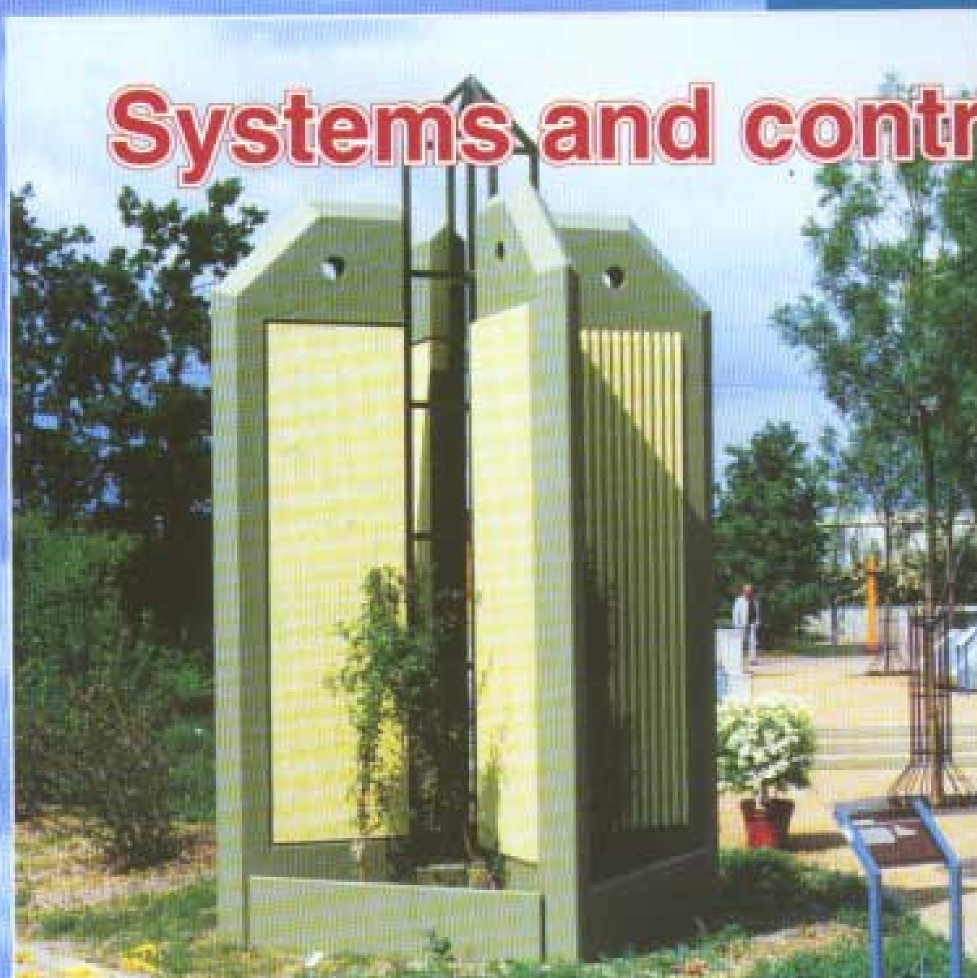
IEA Heat Pump CENTRE NEWSLETTER

VOLUME 15
NO. 2/1997



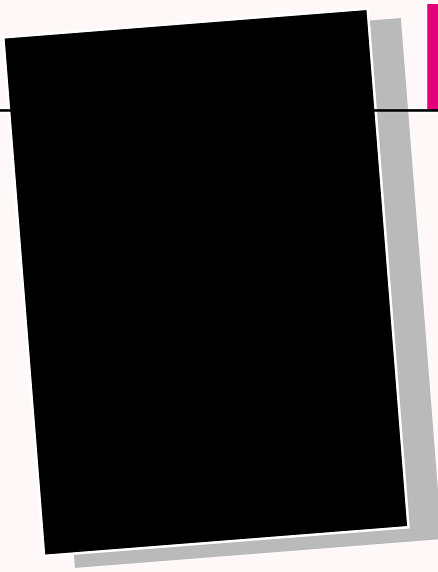
Systems and controls

In this issue:

Large temperature differential storage system
Systems approach with heat pumps in the Netherlands
Ecological balances and heat pumps

IEA
OECD
heat pump
centre

In this issue



Systems and Controls

An optimal design of heat pump systems and their controls contribute to improved energy efficiency and improved reliability and therefore to reduced costs of using heat pump systems for different applications. This issue highlights some successful systems, as well as some integral approaches to achieving optimisation.

Front cover:
The front cover shows a concrete element used for heat absorption from the air, rain, etc. from a heat pump project in Wäghausel, Germany. This project was visited during the Dutch study tour described on page 29.

TOPICAL ARTICLES

An international overview 10

Gerdi Breembroek

Many different heat pump systems are used throughout the world, utilising various control systems. This article gives an overview of the current situation and the measures available to achieve optimisation.

Large temperature differential storage system 16

Makato Kayo, Japan

Elaborate computer simulations in the design stage resulted in the implementation of a large temperature differential storage system in an office building in Japan. Operational results show that the system has contributed significantly to achieving a low energy consumption building.

Residential heat pump systems and controls 19

Hermann Halozan, Austria

To improve both customer comfort and energy efficiency, the heat distribution system and its controls should form an integrated system with the building and the heat pump.

Heading for improved reliability and performance 22

Roar Bang, Norway

The acceptance of heat pumps depends on the energy efficiency, as well as on the reliability of the technology. Both these characteristics can be improved by using an optimal control system.

Systems approach with heat pumps in the Netherlands 24

Onno Kleefkens, The Netherlands

A new plan has been launched by the Dutch government to stimulate further CO_2 emissions reductions. In many of the proposed projects the use of heat pumps is combined with other technologies such as CHP to obtain an integrated system approach, resulting in optimal use of primary energy.

HEAT PUMP NEWS

General **4**
Technology & applications **6**
Working fluids **7**
Markets **8**
IEA Heat Pump Programme **9**

FEATURES

Comment **3**
Books & software **30**
Events **31**

National Team contacts **32**

COLOPHON

Publisher:
IEA Heat Pump Centre
P.O. Box 17
6130 AA Sittard
The Netherlands
Tel: +31-46-4202236
Fax: +31-46-4510389
E-mail: nlnovhpc@ibmmail.com
Internet: http://www.heatpumpcentre.org

Editor in chief:
Jos Bouma
Technical editing:
Hanneke van de Ven / Gerdi Breembroek
Language editing:
Barbara Shapland
Production: Novem Support Group
Illustrations: Offermans EPS
Printer: Huntjens, Stein, The Netherlands

Frequency: quarterly
Printed June 1997

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

ISSN 0724-7028

Total Client Satisfaction by Top Controls and Systems

The quality of heat pumps is now just as good as the quality of boilers. 'Quality' here means that heat pumps have a high coefficient of performance (COP), good reliability, a lifetime of more than 15 years, that they are hermetically sealed and very quiet.

In spite of the high quality of the heat pump itself, user satisfaction varies. Why is this? Bad system integration and poor control often limit the operational quality. Therefore, a new philosophy has been formulated: Total Client Satisfaction by Top Controls and Systems.

Top Controls means that the best technologies are applied to monitor and control the heat pump and the system as a whole. Microprocessor-based software should provide easy handling as on modern personal computers, with a graphic display, a help function instead of a user's manual, and different options for the client and the maintenance organisation. Clear information should be displayed whenever the client wants to check the heat pump. Information such as 'the heat pump is now in heating mode. It has been running for 45 minutes', or 'the heat pump has been stopped by the power utility. It will restart automatically', or 'the heat pump is loading the tap water tank' appears. The screen displays information on temperatures, operational data, problems, maintenance, etc. in clear text.

Top Systems means taking into consideration the characteristics of the heat pump and verifying the completeness and correct interaction in bivalent or multivalent systems. A formal system test is used to check, for example, the priorities of different heat production equipment, the optimal flow through the condenser and the surface temperature of external heat exchangers.

Heat pump systems and controls differ from those of boilers, and require special attention. This is why leading heat pump manufacturers in Switzerland have set up research and education programmes in this field, in association with public R&D programmes.

Total Client Satisfaction means additional business for heat pumps. Top Controls and Systems offer the best support in achieving this goal and an increasing market share of heat pumps.

Hansueli Bruderer
Member of the Swiss National Team
Dr. sc. techn., Managing Director of SAURER THERMOTECHNICS INC.
Heat Pump Manufacturer, Arbon, Switzerland

NON-TOPICAL ARTICLES

Heat pumps and ecological balances 26

Fabrice Rognon, Switzerland

Do heat pumps really contribute to CO_2 emissions reductions? By comparing the ecological effects of different heating technologies this article proves that this technology indeed can contribute to a more sustainable and less polluting energy supply in Switzerland.

Dutch study heat pump promotion abroad 29

Hanneke van de Ven, IEA Heat Pump Centre

A Dutch study tour was organised to visit successful heat pump stimulation programmes abroad. Four projects in Germany and Switzerland were visited during the tour.

Heat pump news

HPC Workshop held in Spain

Spain - On 27 February the IEA Heat Pump Centre (HPC) workshop on Building HVAC Equipment Regulations and Standards was held in Madrid, in conjunction with *Climatizacion '97*. This was one of the largest European HVAC expositions where over 300 firms were represented and 28,000 visitors registered. The workshop was organised by the Spanish National Team, in cooperation with the HPC. It was organised as a follow-up to an earlier analysis study by the HPC on Heat Pump Energy Efficiency Regulations and Standards, published in May 1996.

At the workshop 10 speakers from various countries including Switzerland, Germany, USA, Japan, the Netherlands and host country Spain presented their views on the subject. They represented organisations such as the European Commission, heat pump manufacturers, utilities and standards organisations.

The main conclusion of the workshop was that the existence and application of standards and regulations concerning the specifications and performance of heating, ventilation and air-conditioning (HVAC) equipment facilitate trade and ensure product quality. The implementation of energy-efficiency standards is a powerful instrument for improving products and saving energy.

An increasing awareness among the population, along with an increased sense of respect for the environment, has led to a demand for adequate product safety and quality levels. Certification of products by independent laboratories according to voluntary standards guarantees the performance of appliances, and also provides useful information to users. Energy labelling enables the user to compare the energy consumption and performance and sometimes the operational costs of similar appliances. It provides manufacturers with marketing arguments and users with selection criteria. However, users need to be told how to interpret the information provided and choose the product best suited to their needs and expectations.

Finally, it is important that current standards and regulations are updated and adapted to prevent them becoming obstacles to market penetration or allowing discriminatory treatment of other appliances. The workshop held in Madrid could mark the beginning of a process of information exchange between countries and equipment manufacturers, with possible input and guidance from the IEA Heat Pump Centre and international standards organisations.

The **photo** shows members of both the Spanish National Team and the Heat Pump Programme Advisory Board who met after the workshop. The proceedings of the workshop will be available from the IEA Heat Pump Centre around June 1997.

Source: Ms Hanneke van de Ven, IEA Heat Pump Centre / Mr José Sahún, Gas Natural, Spain

Mexico proposes certification rules

Mexico - The Mexican government has published proposed procedures and policies for certifying products according to official Mexican standards (NOMs) within the jurisdiction of the Secretariat of Commerce and Industrial Development. The proposal affects unitary small equipment, packaged terminal air conditioners and water-source heat pumps. The new procedures allow the issuing of a 'NOM certificate', showing that a product complies with a NOM as verified by a 'NOM Compliance Report', issued by an accredited product certification organisation or by the DGN, the Mexican government enforcement agency. NOM certificates will be valid for one year after date of issue. Under the new rules, a product will be subject to periodic certification testing, or must be produced under an approved quality control system. A 'Product Report for a Foreign Manufacturer' may also be obtained from DGN and used to obtain a certificate of compliance.

Source: Koldfax, February 1997

Users of absorption installations meet in Berlin

Germany - 3 April was the date of the 1997 annual meeting of the Users Club of Absorption Heat Pumps. The group met in Berlin and was hosted by BEWAG, the city's utility. The group is gradually expanding its membership, which reflects the increasing stock of large absorption heat pumps in Northern Europe. A typical heat source for the heat pumps is geothermal heat from great depths (Denmark, Germany, Poland), as well as waste heat from flue gas cleaning processes in refuse incinerator plants (Sweden). The absorption heat pumps are powered by hot water or steam. Only one heat transformer installation, located in the Netherlands, is represented in the group. Valuable information was exchanged at the meeting, and manufacturers invited to the meeting also contributed. Members were kept up to date on plant modifications, operation and new installations.

The group decided to extend its membership to users of absorption chillers, mainly used by district heating utilities and industry. Supplying cooling with district-heat-fired absorption chillers is a growing service offered by district heating utilities. Users of these systems can benefit from membership.

The group concluded their annual meeting with a visit to the single-effect, double-lift absorption chiller located at the Technical University Berlin. The system's concept was developed by the late Prof. Alefeld and the design was by Entropie, Germany. Important features of this district-heat-fired installation are its low water temperature (70°C) at low flow rates, and its compact design. The installation's cooling capacity is 400 kW at a COP of 0.62 at design conditions (95/65°C).

A similar installation recently went on line in Düsseldorf, Germany. Another installation, with a cooling capacity of 3 MW and using geothermal heat, will start operating shortly in Erding, Germany, while in April an absorption chiller will go into operation at Munich airport. This machine is powered by hot water (95/62°C) from the airport's cogeneration system. Finally, it was reported that an advanced absorption heat pump demonstration plant starts operating soon in Nürnberg. This installation is powered by heat from 200 kW fuel cells. The produced heat is supplied to the district heating network.

Source: Mr Jos Bouma,
IEA Heat Pump Centre

Dutch Heat Pump Association founded

The Netherlands - In January 1997 a Heat Pump Association was founded by four large suppliers of heat pumps. The main goal of the association is to enhance the acceptance of heat pumps in the Netherlands.

Rising prices of natural gas, stricter energy performance norms (EPN) and growing interest in saving the environment from pollution, have led to a revival of heat pump technology in the Netherlands. Particularly in new building projects, where an energy infrastructure is not yet available, opportunities for implementing heat pumps are growing. In the next 10 years, one million new houses will be built, and it is expected that the market share of heat pumps will increase rapidly during this period.

The new association wants to combine all the knowledge and know-how on heat pumps available in the Netherlands. It also aims to collaborate with government agencies, utilities and research centres.
A third goal will be to increase the promotional activities in the heat pump field.

Source: Mr Onno Kleefkens, Dutch National Team,
Novem bv, Fax: +31-30-2316491.

Large heat pumps to be subsidised?

Switzerland - The Swiss parliament is considering spending CHF 550 million (USD 380 million) to stimulate the national economy in the period from 1997-1999. Part of the programme concentrates on promoting renewable energy technologies. The slogan for the programme is: "Less concrete for streets, more technology". A total of 16,000 new jobs in the renewable energy sector are expected to be generated and the estimated total investment is around CHF 1.6 billion (USD 1.1 billion). One of the benefits of the programme will be a reduction in unemployment pay of up to half a billion francs. These considerations are accepted by most Swiss political parties and it should therefore be no problem to find a suitable solution in parliament.

The total amount for the energy sector is around CHF 360 million (USD 250 million). The programme will focus on retrofitting public installations and buildings, and the maintenance of governmental properties. CHF 64 million (USD 44 million) is proposed for the private sector. The main applications are the use of solar energy for water heating, the production of electricity in wind parks, district heating by wood burners and the use of waste heat with medium and large heat pumps. Around CHF 25 million (USD 17 million) will be available for subsidising heat pump installations, which will receive financial support of 10-15% of the investment costs.

