IEA Heat Pump CENTRE
NEWSLETTER
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Heat pumps for retrofitting space heating systems

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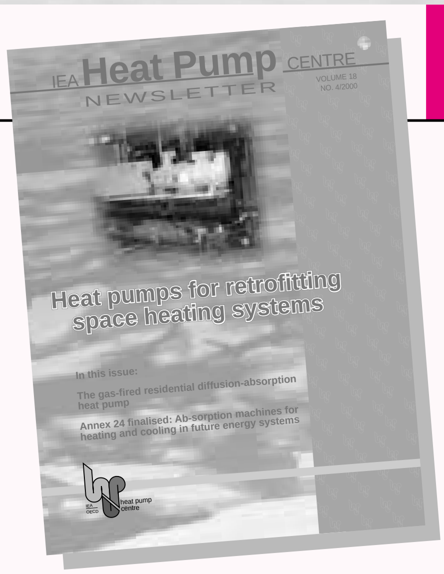
The gas-fired residential diffusion-absorption heat pump

Annex 24 finalised: Ab-sorption machines for heating and cooling in future energy systems

IEA OECD heat pump centre



Front cover: Retrofit heat pump for heating and cooling of an industrial building, Molde, Norway (to be included in HPC-AR9).

In this issue

Heat pumps for retrofitting space heating systems

In many countries, heat pumps are less popular for retrofitting heating systems than for application in new buildings and new industrial plants. In this Newsletter, the focus is on how to overcome technical and market barriers for retrofitting heating systems with heat pumps. Furthermore, the Newsletter focuses on Annex 24 “Ab-sorption machines for heating and cooling in future energy systems” which has just been finalised.

TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

COLOPHON

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Heat pumps for the retrofit market

For reasons of energy saving and emission reduction, Switzerland has promoted heat pump heating since 1937. As a result of coordination with manufacturers, installers and customers, 35% of the heating systems installed in new single-family houses today are heat pumps. However, in the much larger retrofit market this number does not even reach 5%.

This indicates that there is a very large market potential in the retrofit market. This is the case in all of Western Europe. Every new domestic boiler that is installed to replace an old one represents a missed opportunity. In Western Europe, a million times a year, higher CO_2 emissions are accepted than would be the case if state of the art technology were used. If only 10% of all new gas or oil-fired boilers were replaced by heat pumps, additional primary energy savings of more than 1,000,000,000 kWh could be realised every year!

What are the obstacles? The retrofit market is characterised by high supply temperatures and low thermal inertia of the existing heat distribution systems. In comparison to a conventional heat pump, a successful retrofit heat pump must have:

- *a lower drop of heating capacity and a higher performance factor at higher temperature lifts;*
- *a lower compressor outlet temperature at high temperature lifts;*
- *an intelligent control system which takes advantage of the thermal inertia of the building and of the internal heat gains.*

The development of a retrofit heat pump that meets these requirements at a competitive price is actually the main priority of the Swiss Federal Office of Energy's research programme on the utilisation of ambient heat. In order to succeed, compressor manufacturers, engineers in thermodynamics and process control, as well as manufacturers of heat pumps face similar challenges. And - last but not least - the customers themselves have to be convinced of the advantages of retrofitting their homes with heat pumps. A lot has still to be done. Let us tackle the retrofit market together!

Dr Martin Zogg
Head of the Swiss Federal Research Programme on Ambient Heat, Waste Heat and Refrigeration. Swiss alternate delegate in the Executive Committee of the IEA Heat Pump Programme.

NON-TOPICAL ARTICLES

Geothermal heat pumps in focus in the United States

USA - The Geothermal Heat Pump (GHP) technology-specific arm of the US Department of Energy's Federal Energy Management Program (FEMP) helps US federal facilities take advantage of ground-source heat pump technologies. The programme's Internet site offers a selection of information on ground-source heat pumps. FEMP aims to reduce the use and cost of energy in the Federal sector by advancing energy efficiency, water conservation and the use of solar and other renewable energy sources.

A premise of FEMP's GHP program is that a significant number of large federal "best practice" GHP projects must be completed to prove techniques and provide data for tools and guides. National GHP Super Energy Savings Performance Contracts (ESPCs) were included as a component of FEMP's programme to improve the GHP delivery infrastructure. In 1999, the competitive procurement resulted in awards of national indefinite-delivery, indefinite quantity ESPCs to five energy service companies that had demonstrated expertise in the application of GHP systems. Now every federal site has access to at least five quality sources for the family of GHP systems. The GHP Super ESPC contracts are now amended for world-wide use by US federal agencies with facilities beyond the states and territories.

Electric utilities are also strong proponents of GHP systems and many are expected to offer federal agencies private financing and expertise to implement GHP projects through Utility Energy Services Contracts.

The goal of FEMP's geothermal heat pump technology-specific programme is to harness the purchasing power of the federal government to transition GHP systems from their current status as "proven but under-utilised" to a "mainstream energy-cost-saving measure" within the next four years. FEMP has established a GHP Core Team at Oak Ridge National Laboratory (ORNL) to work with data from federal and private-sector projects to address technical issues, prove techniques, and generalise results into GHP tools, guides, and training.

Recent GHP Core Team accomplishments include:

- evaluation of the Fort Polk, Louisiana, GHP project in which 4,000 residences were retrofitted with GHPs;
- an improved method of predicting energy savings from GHP retrofits;
- evaluation of commercially-available ground heat exchanger design software;
- an improved method of determining the thermal properties of soil/rock formations from in-situ tests (see page 26);
- evaluation of GHP-equipped training and educational facilities, based on actual data from schools in the district (see page 5);
- development of GHP guide specifications (see page 26).

Currently, the team is establishing a database of construction cost and annual maintenance costs associated with actual GHP projects. If you can provide data sets or would like more information on this project, please contact Patrick Hughes, at Oak Ridge National Laboraty, USA.

