerland, various programmes are in place to help promote heat pumps. In contrast to the initiatives in neighbouring countries Austria and Germany, the Swiss Heat Pump Promotion Programme has the



▲ *Figure 1: US sales of residential heat pump water heaters.*

active support of the political authorities. **Ms Gabbi Brugger-Mariani** of the Swiss Heat Pump Promotion Group highlighted a recent study which showed that many consumers decided to purchase a more expensive heat pump system because the state said "If you buy a heat pump you're doing something for the environment."Swiss government support for the acceptance of heat pumps appears to be more effective than the subsidies offered by the Austrian and German authorities. Heat pumps have a 30% share of new residential buildings market in Switzerland. In contrast, the heat pump's share in Germany and Austria is just 1%.

A key market sector is the replacement of electric heating systems. Some 230,000 resistance heating systems are used in Swiss homes today, most of which consist of single-room units. Penetration of this market is now expected with the development of a "radiator" heat pump, which is now ready for production.

Super heat pumps

Another marketing challenge is to find market acceptance for the Japanese "super heat pump". Developed between 1987 and 1993, super heat pumps offer exceptionally high energy efficiency for a range of applications. **Mr Takashi Imanaga** of the Japanese Ministry of International Trade and Industry (MITI) described two demonstration projects that are helping to determine how this advanced technology can eventually penetrate the building equipment market.

In the financial years 1993 and 1994, operation of a super heat pump space conditioning system was monitored at Kyushu Electric's research laboratory. The heat pump is a so-called "High Efficiency Heat Pump for Cooling and Heating" used in combination with clathrate thermal storage. The water-to-water unit has a two-stage economizer and a specially-developed screw compressor with an optimized tooth profile. The refrigerant is a zeotropic mixture of HCFC-22 and HCFC-142b. In 1994 the "average daily energy efficiency" was recorded as 4.7 for heating and 5.9 for cooling.

Another "High Efficiency Heat Pump for Cooling and Heating" was built to provide space conditioning for an office building using river water as heat source and sink. A brine loop is used to exchange heat between the heat pump and the river water. During the cooling season, when the river water temperature varied between 19 and 28°C, system COPs of between 5.0 and 6.7 were recorded. During the heating season, COPs of between 4.3 and 5.4 were recorded with river water temperatures of between 10 and 19°C.

The results of this demonstration work prove that super heat pump technology can be applied successfully in practice, although further work is needed to reduce their relatively high initial costs.

A new generation

One way to stimulate the heat pump market is to organize a design competition. **Mr Arne Lögdberg** of the Swedish National Board for Technical Development (NUTEK) described how the Nordic heat pump competition, which was completed in 1995, led to the development of a new generation of heat pump.

Two winning heat pumps were chosen. Both of them use the ground as heat source. The Eufor Markus 2500 Kombi is intended primarily for detached houses with electrical heating. It supplies heat to the indoor air using a warm air fan, and has the option of using a small hydronic heat distribution system as well. The IVT Puls-Greenline is designed primarily for detached houses with hydronic heating systems. It is normally connected to the existing heating system, but can also operate with a warm air fan for use in houses with electrical resistance heating.

Both systems are considered to be about 30% more efficient, and 30% cheaper than previously available heat pumps. By saving between 8300 kWh/year (with the Eufor system) and 9000 kWh (with the IVT system), the typical home-owner in the Stockholm area will make sufficient energy-cost savings to pay back the extra investment costs within seven years.

As well as improved energy saving, the heat pumps also offer better reliability with compressor lifetimes expected to be in the order of 15 to 20 years.

Residential gas systems

A number of factors have created a potentially large market for gas-driven air conditioners in Japan. **Mr Shoji Yoshida** of the Japan Gas Association described a four-year programme to develop practical technology for this market. Around half the costs of this programme were subsidized by MITI, with the rest split equally between four gas utilities, and with equipment manufacturers.

The work focused on four systems: a water-lithium bromide absorption system, an ammonia-water absorption system, a gas-engine heat pump and a Vuilleumier-cycle heat pump. Three systems were developed to the point where field tests could begin and are now being operated in the homes of gas utility employees and at other facilities.

One is a compact, air-cooled water-lithium bromide absorption system for single-room operation, built by Takagi. The other two are gas-engine systems. Both feature a high-speed engine and vertical placement of components. A two-room system built by Honda R&D and Sanyo features direct coupling of the engine and compressor and an integrated exhaust gas heat exchanger and muffler. A three-room system built by Yanmar uses convection cooling to avoid the need for a cooling water pump. All three systems have cooling/heating primary energy ratios (PERs) of at least 0.7/0.75.

Observations from Ab-Sorption '96

Jos Bouma, IEA Heat Pump Centre.

Interest in sorption research is on the increase worldwide. This is evident from the attendance of over 220 participants from 22 countries at the International Ab-Sorption Heat Pump Conference, in Montreal, Canada from 17 to 20 September 1996.

Contributing to the success of the conference were the pre-conference tour and a well-attended workshop on an absorption simulation model (ABSIM) capable of modelling different cycle configurations with different working fluids. Typical of a research-driven conference, most papers presented were research oriented with the exception of a few papers which addressed markets and systems economics.