The Swiss association for the promotion of heat pumps, FWS, had no difficulties recruiting a large number of projects that have not been accomplished due to financial reasons. With the proposed financial stimulation programme it will be possible to find economic solutions for many of them. A decision will be made before summer 1997 and it will be interesting to see if the larger heat pumps are also on their way to playing a more important role in Switzerland.

Source: Mr Dieter Wittwer, INFEL,
member of the Swiss National Team HPC,
Fax: +41-1-2994140

◄ *Photo: Peter Bailer, Project manager at Sulzer Friotherm AG, one of Switzerland's leading manufacturers of larger heat pumps*

Geothermal heat pumps gain popularity

Norway - High electricity prices are now leading many Norwegians to invest in energy saving heat pumps in their homes. Previously, the most common heat pump systems were air-to-air split units, due to relatively low initial costs as well as easy installation and operation. However, for a number of reasons geothermal (rock/ground water) systems are now gaining popularity. Investment costs for a 4-5 kW heat pump unit including drilling, heat source connection and control system range from USD 7,500-10,000.

The depth of the drilled holes range from 75-150 meters, depending on the heating demand, rock type and trickle of ground water in the terrain. Typical power and energy output from the holes are 45 W/meter and 150 kWh/meter/year, respectively. Water-to-water heat pumps, which are always connected to indirect water/glycol systems at the heat source side, supply heat to hydronic heat distribution systems, i.e. floor heating or low temperature radiators. In addition to space heating many units also provide preheating of domestic hot water.

Compared to conventional air-to-air units, the geothermal systems typically achieve a 20-30% higher seasonal performance factor (SPF) and the heat supply is not reduced at low ambient temperatures. The latter is a major advantage since there has been an increased focus on electricity peak load shaving in Norway over the past few years. Geothermal heat pumps are also more reliable than air-to-air systems due to stable operating conditions and a maintenance-free heat source. One of the first geothermal heat pumps installed in Norway has been running for almost 20 years without major operational problems.

There is also renewed interest in using geothermal heat pumps for space heating or space heating/cooling of commercial buildings. As an example, a 6,000 m^2 commercial building in Oslo will subsequently receive its heat supply from 30 drilling holes, 150 meters deep. A new technique, hydraulic depressing, will probably be applied to increase the power output from the holes.

Source: Mr Jørn Stene, Norwegian National Team, SINTEF Energy. Fax: +47-73-593950

Pocket-size heat pumps?

USA - During the ASHRAE convention in January of this year a forum was held entitled "If a wallet-sized absorption heat pump can be built, does anybody care?" Several R&D experts do care, and they discussed lab-testing for such a microtechnology-based system, which can be used for manned portable cooling applications, among others. Now individual components of the miniaturised heat pump system have been built and tested, the next step is to integrate them and test the complete system. Possible applications mentioned include space applications, fire-fighters' suits or chemical warfare apparel, cooling of electronic equipment and heat-actuated air conditioning for vehicles.

For the same capacity, the researchers stated that they can build a heat pump one-tenth the size of a conventional unit. They have not yet proceeded far enough to determine the estimated price of a working system. For manned portable cooling, which they believe is the first practical application, they are working on a battery-pack for an 8-10 hour mission. Testing to date indicates 0.65-0.7 efficiency using a water-lithium bromide working fluid. According to one of the researchers, lighter weight is preferable to achieving higher efficiency for manned portable cooling. Next on the agenda is the production of a working prototype.

Source: Heating, Air Conditioning and Refrigeration News, 17 February 1997

German system combines use of air and ground

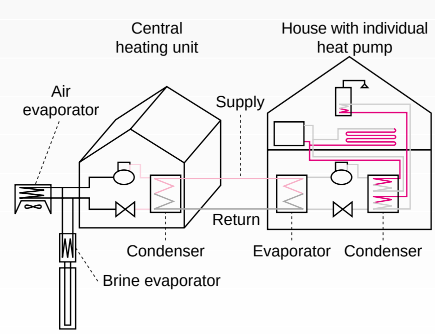
Germany - In the new residential area 'Obstanger' in Stadthagen about 70 living units with an aggregated heat demand of 550 kW will use heat pumps to supply space heating and warm water. A special system is used, combining both air and ground as heat sources, using one central heating unit and an individual electrical heat pump in each house. A schematic representation of the system is given in the **Figure**. All heat pump units are owned and operated by the electricity supplier Electrizitätswerke Minden Ravensburg (EMR). Building activities will start in the summer of 1997.

In the central heating unit an electrical heat pump is installed with two variable speed screw compressors. In the design both the outside air and ground heat are used as an energy source. This is achieved by using a split air-to-water heat pump unit with an additional unit using heat from the ground. The additional section has 12-15 vertical bore hole heat exchangers that go into the ground to a depth of 100 metres. A closed brine loop is used to transfer the heat.

This combined central system provides water at a supply temperature of 10-15ºC to the decentralised heat pump units in the houses via a 'cold water network'. This temperature is fairly constant throughout the year. The individual houses have their own electric heat pump that raises the temperature of the water to a level of 30-40ºC, which is high enough for a modern low temperature room heating system. The heat pump is equipped with a two-step condenser unit that uses the excess heat of the refrigerant to heat domestic hot water to a temperature of about 60ºC.

The total investment for this project is about DEM 1.8 million (USD 1.1 million). Compared to a conventional heating system with gas and oil boilers the new system will use 18% less primary energy. A potential CO_2 emissions reduction of 48% is expected.

Source: Wärmepumpe, March 1997



▲ *Figure: Combined ground- and air-source system.*

New hydrocarbon for supermarket refrigeration

Germany - Linde AG, a company based in Cologne, has installed a refrigeration system working with the hydrocarbon propylene (R-1270) for the 3000 m^2 Magnet supermarket in Bad Freienwalde. Compared with propane (R-290), propylene has a saturation pressure which is approximately 20-30% higher. This has the advantage of increased compressor output, while still remaining in the same pressure region as R-22. Compressor modifications are therefore unnecessary.

The plant supplies the display space in the supermarket via heat exchangers and secondary pumped circuits using glycol or Tyfoxit solution as the heat transfer medium. The total refrigerant charge was 17 kg. This is a huge contrast to the 400 kg which would have been needed with direct expansion systems using R-404A. As with propane or ammonia, safety regulations required mechanical ventilation of the plant room and the use of leakage detectors. Linde will be installing more propylene-based systems for the retail refrigeration sector later this year.

Source: JARN, 25 March 1997

DuPont and Daikin reach refrigerant licencing agreements

Japan - DuPont Delaware, USA announced last January that it has agreed to licence R-410A, R-404A and R-407C refrigerants to Daikin Industries Ltd, Osaka, Japan. Under the agreement, Daikin can make and sell R-410A, R-404A and R-407C in Japan and other countries in the Asian Pacific region. The agreement also provides licences to DuPont under Daikin patents covering R-404A and R-407C in some countries. Daikin is a major equipment manufacturer and producer of fluorocarbons in Japan.

R-410A, a 50% mixture of hydrofluorocarbon (HFC)-32 and HFC-125, is considered a leading replacement for R-22 in some applications. It was originally developed by AlliedSignal USA as Genetron AZ-20. With higher pressure and capacity than R-22, R-410A will be used in new equipment with new system design. In some designs, it has improved energy efficiency.

Developed by DuPont to replace R-502 in low-temperature refrigeration equipment, R-404A is a mixture of R-125, R-143A and R-134A. R-404A is considered the industry standard for replacing R-502 in commercial refrigeration and refrigerated transport.

R-407C, a mixture of HFC-32, HFC-125 and HFC-134A, is a replacement for R-22 with equivalent pressures and performance similar to R-22. It can be used in new or existing equipment with minimal system changes.

Source: JARN, 25 February 1997

Promising outlook for R-407C

The refrigerant R-407C, looks set to replace R-22 in many air-conditioning applications, according to many experts. The National Research Council of Canada and ICI Klea have investigated R-407C and R-410A as alternatives for R-22 in residential heat pumps. The only change made in the test where R-22 was replaced with R-407C, was the installation of an electronic expansion valve instead of a fixed orifice. However, the R-410A conversion involved changing the original reciprocating compressor. According to AKA in Sweden, R-407C is a viable substitute for R-22 in direct-expansion systems and it is being widely used in Sweden in commercial systems.

Source: OzonAction, January 1997
Contacts: NRC, Fax: +1-613-9541235
ICI Klea, Fax: +1-302-8877706
AKA, Fax: +46-31 260274

Hydrocarbons evoke controversy

Germany - The use of hydrocarbons such as propane and isobutane as refrigerants has provoked widely divergent views in European countries and overseas. In Germany, for example, isobutane has now established itself as the principal medium for domestic refrigerators, whereas hydrocarbons are still banned in the USA for all applications. In the UK the route to hydrocarbons was cleared by the publication of a standard allowing a charge of up to 2.5 kg in sealed systems and 25 kg where compressors were located in a separate plant room. Some manufacturers are still reluctant to offer HC-based machines because of the possible problem of product liability (the main objection in the USA) following the misuse or neglect of the compressor. However, butane is already accepted for other types of household use, for example as a propellant in hair spray.

Source: JARN, 25 March 1997

US opposes advanced HCFC production ban

USA - The United States government does not support a proposal from the European Union to phase out production of hydrochlorofluorocarbon (HCFC) refrigerants earlier than agreed in the 1992 Copenhagen Amendments to the Montreal Protocol. The European Union proposes reducing the production capacity from 2.8% to 2.0% and to cease production of HCFCs in 2015. The US government has opposed a faster phase out because they think that an accelerated HCFC phase out would encourage CFC equipment owners to delay decisions on replacing their equipment which in turn would have a negative environmental impact. HCFCs are widely used in the United States in residential and commercial central air systems and for refrigeration, such as in reach-in coolers in supermarkets.

Source: Koldfax, March 1997.

1996 ends with record US shipments

USA - Manufacturers shipped 5,670,665 central air conditioners and air-source heat pumps in 1996, boosting combined US factory shipments by 11% over 1995. A buoyant economy and demand for replacement units propelled the industry to a third consecutive record year, as is shown in the **Figure**.

Low unemployment, low inflation and steady short-term interest rates at the start of 1997 presaged continued healthy growth for the economy, raising prospects that unitary shipments could at least match last year's records when shipments jumped an impressive 582,404 units. Shipments of reciprocating liquid chiller packages, used for comfort cooling in commercial, institutional and government buildings, set a fifth consecutive record at 14,191 units. Products such as heating and cooling coils and packaged terminal air conditioners achieved double digit gains in shipment volume. Combined US and exported shipments of non-CFC large tonnage liquid chillers continued at a near record pace with 9,197 units. A ban on the manufacture of CFC refrigerants went into effect in January 1996. In the US alone, nearly 60,000 CFC centrifugal units need replacement or conversion to other refrigerants.

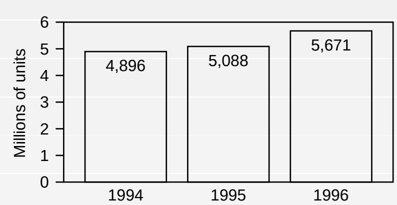
Shipments last year of centrifugal and screw chillers were slightly off the record of 9,444 units shipped in 1995, which was a 32% increase over the previous year. Due to the slower-than-expected pace of replacement, nearly 46,00 CFC chillers will still be in service two years from now, putting much greater pressure on increasingly expensive CFC supplies. New chillers, offering increased efficiency and lower operating costs, are attractive options for resolving the CFC phase-out problem. Beginning in 1999, when 44% of the original 80,000 CFC chillers are replaced by non-CFC chillers, building owners will save an estimated USD 480 million annually by reducing energy usage by 7 billion kWh per year.

Replacement and modernisation are also expected to provide steady business to manufacturers of central air conditioners and heat pumps. Efficiency gains for the new units average about 55% compared to units installed 20 years ago, making replacement a cost-effective choice.

The Commerce Department reports that central air conditioning was included in 80% of the houses built in 1995. In the south, where it is expected that nearly half of the nation's new housing will be built during the next five years, about 98% of the units will have air conditioning.

Source: Koldfax, February 1997

Figure: US Shipments



Clivet aims for DX splits market

Italy - Chiller and fan coil manufacturers Clivet claim that hydro-splits have opened the door to air conditioning (AC) for the traditional heating industry. In Italy over 1,000 small heating installers are now involved with domestic and small commercial AC systems. Clivet recently signed a partnership deal with Denco in the UK, where direct expansion (DX) splits have already established a sizeable market from which hydro-splits could benefit. Clivet says that Sweden has already introduced new laws limiting the amount of refrigerant within the living space, a development which, if followed in the rest of Europe, would be favourable to the hydro-split market.

Source: JARN, 25 March 1997

Ebara to produce absorption chillers in china

Japan - Ebara Corp., Tokyo, one of the top chiller manufacturers in Japan, recently decided to establish a joint venture company for chiller production and sales in Yantai City, Shangdong Province, China, to expand overseas marketing of absorption chillers and chiller-heaters. The partner is Yantai Moon Co. Ltd., a major manufacturer of large refrigeration and air-conditioning equipment. The initial investment is USD 11 million (JPY 1.35 billion), of which 60% is paid by Ebara and 40% by Yantai.

The domestic air conditioning market in China has grown rapidly due to China's more open economic policy, and demand for steam-driven absorption chillers was said to have reached 1,300 units by 1995. The demand for oil/gas-driven absorption chiller-heaters is also expected to increase. Yantai Ebara Air Conditioning Equipment Co. will construct a plant in the suburbs of Yantai City during 1997, and commence production and sales of absorption chillers and chiller-heaters designed by Ebara by early 1998. In future, the annual production will be expanded to 1,300 units.

Since the end of 1995 Ebara has been producing small packaged absorption chillers in China, which are mainly shipped back to Japan to meet domestic demand. In recent years, alongside the rapid expansion of the RAC/PAC (room air conditioner/ packaged air conditioner) market, the chiller market has also grown rapidly. However, since the electric power supply is not good, absorption types are becoming popular as they consume far less electricity. Demand for absorption chillers has therefore grown rapidly from 300 units in 1990 to around 2,000 units in 1996.

In China, there are 30-40 absorption type chiller manufacturers, including 5-6 major ones. For the past few years, to improve their production processes and quality, these local manufacturers have made extensive approaches to the large Japanese and American producers to reach joint agreements. The current Ebara-Yantai joint venture is the fourth project in the field of large absorption chiller manufacturing, following joint ventures set up by Sanyo, Trane and Carrier.

Source: JARN, 25 February 1997

Progress of Annex 24

Sweden - After six months of operation Annex 24 of the IEA Heat Pump Programme, entitled Ab-Sorption Machines for Heating and Cooling in Future Energy Systems, is half way through the first phase of its assignment. Under this phase Annex country reports are being produced which cover relevant areas related to absorption technology, including basic information such as climate, energy use and resources, energy and environmental policy, applications and RD&D. The reports provide information that can be used to more extensively perform and recommend application-oriented R&D where energy efficiency, environmental benefits and economic competitiveness should be particularly emphasised.

Draft country reports from Canada, USA, UK and Italy have already been submitted to the Operating Agent. These reports are currently being reviewed and the UK team has come up with some valuable suggestions and changes to the framework report. These suggestions will be discussed at the first Annex 24 workshop on Ab Sorption Machines for Heating and Cooling in Future Energy Systems, which will be held in Maastricht, the Netherlands in June. The workshop will focus mainly on marketing and application. The main topics of the workshop are presentation and discussion of the country reports, information exchange and discussions, presentations of selected case studies by invited speakers and a preparation of phase 2 of the Annex. In this second phase technical, economic, environmental and political obstacles for the introduction of absorption technology will be identified.