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A milestone in the qualifying contest Swiss Retrofit Heat Pump: decision on field-testing

Switzerland - During the summer of 2000, the four entries submitted for the qualifying contest to select a Swiss Retrofit Heat Pump (SRHP) were tested at the heat pump test centre in Töss, Switzerland. The tests included a detailed cost analysis. The "Swiss Retrofit Heat Pump" contest was introduced in Newsletter 17/2.

Of all the entries submitted, the one from the company KWT (cooling and heating technology), in Bern-Belp, Switzerland best satisfied the requirements of the Swiss Federal Office of Energy (SFOE) for a heat pump for the retrofit market. As the KWT solution represents a significant advance with regard to the use of heat pumps for the renovation of heating systems, the jury appointed by the SFOE opted unanimously to subject the KWT entry to field-testing in the heating season 2000/2001.

The winner of the SRHP contest will only be confirmed after the field tests have been successfully completed. The other participants in the contest also produced interesting solutions, showing their commitment to the common goal. The other entries could no longer be considered for field-testing.

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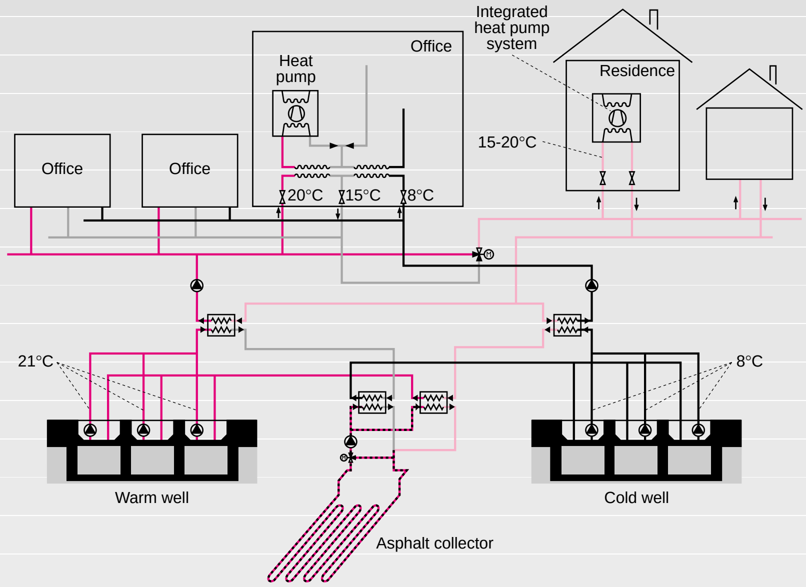
Airport runways to collect 21 MW heat

The Netherlands - Eindhoven Airport, the utility company Essent and Dubotechniek consulting engineers are planning a project in which 80,000 m^2 of asphalt in the airport extension will be used as a heat source for heat pumps in 2,600 new houses and 130,000 m^2 of new office space in the immediate vicinity of the airport. Cold water for space cooling will be supplied from an aquifer. The asphalt heat collectors and the warm and cold wells are planned for 2001. In 2002, the first houses and offices will be connected to the energy system. The system will save 95 TJ of primary energy, corresponding to the annual natural gas use of 3,750 houses.



▲ *Figure 1: The energy system.*

Figure 1 illustrates the system. Individual monovalent heat pumps heat the houses and offices. A low-temperature distribution system is planned in the buildings for high heat pump SPFs. Cooling is accomplished by means of cold water from the aquifer. Simultaneous delivery of heat and cold to the office buildings is made possible by a 3-pipe distribution system. The return water from the offices can be re-used as a heat source for the houses.

Figure 2 illustrates the installation of an asphalt collector. It shows the reinforcing matrix plus the piping through which water flows. In summer, the water collects heat and cools the asphalt. The heat is stored in the "warm well" of the underground thermal storage and used as a heat source for space heating in winter. In winter, the water heats the asphalt, thereby keeping it free of snow and ice. The cold is stored in the cold well and is used for space cooling in summer.

The collectors improve the characteristics of the asphalt - rut formation, frost damage and salt damage are prevented. As a result, it will also be possible to construct the airport extension platforms from asphalt instead of concrete.

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▲ *Figure 2: Installation of the asphalt collector.*

Ground-source heat pumps most cost-effective HVAC option in US schools study

USA - In 1998, the Oak Ridge National Laboratory began a study of 50 schools in the Lincoln Nebraska School District, including four identical recently built elementary schools served by ground-source heat pumps (GHPs). One objective of the study was to determine whether the decision to build the GHPs was the correct one, or whether some other technology would have been more cost-effective on a life cycle cost basis. Data analysed included utility billing data, site-monitored data from the energy management systems, planned and unplanned maintenance cost data from the school districts' own databases etc. The GHPs were found to be the most cost-effective HVAC option for the schools.

Some specific study results include:

- There were seven Lincoln schools (including the four GHP schools) built in the 1990s, with comparable delivery of ventilation air as well as comparable percentages of floor space cooled. On average, the GHP schools use 26% less source energy per m^2 per year than the non-GHP new schools.
- Twelve percent of the 49 non-GHP schools in the district use less energy per m^2 than the GHP schools. However, most of these cool less than 15% of their total floor area and deliver little ventilation air. The GHP schools cool 100% of their floor area and meet the ASHRAE 62-89 ventilation standard.
- The four schools heated and cooled with vertical-bore GHPs had the lowest average unplanned maintenance costs per m^2. It should be noted, however, that the four GHP systems studied are among the newest in the district (3 years on average). Preventive maintenance costs were lowest for schools with air-cooled chiller/gas-fired hot water boiler systems, followed by GHP schools. GHP systems had the lowest total maintenance costs per m^2 of *cooled* floor area.

