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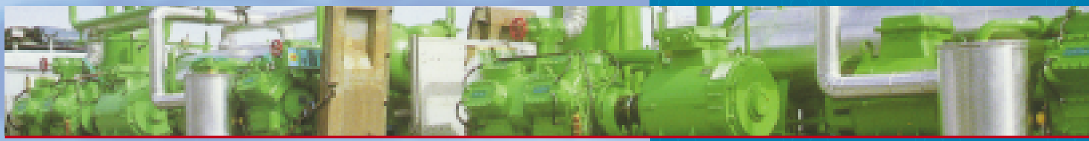

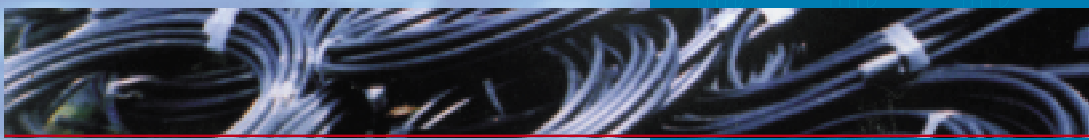

Heat Pumping Systems and Thermal Storage

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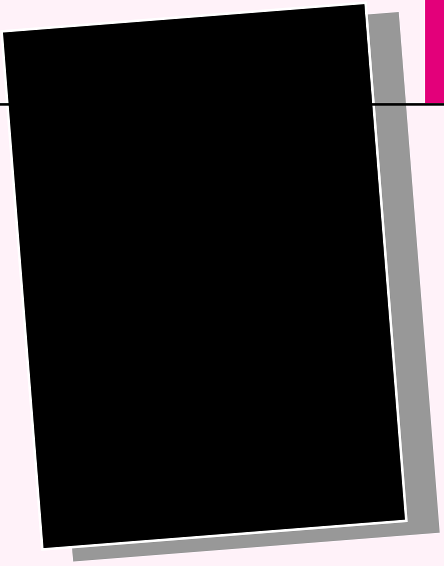
In this issue:

Ground-coupled heat pumps in a large residential installation

Integrated energy systems in Rotterdam industrial area

IEA OECD heat pump centre

In this issue



Large energy systems

Worldwide concerns about CO_2 emissions from energy use have been growing over the past few years. Large energy systems with heat pumps can effectively integrate the heat and cold demands of various users. This issue provides examples of large residential, commercial and industrial projects, where heat pumps have contributed to a higher energy efficiency and a more sustainable energy supply.

Front cover:
The front cover shows a compilation of three illustrations: one of ammonia heat pumps being transported, a map of Seon, Switzerland (see p. 24), and a photo showing pipes used in the application described on p. 16.

TOPICAL ARTICLES

In large, integrated energy systems heat pumps can play an important role in achieving maximum energy efficiency, by recovering waste heat and supplying both heating and cooling. This article describes applications in the residential, commercial and industrial sector. Special attention is given to district heating and cooling systems that can integrate heating and cooling demand from different sectors.

This article describes a project where 4,003 ground-coupled heat pumps are installed in houses at a military base in Louisiana, USA. Considerable energy savings were achieved compared to the situation before the retrofit. A long-term contract for installation and maintenance of the equipment was made with an energy services company, for which part of the revenues will be a percentage of the savings in energy and maintenance costs made at the base.

A programme for advanced utilisation of so-called unused energy has been running for seven years in Japan. The programme aims at enabling energy savings and electric load levelling. Results of the different projects under the programme are presented.

In Rotterdam's industrial area a strategy called "Energy 2010" is presented, which should eliminate and restrict waste and emissions from industrial activities by the companies participating in the projects. By upgrading waste heat to a higher temperature, heat pumps are an important tool in achieving a better integration between heat supply and demand in the area.

HEAT PUMP NEWS

FEATURES

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Kyoto: history repeats itself

The results of the Kyoto conference mean for the Netherlands that between 2008 and 2012 the CO_2-emissions must be reduced by 7% as compared to 1990, while the expected economic growth is over 3%. Calculations show that, amongst others, the energy efficiency of industrial processes must be improved by 50% to achieve this goal. Although this is technically achievable it is certainly a ‘no go’ in economic terms.

The initiative known as ‘Energy 2010’ in Rotterdam industrial area aims to encourage economic growth, while at the same time improving - in absolute terms - the environment and the quality of life in the area. All parties involved (the energy sector, industry, the port authority and the public authorities) cooperate in joint energy projects. Many projects have been developed, ranging from use of residual heat to the implementation of combined power generation, application of heat pumps and Organic Rankine Cycles, to an optimal combination of those techniques both within a company and across company boundaries.

Nevertheless, it appears that sound technical solutions are often not yet economically feasible, so it becomes necessary to transform the social relevance of optimal energy systems into substantial financial terms. A comparison can be made with closed sewer systems. Once upon a time people judged the nuisance of no (or even an open) sewer system no longer bearable and jointly decided to construct (at a social price) the present closed sewer systems, including the treatment of waste disposed into that system. The present environmental load caused by energy use urges society to take decisions to also provide for an optimal containment system.

It is our strong belief that the social relevance of sustainable energy systems should be more emphasised. Society as a whole should take action to provide an appropriate energy infrastructure. It is important to inform society, especially the younger generation, about the essence of sustainability, for in a few years they will be responsible for a sustainable earth and future.

Ir. C.J.M. Asselbergs
President of the Foundation ‘Europoort Botlek Belangen’

Heat pump news

Gas-fuelled heat pump demonstration

USA - Within the scope of the US Department of Energy's NICE3 programme, contract negotiations are going on with Acurex Environmental Corporation, to develop a gas-fuelled absorption heat pump that provides freezing, domestic hot water or boiler preheated water. It replaces conventional electric-driven compression refrigeration systems, water heaters, or boiler preheaters in processes for which both freezing and heating are required. Applications for this heat pump are in food processing, where blast freezing is performed after cleaning or cooking. In such processes, the heat pump's energy requirements would be up to 84% lower, and its emissions would be as much as 87% below conventional systems. In addition, the heat pump operates at a noise level of 80 dB, whereas the compression system usually operates at 110 dB. When operated at partial load, heat pump efficiency remains essentially constant, whereas conventional refrigeration system efficiency drops significantly.

Contact: John Schaefer +1-415-2542420.
Source: US National Team, see also the Internet site (http://syssrv9vh1.nrel.gov/Access/nice3/CCPOPACUREX.html).

The MINERGY concept

Switzerland - The MINERGY concept developed in Switzerland stands for efficient energy use and the persistent utilisation of renewable energies, with a simultaneous improvement in the quality of life, the competitiveness of sustainable technologies and a reduction of damage to the environment. It is a quality label. For products it can be used only if they fulfil the corresponding MINERGY standard. It can be used by everyone as a generic expression to identify ideas, strategies, and technical approaches, etc. which fulfil the MINERGY definition. The quality label should reinforce public confidence in these services and make them more widely known. The owners of the registered MINERGY label are the Cantons of Zurich and Bern.

For example, in the case of houses, the relevant value for the specific energy consumption for space and hot water heating is 45 kWh/m^2 per year, which is about a third of the average consumption of new buildings. Retrofitted buildings may consume a maximum of 90 kWh/m^2, around 45% of the average for old buildings, to meet MINERGY standards. Heat pumps are particularly suitable for achieving these standards, as the non-renewable energy supplied to the building is considered and a correction factor (factor 2) is used to account for the primary energy used in electricity production, which can be considerably offset by an efficient heat pump.

▼ *Figure: The MINERGY logo.*

MINERGY

Single copies of the brochure on the MINERGY concept and a brochure on the MINERGY house for building owners, both in German, can be obtained free-of-charge from AWEL.

Source: AWEL - Energiefachstelle, Dr R. Kriesi, CH-8090 Zurich, Switzerland.
Fax: +41-1-2595159. E-mail: energie@zh.ch

Standards for heat pumps

France/USA - In France minimum technical standards for heat pump installations are prepared in three categories. These include technical standards for air-to-water heat pumps, ground-coupled water-to-brine heat pumps and ground-coupled direct expansion heat pumps with water as the heat sink, all in combination with floor heating and cooling. These standards are prepared by the heat pump commission initiated by the AFF (French Association for Refrigeration) and the ADPM (an association for the promotion of energy management for heat pumps and cooling machines). This commission establishes standards for feasibility studies, designs, user conditions, installation, maintenance and control of heat pumping systems with a maximum heating capacity of 30 kW. It includes machines for heating, heating and cooling and climatisation in residential or small commercial applications. The aim is to establish minimum requirements to prevent malfunctioning installations, but the regulations should not stand in the way of possible innovations.

In the US, the Air Conditioning and Refrigeration Institute (ARI) has published a new standard, No. 290-96, on 'Air conditioning and heat pump equipment incorporating potable water heating devices'. A copy is available from ARI, fax: +1-703-5283816 or from the Internet site (www.ari.org).

Source: AFF, Fax: +33-1-42220042 / Koldfax, November 1997.

Technical information published by ASERCOM

Germany - The Association of European Refrigeration Compressor Manufacturers (ASERCOM) published two 'Technical Information Bulletins' which are available in English, German, French, Italian and Spanish. The topics are 'Hydrocarbon Refrigerants in Refrigerating Systems' and 'Substitution of R-22 in New Air Conditioning Systems'. For a copy contact Mr J.A. Winkler at ASERCOM Office, Mottzstr. 91, D-10779 Berlin, Germany. Fax: +49-30-21479871.

1998 ASHRAE winter meeting

USA - Ground-source heat pumps are a relevant topic at ASHRAE meetings. At the winter meeting in San Francisco, ASHRAE displayed a new publication on this subject (see page 30). A short course on the design of commercial ground-source heat pumps preceded the ASHRAE winter meeting. Two symposiums were held on the design, operation and maintenance of ground-source heat pumps, both open-loop and closed-loop systems. In the first symposium papers were presented on the operation of a hybrid system, on the design and operation of a system in China, and on the use of thermal conductivity testing for loop design. The second symposium covered the development of appropriate wells, design tool development for closed loop sizing, antifreeze acceptability in the US and concerns of state water management organisations, and the use of calibrated engineering modelling in the design of large-scale systems. In the US a new set of easy-to-use and accurate piping design tools has been developed that will give designers more confidence and reduce the cost of ground-coupled heat pump systems by reducing oversizing and piping complexity that has been common in some installations.

The acceptability of antifreeze fluids varies greatly in the US. The only fluid universally accepted is potable water. About half the US states currently have no regulations or recommendations concerning anti-freeze for ground-coupled systems. Some states have no jurisdiction and others require that the fluid be non-toxic. The list of recommended or required antifreeze fluids varies greatly in 16 states. This complex situation has created confusion among practitioners. As the industry grows, it is expected that regulators will react. A number of states now have regulations in the process of adoption, while others are considering such a move. In a separate seminar, the results of monitoring commercial ground-source heat pump systems were discussed.

Three papers on thermally-activated heat pumps are noteworthy. One paper evaluates the relevance of existing heat pump testing and rating method assumptions to a method of test for residential gas-engine-driven heat pumps. The information from the study can be used in finalising a performance standard that fairly and accurately treats gas-engine-driven heat pumps. In the second paper a new absorption heat pump was discussed that uses a new organometallic liquid absorbent and hydrogen or nitrogen gas as a refrigerant. Features claimed are more compactness and higher power density at high efficiency. The concept can be used for absorption-compression cycles and for pure absorption cycles and will be developed further. The third paper concerns the operation and performance of two 350 kW single-effect/double lift absorption chillers in a district heating network in Berlin and Düsseldorf, Germany. The plants have been in operation since 1996 and the paper describes the concept, installation, control strategy and experiences with these pilot plants. These projects demonstrate that space cooling produced from district heat is an interesting service that district heating companies can offer. ASHRAE also organised two symposiums on sorption heat pump systems which included papers on the economics of sorption chillers, so-called hysorb heat pumps, monitoring of an adsorption air conditioner, cross-flow condenser design for ammonia-water heat pumps, ammonia-water bubble absorbers with a plate heat exchanger and heat transfer performance of a coiled tube absorber.

In the area of working fluids, the issues discussed included the development of polyvinyl ether oil for HFC air-conditioning systems, corrosion of metals in contact with new refrigerants/lubricants at various moisture levels with organic acid, refrigerant properties update (Annex 18 of the IEA Heat Pump Programme), new lubricants for HFC refrigerants, and heat transfer and pressure drop phenomena of refrigerant oil mixtures in components, including micro-fin tubes.

The papers presented will be published in the ASHRAE Transactions. A selection of papers is available from the HPC.

Source: Jos Bouma, IEA Heat Pump Centre.

Maintenance data of ground-source heating systems requested

Canada - Caneta Research Inc. is investigating service and maintenance costs associated with ground-source heat pump installations in commercial buildings. Operators of newer ground-source systems are asked to provide maintenance records for these systems. Those with information on multiple or large sites can be compensated for their efforts. This study is limited to installations in North America, and will complement a preliminary study which seemed to indicate that ground-source heat pump installations have lower service and maintenance costs than conventional HVAC systems.

Please contact:
Chris Ireland or Doug Cane, Caneta Research Inc. Tel.: +1-905-5422890. Fax: +1-905-5423160.
E-mail: caneta@compuserve.com

Metric-only labelling to be mandatory in Europe

USA - Effective 1 January 2000 all products sold in Europe must be specified and labelled only in metric (SI) units. Dual units will no longer be acceptable after this date. This EC Directive applies to all products sold or shipped to Europe, i.e. product labels, catalogue listings, technical manuals, instruction sheets, advertising materials and all other forms of product information. A paper entitled “The EC Requirement for SI Units” has been prepared to provide more detailed information on the EC Directive requiring the use of SI Units. Copies of this paper are available from ARI’s Engineering Department (contact Denise Littlejohn) and at ARI’s Internet site: (http://www.ari.org). Fax: +1-703-5283816.

Source: Koldfax, December 1997.

Magnetic heat pump flow director

USA - The National Aeronautics and Space Administration (NASA) plans to transfer the NASA-developed 'magnetic heat pump flow director' technology to private industry for use in industrial applications.