Finally, the Operating Agent has started work on establishing an official home page for the Annex on Internet. This site will include general information about the Annex, progress reports, proceedings, information on upcoming events and contact information for participants and other relevant organisations.

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

Annex 22 and natural working fluids on Internet

Norway - Annex 22 on "Compression Systems with Natural Working Fluids" (1995-97) aims to further develop the technology and expand the knowledge base of the natural working fluids ammonia (NH_3), hydrocarbons, carbon dioxide (CO_2), water and air in compression heat pump, air conditioning and refrigerating systems. The Annex focuses on residential, commercial and industrial heat pumps, air conditioning systems and commercial refrigeration applications.

In order to promote natural working fluids in general and the Annex in particular, the Operating Agent SINTEF Energy has established an Internet home page:

http://www.termo.unit.no/kkt/annex22/

The outline of the site is as follows:

- Front page with links to installation examples;
- "The Natural Way" - natural working fluids vs. synthetic fluids;
- Background information on Annex 22 - motivation, scope, main activities etc.;
- List of Participating Countries with addresses, contact persons, e-mail addresses, home pages etc.;
- Research/development (R&D) and prototype/demonstration (P&D) activities;
- The 1997 Workshop in Gatlinburg, Tennessee, USA;
- Products (reports, proceedings);
- International status including a brief overview on the current and expected use of natural working fluids in compression heat pumping systems;
- A large number of links to other relevant home pages are included.

On the home page there are five photos showing examples of heat pump, air conditioning and refrigerating installations using ammonia, hydrocarbons, carbon dioxide, water and air. By clicking on the photos, sub-menus are revealed presenting more detailed photos and information on the type of application, year of installation, heating/cooling capacity, system design, working fluid, charge, safety measures, etc. The number of installation examples will be increased during 1997.

Source: Mr Jørn Stene, Operating Agent
Annex 22, SINTEF Energy.
Fax: +47-732593950

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
Annex 25 Low-Temperature Low-Cost Heat Pump Heating Systems	25	CH, NL

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).

Systems and controls

An international overview

Gerdi Breembroek

An energy-efficient system requires an optimal design of both the system and its control. A heat pump system should provide year-round reliability and efficiency. How can this be achieved? The first step towards this goal is the system design, which can meet the cooling, heating and domestic hot water requirements in several ways. The second step for optimisation is to choose an appropriate control mechanism from the many which are available. This article describes a number of existing systems and controls used worldwide, and the ongoing developments in this area.

Energy efficient systems

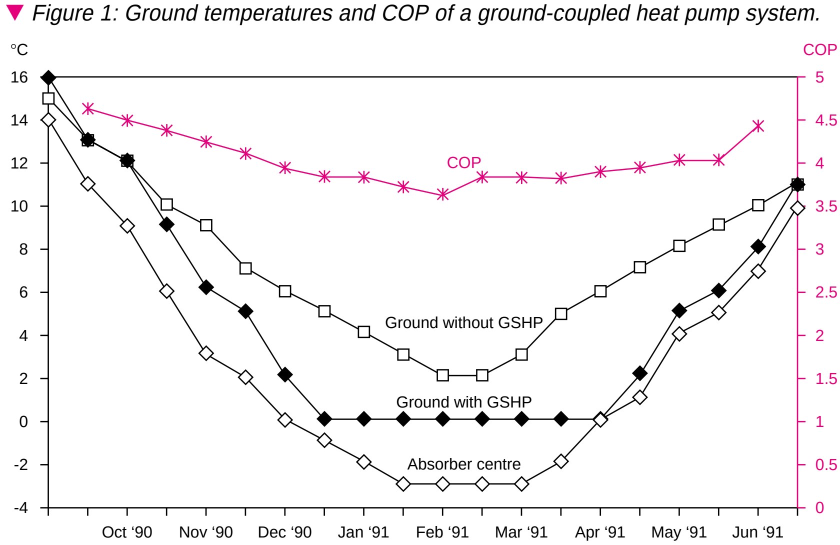
A heat pump system includes at least a heat source, a heat sink, and the heat pump components. Multiple sinks and/ or sources can meet various user needs, such as space conditioning and domestic hot water supply, or space conditioning and electricity load levelling.

One of the methods used to achieve high efficiency is to choose a low temperature lift, i.e. a small temperature difference between heat source and heat sink. Instead of the conventional high temperature hydronic heat distribution systems used in Northern and Western Europe, low temperature heat distribution systems should be installed for heating. This is discussed on page 19. Furthermore, a high temperature heat source is beneficial for heating applications. Ground-coupled systems will be discussed in more detail below, because of their beneficial source temperature. Solar-assisted systems to increase the source temperature will also be addressed.

Another way of achieving energy efficiency is to use integrated heat pump systems, which usually combine hot water heating with space conditioning. In this way, the most energy intensive heat transfer processes in a building are performed efficiently. The integrated systems section will explain how these needs can be combined.

A third focus concerns energy-efficient electricity generation. The increased use of space conditioning equipment gives rise to a potential peak load during daytime. The peak can be levelled by adding a thermal storage unit to the system. Year-round comfort can be provided by storing waste heat in summer, for use as a heat source in winter. Both concepts are addressed in the thermal storage section.

▼ *Figure 1: Ground temperatures and COP of a ground-coupled heat pump system.*



Ground-coupled systems

Ground-coupled heat pumps, both open (ground water) and closed loops, make clever use of the earth's warmth. Compared to air-source heat pumps, these systems benefit from a more constant source temperature (see **Figure 1**). They are frequently installed in Western and Northern European countries and in the USA. The two most popular methods of transferring heat from the earth are via horizontal ground coils or vertical borehole heat exchangers. Seasonal performance factors (SPF) of 3.5 - 4.5, and sometimes even higher, are reported for Austrian heat pump systems, with direct expansion of the refrigerant in the ground coils. The typical tube length for such a system is 600 m for a single family house.

With ingenuity, other efficient ground-related heat sources can be found, such as tunnel water, abandoned boreholes and mines. In Switzerland, a village heating system is fed by tunnel water. The nearby Furka rail tunnel drains ground water at a temperature of 16°C with a heat content of 3.5 MW. The water is circulated in a polyethylene piping loop, and decentralised heat pumps use it as their heat source. In Germany, a school is heated by utilising heat from an abandoned tin mine, via a heat pump and a small cogeneration unit. Thermal spas are also attractive heat sources, as well as warm water from deep aquifers. A clever choice of the heat source helps efficient heat pump operation.

Solar assisted systems

Solar assisted systems use solar energy to increase the heat source temperature. The working fluid directly expands in the solar collector, or a water loop stores the solar energy in a storage tank. In this case, a heat pump system uses the storage tank as its heat source. Collectors are simply mounted on the rooftop.

Solar assisted systems have been installed in some commercial buildings in Japan, though residential systems are also available. During the winter the roof collectors can be used to gain heat. However, in summertime they reject heat, especially at night, when the cold storage system is charged. The cost of the collectors is the main limitation to increased use of these systems.

Integrated systems

Integrated systems for space heating, cooling and domestic hot water heating offer users the benefits of heat pumps for all of these functions. The system must not only be able to perform these functions efficiently in combination, but also individually. An integrated system with dedicated water heating is shown in **Figure 2.** A compressor switches between various heat exchangers to perform the different functions. More sophisticated integrated systems, not shown here, include variable-speed compressors, electronic refrigerant flow control valves and sophisticated control algorithms. **Figure 3** shows the ratio of the capacity for the various functions in relation to the outside temperature. Two functions must usually be performed simultaneously. Balancing these functions is the core activity of an efficient integrated system. Water heating costs can be cut by 70 % for an average US city using an integrated heat pump with dedicated water heating.

Thermal storage

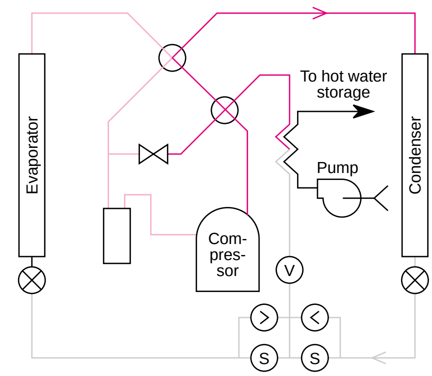
Energy-efficient and cost-efficient electricity generation benefits from a steady demand. This requirement is not always fulfilled, particularly in Japan, where the daytime electricity demand is twice the night-time demand in summer. Thermal storage systems, that store cold at night for daytime use, can achieve the desired load levelling. An example of the influence of ice thermal storage on the electricity demand is shown in **Figure 4.**

The benefits of a cold storage system were experienced in the Tokyo TEPIA building. The cold storage system comprises brine/refrigerant heat exchange, and a static heat exchanger in the storage tank. In the 1991 air-conditioning season, about 70% of the compressor electricity was consumed in the off-peak period from 22.00 hrs to 08.00 hrs. The cooling SPF was 3.5. In the heating season, 69% of the electricity demand was used in the off-peak period, and the heating SPF was 3.4. The need for a heat exchanger in the ice thermal storage system is removed when a direct-contact direct-expansion system is employed, a so-called “flash-freeze system”. A laboratory building in Tokyo was equipped with a flash-freeze ice thermal storage unit with perfluoro-n-pentane as the refrigerant (see **Figure 5)**. COPs for such systems range from 3 to 4, depending on the condensing pressure.

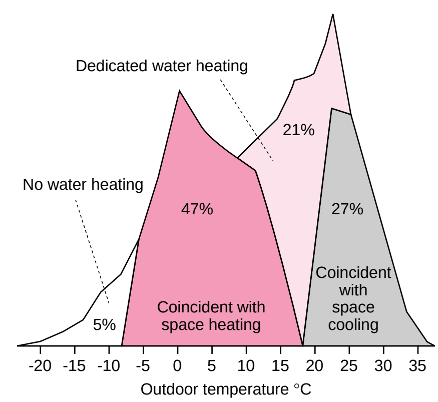
Another application of thermal storage is to store waste heat in summer for use in the winter. Deep aquifers can be used to achieve this. This concept was applied using a heat pump in the recently built ANOVA building in the Netherlands. More information about this project is described in Newsletter Vol 14/3.

Industrial heat pumps

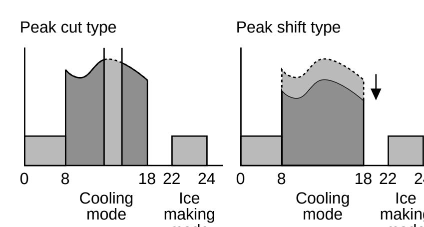
Quite a different subject is the incorporation of a heat pump in an



▲ *Figure 2: Trane integrated heat pump with dedicated water heating.*



▲ *Figure 3: Energy for various operating modes vs outdoor temperature for an integrated heat pump.*

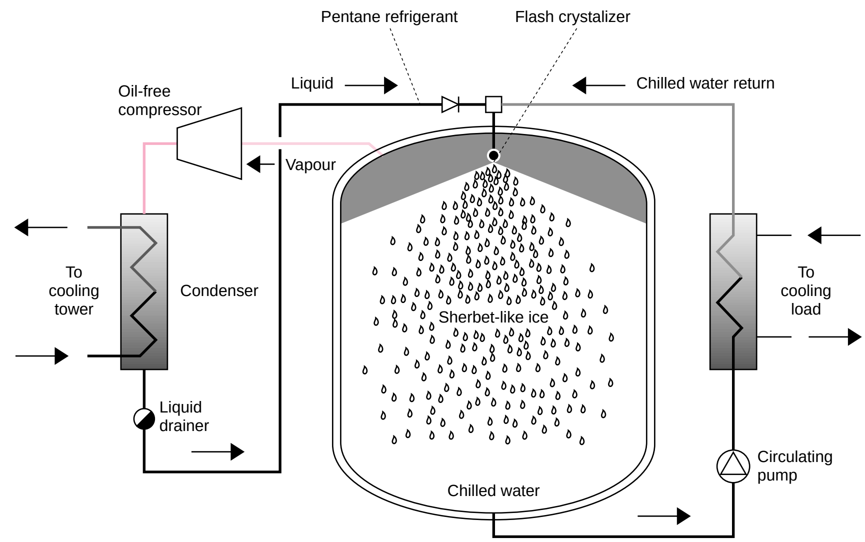


▲ *Figure 4: Load levelling with ice thermal storage.*

11

industrial process. Efficient and cost-effective design of an industrial heat pump system requires a close look at the process heat flows. Pinch analysis is a powerful tool to detect where waste heat can be used for heating in another part of the process.

Process-integrated heat pumps often use process streams as the heat source and heat sink. This means that they can all be regarded as unique and that they should be designed carefully. An integrated approach, considering all hot and cold streams, is essential. The IEA Annex 21 “Global Environmental Benefits of Industrial Heat Pumps” products include a software package which uses pinch analysis.



▲ *Figure 5: Basic configuration of the flash-freeze system.*

Controls

Control systems are needed to adapt the performance to the outside temperature, to regulate the thermal storage system, or remotely switch off a heat pump. The availability of microprocessors, as well as the different conditions in energy-efficient buildings, are factors that currently influence the controls market.

In an efficient, well designed system, proper controls guarantee that the desired indoor conditions and hot water temperatures are achieved, regardless of changes in demand. Optimal comfort in space-conditioned areas should be attained, as well as constant process conditions in industrial environments. The control of industrial heat pumps is part of the entire process control routine, and is specific for each process.

Comfort control not only includes temperature control, but also humidity and air movement. A humid hot climate appears to be warmer than a dry hot climate, and for cold climates, it is the other way around. This fact shows that there is no simple relationship between the variables and people’s thermal comfort. Therefore, concepts were developed to describe the perception of a person’s comfort in a room, using specific parameters. Such parameters include PPD (predicted percentage of dissatisfied) and PMV (predicted mean vote). A control algorithm based on PMV was incorporated into a Matsushita product developed in 1991.

Hardware

Maintaining the desired condition requires being able to cope with different loads. The hardware is crucial to meeting this requirement. The compressor type and the driving motor type influence part load efficiency of the unit. Compressors are available as one-speed, two-speed and variable-speed devices. A one-speed compressor can be turned on and off in response to part load conditions. Two-speed or variable-speed compressors provide more possibilities. With regard to the control hardware, the use of increasingly powerful microprocessors for space conditioning control is growing. This enables the use of advanced control algorithms for maximum energy efficiency and comfort.

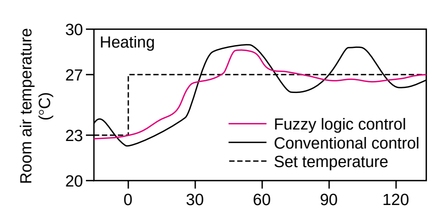
International variety in controls

The hardware and control systems for residential heat pumps vary from country to country. For the two market leaders, USA and Japan, clear distinctions exist.

In the US residential market, a typical control interface is a wall-mounted thermostat. It enables the user to switch between auto, cool, heat or fan only, and select the set-point temperature. The heat pump usually has a fixed-speed compressor, although two-speed systems are available. The compressor is turned on and off in response to the thermostat, to keep the temperature close to the set-point. Heat is distributed by a duct system. Multi-zone systems have been gaining popularity. These systems save energy because more accurate control over all rooms is possible. Control of the systems is either via a thermostat or a sensor for each zone.

In Japan, variable-speed compressors and fans are common. This enables a higher efficiency in part load

▼ *Figure 6: Room air temperature simulation results of fuzzy control and conventional control.*



conditions. These heat pumps are generally microprocessor-controlled. The user interface is a remote controller. Multiple rooms are generally served by different systems and different remote controllers.