The report "Geothermal Heat Pumps in K-12 Schools" can be downloaded free-of-charge from http://www.eren.doe.gov/femp/financing/ghpresources.html.

More information: John Shonder
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Address: see back cover

Cold climates conference addresses hot issues

Canada - The 4th International Conference on Heat Pumps in Cold Climates was held 17-18 August 2000 in Aylmer, Quebec, Canada. Conference delegates chose between technical and marketing/application streams with a wide range of topics addressing the unique technical and marketing requirements for heat pumps in cold climates. A total of 33 papers were presented.

The opening plenary included a keynote presentation by Louise Comeau, formerly of the Sierra Club, who told delegates about the Federation of Canadian Municipalities, Green Municipal Enabling Fund and the Green Municipal Investment Fund, established to encourage and foster community energy planning. The second keynote address was by Jos Bouma of the IEA Heat Pump Centre on international heat pump research and development. He described efforts by governments, professional societies, industry associations and utilities to improve performance, reliability and cost effectiveness and to lessen the impacts and widen the applicability of heat pumps.

Technical programme highlights included:
- advances in ground-source heat pump design tools;
- case studies on cold climate heat pump installations;
- monitored performance from ground-source projects;
- novel applications including geothermal ice rinks, roof-top heat recovery units and a new compressor concept;
- a short course on ground-water heat pump system design.

Marketing programme highlights included:
- heat pump market development activities in the United States and Canada;
- climate change initiatives and measures;
- the latest heat pump standard developments;
- electricity deregulation and industry consolidation in North America and its impacts on the heat pump industry;
- updates on ground-source heat pump water well and borehole construction regulations and guidelines.

One of the Conference highlights was a luncheon address by Patrick Hughes, Manager of the US Federal Energy Management Program (FEMP), on the US Department of Energy and FEMP efforts to make ground-source heat pumps a mainstream technology in the construction and renovation of government buildings in the United States.

Proceedings of the Conference will be available before the end of the year for a price of USD 50. To receive ordering information, simply send an e-mail to the address below.

Source: Doug Cane
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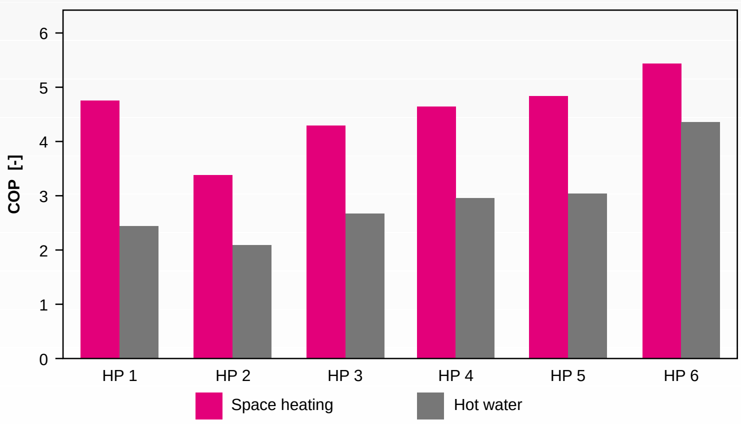
E-mail: caneta@compuserve.com

Snapshot of six heat pumps in field test

The Netherlands - Six heat pumps have been field-tested in a single house in the Netherlands, inhabited by a family with five children. There were significant differences in weighted average efficiencies (see **Figure 1**). The test showed that a central heat pump system for space heating and domestic water heating can reduce primary energy consumption by up to 62% when compared to a gas-fired boiler.

The six heat pumps were all installed in the attic, and controlled by a central control unit. The heat pumps were activated one-at-a-time in the case of heat demand. All heat pumps used the same heat source, water at 12ºC. The average supply temperature for the floor heating was 37ºC, and tap water was heated up to 53ºC by the heat pump.



▲ *Figure 1: COP of the six heat pumps (HP1-6) tested at average supply temperatures.*

Besides the efficiency of the heat pumps, noise levels, energy consumption in case of no heat demand, comfort, and documentation quality were the criteria used to judge the various products. The energy consumption in case of no heat demand varied between 0 and 60 W and was 15 W on average. The noise level of three heat pumps, between 32.7 and 50.3 dB(A), was judged as acceptable by the inhabitants. The other heat pumps had only slightly higher noise levels, between 51.5 and 56.2 dB(A), but produced more noise in the lower-frequency range.

Four suppliers participating in the test have announced product improvements.

Source: Dutch National Team,
Address: see back cover.

EU Phase-out schedule HCFCs finally approved

Belgium - The new regulation on the phase-out of ozone depleting substances was adopted by the European Parliament on 13 June 2000 and by the Council on 20 June 2000. It comes into force on 1 October 2000.

The phase-out schedule was discussed earlier in Newsletter 17/2. The phase-out date for HCFCs in new fixed air conditioners with a cooling capacity of less than 100 kW has been advanced by half a year compared to the previous proposal. The Table shows the approved phase-out schedule.

Concerning CFCs, the EU states: "Use and supply bans for substances whose production and importation has already been banned (notably CFCs and halons in fire-fighting systems) will facilitate the control of illegal trade in these substances. More stringent requirements for handling of ODS, including new staff training schemes, mandatory recovery and destruction and improved monitoring and licensing schemes of these substances, should help in minimising emissions of all ODS prior to their final phase-out."