This technology was developed to direct the flow path of fluid in a magnetic heat pump. The magnetic heat pump contains a rotor of magnetic material that slowly rotates through a magnetic field. The rotor has an enclosure with flow passages to allow heat transfer fluid to move through the rotor. The fluid flows in the opposite direction to the rotation of the rotor, to provide the heating and cooling effect. The fluid flow has to be split into separate hot and cold loops. The flow director is installed between the two loops at their point of separation to develop enough restriction to properly guide the fluid flow through the correct flow path. Both the experimental and computational results have proven the validity of the flow director design. A prototype heat pump that incorporates the flow director technology has been manufactured and tested at the Development Testing Laboratory at the Kennedy Space Center (KSC).

This technology has the potential for wide applications in the production of heat pumps for use in CFC-free cooling and refrigeration systems. Benefits of the magnetic heat pump flow director are increased efficiency, no compressor, easy to manufacture, requires no maintenance and uses no CFCs. NASA is looking for a company for licensing or cooperative development of this technology for use in commercial applications. Inquiries concerning licensing of this NASA patent should be addressed to the Patent Counsel, DE-TPO, Kennedy Space Center, FL 32899, USA. Fax: +1-407- 8672050. E-mail: Technology.Transfer@ksc.nasa.gov.

Source: US National Team, see also NASA Internet site (http://technology.ksc.nasa.gov/WWWaccess/Opport/14.htm).

Heat pump system for laundry

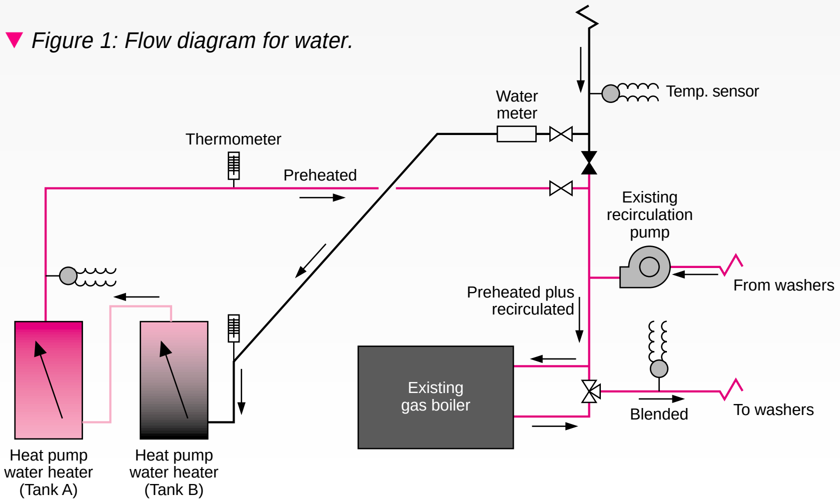
USA - A commercial heat pump water heater (HPWH) has been installed in one of the largest and busiest coin laundries in Knoxville, where large amounts of hot water are used. The Tennessee Valley Authority's Technology Advancements (TVA) group, wanted to test a HPWH and offered to monitor its performance for a year. The HPWH can operate in three modes, i.e. recovery mode (combining water heating and air conditioning), water heating only and air conditioning only. The basic concept was for the heat pump to perform base load air conditioning and water heating and let the existing air conditioner and gas boiler supplement the heat pump.

During periods of low to medium load the heat pump heats the water to 49°C and the gas boiler raises this to 54-57°C. During heavy demand the heat pump cannot meet demand, and the preheated water temperature drops, especially in winter when the incoming water is very cold. The existing gas boiler readily makes up the shortfall. The heat pump used is one of the most efficient air-to-water heat pumps. The refrigerant-to-water coils receive the hot gas from the compressor and exchange the heat directly with the incoming water without requiring a water pump. The hot gas and water are in counterflow, with the outgoing hot water coming in contact with the hottest gas at the top of tank A. The outgoing liquid refrigerant is cooled by the incoming cold water at the bottom of tank B. All pipes and storage tanks are super insulated and many controls such as timers are applied to ensure maximum efficiency. A diagram for the water flow is given in Figure 1.

The coefficient of performance (COP) was extremely high with an average of 4.3 for the year. When operating at this COP the total useful work totals 7.6 units of output for each unit of energy (electricity) used, namely 4.3 for heating and 3.3 for cooling. Around 45% of the total runtime was in this heat-recovery mode. The total installation costs amounted to USD 13,000. With USD 4,000 saved on electricity and gas in the first year, the payback period is expected to be 3.3 years.

Source: ASHRAE Journal, October 1997.

▼ *Figure 1: Flow diagram for water.*



New challenge for geothermal systems

USA - A McDonald's restaurant in Detroit will be the first in the chain to use a geothermal heating and cooling system. If the prototype is successful, the company could implement the system throughout the chain. Instead of a furnace, air conditioner and water heater, the system will use the earth's constant temperature to heat, cool and provide hot water for the 334 m^2 restaurant. A solution of water and environmentally friendly antifreeze in an underground pipe absorbs the heat from the earth. The temperature in the pipe remains steady at approximately 10°C. Pressurising the refrigerant in the heat pump raises its temperature to over 82°C. Reversing the process cools the solution, returning its heat to the earth.

Source: ASHRAE Journal, December 1997.

Reducing CFC use in mobile air conditioning

Malaysia - Malaysia has successfully reduced CFC use in mobile air-conditioning (MAC) thanks to a recycling project funded by the Multilateral Fund of the Montreal Protocol. The project, which cost USD 910,000 and was implemented by the World Bank, involved the distribution of recycling equipment, storage tanks and accessories to 200 MAC service workshops. The equipment was used to recycle CFC-12, the refrigerant most commonly used in MAC units.

A survey in 1997 showed that most workshops were satisfied with the way the project had been run. The project had been beneficial to them since the machines are profit-making. Many workshops have therefore purchased a second machine, and several workshop owners have suggested expanding the scheme to include more workshops and recycling of HFC-134A. The survey also showed that there had been a 20% reduction in CFC purchased by the workshops, which means that at least 20% of the CFCs in the vehicles serviced is being recycled. The project is eventually expected to prevent the emission of 200-350 tonnes of CFC-12 a year.

Contact: Mr Ismail Ithnin, Office for Project Management Under the Montreal Protocol, Department of Environment, Ministry of Science, Technology & Environment, Kuala Lumpur. Fax: +603-2931480, E-mail: ibi@jas.sains.my.

Source: OzonAction Newsletter, Special Supplement No. 4, 1997.

R-22 substitution: reality or wishful thinking

Germany - This headline was the topic of a symposium organised by ASERCOM, the association of European refrigeration compressor manufacturers, in October 1997. The conclusions are summarised below:

- for standard refrigeration applications the following refrigerants are now commonly used worldwide: R-404A, R-507, R-134A and hydrocarbons;
- for air-conditioning applications (up to now by far the largest part of R-22 consumption) the trend indicates that outside Europe (93-94% of the global market) the refrigerants favoured by the manufacturers are R-410A (smaller AC equipment) and R-134A (large chillers). However, for R-410A the full spectrum of components is not yet available. The high pressure requires a redesign of major components;
- for the relatively small European market a split exists as some countries will phase out R-22 for new systems between 1998 and 2002. These countries (Sweden, Germany, Denmark, Switzerland and Austria) cannot wait for R-410A and need intermediate solutions such as R-407A, or flammable hydrocarbons. The other countries, meeting the EU phase-out schedule, will probably follow the global trend.

Source: JARN, November 1997.

Standards organisations join forces on flammables

USA - The safe use of flammable refrigerants is such an important issue that committees of two international organisations have agreed to combine efforts in defining safety guidelines. It concerns the commissions IEC SC61D and ISO TC86/SC1. A third commission, IEC SC61C, did not participate, but approved its own requirements to use up to 150 grams of flammable refrigerants in household refrigerators and freezers. The new ISO/IEC working group is headed by the USA. It is anticipated that the provisions relating to the safe use of flammable refrigerants will be contained in the revision of ISO 5149 and IEC 335-2-40.

Source: Koldfax, November 1997.

Refrigerant options discussed

USA - The Conference ‘Refrigerants for the 21st Century, organised in October 1997 by ASHRAE (American Society for Heating Refrigeration and Air Conditioning Engineers) and NIST (National Institute of Standards and Technology), discussed the various refrigerants and equipment that might play a role in the next century. Mr Calm, from the USA, thought it unlikely that an alternative refrigerant would be discovered or synthesised that meets all the requirements for safety, cost, stability, efficiency and ozone-depletion potential. Trade-offs would be necessary to achieve a balanced solution. He concluded that greater attention is necessary to address both environmental and safety concerns by containment, particularly for compounds with minimal adverse impacts, rather than phase-out.

Mr Kruse, from Germany, had a different point of view. He discussed hydrocarbon refrigerant experiences in Europe and mentioned that 8-10 million appliances using isobutane have been produced in Germany. This trend is expected to continue. According to Mr Kruse, safety issues have been overcome. Natural refrigerants were also discussed by several other speakers. The chairman concluded that the merits of various refrigerants result from a complex combination of attributes, the most important being ODP, GWP, efficiency, safety and cost. Since the importance of these attributes varies according to applications and countries, the merits of these refrigerants are viewed with a corresponding lack of uniformity.

Source: ASHRAE Journal, December 1997.

Slow take-up for gas AC in Europe

Germany - The market for gas absorption and gas-engine chillers in Europe remains relatively small compared with Japan and the USA. The 1997 world air conditioning industry survey by BSRIA (UK) showed that absorption units rated at 350 kW and above represent less than 10% of the total value of the European chiller market. By contrast, in Japan 60-80% of new buildings are now directly or indirectly gas cooled and in the USA the market is expected to reach USD 2 billion by the year 2000.

Although the gas utilities in some European countries are involved in promotion, so far this has not kick-started the market. However, the impulse may come from another direction - as suggested by York International in Mannheim. Energy outsourcing, which is being used to an increasing extent in Germany - particularly as a total package including power generation - could be the key. To maximise year-round efficiency such plants are increasingly being combined with absorption machines for summer operation. York estimates that outsourcing of refrigeration will represent a market segment of 15-20% by the end of the decade and could reach 30% by 2005.

Source: JARN, December 1997.

Gas cooling in Australia

Australia - Australia contains some very big gas cooling plants, some of which have been operating for years, but some large installations have also been commissioned recently. However gas-cooling technology for small users is only just starting trials. Significant changes in the Australian cooling market include CFC phase-out and replacement, close examination of indoor air quality issues by health authorities, increased focus on energy management and costs, deregulation in the energy supply industry and an increasing desire for year-round climate control. Together these factors offer opportunities for gas-cooling technologies to spread and reduce peak electrical consumption. Medium- and small-scale gas-cooling technology has several advantages as well as better energy performance.

The cooling market in Australia has been assessed as having an overall electric motor-driven cooling load of around 9,000 GWh per year in 1995/96 with a yearly growth rate of 3-5%. Half of the electrical demand for summer cooling is from small electrical air-conditioning systems (cooling capacity less than 17.6 kW) used in domestic situations. More than one third of the demand is used to power large and very large systems (cooling capacity over 176 kW) in commercial applications. The three available gas-cooling technologies (absorption, gas engine and desiccant systems) are competitive in the Australian large-size market. It is estimated that with successful marketing, gas could achieve a 15% share of this market. Progress in the smaller and medium-size market will depend on the demonstration of this viable technology and an acceptable price. The Gas Cooling Taskforce has been working on a trial of small-scale gas-cooling technology in Australia, with a major residential project using the York Triathlon. The programme is due to be completed in mid-1998.

Source: Australian Energy News, December 1997.

R-410A RACs available

Japan - Room air conditioners (RACs) using the zero ozone depletion potential (ODP) HFC refrigerant R-410A are now available on the Japanese market. At the seventh treaty nation conference of the Montreal Protocol, it was decided that HCFC refrigerant R-22 used in RACs will be abolished in 2020. Japan aims at total abolition by 2016, by steadily replacing conventional models with those using the new refrigerant.

In the case of packaged air conditioners (PACs), several companies have already announced R-407C models. For RACs, Matsushita and Toshiba have announced the release of models using R-410A. Thanks to the characteristics of R-410A the two Matsushita models feature a larger heating capacity (4.2 kW) when outdoor temperature is low, so that they can be used even in semi-cold districts or mountainous regions. By improving the compressor motor, scroll section and heat exchanger, Matsushita has achieved a very high COP of 4.5.

Source: JARN, December 1997.

New research programme focuses on improvements for the 21st century

USA - A new research programme 'HVAC&R research for the 21st century (21-CR)' will be implemented by the Air-Conditioning and Refrigeration Technology Institute. The 21-CR programme will include research that will enable HVAC&R manufacturers to offer equipment and services in the next decade that, once integrated into building and process applications, will utilise far less energy than today's applications while addressing the comfort and indoor environmental quality needs of building occupants. Improvements can be made to the equipment itself and by better incorporation of equipment into more comprehensive systems for particular applications.

The programme will focus on pre-competitive research providing information and solutions to obstacles that prevent or impede HVAC&R manufacturers from introducing new systems and components. Once these technical challenges have been addressed it is then up to individual manufacturers to apply the research results and to produce products that satisfy market needs. Five subcommittees have been formed by the steering committee, covering alternative systems, energy efficiency, system integration, indoor environmental quality and working fluids. It is anticipated that USD 15-20 million will be spent on research over the next 5-7 years.

Source: Koldfax, January 1998.

Annex 24 experts meeting

Sweden - An experts meeting was held on 21-22 January 1998 in San Francisco, USA. The meeting was held in conjunction with the ASHRAE show and was hosted by the US Department of Energy (DOE).

Based on the country reports that were made in an earlier phase, the Annex members had selected several topics for case studies to be carried out. The objective was that the case studies should compare alternatives for a particular application in terms of energy efficiency, environmental aspects and economic factors. The topics cover a very broad spectrum, including GAX cycles, hybrid systems, low-temperature-driven absorption chillers, chillers and combined heat and power systems, large commercial systems and open cycles. At the experts meeting in January, the progress on these case-studies was discussed. Invited presentations were given by representatives of the American Gas Cooling Centre, US DOE, York and Trane. A technical visit was made to Pacific Gas & Electricity, where a 1.8 MW absorption chiller is installed. The meeting also discussed an outline for an Annex 24 Internet site. An analysis of the country reports will be compiled and printed during the spring of 1998. The work on the case studies continues and an international workshop will probably be organised in September.

Source: Magnus Gustafsson,
Fax: +46-8-105228.