This article highlights selected papers from the conference on the following topics: GAX cycles, load-levelling, applied absorption, new developments, water as the working fluid, VX GAX cycles, solid-sorption, metal hydride air conditioning concepts and an absorbent concentrator.

A special tribute was made to the late Prof. G. Alefeld by Prof. G. Grossman, Prof. B. Spinner and Dr F. Ziegler, and the Prof. G. Alefeld Award was established.

Moving away from the former triennial format of international absorption heat pump conferences, the Ab-Sorption Conference '96 was held only two years after the previous one held in New Orleans, US. Also for the first time, the formula was enhanced to include both absorption and adsorption technologies in one conference. Twelve keynote speakers gave their view on various aspects of this large field.

The main research areas covered in the conference were:

- heat and mass transfer (17 papers)
- modelling (10 papers)
- demonstration and applications (21 papers)
- thermodynamic systems (24 papers)
- additives (5 papers)
- novel liquid and solid/gas pairs (9 papers)
- components, manufacturing and surface treatment (8 papers)
- control (5 papers)
- market studies and commercialization (5 papers)
- liquid-solid properties (2 papers)

GAX cycles

Keynote speaker **Prof. T. Kashiwagi** from the Tokyo University of Agriculture and Technology gave an overview of newly developed advanced thermally activated heat pump systems in Japan. Generator Absorber heat eXchange (GAX) cycles have drawn high interest from Japanese researchers. GAX cycles enable a combination of high performance and simple, cost-effective products. This has resulted in the development of three different types of residential fuel-fired absorption heat pumps which have reached a steady-state primary energy ratio (PER) of 1.3 (0.7 for cooling). Triple-effect absorption heat pumps are studied under the national Unused Energy Utilization Programme. A 75 kW prototype was tested and proved to be better than targeted. However, the more advanced the system, the more complex and higher the cost of the system. Cost reduction is a priority challenge for further development.

Prof. Kashiwagi supported energy cascading as a very powerful and useful method for increasing energy efficiency. He saw a large role to be played for thermally activated heat pumps, as they make an efficient use of waste heat. Even with low temperature (50 °C) waste heat, useful cooling or heating can be achieved, although at a low efficiency level. But when the waste heat is for free, this is not a major constraint.

Load levelling

A new project called Load Levelling Hyper Energy Converting & Utilizing System (LHECUS) was briefly introduced. This project was proposed to the Ministry of International Trade and Industry (MITI) for approval. It links powerful technologies and aims to use energy efficiently in a cascaded form. The technologies include:

- large-scale cogeneration with district heating
- night-time surplus electric power
- energy storage in the form of solutions
- non-insulated transportation of thermal energy
- waste heat-driven high efficiency power generation (Kalina cycle)

Applied absorption

In the keynote speech by **Mr Pizak**, a manufacturer's (Trane) perspective was given on applied absorption systems. While the efficiency of electric compression chillers has increased by about 40%, two-stage steam-fired absorption chillers improved by "only" 20%. Overall in this region the market share of absorption equipment is 10%. Increased market share can be achieved if the following two requirements are fulfilled: improved efficiency by means of direct-fired three-stage systems, and

increased reliability, especially by using better corrosion inhibitors. Other important areas of improvement are controls and materials. Cost improvements are achieved through improved designs, improved manufacturing processes and, in the future, by using cheaper materials.

New developments

An overview of new developments in absorption cooling and heat pumping was given by **Mr W. Ryan** of GRI, USA. In large capacity absorption water chillers, a number of new features are being added, including:

- automatic purge systems lowering the potential for corrosion
- electronic controls and concentration sensing for faster system response
- electronic controls and sensors to avoid crystallization
- lower cooling tower flow requirements
- water temperatures as low as 3 °C

The major technical development is on triple-effect absorption-cycle machines. A number of papers on this subject were presented at the conference. Performance improvements of up to 50% relative to double effect systems are feasible (PER cooling of 1.5). Market introduction of products by Trane, Carrier and York is expected in the period 1997 to '98.

In unitary absorption systems many developments are underway. Most concentrate on improved efficiency of small capacity ammonia/water air conditioners. They will use the GAX cycle. Work on the GAX cycle in the US is currently ongoing in different organizations:

- Carrier Corp. are developing the Phillips Engineering concept under support from ORNL and DoE
- ARCTEC Corp. are developing a heat pump cycle under funding from GRI
- Ohio State and Pennsylvania State University are working on cycle models, component design, testing of cycles for industry etc.
- Robur Corp. developed and tested a GAX air conditioner in the early 1990s under the name Servel
- Energy Concepts Company are developing components for GAX cycles for GRI and others.

Major residential product developments outside the US occur in Japan. Different concepts are being developed as a result of a programme of the gas utilities under the support of MITI. Companies involved in the development of residential absorption equipment include Daikin, Matsushita Corp., and Takagi Corp.