Complete text of the new regulation (pdf-file): http://europa.eu.int/comm/environment/ozone/latest_news.htm

▼ *Table: EU HCFC Phase out schedule.*

Date	HCFCs banned for use in *new*:
1 January 1996	• non-confined direct-evaporation systems • domestic refrigerators and freezers • motor vehicle, tractor and off-road vehicle or trailer air-conditioning systems operating on any energy source, except for military uses (31 December 2008) • road public-transport air-conditioning
1 January 1998	rail transport air-conditioning equipment
1 January 2000	in public and distribution cold stores and warehouses, for equipment of 150 kW shaft input and over
1 January 2001	all other new refrigeration and air-conditioning equipment, with the exception of fixed air-conditioning equipment with a cooling capacity of less than 100 kW and of reversible air-conditioning/heat pump systems
1 July 2002	fixed air-conditioning equipment with a cooling capacity of less than 100 kW
1 January 2004	reversible air-conditioning/heat pump systems
1 January 2010	use of virgin HCFCs shall be prohibited in the maintenance and servicing of existing refrigeration and air-conditioning equipment.
1 January 2015	all HCFCs prohibited

Updated refrigerant recovery and recycling standard

USA - ARI (Air-conditioning and Refrigeration Institute) updated Standard 740. This standard establishes methods of testing and standard rating conditions for recovery, recycling and recovery/recycling equipment. The updated version, 740-98, has become part of the ARI Refrigerant Recovery/Recycling Equipment (RRRE) Certification Programme. ARI Standard 740-98 updates the 1995 version by including requirements for many new refrigerants, including HCFC blends in use today as replacements for R-12 and R-502, as well as HFC blends such as R-404A, R-507, R-407C and R-410A. The 1998 version also specifies representative test refrigerants so an entire category of refrigerants may be rated and certified without testing each individual refrigerant.

Several manufacturers participating in the ARI certification program have already certified recovery ratings for R-400 series and R-500 series (e.g., R-502 and R-507) refrigerants. These and all certified ratings may be found in the *ARI Directory of Certified Refrigerant Recovery/Recycling Equipment*. The July 2000 printed edition of the *Directory* is available from ARI, or may be viewed for free on ARI's Internet site, http://www.ari.org

Source: Koldfax, August 2000

Coca-Cola and Unilever to reduce HFC usage

UK/USA - Coca-Cola and Unilever, two of the world's largest refrigeration users, are taking initiatives to reduce or eliminate the usage of hydrofluorocarbons (HFCs) in soft drink dispensing equipment and freezer cabinets.

Coca-Cola aims to phase out HFCs from all its new equipment by 2004. The company will intensify its efforts to support research and innovation to accelerate the technological development of more environmentally friendly equipment. By the Athens Olympic Games in 2004, Coca-Cola will no longer purchase new cold drink equipment using HFCs where cost-effective alternatives are commercially available.

Unilever, the world's largest manufacturer of ice cream (e.g. Magnum and Solero), has announced a test of freezer cabinets charged with hydrocarbon refrigerants at the 2000 Olympic Games in Sydney. The company has a long-term testing programme for HC charged freezer cabinets in place. If the trials at the Sydney Olympic Games are successful, Unilever will consider using hydrocarbons as the refrigerant for all its freezer cabinets. The company aims for a two-pronged environmental benefit as a result of low power consumption and zero use of global warming substances.

Greenpeace congratulated both Coca-Cola and Unilever for taking these decisions. It has been campaigning for sponsors of the Sydney Olympics, of which Coca-Cola is one, to adhere to the environmental guidelines laid down by the Games organising committee, including the installation of HFC-free refrigeration only.

Source: UK National Team (address see back cover);
The Air Conditioning, Heating, Refrigeration News, 21 August 2000

Trends in the Norwegian Heat Pump Market

Norway - Statistics from the Norwegian Heat Pump Association based on sales in 1999 are now available. The data is based on reports from 31 heat pump suppliers in Norway. A total of 2,615 heat pump installations were reported sold in Norway during 1999. This is a continuation of the growth trend in evidence since 1996. **Table 1** presents data on numbers of heat pumps, per size class, sold in Norway in 1999. **Figure 1** shows market penetration from 1992 to 1999.

The table shows that small and medium-sized heat pumps (< 10 kW) dominate the Norwegian market. This is because most of the heat pump installations are residential heat pumps for single-family houses.

There are now a total of 27,200 heat pumps installed in Norway. This is an increase of 11% compared to 1998. The total annual heat production from heat pumps is 4.0 TWh and the annual energy saving is 2.5 TWh.

Table 2 shows the percentages of heat pumps in Norway that use various heat sources. Sixty-seven percent of the heat pumps installed in 1999 used ambient air as the heat source. There has been a big market for such low-cost systems in the last years, and the market is still growing.

The market share in Norway of heat pump systems based on water or ground source heat is growing despite the higher installation costs involved when compared to systems with ambient air as heat source. This trend may be due to an increasing focus on energy and total cost savings.

Table 1: Number of heat pumps installed in 1999 per capacity class.

Nominal heating capacity [kW]	Number of installations
0-3	775
3-10	1,466
10-25	201
25-100	129
100-1,000	43
>1,000	1

Figure 1: Norwegian heat pump sales

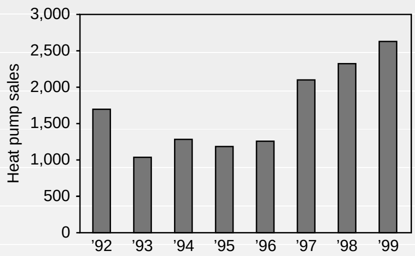


Table 2: Heat source of Norwegian heat pumps.

Heat source	% of total stock	% of 1999 sales
Ambient air	54	67
Exh aust air	30	12
Water, ground etc.	15	19
Others	1	2

Source: Norwegian Heat Pump Association.
More information: Marit Brånås, SINTEF Energy Research
Address: back cover

Canadian Government and GHPC launch initiative

Canada - The Canadian government agency Natural Resources Canada (NRCan) has selected the Geothermal Heat Pump Consortium (GHPC), USA, to help accelerate the introduction of ground-coupled heat pumps in Canada. A three-year initiative has been agreed on.