Advanced controls

The simplest microprocessor control strategy includes a table, from which settings are read as a function of the difference between heat source and heat sink temperature, and the rate of change. Depending on the operating mode (heating or cooling), either of these temperatures is compared to the set-point value. The rule table is developed either by formulating empirical knowledge or theoretical predictions of the air conditioner's performance in the space to be conditioned.

In 1989 Mitsubishi Heavy Industries developed an air conditioner equipped with a fuzzy logic control module. **Figure 6** shows that the fuzzy logic control unit operates more smoothly than a conventional unit. However, the fine-tuning of such systems can be time-consuming. The use of a genetic algorithm to address this problem was first proposed by Toshiba. The developed systems show a very smooth approach to the desired room temperature level, and a rapid response to sudden changes (e.g. an open door). Electricity consumption can be reduced by as much as 20 % compared to conventional control systems.

Low-temperature heating

In contrast to the trend towards more sophisticated controls, low-temperature heating systems in low-energy houses do not need more than a simple response to the outside temperature in order to remain comfortable. In Switzerland, a feasibility study for using heat pumps in low-energy houses (requiring less than 200 MJ/m^{2}a) was performed in 1996. The houses were provided with low-temperature floor heating with a water inlet temperature below 30°C. The transfer rate of heat from the floor

Austria

In single-family houses in Austria, ground-coupled systems combined with low-temperature floor heating systems dominate the market. Direct evaporation and secondary fluid systems are both being used. The specific heat load of the houses is in the range of 50 to 65 W/m^2.

Heat pumps are mainly installed in new buildings. Retrofitting of existing buildings with high-temperature radiators happens relatively seldom because of the low oil price and the small SPFs involved.

The control mechanism used in houses is either a reference room temperature control, which is very efficient in buildings with a high built-in storage mass, or an outdoor air-dependent supply temperature control.

In large commercial applications, where natural ventilation is not possible, dual-mode air conditioning systems are in use for heating, cooling and moving excess heat from rooms with large internal gains to rooms without such gains. Ventilation systems with heat recovery combined with four-pipe systems are popular as distribution systems. The control used is a single-room temperature control.

If waste heat is available small district heating networks with heat pumps cover the heating base load. The controls in these district heating systems measure the supply temperature required by the substations in the buildings. The network supply temperature is then reduced to the minimum possible value to increase the COP of the heat pump. The buildings with the highest supply temperature requirements should be equipped with better insulation and/or larger heat transfer equipment. This is a future effort which will increase the efficiency of the whole district heating system.

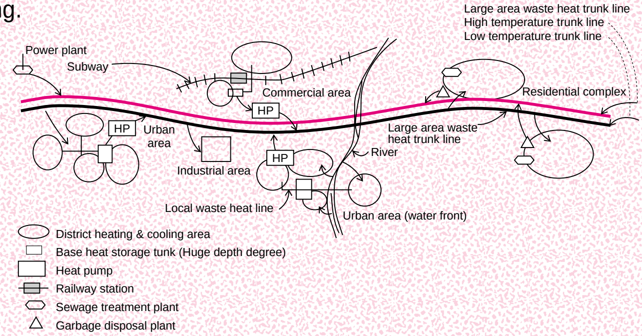
Source: Austria National Team

Japan

There is a wide variety of heat pump systems in Japan. This national topic appraisal will discuss thermal storage systems and the utilisation of waste energy.

Heat pumps are coupled to water thermal storage systems in most commercial buildings in Japan. Thermal storage is required to level out the peak electric power demand during day-time in summer. It also improves the warming-up performance on winter mornings.

The design and operation of heat pump systems with thermal storage has been steadily improved by research and development studies. Current development activities focus on high density thermal storage, e.g. with ice. Such systems require less space in a building.



▲ *Figure: Concept of large area distribution of unused energy utilization system.*

Recycling of urbane "unused" heat and cold can be achieved effectively with heat pumps. The national R&D programme on the development of advanced heat pump systems utilising urbane unused energy is in the final stage of on-site demonstration and verification. The **Figure** shows a district with its plants and buildings, which both use and reject heat and cold from the central piping system.

Authors: Mr Y. Igarashi and Mr T. Yoshii of the Japanese National Team into the room rapidly decreases as the sun warms the floor. Therefore, these systems exhibit a certain amount of self-control. The article on page 19 presents more details on low temperature floor heating.

Switch off during peak hours

In addition to the solar effect, the Swiss study calculated the impact of cut-off periods of two hours. It was demonstrated that a cut-off does not result in a perceptible drop in room temperature. However, the heat demand must be covered in a shorter time, which implies a higher water inlet temperature and a 5% lower SPF. A sophisticated control system is not required. The negligible comfort drop in remotely disconnected systems agrees with experiences in Germany and other European countries, where this type of switch off is applied. The only constraint is the customers' attitude, as their heating strategies have to be adapted to the different situation. Once this hurdle has been overcome, the comfort level can withstand all tests.

Control of multi-split units

The control challenges faced by the multi-split systems are more complicated than for single-split systems. The refrigerant flow must be controlled irrespective of height differences, the operation of the inverter-driven compressor in the outside unit, and the electronic expansion valves in the various indoor units. In Japan, multi-split systems constitute an increasing market share, from well above 20 % of all packaged systems in 1991, to nearly 40% in 1996.

Matsushita Corp. developed "Fuzzy Adaptive" controls for multi-split systems. Governed by a control algorithm, the electronic expansion valve in each indoor unit is controlled to reach the specific desired room temperature. Furthermore, the compressor speed is controlled to reach the set value of the suction pressure or the discharge pressure (for cooling or heating mode respectively). The system is capable of

Norway

Heat Pump System for Heating and Cooling of a Commercial Building

A significant trend in commercial and institutional buildings is improved thermal envelopes, increased internal heat gains as well as growing comfort requirements. The potential of space conditioning heat pumps consequently increases, even in cold climates.

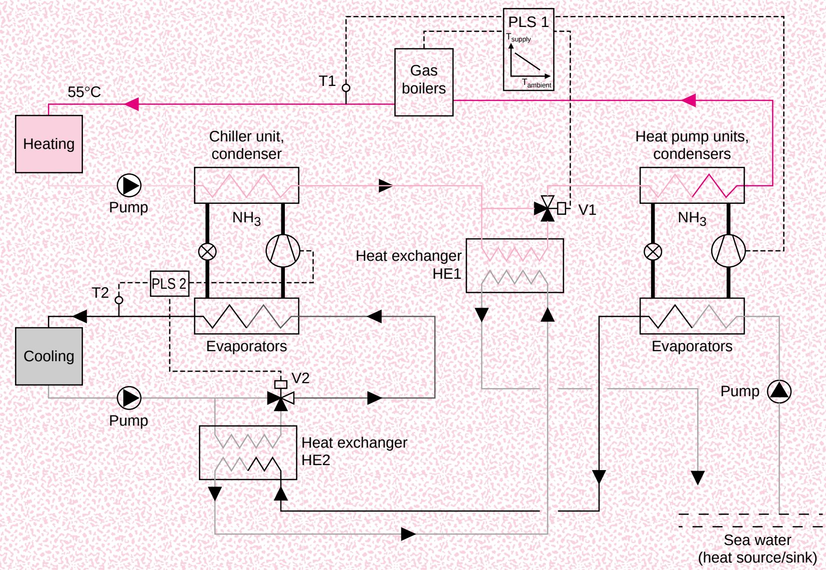
The **Figure** shows an example of a heat pump system for simultaneous space heating, space cooling and pre-heating of water in a commercial building in Trondheim, Norway. Only one of the two heat pump units is shown in the figure. An auxiliary ammonia chiller unit is installed to cover extreme cooling peaks.

The two ammonia (NH_3) heat pump units have a total heating capacity of 900 kW at design conditions, and they cover approximately 50% of the maximum heat demand. Occasional peaks on cold days are covered by two gas fired boilers. The peak load units also serve as a backup system. The heat pump units cover approximately 95% of the annual heat demand.

In *heating mode*, sea water is used as a heat source for the heat pump units, supplying heat to the heat distribution system. In order to achieve a high coefficient of performance (COP), the supply temperature is kept as low as possible. It is controlled by an "outdoor temperature compensation curve", indicated by PLS (Programmable Logic System 1), in the **Figure**. If the heat pump at maximum heating capacity cannot maintain the required temperature T_{supply}, the peak load boiler is switched on and supplies the necessary additional heat.
Compared to conventional oil-fired boilers, gas-fired boilers have higher energy efficiency, lower emissions and superior control characteristics, even at part load.

Space and computer cooling is provided by chilled sea water via heat exchanger HE2. PLS 2 controls the three-way valve V2 in accordance with the setpoint temperature and the measured supply temperature T_2 in the cold distribution circuit.

In *cooling mode*,chilled sea water cannot meet the cooling requirements of the building. The auxiliary chiller unit is then switched on, and the cooling capacity is controlled by PLS 2. The condenser heat from the chiller is used for pre-heating of hot water and space heating, and surplus heat is given off to the sea water via heat exchanger HE1. PLS 1 controls the three-way valve V1 in accordance with the setpoint temperature T_{supply} and the measured supply temperature T_1.



Jørn Stene, Norwegian National Team

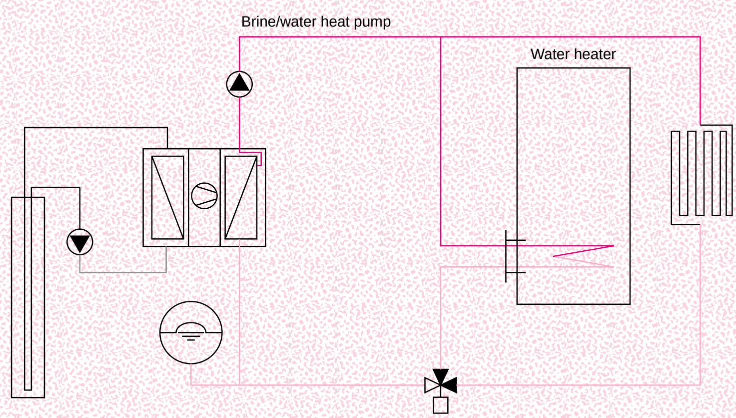
Switzerland

In Switzerland an improvement in heating COP of up to 55% could be achieved by better heat pump units. This marked improvement was found at the test centre in Winterthur-Töss over the past two years. However, the COP only reflects the steady-state performance under laboratory conditions, as described in Standard EN255. The overall seasonal performance factor (SPF) of the combined system can be still much lower, due to bad system integration or inefficient controls. For this reason the Swiss Federal Office of Energy launched several projects to achieve quality assurance:

- consideration of cycling losses by dynamic HP testing procedures
- introduction of a quick testing method, based on parameter identification techniques
- field testing of heat pump units tested in Winterthur-Töss (under the ENERGY2000 programme).

For residential heating systems there is a trend towards simple and robust controls. If sufficient inertia of the building and distribution system is provided, the heat pump can be integrated without buffer storage in the system, see the **Figure**.

User demands have a strong impact on the seasonal performance of a system. The SPF of a brine/water heat pump without domestic hot water heating is 4.1, and for an air/water system 3.1, without backup heater. Additional hot water production however reduces the SPF in a low energy house (<200 MJ/m^{2}a) by 10-25%.



Authors: Swiss National Team

USA

The operation of the central ducted heat pump US system is based on fairly simple logic. The compressor is normally fixed-speed, although there are two-speed systems available. It is cycled on and off in response to the thermostat, to keep the house in a temperature band around the setpoint. The fan speed is mostly constant. The heat pump thermostats are usually two-stage for heating with the second stage used to control supplemental heat.

Commercial installations are far more complex than the relatively simple residential systems. The wide variety of building control products caused the need for a common protocol. In 1995, BACnet (Building Automation and Control networks) was developed by a consortium of Heating, Ventilating, and Air Conditioning (HVAC) companies and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). The first large project that will use the protocol is the 450 Golden Gate project in San Francisco (130,000 m^2, 22-stories), awarded to Alerton Technologies and the Trane Company. Planned enhancements BACnet include interoperability with Internet protocols and new Internet applications.

Authors: US National Team

handling cooling and heating loads simultaneously in one building.

BACnet

In the US, the need was felt for a common protocol for all building automation and control systems. As a result, a consortium of heating, ventilation and air conditioning (HVAC) companies, together with the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) developed Building Automation and Control networks (BACnet). This is a comprehensive communications infrastructure to integrate a wide variety of building control products made by different manufacturers. Around 20 companies are united in the consortium.

The BACnet protocol was approved both as an ASHRAE and an ANSI standard in 1995, and it has been selected as a European Union pre-standard. It enables building owners to obtain competitive upgrades to building control systems, and to integrate controllers that come packaged with HVAC equipment with an energy management or integrated control system made by a different vendor. This standardisation will give the user more flexibility when choosing a control system.

Conclusions

An energy efficient design should combine a good heat source or sink and an efficient distribution system. The development of more sophisticated control algorithms must be adapted to system developments. Integrated systems and large multifunctional buildings require advanced control strategies, while systems with self-controlling properties can be realised cheaply with a fairly simple control system. The use of standardised protocols for commercial buildings will enhance control flexibility.

Author: Gerdi Breembroek,
IEA Heat Pump Centre

Large temperature differential storage system

Makoto Kayo, Japan

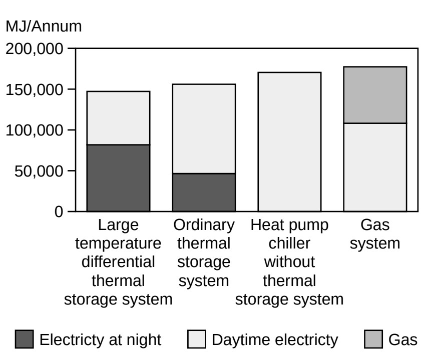
This article describes the design and performance of a large temperature differential thermal storage (LTDTS) system installed in an office building in Japan. Comparisons between the computer simulations at the design stage and the actual operating record prove that the system is operating correctly and that it contributes to energy conservation as well as improving the indoor environment. To accomplish this, it was essential to design energy-conservation-oriented architecture and to improve the efficiency of the building services elements, such as air-conditioning, lighting and public health services, to maintain the indoor air environment at a high level.

The system has been implemented in an eight-storey building with 4,400 square metres of total floor area, completed in 1993 and located in Maebashi-city in Gunma Prefecture in Japan. The system uses a flat type thermal stratification heat storage tank in the underfloor pit and a variable volume heat pump chiller. Serially connected air-handling units and fan coil units are used as the secondary system. The capacity of the thermal storage tank was designed to cover an average demand for one day.

Design stage

Energy conservation and levelling out of the electricity demand are important aspects that contribute to the protection of the global environment. At the design stage, requirements for the building included the fact that it should be a low energy consumption building, the air-conditioning system should have an effective primary energy consumption, the quality of the indoor air environment should be maintained at high level and the design should be cost-effective.

Figure 1: Annual primary energy consumption comparison.



The first step towards these goals is to have an energy-conservation-oriented architecture. The air-conditioning load was therefore simulated for a number of building shapes, different building orientations and two windows configurations. It was concluded that an eight-story building is 24% more efficient than a four- to five-storey building, the orientation does not have a lot of influence and that wide windows cause an increased heating load in winter compared to dispersed small windows.

At the design stage a comparison was made of the following systems:

- large temperature differential thermal storage system;
- ordinary thermal storage system (capacity 50% of daily demand);
- heat pump chiller without a thermal storage system;
- gas system (gas-fired absorption chiller) and heater.