Water as the working fluid

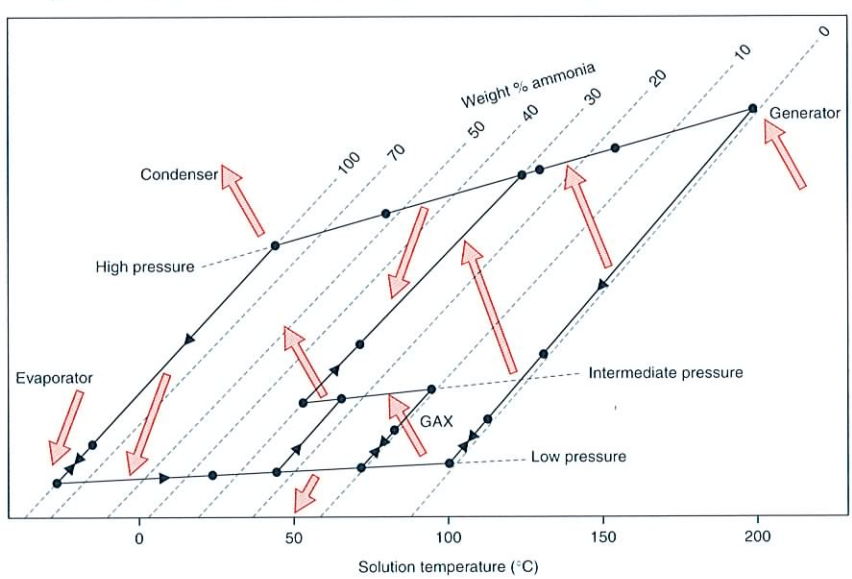
There are also two major developments underway in cycles which use water as the refrigerant. InteRotex from the UK is one of them. They use rotating compact heat exchangers. As the absorbent, a mixture of hydroxides is used, allowing the system to provide a higher temperature lift than water lithium bromide systems. The system can be used for cooling and heating. The other development is by Takagi Company from Japan under funding from MITI. They have developed a compact room type air-to-air water-lithium bromide air conditioner comprising an air-cooled absorber which reduces size and weight. An advanced production process of pressing and automatic welding of the thin steel plates is used for compactness and light weight. The cooling and heating capacities of the unit are 2.2 and 3.5 kW respectively, while the corresponding PERs are higher than 0.7 and higher than 0.75.

Mr Ryan also considered the ongoing electric utility deregulation process in the US and their impact on absorption chillers. He concluded that new arrangements for real-time pricing schedules may discourage the use of electric chillers, the major factor in peak power requirements. This would open up a substantial future for absorption cooling.

VX GAX cycle

Further progress on GAX cycles was reported by **Mr D. Erickson** of Energy Concepts, USA. He introduced the VX (Vapour eXchange) GAX cycle **(Figure 1)**. The cycle incorporates recuperation of absorption heat both to a high pressure generator and to an intermediate pressure generator. This double recuperation would give the cycle higher efficiency than any conventional absorption or mechanical vapour compression cycle. The economics of a conceptual 35 kW

▼ *Figure 1: Vapour-liquid equilibrium diagram for VX GAX cycle.*



cooling design of a VX GAX at a lift of 50 °C indicated that such a system would achieve almost instantaneous paybacks at these and higher lifts. At high lifts the PER of a VX GAX absorption refrigeration unit would be higher than that of single-effect systems and mechanical refrigeration units.

Solid sorption

In a presentation by **Mr Kirol** of Rocky Research, USA, the commercialization of solid-vapour sorption refrigeration devices using ammoniated complex compounds was described. A major benefit is the high power density of these compounds. The units developed feature long life sorbers and enhanced heat and mass transfer, contributing to compact size and cost-effective products. Plans exist to mass produce the products for sale by supermarkets.

In Japan, ammonia absorption chillers will have a second chance to become publicly accepted. Existing standards prohibit the use of ammonia as a refrigerant in chillers. However, increasing environmental pressure almost forces these standards to be reviewed. These circumstances led to a relaxation of some legal restrictions for ammonia water absorption chillers with a low charge. Strategies used for safe installation and operation include high placement of equipment (rooftop) and minimizing ammonia charge.

Absorbent Concentrator

Mr Meckler of the US-based Meckler Group proposed an enhanced absorption system that encompasses a compact absorbent concentrator heat pump unit. Such a unit would be powered by an electric motor and can be retrofitted into or constructed as part of an absorption chiller. The unit essentially works as a compression heat pump equipped with a roots blower, since the heat of compression is recovered as latent heat of evaporation. It increases the volume of refrigerant water and further concentrates the absorbent which results in an overall system efficiency increase of more than 20% in the case of a 1.75 MW chiller. In addition to lower operating costs, a big advantage is that this allows for the use of mild construction steel for the chiller, leading to lower initial costs.

Metal hydrides

In a paper by **Prof. Groll**, from the University of Stuttgart, Germany, three exhaust-gas-driven metal hydride car air conditioning concepts were presented. Although the power density of 30 to 100 W per kg hydride and their efficiency of 0.22 to 0.8 are promising, the large volumes and consequently heavy weight is a major drawback of metal hydrides, and of other solid sorption systems. The application of metal hydride air conditioning systems in trucks, buses or diesel trains seems more likely, as the weight is less critical here.