Since its creation in 1994, the GHPC has been instrumental in increasing the sale of ground-coupled heat pumps in the USA by 20 percent each year. GHPC will be expected to provide technical assistance “to mobilise, condition and transform the Canadian market”, including a package of services to implement a dedicated marketing initiative in Canada among utilities and professional bodies. In addition, GHPC will make available over 200 publications that it has produced since its start.

Source: Earth Comfort Update, July/August 2000

US market forecasts

USA – Unitary air conditioner shipments are expected to decline slightly after the past record years. This is the highlight of the *Economic Outlook* (July 2000) by Honeywell, USA. **Figure 2** shows the shipment history through 1999 and projections through 2005. The forecast concerns all unitary air conditioners, both cooling-only equipment and heat pumps.

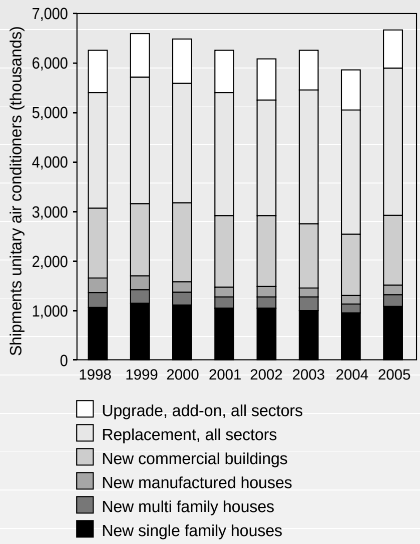


Figure 2: Projected unitary air conditioner shipments.

The Commerce department estimates that 84% of new single-family homes last year had central air distribution systems. This percentage has been steadily increasing since 1991 and is expected to continue to increase. The expansion of housing stock in the South and Southwest of the US (where air conditioning is installed in 99% of new homes) over the next five years leads to the expectation that 88% of new single-family homes will have air conditioning in 2005.

Replacements will be 56% of production by 2005, up from 51% in 1999. The *Economic Outlook* predicts that replacements will decrease slightly to below-trend levels as a result of the increased activity in the years 1997-99.

Source: The Air Conditioning, Heating, Refrigeration News, 21 August 2000

Successful IEA Annex 27 Workshop in Trondheim, Norway

Norway - On 17-19 September 2000, SINTEF Energy Research, Norway, organised a workshop on CO_2 technology in refrigeration, air conditioning and heat pump systems, as an activity of IEA Annex 27. SINTEF Energy Research is designated as Operating Agent in this Annex.

Fifty-eight participants from 14 countries registered for this first workshop. In addition to the Annex member countries Japan, Sweden, UK, USA and Norway, there were also participants from Canada, South Korea, Switzerland, Austria, Germany, Denmark, the Netherlands, Italy and France.

During the workshop there were 11 presentations on international R&D-activities on CO_2-technology. These covered projects involved in the Annex as well as other relevant projects. The programme included papers on feasibility studies, air-conditioning systems using CO_2, simulations of an industrial refrigeration system, development of compressors for CO_2, thermo-syphon with CO_2 in domestic freezers, safety, and several projects on heat transfer and pressure drop characteristics for CO_2. The projects presented were based on studies in Japan (2), Sweden (2), Switzerland, the Netherlands, Norway (2), the UK and the USA (2).

On the second day of the workshop there was a group-work session on selected issues. The subjects covered were systems/application areas, compression/expansion machines, safety, and heat transfer. The aim of the group work was to identify and agree on challenges and possibilities in one of the subjects and make a priority list.

The results from the group-work were presented to all participants and discussed in a plenary discussion. Both the results from the group work and elements from the plenary discussion will be included in the workshop proceedings.

Proceedings from the workshop can be ordered with the order form stapled in this Newsletter.

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Annex 26 Workshop

"Advanced supermarket refrigeration/heat recovery systems"

Sweden - The Swedish Royal Institute of Technology (KTH) and the Oak Ridge National Laboratory hosted the Annex 26 workshop on "Advanced supermarket refrigeration/heat recovery systems". The workshop was held in Stockholm, Sweden, on 2-4 October 2000. The meetings were spread over one and a half days, and a study tour of supermarkets in the Stockholm area took place on the third day. About 70 persons attended the meeting.

Dr Eric Granryd, Chairman of the IIR General Conference, delivered the keynote address "Energy Efficiency as the Leading Edge". Workshop sessions on supermarket systems, energy efficient equipment, modelling and analyses, and field results were held with 18 speakers invited from seven countries. A tour of the KTH Laboratory of Applied Thermodynamics and Refrigeration was included. Papers presented at the meeting will be published in the proceedings and will be posted on the Annex 26 web site (http://www.ornl.gov/annex26) as well.

The United States is the Operating Agent for Annex 26 with Canada, Sweden, and the United Kingdom participating. In addition, Denmark has indicated that it will join the Annex after the workshop. The Annex focuses on demonstrating and documenting the benefits of advanced systems design for food refrigeration and space heating and cooling for supermarkets. A specific goal is to identify refrigeration and HVAC technology options that reduce the total equivalent warming impact (TEWI) of supermarkets.

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Ongoing Annexes

Annex 16 IEA Heat Pump Centre	16	AT, JP, NL, NO, UK, US
Annex 25 Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	25	CA, FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	26	CA, SE, UK, US
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	27	JP, NO, SE, UK, US

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

Heat pumps for retrofitting heating systems – an international overview

Geir Eggen, Norway, and Gerdi Breembroek, IEA Heat Pump Centre

The market potential of heat pumps for retrofitting is much larger than for application in new buildings, but in most countries this potential is not realised. This article provides an overview of what can be done to overcome the technical market barriers, in particular to find solutions for the high distribution temperatures which are often required by existing hydronic heat distribution systems.