Performance simulations

Computer simulations were carried out to evaluate the operational performance of these systems for one year. **Figure 1** shows the primary annual energy consumption of these systems. The gas system has the worst performance in terms of primary energy consumption. Since the capacity of the heat pump chiller without thermal storage is the largest of the three chiller-based systems, this causes problems in controlling the system, in spite of the fact that there is no heat loss via the storage tank. The thermal storage capacity of the chiller for an ordinary system is 50% that of a large temperature differential system. However, the capacity of the primary circulation pumps is nearly the same, and the capacity of the secondary pumps even smaller. Thus, the annual primary energy consumption of the large temperature differential system is the smallest of all.

In **Figures 2 and 3** investment and energy costs are compared for all four

Figure 2: Investment costs comparison.

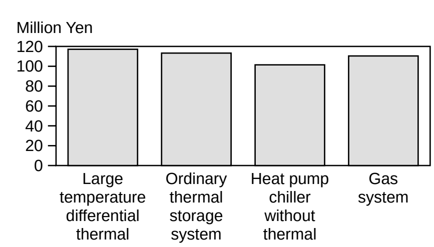
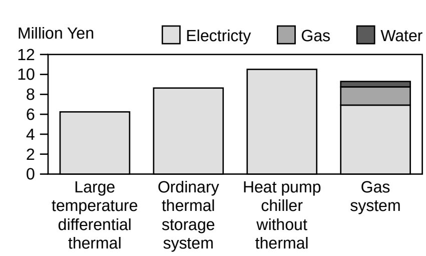
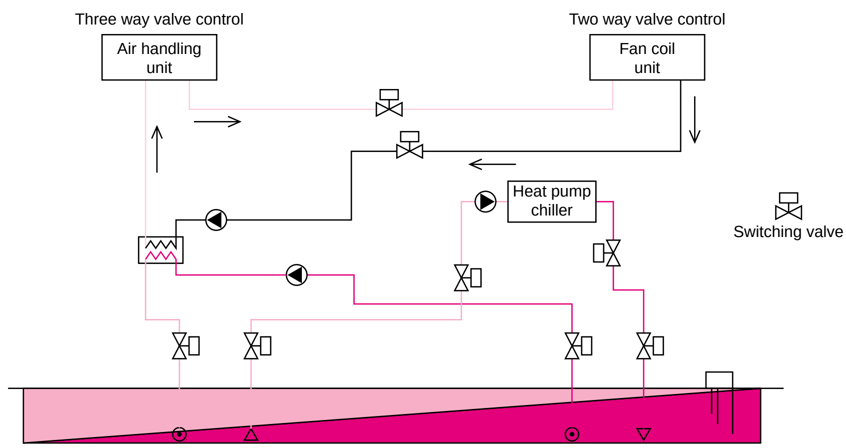


Figure 3: Energy costs comparison.





▲ *Figure 4: Schematic diagram of heat storage.*

systems. The capital cost of the large temperature differential system is the highest, while its energy cost is the lowest. This is due to the low primary energy consumption and the use of inexpensive night-time electricity. The time-span necessary to redeem the capital cost difference with the system without thermal storage and the gas system was estimated to be 3.8 years and 2.4 years respectively. These are economically viable periods.

LTDTS system

The storage capacity can be increased to shift the electricity demand to night-time where possible. Another approach would be to increase the water temperature differential within the tank, such as in the large temperature differential thermal storage system. Expansion of the temperature differential between chilled and heated water for air-conditioning reduces the general disadvantages of thermal storage systems. For example, the size of the storage tank can be reduced, as well as the electricity power consumption for water circulation. A schematic diagram of the thermal storage system in shown in **Figure 4**. The three main elements of the system are discussed below.

System elements

The first element is the large temperature differential flat stratification thermal storage system. To prevent heat loss due to mixing during the storage period, a stratified thermal storage should be achieved. Each storage pit element (1.5 m deep) is connected by an S-shaped connection tube (so-called 'elephant nose'), which allows almost the same performance as a much deeper, but more expensive, storage tank.

The secondary element is essential to effectively discharge all the heat stored at night. It operates well thanks to a temperature difference of 10°C. Dehumidification performance is maintained by allocating the air-handling units to the lower temperature side of the circuit. Air-handling units and fan coil units connected in series may cause poor dehumidification performance, since the average cooling coil surface temperature is increased. To avoid this problem, chilled water is supplied to the fresh air make-up air-handling units and the air-handling units which treat the latent room cooling load. Fan coils installed for the perimeter cooling load are supplied with chilled water from the outlet of the air-handling units. This results in an integrated temperature system. A closed-circuit system is installed for the secondary water circulation to reduce the pump power.

The last element is a chiller developed by Tokyo Electric Power Company and Hitachi Ltd. This is their first installed large temperature differential system. Even if the incoming water temperature decreases, a control system stabilises the temperature of the chilled water and uses night-time electricity effectively. A variable volume chilled and hot water control system has been developed to achieve this. This control system allows the chiller to keep operating until the incoming water temperature reaches 6.5ºC, and adjusts both the heat exchanger primary and secondary water temperature differential as required.

Operational results

The electricity consumed during the period July 1994 to June 1995 is shown in **Table 1**. This shows that 34% of the total annual electricity demand has been used for air conditioning. The annual primary energy consumption of this building per square meter was 78 MJ. This is actually 34% lower than that of average buildings with a thermal storage system, according to an official report issued by the Japan Building Energy Control Engineers Association.

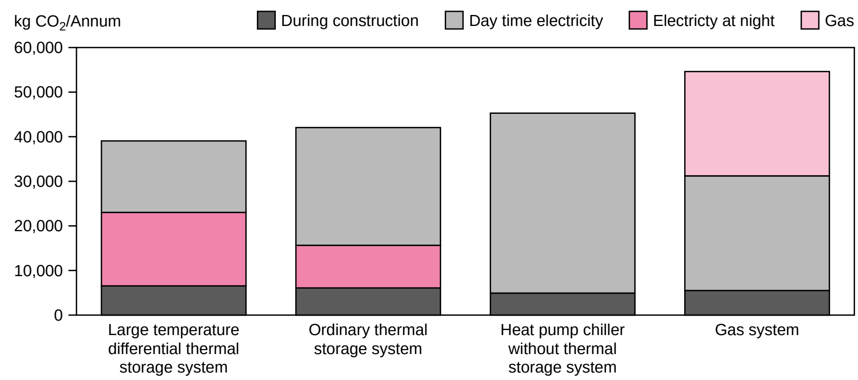
To evaluate the operation of the thermal storage tank, both the summer and winter situation should be taken into account. The results of summertime operation show that the primary chilled water supply temperature is 5ºC and the return temperature is 16ºC, resulting in a temperature difference of 11°C. This

▼ *Table 1: Annual electricity consumption.*

Total electricity consumption	638 MWh/year
Electricity consumption for air conditioning	220 MWh/year
Night-time electricity consumption	148 MWh/year

temperature difference is also achieved during the winter, when the supply temperature is 41ºC and the return temperature is 30ºC. Slightly varying temperature differences are observed in the intermediate seasons, because it is difficult to keep the temperature differential constant when only a small air-conditioning load is required.

The indoor temperature is maintained at 26ºC and 22ºC in summer and winter respectively, while a humidity of 50% is achieved in summer. This means that the system is operating correctly. A survey among the users of the building concerning their satisfaction with the indoor environment showed that only 6% felt uncomfortable, 39% slightly uncomfortable and 55% comfortable.



▲ *Figure 5: CO_2 emissions comparison.*

Environmental aspects

The motivation for implementing a large temperature differential thermal storage air-conditioning system in this building was the understanding that effective utilisation of electricity leads to a reduced impact on the global environment. The proportion of energy generated from fossil fuel is higher during the day than at night. Hence shifting to night-time electricity contributes to the overall reduction of CO_2 emissions, and this also prevents unnecessary investment in the construction of a new power plant.

HCFC-22 is used in the chiller as a refrigerant gas. The chiller is a packaged type manufactured in the factory with no assembly work on site at all. Therefore, there is no possibility of refrigerant leakage on site during installation or operation. To estimate the amount of refrigerant that can leak into the atmosphere, several assumptions were made based on manufacturers' data. The life expectancy of a chiller is 15-20 years. During this period there will be at least one problem whereby the service valve is replaced, causing a 10% gas leakage into the atmosphere. Another 10% gas leakage is expected during disposal of the chiller.

Based on these assumptions a CO_2 life cycle analysis shows that the expected refrigerant leakage is between 1.3% and 1.7% of the total amount of CO_2 gas resulting from normal operation. The conclusion is that this has no significant implication on the evaluation. **Figure 5** shows the equivalent CO_2 emissions of the four compared systems.

▲ *Photo: The building in Maebashi-city, Gunma Prefecture, Japan.*

Evaluation

The building has been designed and operated with the aim of contributing to the protection of the global environment, by levelling out the electricity demand. An evaluation carried out after completion proved that the goals set at the design stage were being realised. This large temperature differential thermal storage air-conditioning system concept can be easily implemented in any type of small office building.

Mr Makoto Kayo
Kajima Corporation
Architectural and Engineering Design Group
5-30, Akasaka 6-Chome,
Minato-ku,
Tokyo 107,
Japan
Fax: +81-3-55612388

Residential heat pump systems and controls

Hermann Halozan, Austria

The main purpose of residential heat pump systems and their controls is to provide an integrated system supplying comfort for the user at minimum energy consumption. This article discusses the ongoing developments to optimise the energy efficiency.

Buildings in Central and Northern Europe are mainly equipped with hydronic heat distribution systems. In these regions heat pumps have to be integrated into the existing systems. If the hydronic system uses radiators as heat transmission surfaces, they are typically sized for maximum supply temperatures of 90°C. However, many of the new systems, which use the floor as heat transmission surface, only require a maximum supply temperature of 35°C.

Efficient heating systems

According to the second law of thermodynamics, the temperature lift achieved using heat pumps is the result of adding exergy to the low-temperature energy (anergy) extracted from the environment. To achieve a high efficiency, the temperature lift between the heat source and heat sink needs to be as small as possible. Therefore the temperature level of the heat source should be as high as possible, and that of the heat sink as low as possible.

Emphasis is often placed on increasing the heat source temperature level, but an additional approach is to lower the temperature level of the heat sink. For floor heating systems this temperature can be relatively low.

Floor heating systems

For a floor heating system, both the temperature of the floor surface, which determines the amount of heat transferred to the room, and the supply temperature of the water required to obtain this floor surface temperature have to be considered.

The floor surface temperature depends on the specific heat load (in W/m^2 floor surface), whereas the specific heat load depends on transmission losses of the building and the heat losses caused by ventilation required for sufficient indoor air quality. The transmission losses can be reduced by the thermal insulation of the building and can demand a heat load of 10 W/m^2. The losses caused by ventilation are in the range of 20-30 W/m^2. Consequently, the total specific heat load amounts to 30-40 W/m^2. These values require a floor surface temperature of only 23-24°C at design conditions.

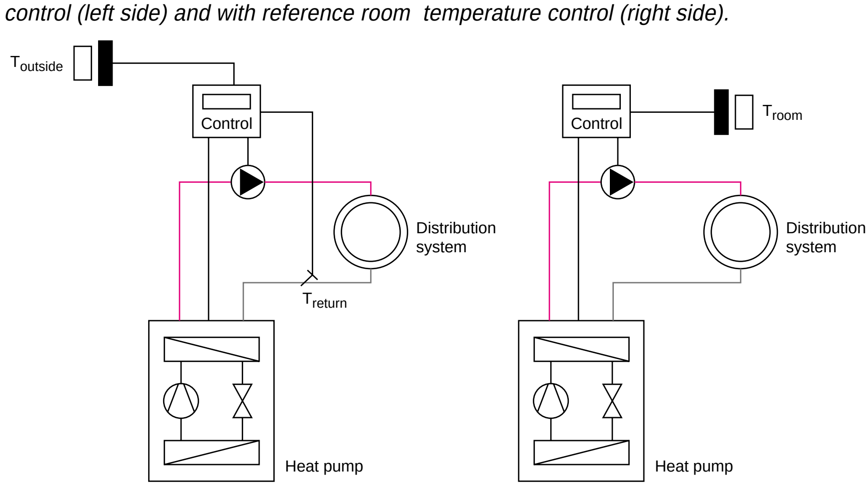
To achieve these surface temperatures several designs can be used. The most common type is a system where plastic pipes are embedded in the floor slab. With10 m of plastic pipe per square meter of a 0.07 m thick floor slab, the required supply temperature will be in the range of 30-35°C, depending on the floor covering. By using plastic mats with integrated water ducts and a stable floor cover, the supply temperature can be reduced to 27-32°C.

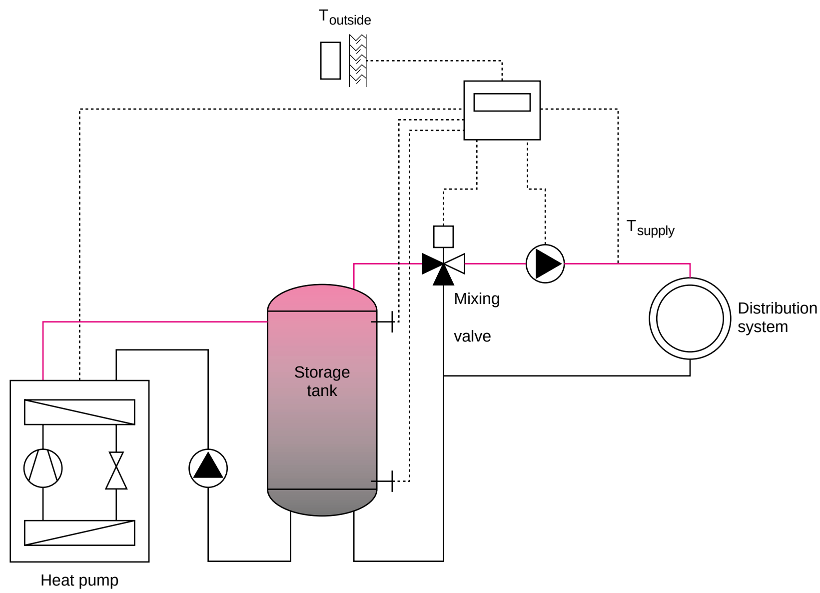
Controls

Control mechanisms are used to attain the right supply temperature necessary to provide the required room temperature. For hydronic heat distribution systems two basic types of controls are in use: the outside air-dependent water supply temperature control and the reference room thermostat temperature control (see **Figure 1**).

The *outside air-dependent supply temperature control* is based on the heat emission characteristics of the heat transfer surface used. If the outside temperature changes it is necessary to adjust the supply temperature to match the changing heat losses of the building. This type of control is suitable for single-family houses as well as multi-family houses. It is a relatively good compromise even though it is not suitable for controlling internal heat gains, especially solar heat. These effects have to be compensated by the building, i.e. by the mass of the construction itself.

▼ *Figure 1: Heat pump integrated directly with outside air-dependent return temperature control (left side) and with reference room temperature control (right side).*





▲ *Figure 2: Heat pump integrated by using a storage tank.*

The *reference room thermostat temperature control* is only suitable for single-family houses. For the room where the thermostat is mounted all influences can be taken into account, not only internal heat gains but also the delay and damping effect caused by the built-in storage mass of the building. Depending on the building structure the morning peak load occurs later, usually at higher outside temperatures, and additionally the peak is damped. This is an important effect, especially for outside air heat pumps.

Heat pumps can either be installed directly or integrated with a thermal storage system (see **Figure 2**). When heat pumps are used directly, the outside air-dependent *supply* temperature control should be changed to an outside air-dependent *return* temperature control to guarantee sufficient running time of the heat pump. The best solution depends on the heat pump unit used and the available heat distribution system.