An efficiency improvement of 10% can theoretically be achieved for a compression-resorption heat pump using the mixture ammonia water. **Mrs Itard** of the Technical University of Delft, the Netherlands, introduced the results of a test on a 30 kW laboratory system and reported that oil-free screw compressors are needed, although for wet compression they are not available on the market as yet. The test had therefore been done with a liquid ring compressor instead, resulting in a poor efficiency and low supply temperatures. When a suitable compressor can be used, the design conditions are expected to be achieved (COP 3.7). It would make this system of potential interest for large resorber (condenser) temperature glide applications.

Other highlights

Additives are used in sorption systems to improve heat and mass transfer. Topics covered in the session on additives include surface tension aspects of solutions with surfactants, measuring the effectiveness of additives using advanced technologies and the effect of graphite-fibre inserts.

Advanced Cycles and Liquid and Solid/Gas Pairs papers were presented on multi-effect complex compound ammonia systems, active carbon fibre-methanol and active carbon-ammonia. Furthermore the physical properties and the performance of polymer desiccant materials and other adsorbents were introduced.

In the *modelling* session papers were presented on GAX cycles and components, heat and mass transfer in desiccant materials and components, falling film absorption on horizontal tubes, vapour-liquid mass transfer, and compressor-driven metal hydride refrigerators and heat pumps.

The papers on *controls* related to the optimization of solid-gas concepts, and to the development and use of fibre-optic measuring devices.

The few *market* related papers included a market assessment for Canada of commercial rooftop GAX absorption heat pumps, a strategy for promoting the industrialization of ammonia absorption systems in Japan, and an experimental evaluation of commercial desiccant dehumidifier wheels in the US.

A major highlight of the conference was the special tribute to the late Prof. G. Alefeld by Prof. G. Grossman, Prof. B. Spinner, and Dr F. Ziegler. The scientific and technical committee of the conference agreed to establish the *Prof. G. Alefeld Award*. This award will be given to the person who has contributed to the field of sorption and who stands out in sorption research. The award will be presented for the first time at the next conference in 1998, for which the location has not been selected as yet.

The proceedings of Absorption '96 are available from the IEA Heat Pump Centre. Details are given on page 8.

Author:
Mr Jos Bouma
IEA Heat Pump Centre

Using heat from a depth of 1500 metres

Gerhard Oppermann, Switzerland

Warm geothermal fluids at a depth of 500 to 3000 m can range in temperatures from 20 to 100°C and provide a valuable source of renewable energy. The first large-scale project for utilizing this so-called hydrogeothermal energy in Switzerland, has been operating since 1994. Using heat pumps, geothermal water at 65°C is used to supply a communal district heating network in a residential suburb of Basel. The results so far are very good. The availability forecasts have been reached and the consumption of fossil fuels has been reduced to less than a half.

Various systems are now available or are under trial for the utilization of geothermal energy. Exploitation by means of borehole heat exchangers down to a depth of 200 m using heat pumps has become widespread in Switzerland for smaller houses. More intense energy, known as hydrogeothermal energy, is available in geothermal fluids at depths of 500 to 3000 m. Such energy resources provide an important source of year-round heating energy.

A renewable resource

The temperature in the interior of the Earth rises with increasing depth by about 3°C per 100 m into the Earth's crust. Today, it is assumed that about one third of the heat flow resulting from this temperature gradient originates from the Earth's core. The remaining heat is generated by the natural radioactive decay of rock in the Earth's crust. Model calculations have shown that this heat flow is greater than the total world energy consumption. Since the cooling of the Earth takes over several thousand million years – a period which is virtually limitless for human beings – geothermal energy may be considered to be a renewable energy source.

Switzerland has neither active volcanoes nor hot springs. The utilization of the Earth's heat is limited to the low-temperature range provided by aquifers at a depth down to 2000 m, whose water is likely to have temperatures of up to 80°C. These can be utilized for space heating and for the generation of hot water for industrial or domestic use.

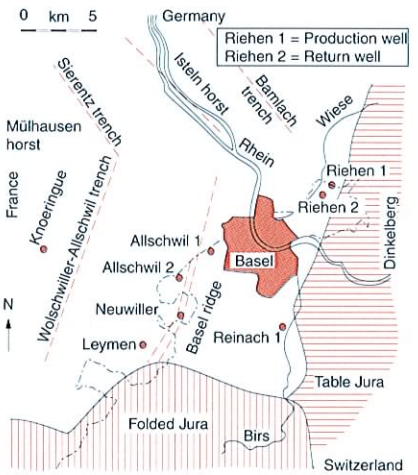
An interesting region

The geothermal situation in the Basel area ( ) is interesting since there is an arching of the Earth's crust in the southern Rhine valley. The thickness of the crust is reduced to about 26 km there. The upper shell limestone, which can exhibit water conductivity as a result of karstification and fissuring, promises to offer an interesting source of aquifers. This prognosis has been confirmed in the lower region of the valley edge according to Dr L. Hauber of the University of Basel.

On the basis of this geological information, energy planners for the town of Riehen, a suburb of Basel, investigated the possibility of using this renewable energy resource for a district heating network, with the aim of minimizing the fuel consumption and reducing the emission of atmospheric pollutants. Boreholes were sunk and a test programme was conducted which confirmed the possibility for long-term exploitation of geothermal energy. The test results provided information about the expected physical, chemical and hydraulic properties of the geothermal water and formed the basis for the design of the geothermal plant.