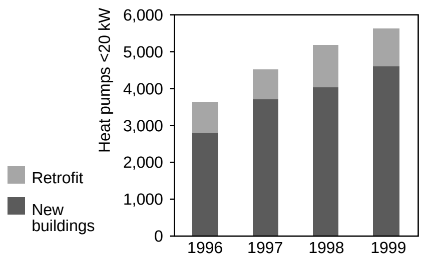
Retrofitting is a means of rectifying existing building deficiencies, improving the standard of a building and, sometimes, making it suitable for alternative uses. Building retrofit often includes heating system retrofit.

Retrofitting of heating systems with heat pumps has its own specific problems. High distribution temperatures in existing hydronic heat distribution systems cause most concern. This article focuses on overcoming this problem. Cooling will not be considered in detail. The geographical focus is on North, West and Central Europe, as the problems with hydronic high-temperature distribution systems are specific to these regions, and other cold climates.

Market

The potential market for heat pumps for retrofit is about 3 times larger than the market for heat pumps in new buildings. Building construction rate is about 2% in most countries. If a heating (and cooling) system needs replacement after 15-20 years useful service, 5-6% of the existing building stock is confronted with a heating system retrofit each year.

However, in most countries the actual market for retrofit heat pumps is smaller than the market for heat pumps in new buildings. Even in the US, where the barrier of incorporating a heat pump in an existing air distribution system is smaller than in most North and Central European countries, only about half of the unitary heat pump shipments replace existing heating and cooling systems (see page 8). In Switzerland, only about 20% of the residential heat pump market (<20 kW) is for retrofit (see **Figure 1**). This corresponds to 3% of the market for replacing/retrofitting existing heating systems. In Germany, heat pumps for retrofitting existing heating systems is estimated at around 25% of the total heat pump market.



▲ *Figure 1: Heat pumps < 20 kW sold in Switzerland for retrofit and for new buildings.*

A significant replacement market exists only in Japan, Norway and - for commercial building applications - in the UK. In Japan, residential heating and cooling heat pumps are replaced every 10-11 years. In 1999, the Japanese replacement market for RAC (room air conditioner) type heat pumps was 5,400 thousand units, which is 88% of the total RAC heat pump market. The 1999 replacement market for heat pump PACs (packaged air conditioners) comprised 440 thousand units, which is 70% of total heat pump PAC shipments. In Norway, air-to-air heat pumps of 3-10 kW comprise 63% of the market volume, and most of these are supposed to be used for retrofitting.

Market barriers

There are several barriers to the use of heat pumps for retrofit. They may be caused by technical restrictions or by economic factors. The main barriers are:

- High distribution temperatures. The traditional hydronic heating systems are high-temperature systems, with design supply temperatures of 90-70°C. This is much higher than the high temperature limits of the heat pump system, which is mostly around 55°C, depending on the working fluid, see **Table 1.**
- As a result of high distribution temperatures, the heat pump system must operate at high temperature lifts between heat source and heat sink. This means a lower COP for the heat pump, and higher superheated gas temperature at the compressor. This higher temperature lift and higher superheat gas

▼ *Table 1: Saturation temperatures for some refrigerants*

Refrigerant	R-404A	R-407C	R-410A	R-507	R-134a	R-290	R-717
Components	44% R125 52% R143a 4% R134a	23% R125 25% R125 52% R134a	50% R32 50% R125	50% R125 50% R143a	R134a 100%	Propane C_3H_8	NH_3
Temperature at 25 bar (°C)	53	55-59	41	52	78	68.3	58
Temperature at 1 bar (°C)	-46 to -47	-37 to -44	-52	-47	-26	-42.1	-33.3
Critical temperature (°C)	74.4	86.4	71.8	71	100.6	96.7	130

temperature cause a shorter life of the heat pump and greater risk of compressor failure. The situation is aggravated by the fact that the source temperature may be low as outside air is the most likely heat source for retrofit applications.

- Heat pumps for retrofit may be less economical than heat pumps in new buildings because the higher temperature lifts result in lower efficiency, thereby reducing the cost savings. Compared with new plants, the retrofit heat pump installation may also require higher cost for equipment, pipes, controls and electric installations.

Reducing heat sink temperature

There are several methods to reduce the heat sink or distribution temperature of an existing heating system. Old hydronic systems in existing buildings have often been designed for higher heating capacities than the actual design heat demands. Therefore, the heat distribution temperatures may be reduced below the actual design values. The heat distribution temperatures may be lowered further by reducing the heat demand through improved insulation of the building envelope. Changing the strategy of reduced room temperatures at night will lead to a lower heat demand in the morning, and lower distribution temperatures will then be sufficient to keep the building warm.

Retrofitting with a new, low-temperature distribution system is another way to improve operating conditions. The best solution from an energy viewpoint is to replace the existing high temperature hydronic system with a new floor heating system, but this may be expensive. Another way to overcome the problems associated with high distribution temperatures is to install additional heat transfer surface in specific rooms.

In many cases, high-temperature heat distribution systems must be accepted. This is certainly true for district heating systems, but also for numerous applications in houses and commercial buildings.

Ductless air-to-air systems

Ductless air-to-air systems are attractive especially when no heat distribution system is in place. In Japan, the market is dominated by such systems and they are also successful in other countries. Such systems can be easily and successfully retrofitted. The performance is similar in retrofit applications and in new buildings. However, most units are not optimised for heating-only applications in cold climates, but for heating and cooling in warmer regions.