Energy efficiency

The energy efficiency also depends strongly on the heat source. With heat pump systems using ground water in combination with the low-temperature heat distribution systems, the achievable seasonal performance factor (SPF) is in the range of 4-5. When outside air is used as the heat source, an SPF of 3 or higher can be achieved.

For outside air heat pumps, both the heating capacity and the coefficient of performance (COP) drop significantly with decreasing heat source temperatures. Because most heat pumps are designed to operate at these lower temperatures as well, this effect results in excess heat production at moderate temperatures. This means that heat pump supply temperatures exceed the temperature required by the system, causing an excess temperature (**Figure 3**). With ground-coupled heat pumps this effect is much smaller because the heat source temperature varies less over time. The best results are achieved with ground water as a heat source, because the water temperature is fairly constant over time (**Figure 4**). Different solutions have been developed to reduce the aforementioned effect.

Possible solutions

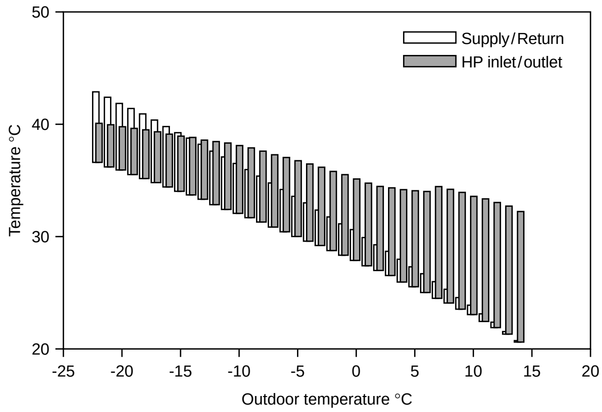
The first solution is integration of a warm water storage tank, which is mainly used for decoupling the flow rates through the heat pump and the heat distribution system. Excess temperatures can now be reduced by increasing the flow rate through the heat pump to lower excess temperatures (see **Figure 5**).

A similar effect can be achieved by using a heat pump with a two-speed compressor or a unit with two parallel compressors. A high efficiency solution is an inverter-driven heat pump with a variable speed compressor (**Figure 6**). This allows the heating capacity to be adjusted to the heat demand over a wide range of outside air temperatures. However, the fan power consumption has to be considered too: at part load conditions the fan consumption can have a significant influence on the COP of the heat pump.

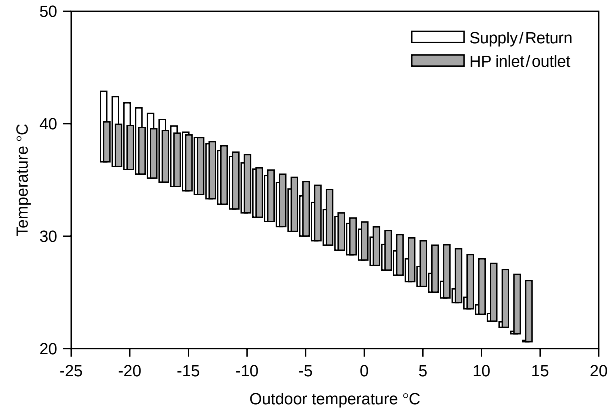
A relatively new approach is used in the case of floor heating systems with tubes embedded in the floor slab. Here the floor slab acts as a thermal store, that is charged by the heat pump and unloaded by the heat transmission to the room. To reduce the excess temperature, i.e. the difference between the required temperature for distribution and the heat pump supply temperature, the flow rate through the floor heating system is increased. The storage function of the floor slab implies that it releases the stored heat over a longer period of time. Therefore, the circulation pump is only running together with the heat pump and not, as in common systems, through the entire heating period.

Future developments

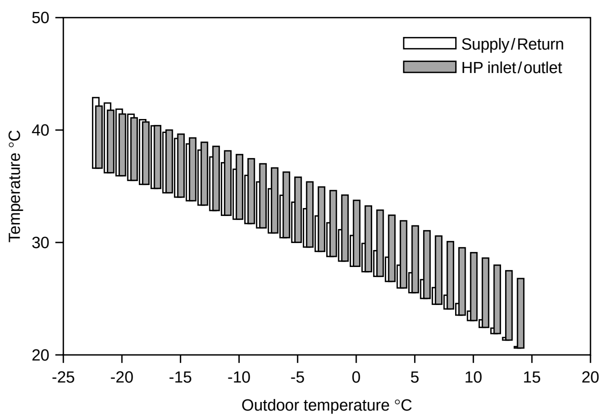
The most important component of a system is the building itself: the lower the heat load, the lower the supply temperature required. Considering the small transmission losses of new buildings, the next step will be a controlled ventilation system with heat recovery. Heat recovery can be accomplished by heat exchangers, by air-to-air heat pumps or by a combination of the two. The heat pump provides not only heat recovery, but also heating if the heat pump outlet



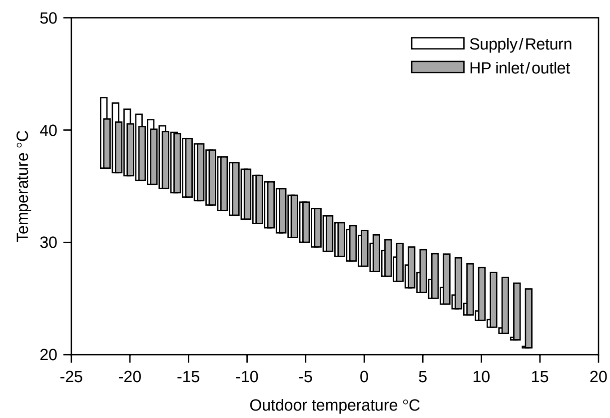
▲ *Figure 3: Supply and return temperature of an outside air heat pump.*



▲ *Figure 5: Supply and return temperature of an outside air heat pump integrated by means of a storage tank.*



▲ *Figure 4: Supply and return temperature of a groundwater heat pump.*



▲ *Figure 6: Supply and return temperature of a variable speed outside air heat pump.*

temperature is higher than the room air temperature. In such a system the additional heat demand becomes very small and the question arises as to whether hydronic systems are still cost-effective.

A solution for using the heat recovery system for heating over the full heating season is the so-called ‘air well’. These are concrete ducts buried in the ground in which the outside air is preheated by the ground, then heated further in the air-to-air heat exchanger, and finally by the heat pump. This is an air-heating system without circulation air, which implies that in summer dehumidification and cooling can be provided as well. Heating SPFs of such systems are in the range of 5-6.

Prospects for heat pumps

For both customer comfort and energy-efficiency, the heat distribution system, as well as the controls, should form an integrated system with the building and the heat pump.

In new buildings with a low heat demand, fresh air heating systems, which consist of controlled ventilation and air heat recovery by a combination of a heat exchanger and an air-to-air heat pump, may replace floor heating systems. The potential SPFs of such systems are in the range of 5-6. Such advanced heat pumps will have no competitors as far as energy efficiency and environmental benefits are concerned.

Author:
Hermann Halozan,
Institute of Thermal Engineering,
Graz University of Technology,
Austria
Fax: +43-316-8737305

Heading for improved reliability and performance

Roar Bang, Norway

If the acceptance and use of heat pumps is to be increased, it is essential to focus on the reliability and high performance of the systems. Since the core justification for heat pump installations is their unique ability to save energy, high performance throughout the lifetime of the system must be emphasised. In addition to improved component/system design and better workmanship, advanced control and monitoring systems can contribute significantly to achieving these goals.

The use of advanced systems for supervisory control and monitoring of heat pumps is a powerful tool for improving the performance and reliability of the plants. In recent years the trend towards using personal computers (PCs) has resulted in a number of industrial automation systems based on Microsoft Windows“ software. When PCs and Windows were introduced in industrial automation systems in the late 1980s, the market was hesitant. However, Windows is now universally accepted and has become a standard for industrial automation workstations. Standard PC equipment is also accepted in many industrial environments. The equipment is relatively inexpensive and, if it breaks down, new equipment and spare parts are generally available. Waterproof keyboards and mouse units allow standard PCs to be upgraded for rougher environments, and special PC equipment is also available for industrial environments.

PC control systems

The PC systems include a graphical man-machine interface (MMI) to generate applications for industrial automation. They enable the user to create an operator interface and to perform data acquisition. It also enables monitoring and control applications for the heat pump plant. Because these systems are general industrial MMI systems, they have the flexibility and tools necessary to meet the requirements for a wide range of heat pump installations.

The PC system forms the supervisory control and monitoring system of the heat pump plant, together with an embedded control system or a control system based on a Programmable Logic System (PLS). The embedded control system or the PLS system performs the basic operations and control functions of the heat pump plant. The PC-based MMI system performs the overall optimisation of the control parameters of the plant, and provides relevant graphical information to the operating staff. A schematic representation is given in **Figure 1**.

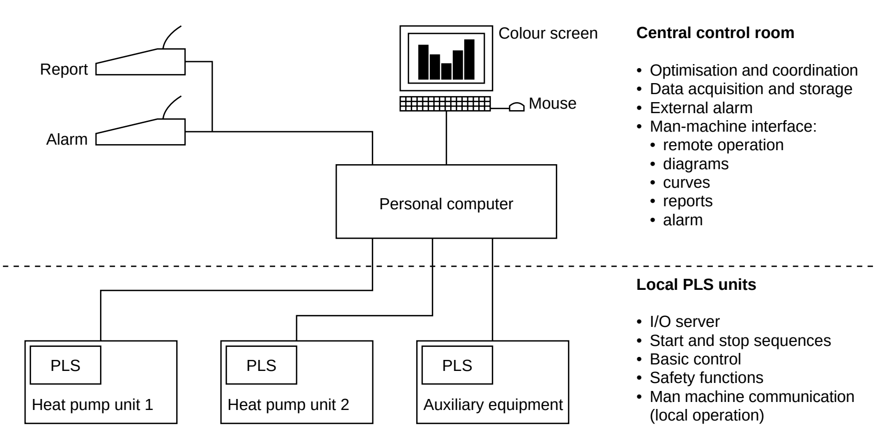
Most of these PC control systems provide the user with a very powerful tool for defining algorithms for overall control of the plant, for example, for coordinating the control system for the heat pump units and the auxiliary boiler in bivalent heat pump plants. The PC control systems also support common use of the Dynamic Data Exchange (DDE) protocol in Windows. This allows the user to include more extensive algorithms for overall control and tools for calculation, for example ‘Fuzzy Logic’ calculations, in the total system.

User-friendly

Today’s generation of PC systems are user-friendly and easy to configure. Programming skills are not required and the development time is short. This gives better results as the development can be carried out by operating staff or others who are familiar with the design and operation of the heat pump plant. Powerful drawing tools make it easy to produce a graphical illustration of the plant.

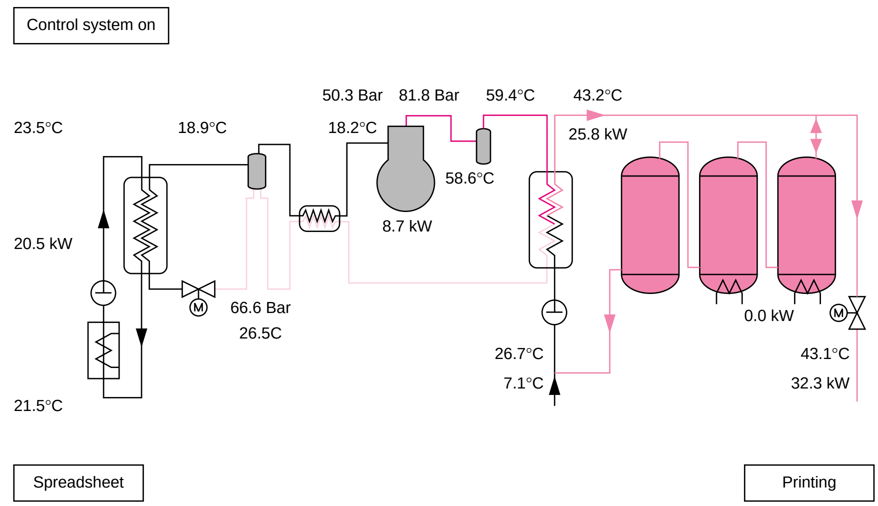
An example of an overview diagram is shown in **Figure 2**. The diagram shows a 50 kW prototype heat pump water heater with CO_2 as the working fluid located at the SINTEF Energy Laboratory. Design, operation and performance of the plant will be described in detail in a later issue of the

Figure 1: Central PC-based MMI system connected to local PLS units



Heat Pump Centre Newsletter. The diagram only shows links to the main analogue values. It also includes a number of hidden push buttons to activate other diagrams in the system. For example, when the operator moves the mouse pointer to such an area and selects it by clicking the mouse button, a diagram as shown in **Figure 3** is displayed on the monitor.

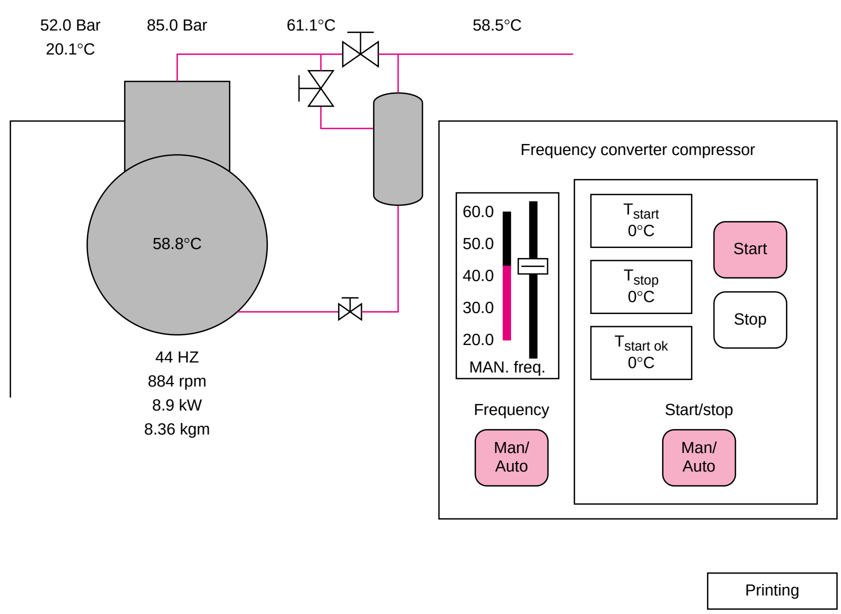
This diagram provides more detailed information on the operating conditions of the compressor. It also contains a control panel for the compressor, to start/stop/change operating conditions, and set points for the controllers. An action push button to close the information screen is displayed in the top left-hand corner of the screen. When this is activated the overview diagram reappears.



▲ *Figure 2: Overview diagram of the CO_2 heat pump water heater.*

Other facilities

Another common facility of modern PC control systems is real-time and historical 'trending' of the measurements from the plant. This is a very powerful tool for monitoring or analysing plant operation. The support of the DDE protocol in Windows is also very convenient for the user when a reporting function needs to be included in the system. A report form can be generated by a standard Windows tool (for example Word for Windows), and real-time or historical measurement values or status information can be imported directly into this form using the DDE function.



▲ *Figure 3: Detailed diagram of the CO_2 compressor.*

Conclusion

Using PC systems to control heat pump installations can contribute significantly to the performance of these installations. The systems are easy to operate, and provide various opportunities for monitoring, analysing and controlling the process. The conclusion is that these control systems are an important tool in creating a better acceptance of heat pumps.