Workshop on deployment activities

Sweden - On 12 May 1998 a workshop on Deployment Activities of Heat Pumping Technologies will be held in Stockholm, Sweden. The objectives of the workshop are to bring together various target groups and discuss experiences and activities to increase the market introduction of heat pumping technologies. The workshop is targeted at manufacturers, branch organisations, information specialists, policy makers and end-users. The workshop will also provide a forum to discuss future activities and plans to speed up the market penetration of heat pumping technologies. Areas covered include the market status, the demand for further R&D and to define certain activities for removing the obstacles. Authors of potential papers for this workshop should send their abstracts (100-150 words) to Dr Peter Rohlin before 1 April 1998. Fax: +46-8-203007.
E-mail: rohlin@thermo.kth.se.

Internet site redesigned

The Netherlands - As announced in the previous issue, the structure of the HPC Internet site (www.heatpumpcentre.org) has been changed. Further improvements and expansions can be expected this year.

Contact: Hanneke van de Ven, IEA Heat Pump Centre.

▶ *Photo: The new home page of the IEA Heat Pump Centre Internet site.*

New address HPTCJ

Japan - On 9 February 1998, the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ) moved to a new office. The new address is:
HPTCJ
Kakigara-cho F Bldg (6F)
28-5, Nihonbashi Kakigara-cho 1-chome
Chuo-ku, Tokyo 103-0014, Japan
Tel.: +81-3-56432374
Fax: +81-3-56414501

Ongoing Annexes

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

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

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).

Large energy systems

An international overview

Hanneke van de Ven, IEA Heat Pump Centre

In many countries improving the efficiency of energy use is a high priority. With the agreements on the emission reduction of CO_2 and other global warming gases including HFCs made at the climate conference at the end of last year in Kyoto, Japan, the need for clean and sustainable energy supply has grown further. This may lead to more integrated energy infrastructures. In such large energy systems, heat pumps can play a key role in achieving a maximum energy efficiency, by recovering waste heat and supplying both heating and cooling.

The large energy systems discussed in this overview include large-scale heat pump systems that generate and distribute heat and cold. This can either be collective installations using a heat pump with a large heating or cooling capacity, but also applications where a large number of small decentralised heat pumps are installed in an area. Following the above, 'large energy systems' applications can be found in various sectors.

In the residential sector, a large system may consist of many individual heat pumps that meet the space heating (and cooling) and the hot water demand, but could also be one central heat pump with an extensive distribution network. Options in between these two extremes also exist. In the commercial sector, large systems often meet heating and cooling demands in large buildings or groups of buildings. In the industrial sector, waste heat that can serve as a heat source for large systems is abundant.

District heating and cooling (DHC) systems often combine surpluses and demands from the different sectors. For example, industrial waste heat can be used as the heat source for the heat pump system, which supplies heating and cooling to both commercial and residential buildings.

This overview discusses conditions that influence the opportunities for large systems and describes the international situation. General aspects of district heating and/or cooling systems are described, and several examples are given of large energy systems with heat pumps, covering all sectors.

Opportunities

Despite the variety of systems included in this topic, there are several circumstances that create opportunities for large energy systems. The first is the availability of waste heat. To reduce losses residual heat (or cold) at one location can be used to meet demand in another, preferably nearby, location. The second positive factor is the presence of a high density of buildings or demand. In regions with both a heating and cooling demand the possibilities for an integrated system with heat pumps increase. Even in regions without a traditional cooling demand, this demand is developing in commercial buildings as a result of new building design, increased internal heat loads and higher comfort demand. Finally, to realise the implementation of a cost-effective large system, an intermediate organisation should coordinate the needs of the various users. This could for example be a utility company supplying the area.

Advantages of large central systems include the security of energy supply, high energy efficiency and low costs per unit of heat generated. However, decentralised systems are more flexible in matching the demands of different users.

▼ *Photo: The two ammonia heat pump units being transported to the Bodø air base.*

International situation

The situation with regard to large energy systems differs widely per country. Examples from several countries are given in the 'boxes' on the following pages. A typical country, where most of the aforementioned factors are present, is Japan. As Japan has to import most of its energy supplies, energy savings have become increasingly important since the oil crisis. This has led to airtight construction and high thermal insulation of buildings. The internal heat gain has risen, making indoor climate control necessary. This particularly applies to urban areas, where the population growth has set a trend towards large interconnected building groups, sometimes even underground. The energy systems must be very stable, reliable and efficient. A system which combines heat and/or cold storage, heat-recovery heat pumps and cogeneration is considered to be the best solution. Over 30 district heating and cooling systems containing heat pumps are in operation in Japan.

In Sweden heat pumps in large energy systems are common. Around 6.5 TWh heat per year, which is around 15% of the total heat supply of district heating, is produced via large capacity central heat pumps. The expansion of heat pump capacity for district heating mainly occurred from 1982-86. The reasons for this were the high oil price after the 'second oil crisis' and the rather low price of electricity. In addition to compression heat pumps, some absorption heat pumps are also used for district heating in Sweden. For compression heat pumps, industrial waste heat is used as a heat source, but sewage water, ground water, sea/lake water and outside air can also be used. The market for district heating in Sweden is now saturated.

In Austria, Switzerland, Germany, the Netherlands and the Nordic countries the climate is relatively cold. There is no space cooling demand for houses, so district systems in these countries supply heat only. A growing number of district cooling systems can be seen. In the US there are not many heat pumps applied in large systems. Some 5,800 district heating systems are used for commercial and institutional applications, but the percentage using heat pumps is not known. Other large systems found in the US usually have large-capacity chillers to provide cooling for a commercial building or group of buildings.

DHC systems

The most obvious example of a large energy system is a district heating and/or cooling system, which may include a heat pump. There are two basic concepts for heat production:

- a central heat pump provides both heating and cooling, with the warm and chilled water distributed in separate pipelines. The central heat pump may utilise the excess heat from the district cooling system as an additional heat source;
- a central heat pump produces tempered water at a low temperature (about 25°C), which serves as a heat source for several local heat pumps producing heat for individual buildings or groups of buildings. The local heat pumps provide heating or cooling whenever necessary, and only one pipe is required for both heating and cooling. This system concept is described in IEA Heat Pump Centre Newsletter 1/96, *"Two-step district heating and cooling"*, pp 23-24.

An advantage of the second concept is that the overall seasonal performance factor (SPF) is higher because the local heat pumps can be matched to the heat distribution temperatures of the different buildings. Also, by producing heat in two stages, the heat pumps operate under more favourable temperature conditions. Another advantage is that investment costs are reduced as a simple and inexpensive (uninsulated) heat and cold distribution system can be used.

District heating heat pump systems use different heat sources, though waste heat is a common heat source. This can be industrial waste heat, waste heat from power stations or waste heat from refuse incineration. Geothermal heat is also used for district heating, for example in France, Denmark, Poland and Canada. In Greece and Sweden air-source systems are installed. The article on page 19 introduces the Japanese programme for 'Development of heating and cooling technology for load levelling and advanced utilisation of unused energy'. This programme was set up to stimulate the use of so-called 'unused energy' in DHC systems.

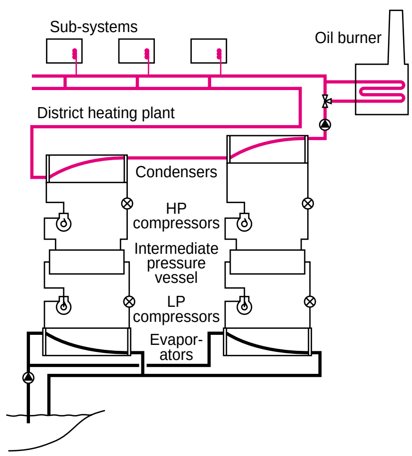
Unused energy is available at a low or medium temperature level, from sources that are currently virtually unused, such as waste heat discharged from refuse incineration plants, sewage treatment plants, subways, buildings or energy held in sea water, rivers, etc. As heat recovery was the topic of the previous newsletter, the Japanese district heating and cooling systems on heat recovery are not covered in this overview. Please refer to No. 4/97 for an overview of large- and small-scale heat-recovery applications.

As far as the types of heat pumps are concerned, mainly electrically driven compression installations are used in DHC systems. However some engine-driven systems are also used. Absorption heat pumps in district heating are used in Sweden, Denmark, Japan and Germany, some use waste heat and others use geothermal heat as the heat source. In the following paragraphs, several examples of district heating and/or cooling systems are described.

Heating with sea water

A district heating heat pump installation that uses sea water as the heat source is installed at the military air base in Bodø, Norway. In 1992 the existing oil-fired boilers were replaced by a heat pump system (see **Figure 1**). The 30 buildings have a peak load demand of 3.8 MW at design conditions and the

▼ *Figure 1: The heat pump installation at the Bodø military air base.*



annual heat demand is 11 MWh. The heat pump consists of two equal two-stage units using ammonia (NH_3) as the working fluid. The required supply temperature from the heat pump at design conditions is 68°C. Fourty bar reciprocating compressors were used in the second stage. Plate heat exchangers and shell-and-tube heat exchangers are used as evaporators and condensers, respectively. The heat pump and oil-fired peak-load boilers are located in a separate building near the sea, and sea water at 170 metres depth is used as the heat source. The average sea water temperature is 7°C. Due to the pure water there have been no problems with fouling of heat exchangers. The SPF of the heat pump installation is 3.5.

Absorption cooling

In 1995 a utility in Gothenburg, Sweden, started to expand their services to customers by supplying environmentally friendly district cooling. Sweden is a country with a low cooling demand. The district heat supplied was based on approximately 70% waste heat from refuse incineration, an oil refinery and sewage water heat pumps. During summer heat supply consists of 100% waste heat from refuse incineration plants and the petroleum industry. This coincides with the peak in space cooling demand. The district heat in summer is used to drive absorption chillers using water/LiBr as the working pair. For maximum efficiency, the temperature of the district heating water during summer is kept at around 90°C. The decentralised chillers are operated and maintained by the utility. A basic prerequisite for cost-effective supply of district cooling is a minimum cooling load for each customer of 500-600 kW. In August 1997, the utility had contracts for district cooling with a capacity of around 14 MW. Some of these contracts will be implemented in 1998. Cooling will then be supplied to office buildings, an amusement park, a hospital, university, etc. A strong feature of the system is that cooling is produced completely CFC-free and that the electricity consumption for cooling is reduced by approx. 70-75%.

'Trigeneration'

A large system for a group of buildings is located in Sydney, Australia. A central energy plant provides the state parliament building, a state library and two hospitals with power, heating and cooling. After one of the electric chiller units broke down in 1995, the decision was taken to install a large-capacity engine-driven chiller. The remaining electric chillers are now used as reserve capacity. The plant has a cooling capacity of 2,110 kW and supplies base chilling capacity during peak and intermediate supply periods between 07:00 and 22:00 hours. Outside those hours the use of off-peak electricity is still cheaper. The central energy plant's cogeneration unit runs on natural gas and diesel. It generates 550 kW of electricity and produces 800 kW of heat. Waste heat is recovered from the engine jacket and run into the system. Both engines can provide all the hot and chilled water required for all four buildings as well as the base load electricity. This project has exceeded expectations. Net savings generated are expected to pay back the loan of USD 263,000 in three years, while reducing greenhouse gas emissions by 55%. The total investment needed was USD 514,000. This system is Australia's first so-called 'trigeneration' installation, producing power, heat and chilling from the same fuel source on site with total waste heat recovery.

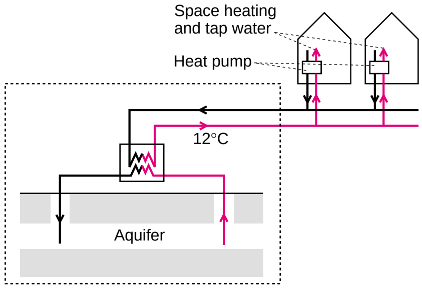
Residential areas

Another example of large energy systems that use heat pumps appears in newly built community areas, where the energy infrastructure is developed from scratch. Before implementation, different options are compared. Large-scale heat pump systems are just one of the heating technologies, others include district heating with cogeneration, solar energy, etc.

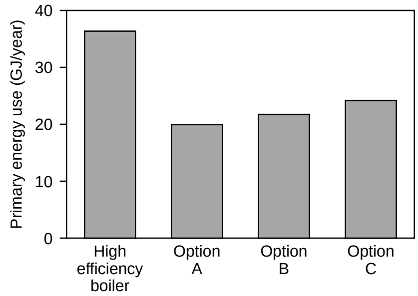
The so-called 'VINEX' projects in the Netherlands include the development of new housing and building areas to meet the new housing demand. The choice of energy supply by gas and electricity, or by electricity alone is based on a range of factors, of which cost is the most important. If all-electric is chosen, electric heat pumps can be used to provide heating. One of the VINEX areas is 'Broekpolder' in Beverwijk, where 500 of the 1,750 houses will have electric heat pumps for space and water heating. The solution for this area consists of decentralised electric water-to-water heat pumps, an aquifer for energy storage and a distribution network to transfer the heat between the aquifer and the houses. Three options were compared:

A) individual heat pumps for space and water heating (see **Figure 2**);
B) space heating heat pumps for groups of 10 houses and individual booster heat pumps for water heating;
C) a central heat pump for the entire district and individual booster heat pumps for water heating.

The annual primary energy use for the three options was compared, as well as for the conventional situation with a



▲ *Figure 2: Configuration with decentralised heat pumps and an aquifer.*



▲ *Figure 3: Annual use of primary energy for space and tap water heating.*

high-efficiency boiler (see **Figure 3**). Costs were also compared. The first option gave the best results, both cost and energy-wise, and will be realised for 500 houses. Together with other energy-saving measures, such as improved insulation, CO_2 emissions will be reduced by over 50% depending on the efficiency of electricity production. Another large-scale residential application is located in Louisiana, USA and is described on page 16. This installation consists of 4,000 individual reversible ground-source heat pumps.