Refrigerants

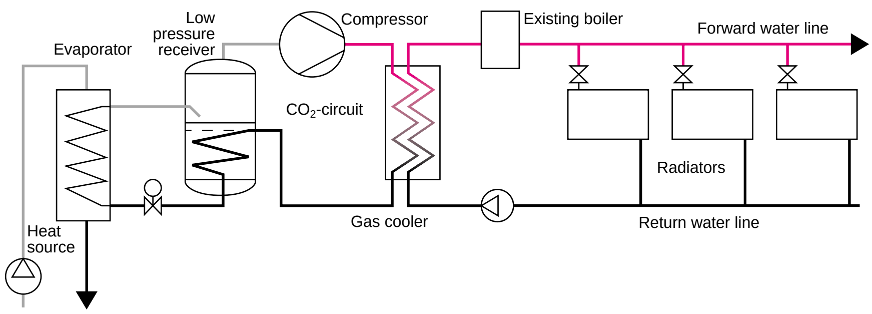
The application range of HFC-refrigerants is limited to 60-65°C as the highest recommended temperature limit in one stage small and medium-size heat pump systems. With the use of larger centrifugal R-134a compressors in large two and three stage heat pump plants, the temperature limit may be increased to more than 80°C. For small and medium size heat pump systems, higher temperature limits may be achieved by using natural working fluids such as hydrocarbons, ammonia and carbon dioxide.

The *hydrocarbons* butane, iso-butane and mixtures of hydrocarbons may be used up to 100°C. Especially in heat pumps for retrofit, there will often be restrictions on the use of flammable working fluids, related to the absence of a suitable machinery room etc.

Ammonia is a well-known working fluid with excellent thermodynamic properties. However, the rather high condenser pressures limit the application in heat pumps at higher temperatures when 25 bar equipment is used. For use at higher temperatures for space heating purposes, compressors are available for head pressures of 40 bar. These can be used safely for water temperatures up to 70°C. However, ammonia is toxic and flammable, and this restricts the use in heat pumps for retrofit.

Carbon dioxide (CO_2) is a natural fluid which is neither toxic nor flammable. It can be used as refrigerant in a transcritical process. The CO_2 heat pump operates at considerably higher pressures on the high-temperature side (80-130 bar) than more common heat pump systems. The CO_2 heat pump may be used up to approximately 100°C. **Figure 2** shows how a CO_2 heat pump can be incorporated in a heating system.

The heating system must be modified to fit the high temperature glide of the CO_2 heat pump. Normally, a 20°C difference between supply and return temperature is maintained. By decreasing the water flow rate through the hydronic system, this difference can be increased. The system will supply domestic hot water without any loss in energetic efficiency. At present, the CO_2 heat pump is in the prototype stage. For a successful development of this promising heat pump technology, compressors and other components will have to become commercially available.



▲ *Figure 2: Principal piping diagram of residential CO_2 heat pump in a hydronic distribution system.*

Cycles and controls

Two stage compression for higher temperatures, compression with liquid injection, transcritical cycles with hydrofluoroethers[1] could in principle lead to heat pump systems with improved chances on the retrofit market.

The research and development programme 2000-2003 of the Swiss Federal Office of Energy (SFOE) focuses on development of new heat pump systems for the retrofit sector and the improvement of the overall system (heat source, heat pump, distribution system and building). Work has already started in several projects:

- Development and testing of new cycles for high efficiency and high thermal output at the high temperature lifts customary in the retrofit market, amongst others by two-stage compression heat pumps. **Figure 3** shows one of the cycle concepts investigated by way of example;
- Research on components with low liquid hold-up, which are also suitable for natural refrigerants;
- Development of new, intelligent control concepts with system diagnosis for high efficiency with low storage volume;
- Development of safety systems for natural working media.

The news item on page 4 reports on the current status of the competition "Swiss retrofit heat pump". Extensive information on research and development initiated by the SFOE can be found at http://www.waermepumpe.ch/fe (German, French, English).

1 *Brandes et all.*, High temperature heat pumps for retrofitting hydronic heating systems of existing buildings and for waste heat recovery in industry, *6th IEA Heat Pump Conference, Berlin, Germany, 1999*

Absorption systems

Thermally activated heat pumps have the advantage of a high-temperature driving energy. Gas-fired absorption heat pumps are therefore particularly interesting for the retrofit market. The article on page 15 gives details on the 4 kW diffusion absorption heat pump which is being field tested by Nefit Buderus in the Netherlands (and Germany).

Newsletter 15/1 introduced a gas-fired absorption heat pump developed by Heliotherm in Austria, also developed for the retrofit market. The 18 kW heat pump can be used with various heat sources. A prototype will be tested intensively in the 2000-01 heating season and a large field test is planned in 2001.

Other aspects of successful retrofitting

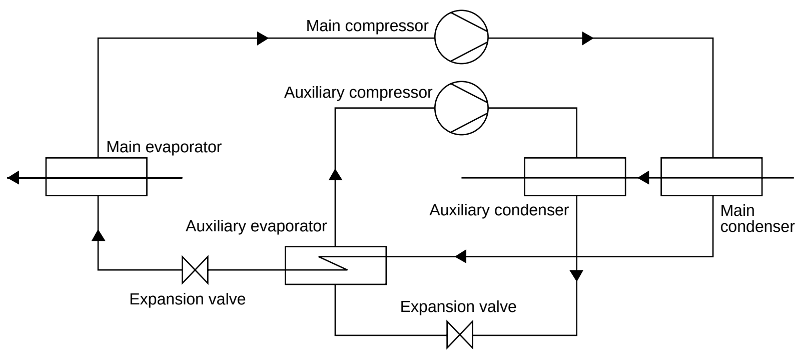
High-quality advice, design and installation as well as system economy are also crucial in the retrofit market. With regard to the economy, the installation should be designed for maximum operating hours. From that viewpoint, integrated systems for space heating and hot water production are preferable. Heat pumps for retrofitting the heating system of an elderly home with a constant heat demand may be more successful than in a school, which is only occupied eight hours a day. With regard to the system design, it is important that the hydronic concept guarantees a minimum return temperature in order to achieve maximum heat pump efficiency. Also, there are often practical limitations to the space for the new installation and large buffers are often not feasible.