Sinking the wells

The analysis of the geothermal water showed that the heat carrier was a highly mineralized water containing 17 g/l of dissolved minerals and large



▲ *Figure 1: Tectonic situation showing the position of the boreholes.*

amounts of CO_2 and N_2. To comply with the water protection law, two wells were made so that the water could be returned to the shell limestone after the heat extraction.

The two boreholes are 1 km apart and function as artesian wells, providing a natural yield of 6 l/s of geothermal water. The water source in the production well which is located in the upper shell limestone, is two metres thick and lies at a depth of 1496 m. A submerged pump was installed at a depth of 390 m to pump up the geothermal water at about 64°C via a closed pressurized system into the heating plant. There, heat is extracted from the water and it is reinjected in the second borehole at a pressure of about 20 bar.

How it works

In the heating plant, the geothermal heat is transferred to an intermediate loop

(see **Figure 2**). The high temperature level permits some heat to be transferred directly via a heat exchanger to the return flow from the district heating network, which is at 60°C. Depending on the operating conditions, the thermal power of this direct utilization varies between 300 kW and 700 kW.

Further extraction of the geothermal energy takes place in two plants, each consisting of an electric heat pump driven by a gas-fired cogeneration unit. The high heat source temperature results in extremely favourable conditions for the heat pumps, resulting in coefficients of performance (COPs) of between 4.5 and more than 5. A third air-source heat pump recovers radiant heat from the cogeneration engines.

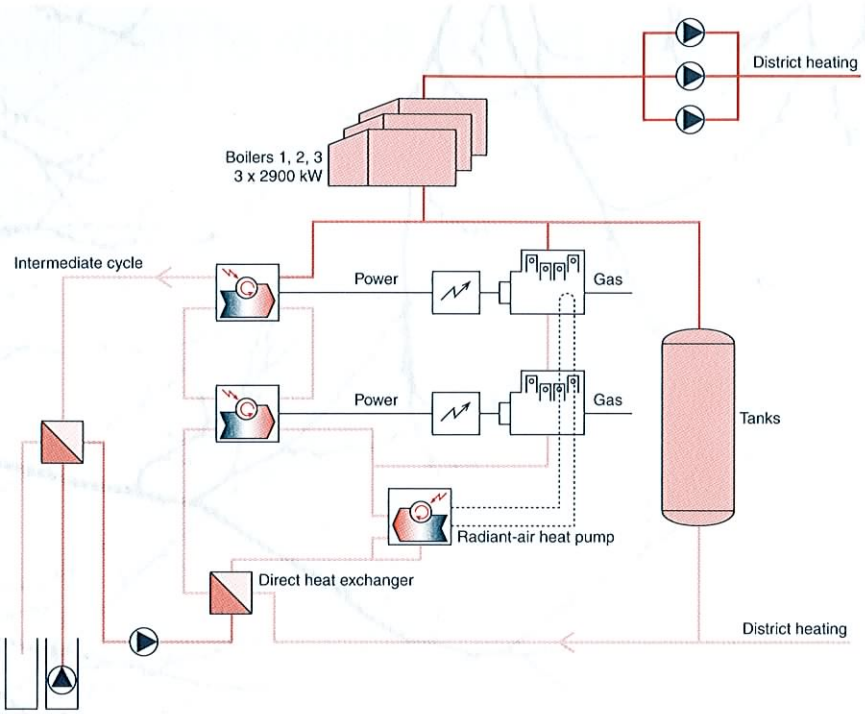
The heating plant is designed as a base load plant and covers about 80 - 85% of the annual energy demand. Peak load is met by three oil-fired hot water boilers of 2.2 MW each.

Three hot water storage tanks, each with a volume of 100 m^3, make it possible to minimize the frequency with which the motoroperated plants are switched on. This has a positive effect on the service life. Moreover, it allows the cogeneration units to be operated during peak charge times. This energy management earns a respectable proportion of the annually operating revenue. The electric heat pumps are normally driven by the cogeneration units. In the event of failure, or during off-peak electricity periods in summer, the heat pumps can be operated with electricity from the local network. The electric energy for pumps and other auxiliary components is generated by the cogeneration units on an annual balance.

Further details of the system are given in **Table 1**.

Avoiding corrosion

Owing to its high mineral and carbon dioxide content, the geothermal water is very corrosive, necessitating a careful choice of the materials used. The connecting pipelines laid in the ground were made of synthetic piping, and stainless steel was used for fittings and instrumentation. The heat exchangers of the geothermal cycle consist of titanium-alloy steel (See **photo**).