Waste heat from fuel cells

In Nürnberg, Germany, an advanced pilot plant has been built in which fuel cells are combined with an absorption heat pump to produce heat for a residential area of 763 apartments. In fuel cells chemical energy from hydrogen or natural gas is directly converted into electricity and waste heat at two temperature levels. Major advantages of fuel cell electricity generation are a high electric efficiency (40-60%), almost no moving parts, with minimal emissions and noise generation. The pilot plant will provide roughly 20% of the heating and 60-70% of the electric power demand in the housing area. The fuel cell requires cooling at 40°C, while the existing heating network has return temperatures of 50°C. By applying an absorption heat pump that uses the excess heat of the fuel cell plant as driving energy and as the heat source, a very energy-efficient solution is obtained, as no separate cooling device is needed. A system diagram is given in **Figure 4**. The estimated investment costs for the heat pump are USD 111,000, and the annual operation costs are USD 1,667. With annual electricity savings of 16,000 kWh and heat savings of 600 MWh, the payback period varies between 10 and 26 years, depending on the heat price and interest rate.

Industrial areas

Large energy systems with heat pumps are interesting in industrial regions,

Austria

Because of the climatic conditions (around 3,500 heating degree days, design temperatures between -10°C and -18°C in the populated regions) the dominant space conditioning need in Austria is heating. Until now cooling has only been required in commercial/institutional buildings. Around 70% of the electricity is generated from hydropower, depending on the water levels of the rivers. The reduced water levels during winter time, as well as winter peaks in electricity consumption, are covered by thermal power stations using coal or gas; many of them are cogeneration plants, supplying the larger cities with heat and providing electricity and process heat to industry.

These general conditions result in a limited application of heat pumps for large energy systems. Heat pumps are mainly used in regions where the supply density is too small for district heating systems, i.e. in city suburbs and in rural regions with a low population density.

However, as part of a larger system heat pumps become interesting where waste heat from industry or heat from hot springs is available as a heat source. Heat pumps are used for providing base load in small district heating networks with overall capacities in the range of 4-10 MW. One company operating large cold stores is already upgrading its waste heat using heat pumps and supplies it to a large district heating network. Such heat sources are not yet used intensively, but they will achieve an increasing share of heat production using heat pumps in the near future.

Source: Hermann Halozan, Austrian National Team

The Netherlands

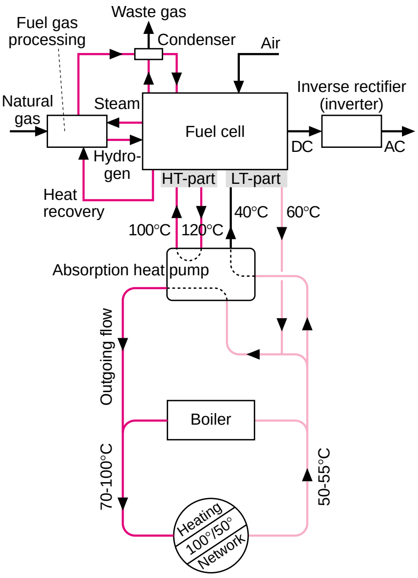
A first step towards achieving a high energy efficiency is to optimise the system design of the residential/commercial building, greenhouse or industrial process. If the energy demand is sufficiently lowered the second step, integrating the systems into a larger infrastructure, can be made.

Four heat pump projects play an important role in the Netherlands at the moment. The project 'Oostelijke Handelskade' in Amsterdam combines cooling from a cold source aquifer in summer time with heating 100,000 m^2 of offices and 800 residences with heat pumps using the same aquifer as a heat source. The system, which has been demonstrated in the Anova-offices in Amersfoort, thus serves a larger infrastructure more efficiently than individual systems. The second project, 'Broekpolder' in Beverwijk, is described in the main article. The project 'Noordpolder' (for 1 km^2 of greenhouses) compares traditional greenhouse heating with heat distribution from combined cycles and individual absorption heat pumps. In this project the absorption heat pump is the clear winner both on energy and costs. The project for Rotterdam industrial area is discussed in this Newsletter in a separate article (see page 22). In an area near Vlissingen a similar study has been started that assesses how low-temperature industrial heat can be used for new greenhouse areas by using heat pumps.

With the rapid growth of residential areas and the ongoing process of for restructuring greenhouse areas, opportunities for further optimisation of energy infrastructures with heat pumps are abundant in the Netherlands.

Source: Onno Kleefkens, Dutch National Team

▼ *Figure 4: System layout for the German project with fuel cells and absorption heat pumps.*



where large amounts of waste heat are available, and high heating and cooling demands exist. Industrial waste heat can be supplied to a district heating network with industrial and other users. Another possibility is to couple existing cooling and heating demands within an industrial area by applying a large energy system with heat pumps, see page 22 for an example.

In one of the largest Dutch industrial areas near Rotterdam, options are being studied for an effective way of eliminating and reducing waste heat production and emissions from industrial activities. A primary goal is the optimum use of waste heat by participating companies. Applications for waste heat can be threefold. Firstly, it is estimated that about 100 MW of waste heat can be reused by the producing companies by upgrading waste heat with heat pumps. Secondly, heat can be exchanged between companies. A third possibility is to supply heat to greenhouses in the nearby Westland area (see Newsletter article No. 4/97, p. 25). Remaining waste heat can be made useful by lifting it to a higher temperature level with heat pumps, by using it for absorption cooling or by using it for production of electricity in an Organic Rankine Cycle

Switzerland

In Switzerland heat pumps are rarely used in large energy systems. However, district heating with heat pumps is implemented at the campus of the Swiss Federal Institutes of Technology in Zurich and Lausanne.

Heat recovery from water purification plants can offer interesting possibilities for using heat pumps on a larger scale. An installation in a sporting centre near Bülach takes heat from a water purification plant at 8°C. The six heat pumps with a total heating capacity of 480 kW meet 85% of the heat demand at an SPF of 3.0, substituting 117,000 litres of oil per annum. The heat is used for the swimming pool, space heating and hot (tap) water heating.

New programmes, such as the new energy law in the canton of Zurich, allow subsidies for large private projects with a capacity of at least 300 kW_{th}. This limit is reduced to 150 kW_{th} for communal projects if a substantial part is covered by the community. To avoid oversized installations, the yearly operation time is also taken into consideration. The E2000 investment programme offers subsidies for replacing existing heating systems with renewable energy sources. The investment costs must exceed USD 34,500 and the heat pump should cover more than 50%. Subsidies amount to USD 138/kW_{th} for air-to-water heat pumps and USD 207/kW_{th} for brine- or water-to-water heat pumps, up to a maximum of 10% of the accountable investment costs or USD 483,000. District heating users are granted USD 110/kW_{th} up to 15 kW_{th}. Above this, subsidies are reduced to USD 10/kW_{th}. This subsidy scheme is favourable for large energy systems equipped with heat pumps.

Source: Thomas Afjei, Swiss National Team

USA

A large system in Boston, USA is the Harvard University Medical Area Total Energy Plant (MATEP), which was completed in 1980. MATEP provides steam, chilled water and electricity to over 836,000 m^2 of space in facilities throughout the area that houses six hospitals with over 2,000 beds. By recapturing and reusing the heat that would be wasted in a conventional power plant, MATEP is designed to produce 30% more energy per litre of oil than normal electric power generating plants in Massachusetts. The key to cogeneration is the use of the hot exhaust from the diesel engines. MATEP is fired by both natural gas and fuel oil. In total 62 MW of electricity, 408,000 kg steam per hour (supplied at 184°C and 9.6 bar), and 28,448,000 kg per hour of chilled water (at 4.5°C) can be produced.

The plant has six 7 MW diesel generators, two heat-recovery steam generators (HRSGs) which provide heat as well as hot water, and three conventional boilers. There are also two steam turbines that produce electricity and seven chillers that provide cooling. Other plant equipment includes eight cooling towers. The conventional boilers comprise three high-pressure units that generate steam. The steam drives the extraction/condensing steam turbine generators and powers the turbine-driven chillers. These are used mostly to meet standby or peaking needs in summer or to balance plant steam and electric loads. The electric chillers are used to meet nearly all air-conditioning demand. MATEP can supply approximately 95% of the total electrical needs of the hospitals.

Source: US National Team, see also www.matep.com

Norway

The application of district heating systems is rather limited in Norway, due to the extensive use of electric resistance heating in commercial buildings. Another limiting factor is the lack of densely populated areas. In 1996 only 1.5 TWh or 3% of the total heating demand in buildings was met by district heating systems.

Due to the relatively cold climate in Norway, district heating systems with heat pumps are always designed as bivalent systems with two or more heat pump units in combination with a peak load heat source. Oil or gas-fired boilers or electro boilers are common peak load units. Although the heat pumps are designed for 40-60% of the maximum heating load, they meet 90-95% of the annual heating demand. The supply temperature ranges from 80-90°C at design conditions (at -10°C to -20°C). In order to obtain a high seasonal performance factor (SPF) for the installations, the supply temperature is reduced at increasing ambient temperatures, with a minimum at approximately 65°C. Moreover, the peak load boilers are only used when the heat pump units at maximum capacity cannot meet the heating demand. Sewage, sea water and ground water are the most important heat sources. Since there is renewed interest in energy conservation as well as in new, renewable energy sources in Norway, district heating and cooling systems with heat pumps are regarded as interesting options in a number of new projects. The Table provides an overview of current heat pump installations in district heating (and cooling) systems in Norway.

Location	Heat pump heating capacity	Heat pump cooling capacity	Heat source	Working fluid	Year of installation
Skøyen Vest - Oslo	2.1 MW	–	Sewage	CFC-12*	1983
Sandvika	13 MW	9 MW	Sewage	HFC-134a	1988
Ålesund	6 MW	–	Sea water	HFC-134a	1989
Bodø	1.8 MW	–	Sea water	Ammonia	1992
Stjørdal	1.4 MW	–	Sewage	Ammonia	1993
Bergen	2 MW	1.5 MW	Sea water	Ammonia	1995-97
Gardermoen	8 MW	6 MW	Ground water	Ammonia	1997

* To be retrofitted to HFC-134a

Source: Mr Jørn Stene, Norwegian National Team

Japan

Heat pump applications in large energy systems in Japan started in the beginning of the 1980s with an urban district energy system. The first large heat pump system for district heating and cooling in an urban area was installed in 1983 in Hikarigaoka-park town, as a pioneering large heat pump system.

Currently, in 33 locations large heat pumps are installed and in operation for district heating and cooling purposes. Various heat sources and sinks are used for those systems. They utilise outdoor air, building internal heat, sewage water, river water, sea water, ground water, etc. Most systems are coupled with thermal storage systems and use off-peak electricity, which contributes to load levelling.

Two national R&D programmes aimed at developing advanced heat pump technologies for large energy systems are now being carried out. The first is the ‘Unused energy utilisation technology programme’ that started in 1991. This programme is described in the article on page 19. The other is the ‘Eco-energy city / broad energy network system programme’ that has run since 1993. Various heat pump systems are in development under those programmes.

Source: Mr Takeshi Yoshii, Japanese National Team

(ORC). The amount of energy saved by the ‘Use of Industrial Residual Heat Project’ is estimated at 525 MWth, which equals a CO_2 emission reduction of 400,000 tonnes per year.

Large energy system design

The design of large energy systems can be complicated. Adapting the supply temperature to the most demanding (highest temperature) users is detrimental to the overall system performance. To avoid this problem, a good solution is a centralised plant with heat pumps (and often cogeneration) and additional decentralised heat pumps for users that require a higher temperature. Computer programs can help designers in simulating and optimising the system configuration. A good example is the so-called ‘environomic’ model developed in Switzerland. It includes thermodynamic, economic and environmental characteristics associated with the entire life cycle of the system equipment. Another example is the Japanese programme on unused energy, under which a plant planning system was developed. By entering a minimum set of data such as location, scale of buildings and characteristics of heat source and equipment, a proposed plan for using unused energy is quickly evaluated from the points of view of energy, environmental impact and economy.

Conclusion

Large energy systems with heat pumps are applied in residential, commercial and industrial areas. The factor common to all these applications is that they use heat pumps to effectively integrate the heating and cooling demands of different users within the system. The various examples given in this overview show that heat pumps, either centralised or decentralised, are a very powerful technology to optimise the energy efficiency of large systems and districts, thus contributing to a reduction of CO_2 emissions.

Hanneke van de Ven,
IEA Heat Pump Centre

Ground-coupled heat pumps in a large residential installation

By Don Best, USA

In 1994 the US Army made the decision to convert the family housing at its large Fort Polk Training Center in west-central Louisiana to geothermal heating and cooling. The 20-year contract, assigned to Co-Energy Group, an energy services company based in Las Vegas, Nevada, called for the installation of 4,003 ground-coupled heat pumps (GCHPs) – along with other energy-saving measures – to service all of Fort Polk's on-post housing units. According to the terms of the shared savings contract, Co-Energy Group would bear all of the up-front costs of the project and assume responsibility for maintenance of the installed equipment for the duration of the contract, in exchange for a 77% share of the energy and maintenance savings realised by the Army.

The project at Fort Polk was the first of this magnitude for the geothermal industry. The base housing area is actually a small town in itself, with some 12,000 inhabitants. Apart from the scale of the project, there were serious questions whether GCHPs could really deliver the energy savings needed to make the investment cost-effective. To make matters worse, project organisers knew that the design tools available to size the ground loops were far from perfect and that higher-than-expected maintenance costs on the equipment might reduce their profits. However, several factors finally persuaded the Army and the project organisers to proceed with the project.

Decisive factors

The first important factor was that the energy consumption at the base needed to be reduced. A 1994 executive order directed all federal facilities to implement plans to achieve a 30% reduction in energy use, relative to 1985 consumption, by the year 2005. Of course, those savings might be achieved by various means other than geothermal.

A second important factor was a demonstration project at Fort Polk to compare the performance of state-of-the-art air-source heat pumps to that of state-of-the-art geothermal models. The test convinced engineers that geothermal installations – if properly installed – could deliver the savings.

Finally, the fact that in the event of a bad project result, the energy service company and the heat pump manufacturer would be left with the problem. All of the investment capital was either provided or arranged by them, and for the most part, the reputations at risk were theirs.