® Microsoft and Windows are registered trademarks of Microsoft Corporation.

Author:
Mr Roar Bang
SINTEF Energy
7034 Trondheim, Norway
Fax: +47-73-593950
Email: rbang@online.no

Systems approach with heat pumps in the Netherlands

Onno Kleefkens, The Netherlands

The systems approach with heat pumps in the Netherlands has been stimulated by a new government plan for the reduction of CO_2 emissions. Many of the projects for this plan deal with heat pumps, in combination with other technologies, such as combined heat and power (CHP) and an organic Rankine cycle (ORC), to combine the effects of technologies for optimal energy conservation.

Plan for CO_2 reduction

From the results of past efforts to reduce CO_2 emissions, taking into account the fast 3% growth of the economy, it has been predicted that by the year 2000 emissions of CO_2 will still be increasing. At the end of 1996 the Dutch government therefore decided to allocate a budget of NLG 750 million (USD 400 million) for projects which can provide additional energy conservation. Tenders were requested for projects meeting the criteria of innovation, cost effectiveness, commitment of market parties and local governments, and synergy with other government goals.

The projects were tendered in three categories :

- projects covering increased efficiency of the infrastructure for built-up areas, industrial areas and areas with greenhouses;
- projects aimed at the development of clean and renewable energy;
- projects aimed at breakthrough technologies.

By February 1997 at least 50 projects had been proposed in the first category alone, so the tenders can be regarded as successful. Heat pumps appear in many of the proposed projects.

Combination with CHP

The main factors in making a decision on the use of energy technology often include the efficiencies of the stand-alone technologies. However, in dealing with newly built areas for domestic and commercial buildings, greenhouses and industry it is important to find an optimal solution for the total energy demand by combining different beneficial technologies.

Cogeneration is a popular technology in the Netherlands. In a CHP-unit heat and electricity are generated at a ratio of 1.2:1 to 1:1. The demand for heating and electricity has different ratios for different users. For the Dutch industry the average ratio is 4:1, for greenhouses 4.5:1 and for domestic users 5:1. Because the demand ratio differs so much from the generating ratio, either a large part of the heat demand must be covered by conventional boilers or, if the CHP is designed to cover the total heat demand, a surplus of electricity is be generated. This surplus then has to be exported to the grid, where it can be used in a location that has a conventional heating system. The energy conservation of 12-15% which could be reached with CHP is thus reduced to a meagre 6-9%.

The imbalance of the energy production can be brought into equilibrium by using electrically-driven heat pumps. The external demand for heat is reduced and turned into an increased demand for electricity, moving the energy demand towards a ratio of 1:1. The savings on primary energy and thus the reduction of CO_2 emissions in this combination can be up to 45%.

Residential buildings

The first step towards achieving a high energy efficiency is to optimise the system design. The development of an integral system design for residential buildings has been stimulated by the Dutch Heat Pump Systems Competition, which was started last year. The competition focuses primarily on the design of heating concepts with electric heat pumps for three types of newly built houses, and cooperation between manufacturers, consultants and installers is required. By the end of 1996, 27 different concepts had been proposed by 12 different consortia. At the moment 11 systems are still in the race.

The second step is the integration of systems for newly built areas into a larger infrastructure. At least four major energy-distribution companies have proposed projects of up to 17,000 houses, to be heated by heat pumps or a combination of heat pumps and cogeneration. A typical project is based on the assumption that per house 1000-1200 m^3 of natural gas is used for space heating and hot water. One example is a project of about 3,600 houses with a heat demand of 137 TJ. This heat is produced by CHP (33 TJ), a central heat pump (100 TJ) and conventional gas boiler backup (4 TJ). When a seasonal performance factor of 3 is assumed for the heat pump, an estimated energy saving of over 40% can be achieved (2,800 tons CO_2 emissions reduction per year) compared to ‘conventional’ systems (high efficiency boiler at 90% efficiency and power generation at 54%).

As the surplus electricity from cogeneration is taken up by the grid, one distribution company developed the idea of system-integration even further. By planning cogeneration at one

▼ *Table 1: Energy comparison for CHP and conventional situation.*

	Combined	Conventional
Boiler (greenhouses)	0.30 PJ	1.51 PJ
CHP	3.57 PJ	—
Central power	—	4.03 PJ
Boilers (surrounding)	5.82 PJ	5.82 PJ
Total energy use	**9.69 PJ**	**11.36 PJ**
Savings	1.67 PJ = 15%	

▼ *Table 2: Energy comparison for CHP and heat pump combination and conventional situation.*

	Conventional	HP/CHP
Boiler (greenhouses)	1.51 PJ	0.30 PJ
CHP		3.57 PJ
Central power	4.03 PJ	—
Boilers (surrounding)	2.49 PJ	—
Total energy use	**8.03 PJ**	**3.87 PJ**
Savings		4.16 PJ = 52%

location and using the extra electricity for electric heat pumps in a new set of buildings miles away, a first step towards a planning for a nationwide infrastructure is made.

Greenhouses

The drive towards energy saving in greenhouses through efficient infra-structures has resulted in large co-generation projects in the Westland area of the Netherlands. The energy saved by these projects compared to traditional heating with a gas boiler could reach 12-15%. Based on these experiences projects have been proposed that use heat pumps as a solution for flexibility, increased energy conservation and reduction of investment risks. The latter is of particular importance where the growth of an agricultural area will take some years to develop, and large-scale cogeneration would be a large investment risk. However the figures for possible savings with the combination of heat pumps and cogeneration are impressive.

The energy use in a 100 ha area of greenhouses is calculated for central cogeneration, conventional energy generation with high efficiency boilers and 40% efficient power generation. The heat/power-ratio in a greenhouse is assumed to be 4.5:1. It is further assumed that the 'exported' electricity is used in a location heated with conventional high efficiency boilers, where the heat/ power-ratio is 4:1. With CHP, 35% of the primary energy input is used for heat production and about 45% for electricity production. The yearly use of heat in the greenhouses is 1.36 PJ, electricity use 0.3 PJ and the energy use for generating CO_2 is 0.16 PJ. With CHP generating 80% of the heat, 1.61 PJ of electricity is produced. The total energy savings amount to 15%, as shown in **Table 1**.

If electricity from cogeneration is used to power heat pumps, the energy savings are much higher. The same assumptions are made for the heat/ power-ratio, while the COPs of the heat pumps are rated as low as 3. Of the electricity which is exported (1.3 PJ) about 0.74 PJ is used for driving the heat pumps generating 2.24 PJ of heat. If a conventional method is used this would cost 2.5 PJ of primary energy. Total energy savings amount to 52% (see **Table 2**).

The proposed project is based on the philosophy that at the start of the project only a few greenhouses will be operational. The heat pumps will be connected through a heat distribution system, thus the greenhouses have to be built in groups. Electrically-driven heat pumps will be implemented, using electricity from the national grid during the first phase of the project. In the second phase, when a larger body of efficient electricity users is created, a cogeneration plant can be built optimising the whole energy balance for the greenhouse area. This cogeneration plant can be driven with biomass (from the greenhouses) to generate CO_2 (for the greenhouses).

Future energy use

The system design for new residential buildings is a very important part of an integrated vision of future energy use. These ideas can be taken a step further into the development of low energy houses with low temperature heating which must be built at acceptable costs to be able to cope with future demands. However, the internal heat balance for these types of houses is completely different and needs further development in which international collaboration is necessary. With the ongoing procedures for restructuring large greenhouse areas, initiatives with heat pumps and cogeneration can show the way towards further optimisation of the infra-structures.

Author:
Mr Onno Kleefkens
Dutch National Team and Netherlands Agency for Energy and the Environment (Novem)
Fax: +31-30-2316491

Heat pumps and ecological balances

Fabrice Rognon, Switzerland

In Switzerland the use of heat pumps as an effective energy technology within the policy for CO_2 emissions reduction has recently been brought into question. Consequently, the funding of technology developments by the Swiss government's Energy 2000 Action Programme has also been questioned. This article shows that heat pumps are currently playing a major role in the Swiss energy situation, and that the technology can contribute significantly to CO_2 emissions reduction.

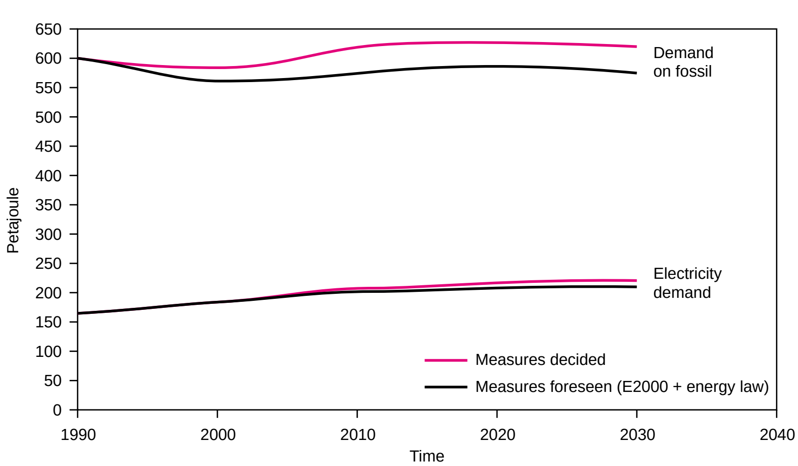
With the Energy 2000 Programme the Swiss government hopes to achieve a more sustainable and less polluting way of establishing the country's energy supply. In **Figure 1** the perspectives on the future energy demand in Switzerland are presented. It is clear that heat pumps can only be acceptable within the programme if they genuinely contribute to its objectives. At the outset of the Energy 2000 support programme, the question was posed: 'what is the best way of providing the driving energy for heat pumps, and what effect would this have on the energy and ecological balances?'

HP driving energy

For thermally-driven heat pumps it is evident that their contribution to CO_2 emissions reduction depends only on their primary energy ratio (PER), which normally has a value of approximately 1.5. For electrically-driven heat pumps, however, the entire chain of events including the 'history' of the electricity source should be taken into account. To indicate the possible benefits, the original situation should be compared with the alternative of using a heat pump.

In retrofit situations a large number of electric resistance heaters can be replaced by heat pumps or other regenerative energy sources. Accordingly, 50-70% of the electricity currently used for resistance heaters can be used for powering heat pumps. The heating capacity of the 230,000 electric resistance heaters currently installed amounts to 6% of the total electricity production, or 11% for the six winter months. Replacing electric resistance heaters is beneficial to the owners, who sometimes replace these heaters themselves [1]. Government involvement in this area has thus been confined to initiating a new product to replace the electric room heater.

▼ *Figure 1: Perspectives on energy demand in Switzerland.*



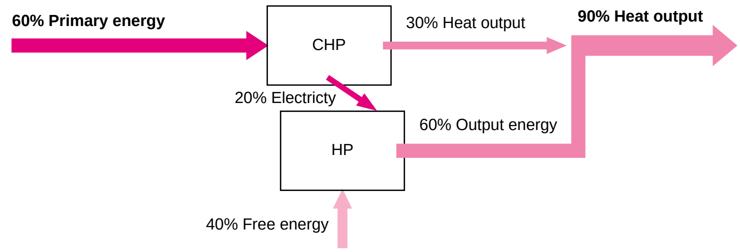
Statistics showing the number of units replaced are currently being prepared.

Further heat pump driving power can be gained from increased electricity production from waste incineration plants (WIP) and from combined heat and power plants (CHP), which as a rule are powered by fossil fuels. The policies concerning the production of electricity from WIP and CHP are included as complementary measures set out by the Energy 2000 Renewables Energy Department. Additional energy production from these generators should exceed the additional electricity consumption caused by the increased use of heat pumps.

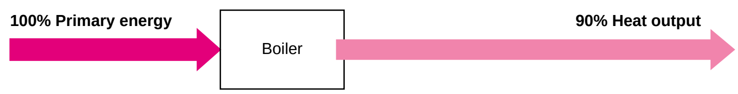
Current energy balance

Electricity production figures for WIP and CHP, as well as figures on the electricity consumption of electric heat pumps, have been included in the Annual Report of the Energy 2000 Renewables Energy Department, which was issued in September 1996. The figures show that from 1990 onwards, an additional 164 GWh per year was required for new heat pumps. However, in the same period an additional 96 GWh per year was generated by WIP and 336 GWh per year by CHP plants.

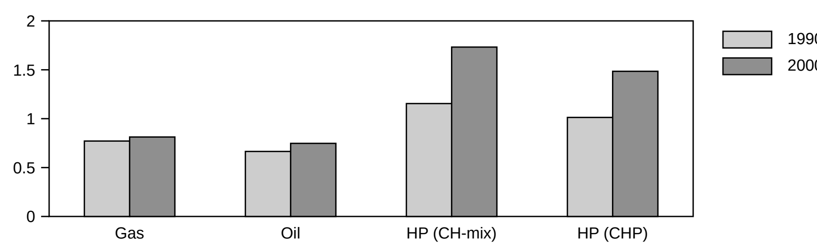
Additional power production from these two "sources" is more than 2.5 times the additional electricity consumption of heat pumps. The increase from CHP alone covers the supplementary needs of heat pumps. In 1995, WIP and CHP plants generated a total of 753 GWh more electricity than consumed by all Swiss heat pumps together.



▲ *Figure 2: Energy situation for a combination of CHP and a heat pump.*



▲ *Figure 3: Energy situation for a conventional heating system.*



▲ *Figure 4: Heat output using primary energy from non-renewable sources.*

The additional electricity requirements for new heat pumps therefore present no difficulties. Electricity from waste incineration is available pollution-free, as long as waste incineration is not fully exploited for energy production.

Conventional heating plants

Although the current situation is favourable for an increased use of heat pumps, the energy balance for a less favourable situation should also be compared to the energy balance of a conventional heating plant. In this case, it is assumed that the potential for replacing electric resistance heating and generating electricity by WIP has been fully exploited, so that electric power for heat pumps must be generated from fossil-fuelled CHP. This situation is shown in **Figure 2**.

When this situation is compared with **Figure 3**, representing the energy situation for a conventional heating plant, it is clear that conventional heating plants require about two thirds more fossil fuel to produce the same heat output.

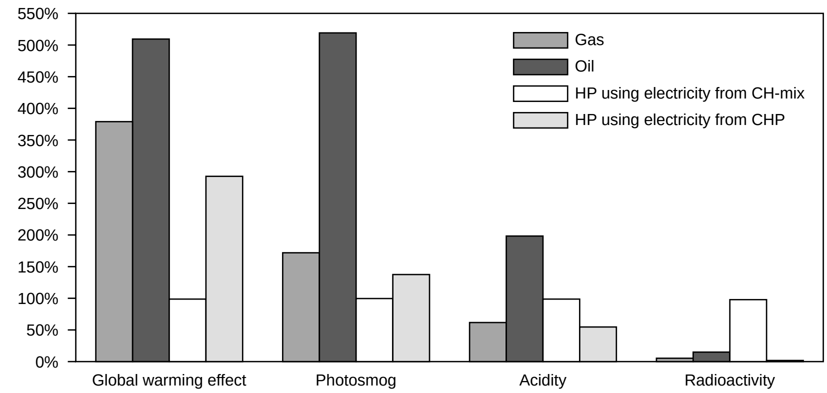
In addition to analysing energy consumption, another variable that can be considered is the heat output as a fraction of non-renewable primary energy used (including all production phases: extraction of raw materials, materials production and plant manufacture, as well as plant operation and disposal). The comparison includes the heat produced by burning oil and gas and by using heat pumps. For heat pumps the history of the electricity used as driving energy is taken into account. Within the Energy 2000 programme, three modes of electricity production relevant to the energy and ecology balance are discussed: CH-Mix, WIP and CHP. The CH-Mix takes into account the amount of electricity imported from other European countries during the winter.