▲ *Figure 2: Simplified diagram of the plant.*

Building the network

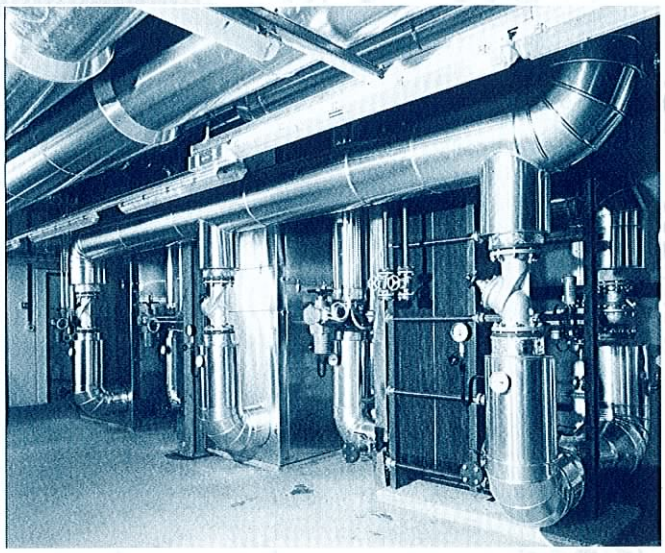
The idea of a district heating network in the centre of Riehen village arose as a result of the energy policy objectives of minimizing the final energy use and reducing the emissions of atmospheric pollutants. Furthermore, the poor condition of the existing oil-heating in many houses demanded immediate action. The construction of the peak boiler plant began in 1989 to supply the growing district heating network until the geothermal plant started operation. This meant that by the time the geothermal plant was commissioned, in 1994, the heat demand had grown to allow a very high utilization factor of the geothermal plant when it went in operation. Further expansion of the network was completed in 1996 to include a total of about 160 heat supply contracts.

Optimizing the system

Consulting engineers, GRUNEKO AG, were commissioned by the Federal Office for Energy of Switzerland to carry out measurements and to evaluate the plant over an operating period of two years. The results of this and other monitoring activities has allowed the base load of the plant to be constantly improved from commissioning to the present day. By alteration of pre-set data and phasewise switching in of the control system for automatic and optimized operation, it was possible to increase the degree of utilization.

Reducing pollution

Compared with individual heating systems, the final energy consumption is reduced by about 20,000 MWh/a to half its original value using geothermal energy. 50% of the required useful heat is now supplied by the renewable geothermal energy source. The reduction in fossil fuel consumption and



▲ *Heat exchangers in the geothermal cycle.*

Network	
Connected load of heating network	15 MW
Network design	95/60 °C
Geothermal source	
Depth of borehole 1	1547 m
Depth of borehole 2	1247 m
Temperature of geothermal water	64°C
Water-source heat pumps	
Heating capacity	2 x 1410 kW
Seasonal performance factors (1995)	4.6 and 4.7
Radiant air heat pump	
Heating capacity	300 kW
Seasonal performance factor (1995)	3.5
Cogenerators	
Power capacity	2 x 834 kW
Total energy efficiency (1995) (based on higher heating value)	96% and 99%
Peak boilers	
Capacity	3 x 2900 kW
Heating efficiency (1995) (based on higher heating value)	90%, 86% and 93%
Energy characteristics	
Heat yield from geothermal energy	16000 MWh/a
Gas and oil consumption	19400 MWh/a
Electricity consumption	4900 MWh/a
Electricity production	4400 MWh/a
Heat production	34200 MWh/a

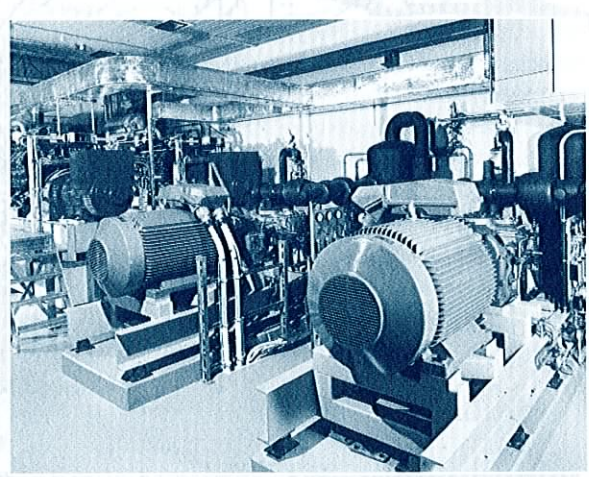
▲ *Table 1: System data.*

the use of modern flue gas purification equipment has substantially reduced emissions of SO_2 and NO_x. And CO_2 emissions have been reduced to less than half.

Outlook

The low price for fossil fuel and the high capital costs of geothermal utilization for a district heating system are at the moment not encouraging conditions for new projects. There are nevertheless some interesting possibilities to investigate both in Switzerland and further afield.

When considering potential projects it is most important that preliminary investigations carefully clarify not only the geophysical suitability, but also the possible market for heat sales. The experience gained to date from the plant described in this article shows that the operational reliability of hydrogeothermal plants is not inferior compared with other heat generation technologies.



▲ *Heat pumps and cogeneration units (back left).*

Author:
Mr Gerhard Oppermann
GRUNEKO AG
Consulting engineers
Güterstrasse 137
4002 Basel, Switzerland
Tel: +41-61-367-9595
Fax: +41-61-367-9585

Review of Low Energy Cooling Technologies
Available from the IEA Air Infiltration and Ventilation Centre, University of Warwick Science Park, Coventry, UK.
Fax: +441203-416306, E-mail: airvent@aivc.org December 1995.
Price: GB£ 15.
Produced under Annex 28 of the IEA Implementing Agreement "Energy Conservation in Buildings & Community Systems", this report reviews the application of alternative cooling strategies to buildings, such as night-time cooling, ground cooling, slab cooling, evaporative cooling and desiccant dehumidification.