Heat pump design

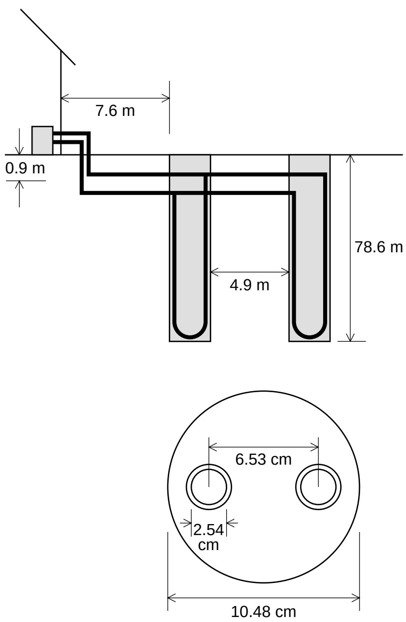
With the Army ready to go forward and Co-Energy Group positioned to provide financing, Climate Master, based in Oklahoma City, was working to redesign some of its smaller-capacity GCHPs for the project. This was necessary because nowhere in the industry was a high-efficiency geothermal heat pump of 5.3-7.0 kW available, that was needed for these residential units. Climate Master's parent company, LSB Inc. stepped forward and became an equity partner when the cost estimate ballooned from USD 15 million to USD 19 million.

The compact, integrated design of the new heat pump was a big plus when installing the heat pumps in houses that tend to be tight on space. Each of the 4,003 GCHPs has its own ground heat exchanger, consisting of two vertical, U-shaped pipe loops placed in separate bore holes and connected in parallel (see **Figure 1**).

Co-Energy Group installed the heat pumps in nominal capacities of 5.3, 7.0 and 8.8 kW, with one heat pump per home. Prior to the retrofit, 3,243 of the homes (81%) had air-source heat pumps and electric water heaters. The remainder (760 units) had central air conditioning, gas-fired furnaces, and gas water heaters.

Seventy-five percent of the new heat pumps utilise desuperheaters, which

▼ *Figure 1: Layout of an individual ground-coupled system.*



recover super heat from the heat pump and dump it into the water heater. In the other 25% of the homes, the heat pumps and water heaters were too far apart to make desuperheater installation practical. Co-Energy Group also installed attic insulation (where needed), low-flow showerheads, and compact fluorescent lights.

Bore holes

At the project's peak, 100 bore holes a day were drilled to depths of 61-79 m. By the time the crews installed the last of the heat pumps at the end of the summer of 1997, they had drilled a total of 560,000 m of 10.5 cm bore. Since the upper 0.91 m of bore is not part of the heat exchanger, the total installed heat exchanger length at Fort Polk was 552,000 m. Co-Energy Group installed a total of 1,104,000 m of 2.5 cm SDR-11 high-density polyethylene pipe in the bores, which they backfilled with standard bentonite-based grout.

Energy savings

An assessment of the project, recently completed by Oak Ridge National Laboratory (ORNL), concluded that the GCHPs and other retrofit measures installed at Fort Polk resulted in large energy savings (see **Figure 2**). Electrical consumption for a typical year dropped from 79.2 million kWh to 53.6 million kWh. This is a reduction of 25.6 million kWh, or 32%. These savings occurred even though 100% of the housing was all-electric after the retrofit, compared with only 80% before. In addition, the facility is saving 27 TJ of natural gas per year.

As we might expect, the average savings on houses that were originally all-electric was substantially higher than the savings for homes that had used natural gas prior to the retrofit, measuring 35% and 14%, respectively.

ORNL concluded that the project has been a real success. It has surpassed the requirements of Executive Order 12902. In trying to break down the energy savings, preliminary findings (based on measurements from just one of 16 electric feeders) indicate that 30% of the energy savings can be attributed to the GCHPs, 36% to the desuperheaters, 29% to the fluorescent lighting, and 5% to the low-flow showerheads.

Maintenance

Under the terms of the contract the Army is paying Co-Energy Group USD 261.95 per home per year to maintain the equipment at Fort Polk. (This is 77% of the estimated 20-year average baseline maintenance cost of USD 335.83 per home.)

Project organisers say that one of the most appealing aspects of the contract – from the Army's standpoint – is that it enables the base commander at Fort Polk to effectively cap maintenance costs and turn the responsibility for maintenance over to a third party. To fulfil that responsibility, Co-Energy Group employs a full-time staff of 12 maintenance workers at Fort Polk.

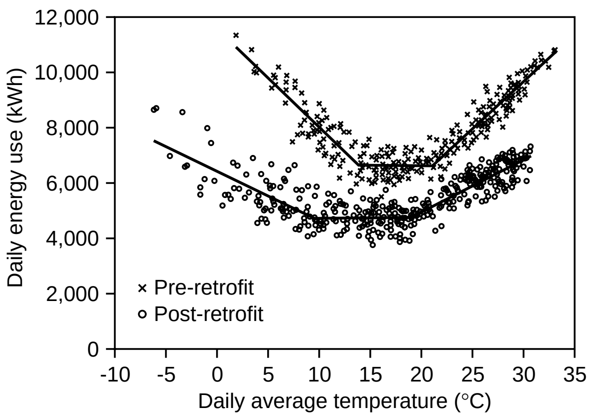
While no one knows exactly what the project's maintenance costs are going to be in the years ahead, one thing is clear: Co-Energy Group has a strong vested interest in performing preventive maintenance on the systems – scheduled at six-month intervals – whereas the Army had frequently left HVAC maintenance at Fort Polk unfunded or deferred to the following year. This interest in preventive maintenance results in better comfort and reliability for inhabitants, as well as in better performance and a longer lifetime for the equipment.

It is expected that GCHPs will require substantially less maintenance than air-source heat pumps. Experience has shown that the performance of an air-source heat pump degrades over time (as much as 20% off its original rating) as the outdoor coil gets fouled up and dirty. This leads to comfort complaints and service calls. In a project such as Fort Polk, where the equipment's performance determines the energy savings, and the energy savings determine the return on investment, absence of ongoing degradation is a real benefit. The GCHPs are expected to perform at a constant level during their lifetime. The ground loop is even expected to last 50 years or more, so it can serve new generations of heat pumps in the future.

Evaluation

With hindsight, there are several things that project organisers might have done differently, especially in sizing the ground loops.

Prior to making a final sizing decision on the ground heat exchangers, the designers ran on-site soil conductivity



▲ *Figure 2: Comparison of daily energy use before and after retrofit.*

▼ *Photo 1: The drilling at Fort Polk took nine months.*

▼ *Photo 2: Over 1,000 km of pipes were installed.*

tests on three ground heat exchangers at Fort Polk, using test equipment brought to the site on a trailer. But the equipment, that was in its first generation at the time, was not up to the challenge, forcing the designers to rely on tabular data and educated guesses.

The designers also had to choose from a number of different ground heat exchanger sizing methods, none of which could be used with complete confidence. In the end, they decided to install the largest of the recommended sizes due to the severe consequences of undersizing 4,003 separate ground heat exchangers.

Subsequent evaluation, conducted by the ORNL-led team, shows that the designers may have oversized the loops by as much as 20%. In other words, they could have potentially reduced the depth of the bores from 24 to 19 m per kW on average. Overall, that would have translated into a 111,800 m reduction in drilling, which would have saved approx. USD 1.3 million.

The evaluation suggests that Co-Energy Group might also have downsized other elements in the project without any performance penalty. For example, smaller ground loop pumps could have been used, saving USD 20 each on their purchase price and 40 W of electricity in operation. The study also suggests that 1.9 cm diameter pipe rather than 2.5 cm would have provided adequate water flow to the heat pumps. While this change would have required slightly more vertical bore, the savings on pipe would have more than offset the difference.

Future installers might also consider other approaches to backfilling the bore holes. Thermally enhanced grout, which was not readily available at the time, would be one option. Another possibility would be simply to backfill the holes with sand or drill cuttings and seal the top to prevent surface water runoff from contaminating ground water. However, environmental consequences of those solutions should be checked.

In spite of these negative points, the ORNL evaluation concluded that the results have been excellent, especially when bearing in mind that tools available to the designers in 1993 were fairly crude compared to what is on the market now.

Spin-off

In light of the Army's positive experience at Fort Polk, other military facilities are adopting geothermal heating and cooling. To date, 220 GCHPs have been installed at Fort Irwin in the Mojave Desert, 200 more are going in at Aberdeen Proving Grounds in Maryland, and more than 1,500 are scheduled at the Little Rock (Arkansas) Air Force Base. Vice-president Al Gore recently honoured the Fort Polk project with a Hammer Award for its energy-saving and environmental attributes.

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Advanced utilisation of unused energy

Morino Kimio, Japan

In order to achieve energy savings and electric power load levelling, a programme entitled “Development of heating and cooling technology for load leveling and advanced utilization of unused energy” has been implemented in Japan. This seven-year plan was started in 1991, and its set-up was described in Newsletter No. 3/91, pp 4-7. The general objectives were to reduce energy consumption, limit the emission of greenhouse gases and level the electric power load. ‘Unused energy’ is energy that is available at a low- or medium-temperature, that is currently not in use. Research and development projects in six subjects were undertaken jointly by the New Energy and Industrial Technology Development Organisation (NEDO), the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ) and 23 enterprises, with the support of the Agency of Natural Resources and Energy, Ministry of International Trade and Industry (MITI).

The expansion of energy consumption along with socio-economic activities is accelerating the consumption of fossil fuels. There is also increasing concern about the global environmental issues, such as global warming. Current trends show significant growth of the peak electric power demand, producing a larger gap between daytime and night-time power demand. To solve these problems without lowering the present standard of living, it is important to promote energy savings by effectively utilising all available energy resources.

Unused energy

In most cities various types of unused energy are available in abundance, such as waste energy discharged from refuse incineration plants, sewage treatment plants, subways, buildings or energy held in sea water, rivers, etc. These low- and medium-temperature energy resources, or ‘unused energy’, can help to solve the aforementioned problems. Unused energy can efficiently function as a heat source or heat sink for heat pumps in a district heating and cooling system (DHC). If this system is combined with thermal energy storage it can also contribute to power levelling.

Practical use of unused energy has gradually become more accepted. In Japan 36 DHC plants are now using it as their energy source. However, further technology development is necessary to use the majority of unused energy resources. New technologies should solve mismatches in geography, time and temperature between the heat demand and the generation of unused energy.

R&D themes

Within the programme research and development was conducted following six themes:

- high-performance heat exchanging technology;
- high-efficiency heat production technology;
- high-density heat transportation technology;
- high-efficiency heat supply technology;
- large-scale urban type thermal storage technology;
- optimum plant planning and operation technology.

In 1994 system component technologies were developed. The achievement of targets was ascertained by performing tests in the factory. From 1994 to 1995, demonstration equipment was designed, manufactured and installed at test sites. Trial operations were also conducted. Finally, from 1995 to 1997, demonstration tests were carried out under actual loads in locations across Japan where unused energy is available. In this way more efficient DHC systems are created by combining some of the component technologies developed under individual projects of the programme.

The target values of each of the individual projects are shown in **Table 1**. The following paragraphs describe some of the technologies developed under this programme.

Heat exchange and production

An efficient DHC system starts with efficient heat exchange and heat production technologies. Under the theme of high-performance heat exchanging technologies three heat exchangers were developed for sea water, sewage water and waste air, with performances which are higher than for conventional systems.

To increase the efficiency of the heat production equipment, a *refrigerant/ water direct-contact ice-making screw heat pump* was developed. The heat pump corresponds to load fluctuations and utilises relatively low-grade unused energy such as river water. An ice storage tank is attached to contribute to electric power load levelling. It could be used for DHC, as well as for industrial cooling, building air conditioning, etc. The *sea water direct-intake type screw heat pump* delivers high temperature water (60°C). For increased performance sea water is taken in directly. In the demonstration test it was confirmed that the equipment operated well with sea water at 2°C. Corrosion is avoided adopting titanium as a material for the evaporator. There is also a mechanism for preventing problems caused by marine creatures.

Another objective was the development of *a large-capacity turbo heat pump* capable of exhibiting up to 42 MW of unused energy on a large scale. It delivers 70°C water with improved partial load performance. This was achieved by developing a back-counterflow four-stage turbo compressor, with vane control technology and an economiser. A COP of 3.2 was achieved at heat source inlet/ outlet temperatures of 12-15°C.

To provide a heat pump system with an improved COP that could use alternative refrigerants such as R-134A (ozone depletion potential: zero), a *high-efficiency turbo heat pump* was developed with a cooling COP of 6. The high partial load performance was achieved by developing a three-dimensional vane wheel and variable vane turbo compressor. The capacity can vary from 10-100% using an inlet vane, diffuser vane control and speed control of the drive motor.

An *absorption heat pump* corresponding to a low-temperature heat source (7°C) was also developed. To recover heat from a low-temperature heat source (such as river water, sea water etc. in winter) a dual-loop double-effect system was developed by combining a water/LiBr cycle with a TFE/NMP cycle, which works in the low-temperature range. Demonstration tests confirmed that the equipment operated well with a heat source of 5°C. Furthermore, a *high-efficiency triple-effect absorption heat pump* was developed, combining a water/nitrate system with a water/LiBr system. This machine can be driven by high-temperature steam (240°C) from an incineration plant, and can produce chilled/hot water by utilising low-temperature heat available from sources such as a sewage treatment plant. The demonstration test was conducted using a model with a thermal output of 100 kW.

Finally, a *low-temperature (60°C) driven absorption refrigerating machine* was also developed. Because of the double-lift cycle used, this machine can be driven by low-temperature waste heat, such as from cogeneration, fuel cells, solar systems or even waste water from a single-effect absorption refrigerating machine. The demonstration test showed a cooling COP of 0.58.

Heat transportation

For extensive utilisation of unused energy, it is necessary to have an efficient and economical heat transportation system that can overcome mismatches between supply and demand locations. To achieve this, a project on high-efficiency heat transportation utilising ice slurry and PCM (phase changing material) was implemented. Research and development was carried out using the latent heat of ice slurry (for low-temperature heat from 0-14°C) and PCM capsule slurry (for high-temperature heat from 40-70°C). The demonstration test confirmed that the PCM capsules have a durability of over 100,000 cycles.

Heat supply technology

Highly efficient heat supply technology is the next prerequisite for an efficient large energy system. The *primary/ secondary-side large temperature difference heat supply system* consists of a small flow rate primary-side heat exchanger, a small flow rate fan coil unit (FCU) and a high-temperature difference thermal energy storage system. This system will result in a reduction of over 15% in energy use compared to a typical conventional district heat supply system, see also Newsletter No. 3/97, p. 18.

The second project involves a *multi-purpose decentralised heat pump system*. This system meets the demand for heating, cooling and domestic hot water supply, while recovering waste heat from cooling. The concept of this system is based on the connection with an unused energy pipeline, which can be used as a heat source or heat sink for the multi-purpose heat pump.