For 1990 values, a seasonal performance factor (SPF) of 3.0 is assumed, together with a global warming potential (GWP) of the refrigerant equivalent to 1700 and a 30% electrical efficiency of CHP plants. The values shown for the year 2000 are based on an SPF which is 50% higher - this has already been achieved in pilot plants. Other assumptions are that 50% of the heat pumps use refrigerants that do not contribute to global warming, that electricity generation efficiency is 14% higher in 2000, and that oil and gas heating is 10% more efficient than today. The results of the comparison are shown graphically in **Figure 4**.

In energy terms, the combination of CHP with a heat pump is equivalent to a fossil-fuelled heat pump. The only difference is that the heat pump is not coupled mechanically to the combustion engine, but is driven by electricity from the grid. This allows increased flexibility and ensures greater reliability.

Ecological balance

To compare the different options ecologically, the Life-Cycle-Analysis method is used. This method uses a so-called ‘ecology inventory’ [2] including all production phases. In a second step it evaluates the individual effects of relevant pollutants on the environment as well as their combined effect. The



▲ *Figure 5: Environmental effects of heat pumps compared with those of gas and oil heaters.*

results of the comparison for the situation in 1990, (i.e. electricity production via a 162 kW CHP installation driving 10 kW heat pumps using geothermal wells with an SPF of 3.0), are based on recent studies [3,4,5 and 6], and are given in **Figure 5**.

They show that the combination of CHP plants and heat pumps is considerably better than oil or gas heating with regard to global warming and radioactivity. It is also slightly better than gas, and far better than oil, when considering photosmog (ozone on ground level) and acidity.

Furthermore, the combination of CHP and heat pumps offers a large short-term development potential. In particular, the global warming effect is expected to decline due to the increased use of natural refrigerants, which have a considerably smaller global warming potential than those currently being used.

Ecological advantages

As shown in the previous paragraphs, the use of heat pumps has many advantages.

Firstly, heat pump plants mainly utilise renewable energy. Efficiency is steadily increasing thanks to concerted efforts in research and development, pilot and demonstration plants, and the support of the Swiss Heat Pump Test and Training Centre, as well as the Swiss Association for the Promotion of Heat Pumps. In other words, the proportion of renewable energy is steadily increasing. It is also clear that the electricity demand for heat pumps is being covered by the increased electricity generation from CHP and WIP.

Secondly, even on the basis of the less favourable situation of combined CHP and electrical heat pumps under present-day conditions, 110-170% of useful energy output is produced from 100% primary energy. Research and initial pilot plants indicate an improvement potential of 180-250% of useful energy produced. The amount in excess of 100% is the net utilised renewable energy.

Finally, an important advantage of heat pumps is that the environmental effects are already more favourable than those of gas or oil heating. The achievable values in the short term - i.e. by the year 2000 - will increase this difference. Heat pumps, together with modern combined heat and power plants, have a large potential of reducing CO_2 emissions and primary energy needs. The strategy to produce the electricity required will allow heat pumps to contribute significantly to the success of the national Energy 2000 Programme.

[1] Strebel / Seidinger: Market analysis on single-room heat pumps in Switzerland, Draft National Report within Annex 23 work-group, BEW, 1996.

[2] Frischknecht et al: Ökoinventare für Energiesysteme, ETH, Zurich, 1996.

[3] R. Frischknecht: Oekologische Bewertung von Systemen der solaren Wassererwärmung sowie der Wärme-Kraft-Kopplung, ETH, Zürich, 1994

[4] T. Weibel: Vergleichende Umweltrelevanz des Einsatzes alternativer Kältemittel, Forschungsprojekt UAW, BEW, 1996

[5] Prof. P. Suter: Umweltbilanz der BHKW-WP-Technologie, Tagungsband zur 3. UAW-Tagung vom 7. Mai 1996 über Neue Technologien für Kleinwärmepumpe und Klein-BHKW, BEW, 1996

[6] Prof. P. Suter: Stellungnahme zu M. May: Graue Energie und Umweltbelastungen von Heizsystemen, Thal/ETH Zürich, 1996

Swiss Federal Office of Energy (SFOE)
Ambient heat and CHP
Mr F. Rognon
CH-3003 Bern, Switzerland.
Tel: +41-31-3224756
Fax: +41-31-3824403

Dutch study heat pump promotion abroad

Hanneke van de Ven, IEA Heat Pump Centre

The Netherlands Agency for Energy and the Environment (Novem) recently organised a study tour for representatives from Dutch electricity/gas utilities and policy makers, to bring heat pumps to their attention. Four projects in Germany and Switzerland were visited so that the participants could become acquainted with the technology and see for themselves the opportunities for heat pump installation and application. The emphasis during this tour was on electrical heat pumps.

During the 1970s many heat pumps were installed in Germany and Switzerland in response to the oil crisis. In the 1990s renewed interest in heat pumps has been observed, this time triggered by the need for CO_2 emissions reduction.

Constraints

The three most important constraints for increased use of heat pumps are initial cost, lack of awareness and knowledge among architects and installers, and the relatively low temperatures that can be achieved using heat pumps. This last aspect lowers the application potential in retrofit situations.

Examples

An installation in Kochel am See, near Munich, was visited, where three multi-family houses are equipped with six ground-coupled electric heat pumps for monovalent space heating and tap water heating. From 21 boreholes, a closed brine loop transfers the heat to the heat pumps (capacity 210 kW each), which heat the water in the floor heating system to 30-50ºC. In evaluating the project, it was emphasised that it is essential to inform users prior to commissioning. Control problems arose because the users regularly setting turned the thermostat to control the room temperature. However, the system performs best under stable conditions that guarantee adequate running time of the heat pump.

A second installation concerned a project in Königsbrunn: combined heating of approximately 800 houses and a complex of thermal baths and swimming pools. Although the installation operates without major technical problems it is not economically successful now, as the economic feasibility of the project was assessed based on rising energy prices of the mid-1970s.

In Waghäusel a third project was visited. Here concrete construction parts have been used as heat absorbers (similar to the installations described in Newsletter Vol.15/1, page 28). The **photo** below shows the concrete heat absorbers at the roof of the garages. The Dutch visitors particularly admired the way in which the equipment had been integrated with the environment.

The fourth project in Riehen has already been described in Newsletter Vol.14/4, page 27. The Swiss heat pump test centre in Töss was also visited.

Stimulation measures

In Germany the use of electrical heat pumps is stimulated by the federal and some state governments, and by some electricity suppliers. Government subsidy to reduce the initial investment costs can be as high as DM 4,000 (USD 2,400), depending on the capacity. In many cases an additional subsidy is available from the electricity company. To receive the government grant a minimum seasonal performance factor (SPF) is required; for example, an SPF of 3.2 for air-to-water heat pumps. Another financial instrument is an electricity tariff reduction of up to 50%, usually offered in exchange for disconnection of the installation during peak hours. In most cases, three shut-off periods of two hours are allowed per day. End-users do not experience less comfort, as long as the shut-off periods are separated by operational periods of at least two hours.

▲ *Photo: Garages with concrete heat absorbers on the roof in a project in Waghäusel.*

Several other promotional activities have been set up in Germany and Switzerland, varying from training courses for installers and architects, to advertisements and invitations to visit demonstration sites.

The Dutch situation

Although activities in the heat pump market have increased considerably in the Netherlands over the past few years, the situation is not yet as favourable as in Germany and Switzerland. This study tour highlighted the fact that a realistic financial support programme is essential. Collaboration with foreign institutes is also advantageous. Finally, a programme of promotional activities to introduce low-temperature heating systems to a wide audience can accelerate the implementation of heat pumps.

Ms Hanneke van de Ven
IEA Heat Pump Centre

Proceedings of the 1996 Refrigeration Conference at Purdue
Available from: IIR, 177 Boulevard Malesherbes, F-75017 Paris, France. Fax: +33-1-47631798. Price; USD 80, 547 pages, 1996.
These proceedings contain 83 papers. Subjects covered include: R-22 substitution, R-502 R-503 substitution, capillary tubes, industrial aspects of the use of zeotropic refrigerants and alternative refrigerating techniques.

Förderprogramme und Unterstützungsmassnahmen zum Wärmepumpen einsatz
Available from: Fachinformationszentrum Karlsruhe, Bibliographischer Service, 76344 Eggenstein-Leopoldshafen, Fax: +49-7247-808 135. Price: DM15 plus postage, 1997. German language.
This brochure gives an overview of the German stimulation programmes and measures for the use of heat pumps, provided by the federal and state governments and utilities. It is an updated, comprehensive version of a brochure that was republished by the Informationszentrum Wärmepumpen und Kältetechnik (IZW).

Numerische Untersuchung einer periodisch arbeitenden Adsorptionswärmepumpe
Available from: Shaker Verlag Gmbh, PO Box 1290, D-52013, Aachen, Germany. Fax: +49-2407-95969. Price: DM 79, 96 pages, 1997. ISBN 3-8265-2042-4. German language.
This report presents the results of numerical research on a cyclic Ad-Sorption heat pump. The research concentrated on improvement of the heat transfer in a zeolite MgA-water heat pump.

Investigation of Flushing and Clean-Out Methods for Refrigeration Equipment to Ensure System Compatibility
Authors: John J. Byrne, et al. Available from: ARTI Database c/o James M. Calm, 10887 Woodleaf Lane, Great Falls, VA 22066, USA (reference DOE/CE/23810-73).
This is the final report and evaluates methods for removing contaminants and mineral oil from refrigeration systems when retrofitting CFC-12 to HFC-134a. Summarises results from laboratory and field tests of these mineral oil removal techniques.

Study of Lubricant Circulation in HVAC Systems
Authors: Biancardi, Michels, Sienel and Pandy. October 1996. Available from: ARTI Database c/o James M. Calm, 10887 Woodleaf Lane, Great Falls, VA 22066, USA (reference RDB 6C04 and 6C05).
The report summarises the findings of the evaluation of lubricant circulation characteristics of R-407C/polyolester lubricants, R-407C/ mineral oils and HCFC-22/mineral oil in a representative residential heat pump system.

INTERNET SITE

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

http://www.heatpumpcentre.org

Ozone Protection in the United States
Available from: WRI Publications, PO Box 4852, Hampden Station, Baltimore, MD 21211, USA. Price: USD 15, 120 pages, November 1996.
This report is published by the World Resources Institute, and is an expansion of work reported in January 1996 in „Marking a Milestone in Ozone Protection: Learning from the CFC Phase-out“. It contains an overview and several case-studies, as well as papers written by various authors.

Energy in Buildings
Software program available from: Skarland Press AS. Fax: +47-22-693650.
This program is a Windows-based program for energy and effect analysis of buildings. The program calculates, among others, the heat balance for a building with variable losses and gains, energy requirements for cooling and total energy costs. It can also simulate most imaginable energy efficiency measures for a building, and calculate their profitability.

Thermal Energy Storage
Available from ARI-TES, 4301 North Fairfax Drive, Suite 425, Arlington, VA 22203, USA. Price: postage.
This ARI-brochure explains the principle of thermal storage and the advantages of this technology for air conditioner and heat pumps, through graphics and useful statistics.

AVAILABLE FROM THE HPC

Proceedings of the Workshop on

Building HVAC Equipment Regulations and Standards

held in Madrid on 27 February 1997

Order your copy with the RESPONSE CARD
Order No. HPC-WR-18
Price NLG 120
or NLG 60 in HPC member countries
(see back cover)

Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

Industrial Heat Pump Screening Program
Software program, April 1997
Order No. HPP-AN21-3
NLG 100 or free on ordering HPP-AN21-1.
NLG 50 in HPC member countries (see back cover) and in Ca, Fr, Ja, Nl, No, Se, UK and USA

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

Comparisons of Equations of State with Experimental Data for R32 and R125
Annex 18 Report, March '97
Order No. HPP-AN18-4
NLG 80, or NLG 40 in HPC member countries (see back cover) and in Canada, Denmark, Sweden and the UK.

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

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

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

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

For a list of all publications and events, visit the HPC Internet Site at http://www.heatpumpcentre.org

Modeling and Design of Vapor Compression Systems with an Emphasis on Refrigerant Mixtures
Short course at Purdue University
21-23 July 1997 /West Lafayette, Indiana, USA
Deadline for registration: 7 July 1997
Contact: Cynthia Quillen, Herrick Laboratories, Purdue University
Fax: +1-765-4940787
E-mail: quillen@ecn.purdue.edu

Mathematical Modeling for the Computer Simulation of Positive Displacement Compressors
Short course at Purdue University
23-25 July 1997 / West Lafayette, Indiana, USA
Deadline for registration: 9 July 1997
Contact: Cynthia Quillen, Herrick Laboratories, Purdue University
Fax: +1-765-4940787
E-mail: quillen@ecn.purdue.edu

Heat Pumps in Cold Climates
Third International Conference
11-12 Aug '97 / Wolfville, Canada
Contact: Mr Doug Cane, Caneta Research, Mississauga. Fax: +1-905-5423160
E-mail: 104666,736@compuserve.com

Clima 2000
30 Aug - 2 Sep '97 / Brussels, Belgium
Contact: SRBII, Brussels.
Fax: +32-2-5117597

Heat Pipes, Heat Pumps, Refrigerators
8-12 Sep '97 / Minsk, Belarus
Contact: Prof. Leonard L. Vasiliev, Luikov Heat & Mass Transfer Institute, Minsk.
Fax: +357-172-322513,
E-mail: allusr@avtlab.itmo.by

Air-Conditioning in High-Rise Buildings
9-12 Sep '97 / Shanghai, China
Contact: Shanghai Society of Refrigeration. Fax: +86-21-63277108

Ventilation and Cooling
IEA AIVC 18th Annual Conference
23-26 Sep '97 / Greece
Contact: Ms Rhona Vickers, Air Infiltration and Ventilation Centre
Fax: +44-1203-692050
E-mail: airvent@aivc.org

Refrigerants for the 21st Century
Sponsored by ASHRAE & NIST
6-7 Oct '97 / Gaithersburg, MD, USA
Contact: Wm. W. Seaton at ASHRAE
Fax: +1-404-3215478
E-mail: bseaton@ashrae.org

Heat Transfer in Natural Refrigerants
6-7 Nov '97 / Maryland, USA
Contact: Dr Radermacher, Center for Environmental Energy Engineering, University of Maryland.
Fax:+1-301-4052025,
E-mail:rader@eng.umd.edu

3. Symposium Erdgekoppelte Wärmepumpen
20-22 Nov '97 / Giessen, Germany
Contact: Dr. B. Sanner
Fax: +49-641-9936109

Natural Working Fluids '98
IIR Gustav Lorentzen Conference
2-5 June 1998 / Oslo, Norway
Deadline for abstracts: 1 Sep '97
Contact: Turid Slotnaes, NWF '98,
Fax:+47-2206-7350

IEA HEAT PUMP PROGRAMME EVENTS

IIR - Linz 97 Heat Pump Systems, Energy Efficiency and Global Warming
Sponsored by IEA Heat Pump Centre.
28 Sep - 1 Oct '97 / Linz, Austria
Deadline for abstracts: 26 May 1997
Contact: Mrs. Ulrike Gerhard, TU Graz, Austria. Fax: +43-316-8737305

2nd Annex 22 Workshop on Compression Systems with Natural Working Fluids
2-3 October '97 / Gatlinburg, USA
Contact: Mr Jørn Stene, SINTEF Energy, Trondheim (see back cover).

Next Issue

Residential Heat Pumps
Volume 15 - No.3/1997