Advancements in Absorption Heat Pumps
Available from Gas Jigyou Shinbun Co. (Gas Industry News).
Fax: +81-3-3239-5990. May 1996, 335 pages, Japanese.
This tutorial and specialist book was written by members of a study circle on advanced absorption heat pumps organized by the Heat Pump Technology Center of Japan (HPTCJ) and coordinated by Prof. Kashiwagi of Tokyo University of Agriculture and Technology. The publication has won a special award from the Japanese Association of Refrigeration (JAR).

Absorption Chillers and Heat Pumps
Herold K.E. and Radermacher R. Published by CRC Press, Inc., Florida, USA. Fax: +1-800-374-3401. ISBN: 0-8493-9427-9, 1996, US$74.95
This book offers an in-depth description of absorption chillers and heat pumps, focusing on relatively simple systems that employ working fluids in the liquid and vapour phase. Aimed at newcomers to the field, it discusses the thermodynamic and transport properties of working fluids and their influence on performance.

Replacing CFCs in Thermodynamic Systems
(Remplacement des CFC dans les Systèmes Thermodynamiques) Published by Société Française des Thermiciens (SFT), 3, rue Henri Heine, 75016, Paris, France. June 1996.
Proceedings of the conference held in the offices of Electricité de France in Moret-sur-Loing on 12 June 1996. The ten papers cover topics ranging from regulatory developments to application examples in skating rinks and malt-making facilities.

Geothermal Solution for College's Heating / Air-Conditioning System
Published by IEA CADDET Energy Efficiency, Sittard, The Netherlands, Fax: +31-46-451-0389, E-mail: nlnovcce@ibmmail.com RESULT 255.
This 4-page brochure highlights the benefits of a ground-source (geothermal) heat pump system at Sallam Community College in Carneys Point, New Jersey, USA. Using 50 borehole heat exchangers, the heat pump system has cut the college's annual heating and cooling bill by US$ 60,000.

Closed-Loop Geothermal Systems Slinky™ Installation Guide
Published by the International Ground Source Heat Pump Association (IGSHPA), Oklahoma State University, USA. Fax: +1-405-744-5283. Price US$ 35 (non-IGSHPA members).
The Slinky ground heat exchanger, which has a coiled configuration, was developed at Oklahoma State University in 1990. This 60-page manual shows and explains all the steps of Slinky installation, from designing the heat exchanger to excavating and backfilling the trenches.

Refrigeration, Climate Control and Energy Conservation
Proceedings of the International Institute of Refrigeration (IIR) Conference held in Melbourne, Australia in February 1996. Available from the IIR, Paris, France. Fax: +1-4763-1798, E-mail: iifiir@ibm.net Price FRF 180, 272 pages.
Contains 24 papers on modern heat pump technology, air conditioning and climate control, advances in refrigeration machinery and the thermophysical properties of refrigerants.

PsyCalc
Available from the Linric Co., USA. Internet: http://www.linric.com or Tel.: +1-800-322-6154. Price US$ 49.95
This windows-compatible software has been developed to meet the needs of HVAC engineers. It allows the user to perform psychometric calculations whilst running a spreadsheet or other program. It can calculate properties such as dry bulb and wet bulb temperatures, relative humidity, dewpoint temperature, humidity ratio, enthalpy, vapour pressure and specific volume. For example, it can find the properties of mixing two air streams.

An invitation

to an IEA Heat Pump Centre Workshop on

Building HVAC Equipment Regulations and Standards

Organized by the HPC Spanish National Team

Held in conjunction with the international trade fair "Climatización" this workshop is of particular interest to manufacturers and standards organizations.

Contact the IEA Heat Pump Centre for further information (see back cover)

Madrid, Spain
27 February 1997

Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

Industrial Heat Pumps
Annex 21 Workshop Proceedings, Oct '96
Order No. HPP-AN21-4
NLG 120, or NLG 60 in HPC member countries (see back cover) and in Canada, France, Sweden & UK

A Better Way to Meet Heat Demand
HPC Brochure, Sep '96
Order no. HPC-BR4
Free-of-charge

5th IEA Conference on Heat Pumping Technologies
Conference Proceedings, Sep '96
Order No. HPP-CONF5
Price NLG 250 - no discount for member countries

Ab-Sorption 96
Conference Proceedings, Sep '96
Order No. HPC-ABS96
Price NLG 300 - no discount for member countries

Heat Pumps in the UK: the New Opportunities
Workshop Proceedings, July '96
Order No. HPC-WR-17
NLG 120, or NLG 60 in HPC member countries (see back cover) and in UK

Heat Pump Energy Efficiency Regulations and Standards
HPC Analysis Report, June '96
NLG 160, or NLG 80 in HPC member countries (see back cover)

Systems and Controls for Energy Efficiency
HPC Workshop Proceedings, May '96
NLG 120, or NLG 60 in HPC member countries (see back cover)

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

ASHRAE Winter Meeting
25-29 Jan '97 / Philadelphia, USA
Contact: ASHRAE.
Tel: +1-404-636-8400,
Fax: +1-404-3215478

Climatización '97
25 Feb - 1 Mar '97 / Madrid, Spain
Contact: IFEMA, Madrid.
Fax:+34-91-722-5790