Thermal storage

For the theme of large-scale urban type thermal energy storage technology, an *underground thermal energy storage tank* was developed. The tank has a space-saving design, with a large capacity and high efficiency through temperature stratification underground thermal energy storage tank. Both the demonstration test of the installation and the performance tests were carried out using a reduced scale model, 2 m in diameter and 100 m in depth.

Plant planning

Apart from optimising all the individual components for a DHC system, major savings can be made by optimum plant planning and operation technology. Therefore, a new *optimum plant planning system* was developed. This is a simulation program for quick planning and evaluation of a district heating and cooling plant with unused energy as the heat source. By entering a minimum set of data such as location, scale of buildings and characteristics of heat source and equipment etc., a proposed plan is quickly evaluated with regard to energy, environmental impact and economy.

An optimum *plant operation system* also contributes to increased utilisation of unused energy and load levelling. This system consists of a prediction function of the heat demand and the amount of unused energy generated, and a plant optimisation simulator. It optimises the electric power shifting rate, power peak cut rate, unused energy using rate and energy cost.

Energy savings

In the final evaluation of this programme, a system consisting of component units developed under the different projects for utilisation of *low-temperature* unused energy was compared to a conventional system that is not utilising unused energy. A calculation model showed that about 30% energy savings can be achieved,

▼ *Table 1: Targets of the projects executed under the six R&D themes of the programme on unused energy.*

High performance heat exchanging technology	*Target*
High efficiency plate type heat exchanger for sea water with bio-fouling technology	U=5,815W/m^{2}K; NTU=5-8
High efficiency plate fin type heat exchanger for waste air and sewage water	Heat transfer efficiency for waste air :1.3 (1.0) for sewage water :1.5 (1.0)
High efficiency heat production technology	
A direct contact ice making screw heat pump	Ice making COP: 3.4 (3.0)
A sea water direct intake type screw heat pump with bio-fouling technology	Heating COP: 3.0 (2.4)
Large capacity turbo heat pump, for 70°C water supply and improved partial load performance	Heating COP: 3.2 (2.9)
High efficiency turbo heat pump, with improved partial load performance	Heating COP: 3.8 (3.35) Cooling COP: above 6.0 (4.8)
Absorption heat pump for low temperature heat source (7°C)	Heating PER: above 1.4 (1.0)
High efficiency triple effect absorption heat pump	Heating PER: 1.8 (1.0) Cooling PER: 1.5 (1.3)
Low temperature (60°C) driven absorption refrigerating machine	Cooling PER: 0.53
High density heat transportation technology	
High efficiency heat transportation system with ice slurry and PCM slurry	Heat transfer factor : 3.3 (1.0) at cooling IPF 15% Heat transfer factor : 1.8 (1.0) at heating PF 15%
Large-scale thermal storage technology	
Large capacity temperature stratified underground thermal energy storage tank	Volumetric efficiency 90% Heat loss rate 5%
High efficiency heat supply technology	
Small flow rate, large temperature difference heat supply system	Primary energy reduction rate: more than 15% compared to a typical district heat supply system
Decentralised multi-function heat pump system for heating, cooling and domestic hot water supply	Primary energy reduction rate: 30% in water conveying system 23% in refrigerant conveying system compared to a conventional system
Optimum plant planning and operation technology	
A simulation program for quick evaluation of a district heating/cooling plant	Shortening of evaluation time requirements to 1/7
Optimum plant operation system	A 20% improvement in overall economic efficiency

Note: COP = coefficient of performance, PER = primary energy ratio, IPF = ice packing factor, PF= packing factor, U = heat transfer coefficient, NTU = number of transfer units. The values between brackets represent the current level of performance.

while for the environmental load (CO_2, NO_X, SO_X), similar effects will occur.

A system consisting of component units developed under the project for advanced utilisation of *high-temperature* unused energy achieves around 40% energy-saving effect and significant environmental load-reducing effects (40% CO_2, 21% NO_X, 42% SO_X). The thermal energy storage system developed under the project might improve the electric power load levelling by 20-40%.

Economy

In the evaluation cost aspects were also taken into account. It was concluded that most of the components developed under the programme (e.g. heat exchanger, compression type heat pump, some absorption type heat pumps and the thermal energy storage tank) are also superior in economy and ready to be applied. However, some hardware needs further cost-reduction efforts, in spite of the fact that target performances were met. In future, in order to contribute to energy-saving and global environmental improvement on a large scale, an effort should be made to disseminate the outcome of this programme to the actual markets.

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Integrated energy systems in Rotterdam industrial area

Jef Jacobs and Onno Kleefkens, The Netherlands

In April 1996 a strategy entitled 'Energy 2010' was presented concerning a new energy concept for Rotterdam industrial area in the Netherlands. The plan is based on scientific studies and shows creative and revolutionary ideas and solutions for the energy-infrastructure of one of the leading industrial areas in the world. Rotterdam Rhine Maas estuary, being the largest open harbour in the world, plays an important role in the Dutch economy. An optimal energy infrastructure would strengthen this position. Government, industry and utilities are collaborating in this project. A recent inventory of residual process heat and the demand for low-temperature process heat across the area has generated a sizeable list of projects in which heat pumps could play an important role. Six of the largest projects now proposed will result in reduced CO_2-emissions of 1,060,000 tonnes per year. This is 25% of the additional target in the new governmental plan on CO_2-emissions reduction.

The strategic vision of Energy 2010 covers the existing area as well as new (to be developed) areas and includes four objectives:

- it must contribute to the prosperity of the area by developing an attractive, customer- and environment-friendly energy concept;
- optimum coordination between energy demand and supply must be achieved;
- energy supply should be reliable, affordable and clean;
- it must create possibilities for projects to be realised by the market between now and 2010.

To achieve these goals cooperation between the public authorities, industry and the energy sector is vital, and somehow the supply to energy-users must be guaranteed. The Industrial EcoSystem (INES) project was started in 1993 by the organisation Europoort Botlek Belangen (EBB), an association of companies in the region. The main objective of INES is to find an efficient and effective way of eliminating and restricting waste and emissions from industrial activities by the companies participating in the project. Over 60 companies in the area, mainly in the chemical industry, have taken up the challenge of analysing their energy structure. A substantial amount of residual heat has already been identified. The focus is on optimal exchange of residual heat between individual companies. A number of new projects have been initiated, many of which are now reaching the implementation stage.

Optimum use of residual heat

Based on a pinch analysis an extensive feasibility study is being carried out (since 1997) among a number of companies in the region to assess the possibilities for using industrial residual heat. To do this, an organisational, logistic and physical infrastructure is required. To use the waste heat as close to the source as possible prior to transporting it to other areas, the area has been divided into four clusters.

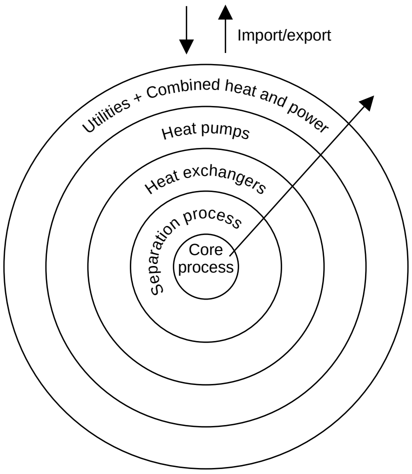
In Rotterdam industrial area large quantities of industrial waste heat are produced that are currently removed in air-coolers or water-coolers at different temperature/quality levels. At the high quality level above 100°C, at least 2,000 MWth is available. This is a potential CO_2-emissions reduction of 1.6 million tonnes (assuming a power generation efficiency of 55%). Based on their pattern of use and desired temperature level, tank farms seem to be potential users. Besides a 'direct' exchange of heat between companies, several technologies can be used to make the available heat suitable for reuse. This includes conversion of residual heat into electricity via Organic Rankine Cycles (ORCs) and upgrading it with heat pumps.

The multiple shell model shown in **Figure 1** illustrates the procedure for process-optimisation. Optimising a process starts at the core of the process, and continues outwards by applying and optimising heat exchangers, heat pumps and finally installing combined heat and power and/or other utilities. When more processes are present on a site, or a cluster of processes exists, new shells can be drawn around these processes or clusters.

Industrial heat pumps

Industrial heat pumps transform waste steam, the temperature of which is just too low for direct use, to a higher temperature. This is important, for example, for the distillation technology that is used on a large scale in refineries and petrochemical plants in the area. Such heat pumps are already being used in the Botlek region. Examples are the propane/propylene splitter at Shell Pernis, which results in steam savings of 35 MWth and 48,000 tonnes CO_2 emissions reduction a year, and the isobutiniser at ARCO Chemie Rozenburg which saves 15 MWth of

▼ *Figure 1: Multiple shell model for process optimisation.*



steam and 21,000 tonnes CO_2 a year. The challenge for the 'industrial heat pumps' project is to bridge larger temperature differences than those typical in distillation processes. At present research is continuing into a new type of heat pump, which can raise the temperature of residual heat by at least 40°C.

A current disadvantage of many industrial heat pumps is that the return on investment is too low and the payback period too long. PWK, a Dutch agency specialising in combined heat and power projects, and the Netherlands Agency for Energy and the Environment (Novem) have therefore studied the existing financing options. In cooperation with Rabobank International, EBB, and utility company ENECO, a model has been developed for setting up a heat pump organisation to improve the financing possibilities. The intention is that this heat pump organisation will operate and maintain a large number of heat pumps in various industrial companies. In Rijnmond around 10 possible heat pump projects have been identified already. A recent estimate by TNO (the Dutch Organisation for Applied Scientific Research) indicates that the potential is much larger: by the year 2010 some 600 MW of heat can be saved through heat pumps. This is 10% of total heat demand in the region. By the year 2000 a number of heat pump installations are planned with a thermal load saving of 100 MW and a reduction of 140,000 tonnes CO_2 a year.

An important aspect of this project is the effect of electrically driven heat pumps on the improvement of the energy demand/supply situation. In the Dutch industrial sector the heat to power ratio of energy demand is approximately 4:1 and in Rijnmond it is actually around 10:1. The heat to power ratio of supply from CHP plants is around 1:1. With the aid of heat pumps the external demand for heat is reduced and the demand for electricity increased, causing a shift towards the supply ratio of 1:1. Such a structural improvement in the energy supply is vital for optimised energy savings.

Other use for waste heat

Other areas where residual heat could be used also exist nearby, for example a housing area due to be built in the near future. Integration with new housing areas in Rotterdam is of particular interest because a district heating system is already operated there. Another market for residual heat on the northern side of Rijnmond is the greenhouse area in the Westland, which is of interest because of the high heat demand per square metre. Refer to Newsletter No. 4/97, p. 25 for more information on the use of waste heat in greenhouses.

A new development for this area is the conversion of waste heat into electricity with an Organic Rankine Cycle (ORC). This electricity can be used in heat pumps, which can heat, for example, greenhouses or offices and other buildings. Thus the waste heat can be used all year round and the reduction in CO_2-emissions is even larger than by distributing warm water.

New opportunities

In order to strengthen the competitive position of Rotterdam-Rijnmond, the partners in the current projects, are closely involved in the development of Maasvlakte 2, that will stretch from Rotterdam over 60 km to the coast and into the sea on new (to be regained) land. The creation of this area is seen as the most suitable solution for the lack of space in the Rotterdam port and industrial area.

In the context of the Energy 2010 objectives, great progress can be made on Maasvlakte 2. It has been concluded that technological innovations within the limitations of existing installations can achieve a 30% improvement in energy efficiency. For a new area the efficiency can be increased by 50% by using the latest technologies and with the availability of an optimal infrastructure. For the implementation of Maasvlakte 2, generation of energy with sustainable or clean technologies and the limitation of harmful emissions will be emphasised. As well as using new sustainable production processes and new technologies (such as process intensification and distillation sequencing) all the relevant possibilities for sustainable and efficient energy supply will be used where possible. This includes heat pumps, ORCs, wind and solar energy, energy from biomass, H_2/CO technology and combined heat and power.

Energy 2010 and the companies in the Botlek area that are united under EBB, support these projects to achieve a reduction in emissions, even with an economic growth rate of over 3% a year. In this way, Rotterdam industrial area can bring the government's ambitious environmental and economical targets several steps closer.

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(see back cover)

District heating with waste heat from water supply

Heinz Bürki, Switzerland

In the project in Seon, Switzerland, waste heat from drinking water extraction is used as a heat source for heat pumps that supply heat to the district heating network. Simultaneously, the electricity, water and district heating supply are optimised by a central load management system. Using the periods with low electricity tariffs makes the heat supply to the district system with heat pumps cost-effective. Experiences during the first heating period have been very positive. After the initial adjustment of the heat transfer and storage installations, consumers have enjoyed a trouble-free and adequate heat supply. This in turn led to more customers requesting connections to the district heating system, thus initiating an expansion of the network. In the final configuration three heat pumps produce a heat output of 1,450 kW. This yields an annual saving of 780 tonnes of CO_2 emissions and 1,050 kg SO_2 emissions. These reductions improve the air quality in Seon.

The overall aim of the project is to use potential energy available within the district, preferably renewable energy resources such as wood or waste energy. This idea is readily accepted by the population. This was already shown in 1982, when a wood-chip-fired combined heat power station with an output of 650 kW and a 400 kW air-to-water heat pump were installed to heat several sports halls, a school and the local council building. The aforementioned projects make a considerable contribution to the clean air standards of the community. To realise such projects it is often not the technical feasibility, but the financial and political feasibility that is decisive. In this case, the project was submitted for approval as a complete package, including water and district heating supply.

In order to guarantee the long-term water supply for the Seon district, the local authorities decided in 1987 to open up an assumed deep ground water aquifer. The ground water temperature is 19.5°C. For transfer to the district water supply network, the water temperature should be cooled to approximately 10-12°C. Initially, no satisfactory solution was found to use the waste heat that would become available from the cooling process. This was solved in 1993 when plans were made for two large residential building projects in the centre of Seon, which were suitable for connection to a district heating system. The project was started in 1994 and was implemented in several phases. The last phase was completed in 1997, and the central control system has been in operation since the winter of that year.