International Air Conditioning and Refrigeration Conference
24-26 Mar '97 / Tasmania, Australia
Contact: AIRAH, Melbourne.
Fax: +61-3-9328-4116

Cold Climate HVAC '97
30 Apr - 2 May '97 / Reykjavik, Iceland
Contact: Cold Climate HVAC '97,
Reykjavik. Fax: +354-5625859

The World Waste-to-Energy Conference and Exhibition
27-29 May '97, Amsterdam, Netherlands
Contact: European Media Marketing,
London, UK. Fax: +44-171-793-8007

Eighth International Stirling Engine Conference and Exhibition
27-30 May '97 / Ancona, Italy
Contact: Prof. C.M. Bartolini, Università di Ancona. Fax: +39-71-280-4239

Heat Pumps in Cold Climates
11-12 Aug '97 / Wolfville, Canada
Deadline for abstracts: 30 Mar '97
Contact: Mr Doug Cane, Caneta Research, Mississauga. Fax: +1905-542-3160,
E-mail: 104666,736-@compuserve.com

Clima 2000
30 Aug - 2 Sep '97 / Brussels, Belgium
Contact: SRBII, Brussels.
Fax: +32-2-511-7597

Heat Pipes, Heat Pumps, Refrigerators
8-12 Sep '97 / Minsk, Belarus
Contact: Prof. Leonard L. Vasiliev,
Luikov Heat & Mass Transfer Institute,
Minsk. Fax: +357-172-32-2513,
E-mail: allusr@avtlab.itmo.by

Air-Conditioning in High-Rise Buildings
9-12 Sep '97 / Shanghai, China
IIR Conference
Contact: Shanghai Society of Refrigeration. Fax: +86-21-6327-7108

Heat Powered Cycles
15-17 Sep '97 / Nottingham, UK
Contact: Conference Secretariat,
University of Nottingham.
Fax: +44-115-951-3159

Heat Transfer in Natural Refrigerants
6-7 Nov '97 / Maryland, USA
Contact: Dr Radermacher, Center for
IIR Conference
University of Maryland.
Fax:+1-301-405-2025,
Email:rader@eng.umd.edu

IEA HEAT PUMP PROGRAMME EVENTS

Building HVAC Equipment Regulations and Standards
27 Feb '97 / Madrid, Spain
IEA Heat Pump Centre Workshop
Contact: IEA Heat Pump Centre.

CO_2 Technologies in Heat Pumps and Air Conditioning
13-14 May '97 / Trondheim, Norway
Organized jointly with IIR
Contact: Mr Jørn Stene, SINTEF Energy, Trondheim (see back cover).

Heat Pump Systems, Energy Efficiency and Global Warming
Sep '97 / Graz, Austria
IIR Conference co-sponsored by the IEA Heat Pump Programme
Contact: Dr Hermann Halozan, TU Graz, Austria (see back cover).

Next Issue

Thermally-Activated Heat Pumps
Volume 15 - No.1/1997

International Energy Agency

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

IEA Heat Pump Programme

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

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

Novem

Netherlands agency for energy and the environment

IEA Heat Pump Centre
Novem, P.O. Box 17
6130 AA Sittard, The Netherlands
Tel: +31-46-4202-236
Fax: +31-46-4510-389
E-mail: nlnovhpc@ibmmail.com
Internet: http://www.heatpumpcentre.org

National Team Contacts

Austria
Mr Hermann Halozan
TU Graz, Inffeldgasse 25
A-8010 Graz, Austria
Tel: +43-316-873-7303
Fax: +43-316-873-7305
E-mail: halozan@iwt.tu-graz.ac.at

Japan
Mr Yoshio Igarashi
Heat Pump Technology Center of Japan
Galant Toranomon Bldg. (3F), 2-7-3,
Toranomon, Minato-ku, Tokyo, Japan
Tel: +81-3-3507-0071 Fax: +81-3-3507-0076
E-mail: ldk00100@niftyserve.or.jp

The Netherlands
Mr Onno Kleefkens
Novem, P.O. Box 8242
3503 RE Utrecht, The Netherlands
Tel: +31-30-2393-449
Fax: +31-30-2316-491
E-mail: nlnovokl@ibmmail.com

Norway
Mr Jørn Stene
SINTEF Energy
Regrigeration and Food Engineering
N-7034 Trondheim, Norway
Tel : +47-7359-1642 Fax: +47-7359-3950
E-mail: jornstene@energy.sintef.no

Spain
Mr Gabriel Carrasco
AEDIE
Ríos Rosas 32, 2nd floor
28003 Madrid, Spain
Tel: +34-1-442-5833 Fax: +34-1-442-7075
E-mail: gangel@iies.es

Switzerland
Mr Thomas Afjei
c/o INFEL/FWS
Lagerstrasse 1, Postfach,
CH-8021 Zürich, Switzerland
Tel: +41-1-299-4141 Fax: +41-1-299-4140
E-mail: infel@access.ch

USA
Ms Melissa Voss
Oak Ridge National Laboratory
Building 3147, P.O. Box 2008
Oak Ridge, TN 37831-6070, USA
Tel: +1-423-574-2694
Fax: +1-423-574-9338
E-mail: vossmk@ornl.gov