Technical description

The layout of the ground water pumping station with water treatment and the district heating system is given in **Figure 1**. The water pumping and treatment installation includes a 325 m deep filter well, where a speed-regulated pump (maximum delivery 90 m^3 per hour) is installed at a depth of 100 m. The water is cooled to 10°C in a plate heat exchanger and conveyed through the water treatment system to an equalising reservoir. The water treatment comprises ozonisation, two sand filters, an active carbon filter and an aeration column. From the equalising reservoir the drinking water can be pumped into the supply network and reservoirs.

In the heat production process the primary circuit of the three heat pumps receives waste heat via the plate heat exchanger of the water pumping and treatment installation. The heat pumps are equipped with screw type compressors and each has a heating capacity of 450 kW. Each heat pump has a separate control system for switching the compressor on/off and temperature regulation. Temperature pre-setting and enabling of the heat pumps is accomplished by the central processor. The heat pumps run independently in case the central processor fails. The hot water temperature on the supply side is 55-60°C.

Heat is transferred to the individual consumer substations via the district heating pipeline suitable for hot water up to 130°C. The substation storage installations can store enough heat to meet the demand for one day, at an outside temperature of -5°C. When the temperature drops further, recharging can take place during the day. Electric backup heating is installed in the storage tanks to cover demand in an emergency situation.

The output of the heat pumps at full load is approximately 1,400 kW. Assuming nine hours of heat pump operation at night (at low tariff) and a 15-hour supply period, a continuous demand of 840 kW can be covered during the supply period. Initially, consumers with a total demand of 500 kW were connected. This resulted in a reserve capacity of 340 kW. As requests have been received for new connections with a total demand of 390 kW, an extension of the system is necessary. Because the planned expansion will not be sufficient to continuously supply all government buildings in Seon, an additional wood-chip-fired heating system comes into operation below 3°C.

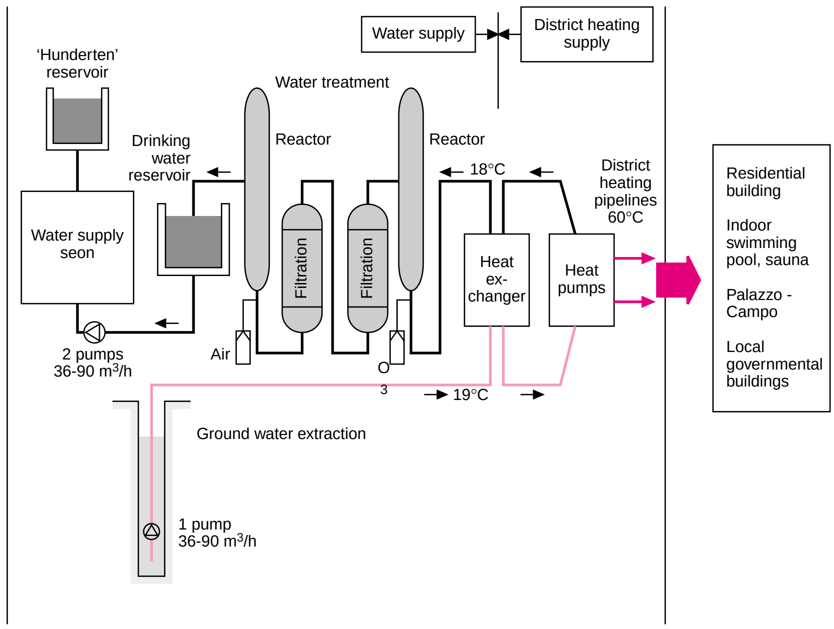
Control and optimisation

Linking the water supply, district heating supply and electrical power generation, requires a central processor which controls and optimises all operations. In principle there are three intervention levels:

- the *coordinating level*, which performs the control, regulation and alarm processes;
- the *emergency operating level*, which guarantees a partially restricted operation for the sectors water, district heating and electricity;
- the *local level*, which permits direct modification of the installation parameters.

To guarantee economic operation of the systems, by far the most important function of the program is the central load management, which optimises the load management of the sectors electricity, water and district heating.

▼ *Figure 1: Diagram of the ground-water pumping station with water treatment and district heating system.*



Financial aspects

The costs of the project consisted of five components: the probe drilling (USD 238,000), full drilling and well lining (USD 653,000), planning costs (USD 87,000), construction of the ground water pumping station and water treatment station (USD 2,030,000) and finally the heat power station, substations and the district heating network (USD 1,653,000). The total costs amounted to USD 4,661,000.

Because the local energy and water supply companies are independent, the new district heating system had to be cost-effective. It was also clear that connection charges and energy prices had to be competitive with other heating systems. The national and regional governments in Switzerland are promoting innovative energy engineering solutions under the framework of the Energy 2000 programme. The Seon project, 'substitution of a cooling tower by heat pumps' was classified as a 'pilot and demonstration object' and received a single investment contribution of 27% of the non-amortisable extra costs compared with a conventional solution (USD 473,000). The regional government of Aargau contributed USD 204,000. A financial plan was drawn up which, in the medium term shows a balanced account with competitive tariff rates. The result is that all consumers who had requested connections to the district heating network could be contracted.

Loan proposals had to be approved by the local council before the project could start. As a preparatory step the local authority presented the project to the public in the daily press and arranged an informative meeting for members of the public. The project was approved almost unanimously.

Evaluation

Although the new district heating supply has only been in operation for a short time, some lessons have been learned from this project. The first is that overall consideration of each sector is necessary during the planning phase. Secondly, demand must be known and adequately taken into account for all consumers. This particularly applies to large applications such as the indoor swimming pool. The actual consumption of the users is usually lower than calculated. Frequent and unnecessary alarms can be avoided by proper control of the transfer stations in the different households. Finally, it can be concluded that if the parameters of the district heating systems are set correctly, handling is simple and trouble-free.

The supply of district heat must remain attractive and the awareness of the people involved should be improved or at least maintained. The search for new customers, new energy sources and new expansion possibilities is a continuous and ongoing process. Only in this way can long-term financial and political success be guaranteed.

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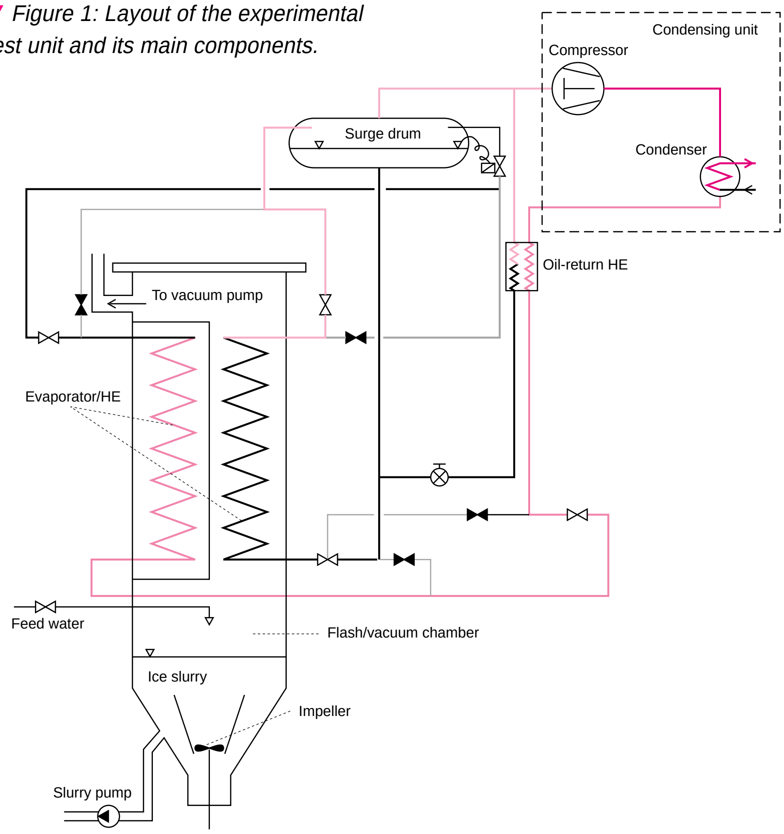
A vacuum-freezing system for heat pumping applications

G. Reza Zakeri and Jørn Stene, Norway

In many regions water from lakes and rivers represents a high-quality heat source for residential, commercial and industrial heat pump systems. However, in cold climates the water temperature during the winter season may be close to zero, and the possible heat extraction is limited when conventional evaporator systems are applied. Vacuum-freezing systems, which previously have been used for desalination applications, water chilling and ice slurry production, are now regarded as a promising technology for utilising cold water as a heat source. These systems make use of the latent heat of water and of the triple point of water where solid, liquid and vapour can coexist in equilibrium. Currently available system designs for vacuum freezing are mainly based on water vapour compression. This article describes a promising new system design where the water vapour compressor is eliminated.

The technical and economic performance of a heat pump is closely related to the characteristics of the heat source. An ideal heat source should have a high and stable temperature during the heating season in order to achieve a high seasonal performance factor (SPF) as well as stable operating conditions for the heat pump system. In regions where neither sea water, ground water, rock or ground-source systems can be applied, water from lakes and rivers may be an interesting heat source. In cold climates the main challenge when designing a system is the relatively low water temperature in winter and potential problems with freezing of the evaporator. By employing the latest generation of vacuum-freezing systems, large quantities of energy can be extracted from cold water.

Figure 1: Layout of the experimental test unit and its main components.



Applications

In addition to being a technology for heat pump plants, the vacuum-freezing system can be used for production of ice slurry in thermal-storage systems for peak shaving purposes. The pumpable ice slurry can be generated at off-peak periods and distributed during the daytime using cold distribution systems in individual buildings or large district cooling systems. In Japan a number of district cooling systems make use of the ice slurry technology.

Cost improvements

The high investment costs as well as the compressor technology have previously been the main limiting factors for widespread use of the vacuum-freezing technology. Due to the high specific volume of water (m^3/kg) at or below the triple point, the volumetric capacity of the compressor must be considerable. The compressor should also have an acceptable energy efficiency at high pressure ratios.

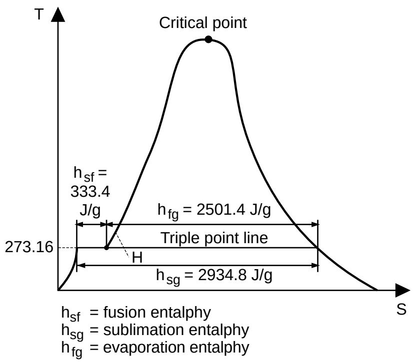
As a consequence of the limited assortment of suitable compressor types and the large dimensions of the compressors, the investment costs for a conventional vacuum-freezing system are rather high. Even for production of chilled water or ice slurry, this has limited the application of vacuum-freezing systems to large-scale industrial plants above 1 MW cooling capacity. By using an alternative design for the vacuum-freezing system which eliminates the water vapour compressor, the profitability of these systems may be considerably improved due to reduction of both investment and running costs.

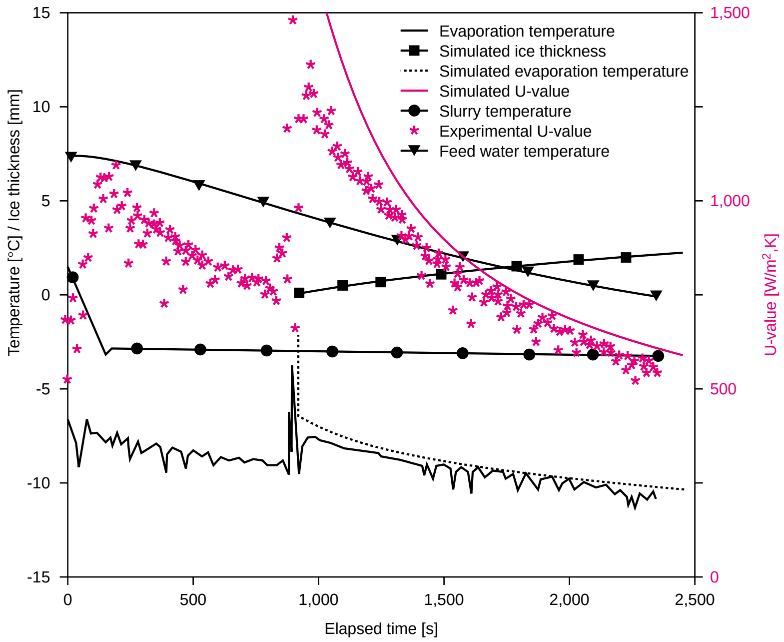
System design

A principle drawing of the test rig for the new system design, a vacuum-freezing refrigerating circuit (VFRC), is shown in **Figure 1**. The system consists of a vacuum flash chamber that includes two built-in heat exchangers and a condensing unit. A vacuum pump is connected to the flash chamber in order to remove the non-condensable gases.

Cold feed water (the heat source) is throttled into the flash chamber where the pressure is at or below the triple point. The resulting flash vapour is removed by freezing by one of the heat exchangers that functions as an evaporator, i.e. the evaporator extracts heat from the heat source. Because the ice slurry generation takes place by direct contact heat transfer there is a negligible temperature difference between the flash vapour and the ice slurry. In the throttling process about 88% of the total ice generation takes place as suspended ice crystals (ratio of the evaporation enthalpy and the sublimation enthalpy), ice slurry, while the remaining 12% flash vapour freezes as an ice layer on the evaporator surface (ratio of the fusion enthalpy and the sublimation enthalpy). The temperature entropy diagram of the flashing process of the feed water solution is shown in **Figure 2**. The slurry is removed by the slurry pump. The evaporator system was constructed with gravity feed (natural circulation) in order to obtain a higher overall heat transfer coefficient, while HFC-134a was used as working fluid for the test unit.

▼ *Figure 2: The flashing process of feed water solution in the T-s diagram.*





▲ *Figure 3: Sample of experimental results.*

Cyclic operation

The two heat exchangers in the flash chamber are operated cyclically. One is functioning as an evaporator as mentioned above, whereas the second goes through a de-icing process, recovering the stored refrigeration capacity. Because only 12% of the total ice generation freezes on the evaporator surface the ice layer growth, which is the most significant heat transfer resistance, is very slow. The de-icing (defrosting) process is carried out using high-pressure warm refrigerant condensate recovering the stored refrigeration capacity in the ice layer. As a result, the de-icing process can be performed with minimal energy losses compared to conventional hot-gas defrosting. This is very crucial for the energy efficiency of the system, especially when the main function of the system is generating ice slurry. This aspect will also ensure almost continuous operation of the unit.

The components used in the system are all state-of-the-art technology, and there are no tailored components. Because there is no expensive water vapour compressor, the investment costs of the new system are expected to be lower than conventional vacuum-freezing systems.

Experimental results

Figure 3 shows a sample of experimental results. This test run is composed of two periods. In the start-up period (0-900 seconds) the flash vapour is de-sublimated on one of the heat exchangers. The second period (900+) represents normal operating conditions: the ice layer is melted off this heat exchanger by hot refrigerant condensate, while the other heat exchanger functions as the evaporator. The simulated curves shown are the overall heat transfer coefficient, the evaporation temperature and the resulting ice layer thickness on the evaporator. The feed solution has a salinity of around 3.5%, which is the standard salinity of sea water.

The temperature difference between the slurry and the evaporator, which is the overall driving force, varies from 5°C to around 8°C, which is small. The corresponding overall heat transfer coefficient drops from approx. 1,250 W/m^2K to 600 W/m^2K during the same operating period. The ice layer growth on the outside surface of the heat exchanger is, as expected, very low, attaining a value of less than 2.5 mm at the end of the test. This simulated value was also in agreement with the visual observation of the ice layer thickness. As a result, a heat pump system based on this new system design can be operated efficiently throughout the heating season with nearly constant evaporation temperature independent of outside air temperature.

Summary

An experimental test rig based on a new energy efficient system design (vacuum freezing refrigerating circuit - VFRC) has been constructed. The system utilises the vacuum-freeze triple-point principle. Flash vapour is de-sublimated on a refrigerated heat exchanger surface. The de-sublimated ice layer is melted off the heat exchanger surface using high-pressure hot condensate, recovering the stored refrigeration capacity in the ice layer. The system operates with approximately constant evaporation temperature regardless of the heat-source temperature. This makes river and lake water in colder climates suitable as a heat source. The new VFRC system design is suitable for both small capacity ice slurry generators as well as commercial heat pump systems.

Acknowledgements

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Graham, Terence, Tokunaga, Kensuka, Goldstein: "Application of Crystal Ice Generation in District Heating and Cooling". *Proceedings of the 80th Annual Conf. of the Int. District Heating and Cooling Association, Vol. LXXX, 1989, pp. 246-258.*

German symposium on heating and cooling with ground-coupled heat pumps

The interest in ground-coupled heat pumps (GCHPs) in Europe is growing and the technology is increasing its market share. In Austria this share is 83% of all space-heating heat pumps. More than 60,000 GCHPs are installed in Europe. The installed heating capacity was 632 MW at the end of 1996. These heat pumps produce 1,554 GWh of heat annually, while extracting 929 GWh renewable energy, avoiding the emission of 768,000 tonnes CO_2 compared to oil-fired boilers. The third symposium on GCHPs where these data were unveiled was held on 20-22 November 1997 in Rauischolzhausen, Germany. Highlights of this symposium are presented in this article.

Standards

VDI standard 4640 'Thermal use of the ground' is under development in Germany. It covers open, closed and direct expansion GCHP systems. This standard consists of Part 1 - Fundamentals, Environment and Licensing, and Part 2 - Design and Construction of Ground Heat Exchangers, including direct expansion technology, pipe arrangements, dismantling and heat distribution system requirements. The standard will include a list of heat extraction rates, dependent on the local formation and hydrological situation. Part 1 and 2 are under public review and are scheduled for implementation after May 1998. Part 3 will appear later, and will cover Ground Storage of Energy. VDI 4640 has not been developed as a real standard, but is meant as a guideline.

Experiences

The largest power utility in Germany, RWE, has many years of experience with residential heating-only GCHPs. Today systems with vertical ground heat exchangers are by far the most popular solution both for retrofitting and new houses. Only monovalent systems are cost-effective. Installation costs decreased due to competition, improved drilling techniques and technology improvements. In 1997, RWE's service area had around 544 installations, of which 337 used vertical probes. On average, two or three probes are required per residential installation. Extraction rates of 80 W/m are typical in this region. The typical seasonal performance factor (SPF) of the installations ranges from 3.5 to 4.5. RWE's long-term experience means that no installation suffers from decreasing heat extraction rates or insufficient thermal regeneration. RWE's goal is to continue stimulating the use of vertical ground loop systems by offering customers a fixed heat price per kW heat extraction.

Four papers gave field data of different system concepts, including a single probe (105 m length) monovalent heat pump system, a loop system for an office building (32 probes, each 135 m length) in a monovalent installation (185 kW heating), and a system consisting of 19 probes each 200 m deep, used for heating (460 kW) and cooling (130 kW). The latter bivalent heat pump installation (250 kW) has an SPF of 3.3.

Energy piles

A separate session discussed the use of concrete piles and building parts that are in contact with the ground as heat exchangers. So-called energy piles are offered by some companies in Austria and Switzerland. An advantage of the piles is that, in addition to the overall building costs, only limited additional costs are made for the integrated plastic heat exchanger tubes. In an institutional building in Switzerland, concrete floors and walls in contact with the ground are equipped with polyethylene tubes for heat extraction. The need for large concrete supports for commercial and institutional buildings in cities is growing. Both heating and cooling can be provided through the concrete support system. This concept allows buildings to be cooled in a cost effective way. Approximately 450 small and large systems are currently installed.

So-called massive heat absorbers are successfully used in combination with residential heat pumps (8 kW) in 22 houses in Oberhausen-Rheinhessen, Germany. By placing the absorbers in the ground with the upper part standing free, a combined solar/ambient/ground heat absorber is achieved. The absorbers clearly act as a heat storage system operating on a day/night (ambient) and a seasonal (ground) cycle. A typical absorber has a footprint of 4 m^2 and provides 7 kW cooling at -8°C. The measured COP of the systems is 3.4, though 3.8 has been achieved in optimised installations. The cover of Newsletter 15/2 shows a picture of such an absorber.

Ground loops

Using pure water instead of a brine enables higher evaporator temperatures and COPs, but is also more expensive due to longer tube lengths. The minimum water temperature is 5°C. The use of water requires a precise design of the loop system based on local geologic and hydrological conditions. A dozen installations using water in the loop are installed in Western Europe and their performance is satisfactory (SPF > 4).

A Swiss paper reported on a solar-assited ammonia compression heat pump equipped with two earth probes, each 100 m in length. Heat from a solar collector is supplied to the ground for regeneration purposes. The earth probes are of a special design, and consist of a central feeder tube and eight small thin-walled riser tubes in which the fluid heats up. The typical heat extraction rate with this concept is 30-40 W/m and peak loads of 110-130 W/m are achieved. The incremental costs of the probe system are recovered by increased energy cost savings.

A new system presented by a Dutch firm enables quick installation of ground loops up to 50m length in soft formations by pressing down a hard metal core to which two plastic tubes are connected. The core is lost. The tubes are installed at an angle so the tube can be longer. It is claimed that this method is cheaper than drilling.

Solar-assisted heat pumps

A solar-assisted ground-coupled heat pump in an institutional building in Germany is equipped with 15 U-type loops of 32 m each and a 110 m^2 solar collector. The refrigerant of the heat pump is propane. Solar heat is directly used for water and space heating, while surplus heat is stored in the ground for use by the heat pump in winter. More than 40% energy savings are achieved. Another German solar-assisted ground-coupled heat pump installation is installed at a home for the elderly. The ground loop consists of 28 probes of 100 m length each. Waste heat from the central refrigeration system is stored in the ground to support thermal recovery. The solar collector and an electric boiler act as peak heat generators and the heat pump provides base load heating. The system also includes two warm water storage tanks for load balancing. The ground loop is the first installation applied in a spa area near Stuttgart.

Various presentations on aquifers and their use for heating, cooling and thermal storage were given, amongst them a cooling application at the Reichstagsgebäude in Berlin. Improvements in the design process of ground-coupled heat pump systems can still be made. In a special session new design programs and developments were discussed. The proceedings of the symposium will be published by IZW, Karlsruhe, Germany.

Jos Bouma, IEA Heat Pump Centre

Books & software

Heat pump systems, energy efficiency and global warming
Available from: IIR, 177, Boulevard Malesherbes, 75017 Paris, France. Fax:+33-1-47631798. 260 Pages, 1997. Price: FRF 200
Proceedings of a meeting held in Linz, Austria in September 1997. The main topics include heat pump systems in district and individual heating and cooling, industry and wood drying, energy consumption, investment and running costs, alternative refrigerants in particular mixtures, CO_2, hydrocarbons, Stirling and sorption systems, status of heat pumps in Austrian provinces and in other countries.

Ground-source heat pumps: Design of geothermal systems for commercial and institutional buildings
Authors: Stephen P. Kavanough and Kevin Rafferty.
Available from: ASHRAE Customer Service, 1791 Tullie Circle NE, Atlanta, GA 30329, USA. Fax: +1-404-3215478.
E-mail: orders@ashrae.org. Price: USD 58. Published in 1997.
Topics covered in this book include a general introduction of heat pump units for ground-source applications, ground heat exchanger design, pumps and piping, ground water heat pumps, surface water heat pumps and economics of ground-source heat pump systems.

Air conditioning in high rise buildings '97
Available from: IIR, 177 Boulevard Malesherbes, 75017 Paris, France. Fax: +33-1-47631798. 2 Volumes, 695 pages, 1997. Price: FRF 350.
These proceedings contain around 100 papers from this meeting, which was organised by the Chinese Association of Refrigeration and the Shanghai Society of Refrigeration and held in Shanghai, China on 9-12 September 1997. The proceedings provide a description of current construction in China, Japan and other countries. The topics include general control-system design of split systems and fluctuating air cooling, energy consumption, optimisation and heat recovery, heat pumps and thermal storage for load-levelling.

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Annex 18 report, January 1998.
Order No. HPP-AN18-5.
NLG 80 or NLG 40 in member countries and in Ca, Ge, Se and UK.

HPP Annual Report 1997
Order No. HPP-1997

Renewable Energy for a Cleaner Future
Order No. HPC-BR-5. November 1997.
Brochure Free-of-charge.

Compression Systems with Natural Working Fluids
Annex 22 Workshop Proceedings, March 1998. Order No. HPP-AN22-3.
NLG 120 or NLG 60 in member countries and in Ca, Dk, Se and UK

CO_2 Technologies in Heat Pumps, Refrigeration and Air Conditioning Systems
Workshop proceedings, March 1998
Order No. HPC-WR-19. NLG 120 or NLG 60 in HPC member countries

Ab-Sorption Machines for Heating and Cooling in Future Energy Systems
Annex 24 Proceedings, December 1997
Order No. HPP-AN24-1
NLG 160 or NLG 80 in HPC member countries and in Ca, It, UK

Building HVAC Equipment Regulations and Standards
Workshop Proceedings, June 1997
Order No. HPC-WR-18 NLG 120 or NLG 60 in HPC member countries

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Thermische Nutzung des Untergrundes nach VDI 4640, Blatt 1 und 2
(Workshop on Thermal Use of Ground – Standard VDI 4640)
21 April 1998 / Dusseldorf, Germany
Contact: VDI-GET,
fax: +49-211-6214161.

Heating and Air Conditioning of Buildings
Energy and Environment Conference
9-11 May 1998 / Maribor, Slovenia
Contact: Prof. Dr Jurij Krope, University of Maribor . Fax: +386-62-2207990.
E-mail: jurij.krope@uni-mb.Sl

Natural Working Fluids '98
IIR Gustav Lorentzen Conference
2-5 June 1998 / Oslo, Norway
Contact: Turid Slotnaes, NWF '98,
Fax: +47-22067350

Air-Conditioning & Refrigeration New Tech '98 (ART'98)
Environmentally Friendly Refrigeration '98 (EFR'98)
June 1998 / Beijing, China
Exhibitions organised by the Chinese Association of Refrigeration
Contact: Beijing Onis Expo Co.,
Mr Liang Liang. Fax: +86-10-62172249.
E-mail: onis@public3.bta.net.cn

1998 International Compressor Engineering Conference; and 1998 International Refrigeration Conference
14-17 July 1998 / West Lafayette, Indiana, USA
Contact: Cynthia Quillen, Purdue University, Fax: +1-765-4940787.
E-mail: herlconf@ecn.purdue.edu

Eurotherm seminar on Thermodynamics, Heat and Mass Transfer of Refrigeration Machines and Heat Pumps
6-7 July 1998 / Nancy, France
Contact: Prof. M FEIDT, LEMTA - University of Nancy
Fax: +33-3-83595551.
E-mail: mfeidt@ensem.u-nancy-fr

Hygiene, Quality and Security in the Cold Chain and in Air Conditioning
16-18 September 1998 / Nantes, France
Contact: Symposium Nantes 98.
Fax: +33-02-51882020

1999 International Sorption Heat Pump Conference
24-26 March 1999 / Munich, Germany
Contact: Dr Martin Hellmann, ZAE Bayern, Walther-Meissnerstrasse 6, D-85748 Garching, Germany Fax: 49-893294-4212
E-mail: martin.hellmann@physik.tu-muenchen.de

20th International Congress of Refrigeration of the IIR
September 1999 / Sydney, Australia
Refrigeration into the 21st century
Contact: Congress Secretariat, GPO Box 128, Sydney NSW 2001, Australia
Fax: +61-2-2622323. E-mail: tourhosts@tourhosts.com.au

IEA HEAT PUMP PROGRAMME EVENTS

Workshop on Deployment Activities of Heat Pumping Technologies
18 May 1998 / Stockholm, Sweden
Contact: Magnus Gustafsson, Royal Institute of Technology, Department of Chemical Engineering and Technology, S-10044 Stockholm, Sweden Fax: +46-8-105228. E-mail: magu@ket.kth.se

Heat Pump Systems for Single-Room Applications
Annex 23 Workshop.
16-19 June 1998 / Niagara Falls, USA
Contact: Frank Lenarduzzi, Ontario Hydro Technologies, Fax: +1-416-2076565

Heat Pumps - A Benefit for the Environment
6th IEA Heat Pump Centre Conference
30 May - 2 June 1999 / Berlin, Germany
Technical visits on 3 June 1999
Sessions on market status / strategy, technology applications and systems.
Invited speakers and call for posters.
Information available from the Heat Pump Centre (see advert on p. 28).

Next Issue

Heat Pumping Systems and Thermal Storage
Volume 16 - No.2/1998

International Energy Agency

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

IEA Heat Pump Programme

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

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

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