CO_2 reduction potential

"Heat pumps can cut global CO_2 emissions by more than 6%" stated the IEA Heat Pump Programme brochure published in 1997. This potential will be realised when 50% of buildings are heated with state-of-the-art heat pumps, which would reduce CO_2 emissions by at least 30% when compared to other space heating methods. This message has lost none of its validity. But to realise this potential, the market for retrofitting with heat pumps must be increased. Otherwise, the day when 50% of space heating demand is realised by heat pumps will remain far in the future.

Conclusions

There is a large potential market for retrofit heat pumps. However, there are several technical and economical barriers to the use of retrofit heat pumps in existing buildings. These problems are especially related to high distribution temperatures, which cause reduced energy efficiency and poor economy of the heat pump system. Measures to reduce the hydronic distribution temperatures and the use of specially designed heat pumps may solve these problems.



▲ *Figure 3: Heat pump process with separate loop for condensate subcooling for the retrofit market.*

Ongoing HPC project

The information in this article was gathered within the framework of the ongoing HPC project "Heat pumps for retrofit". At the time of publication of this article, the draft report is out for review. The report will be available from the IEA Heat Pump Centre in Spring 2001, and costs NLG 240 (NLG 80 in HPC member countries). Please use the order form stapled in this Newsletter.

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Heat pumps for space heating in retrofitting residential buildings

Hermann Halozan, Austria

The present heat pump market concentrates on new buildings. Improved building standards, thermal insulation of the building envelope and the installation of low-temperature heat distribution systems form the ideal basis for efficient heat pump systems. However, the size of the market involving new buildings is only about 1% of the market involving existing buildings.

The much larger market potential for retrofitting existing buildings is not being utilised because of three main reasons: the prevailing high-temperature hydronic systems that require bivalent heat pump systems with sophisticated control; the lower seasonal performance factors (SPF) due to the higher heat pump outlet temperatures; bad experiences in the eighties. However, two current problems also have to be dealt with: reduction of greenhouse gas emissions and the high oil price. How can we deal with these problems - or perhaps even make use of them - to encourage the introduction of heat pumps in retrofitting residential buildings?

The problem of greenhouse gases and global warming is dealt with in the Kyoto protocol, which is intended to reduce the emission of greenhouse gases, among others by burning less fossil fuel. The problem of high oil prices can pose risks to our economies if not adequately dealt with. In this context, it might be interesting to look back at the seventies and eighties, when instead of "Kyoto", energy security was the driving force.

1980: Energy security

As an international response to the second oil crisis in 1978, the IEA published its "Strategy Study", to reduce the dependency on imported oil in 1980. The document identified the space-conditioning sector as the sector in which the largest energy saving potential could be quickly realised. Solar energy, district heating and heat pumps were shown to have the potential of saving 600 million tons of oil per year by the year 2020. Heat pumps would contribute about 80% to these savings.

In Austria, the first governmental Energy Report (Energiebericht) was published, which stated that the most promising sector for oil conservation was the space-conditioning sector. Oil consumption could be reduced drastically by means of thermal insulation, heat pumps, solar energy and district heat produced by co-generation plants.

A period of heat pump market growth then began. The heat pumps installed in Austria after the second oil crisis were either ground water heat pumps for monovalent systems for new buildings, or they were outside air heat pumps for bivalent systems, mostly combined with existing oil-fired boilers, for retrofitting existing buildings. In the beginning, the bivalent systems for retrofitting existing buildings had the larger market share.

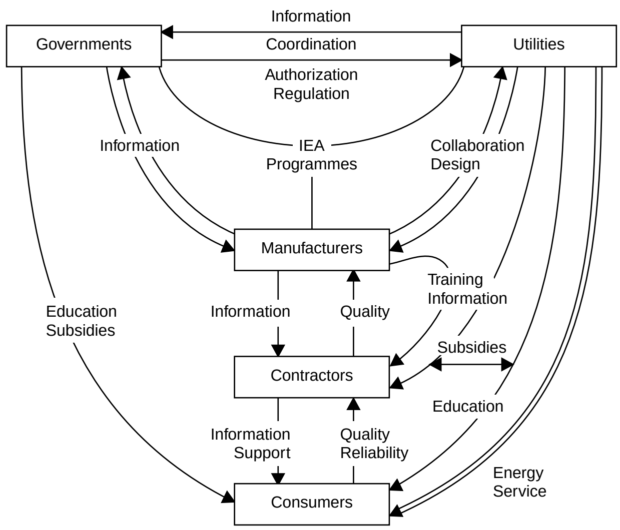
However, the promising start was rapidly followed by a breakdown. Too many mistakes were made during the market start-up period and faulty systems that broke down destroyed the reputation of the heat pump. The fact that there was no European market did not improve matters much. Finally, the rapid drop of the oil price in 1986 together with the fact that the Austrian Government decided to end the tax reduction for heat pumps significantly reduced sales figures, especially for bivalent outside air heat pump systems for retrofit. The operation of an oil-fired system alone became cheaper than that of a bivalent outside air heat pump system.

Barriers

The above developments led the Heat Pump Centre in 1985 to organise a workshop on "Electric Heat Pumps for Retrofit in Existing Small Residential Buildings (Hydronic Systems)" in Graz to discuss the situation of the European heat pump market and to identify the barriers to a successful market introduction. The results of this 1985 workshop are summarised in **Figure 1**.

The conclusions of the 1985 workshop can be summarised as follows:

- Collaboration between governments, utilities, manufacturers and installers is needed to determine appropriate roles for each.
- Utilities and governments have proven very effective in some countries in promoting heat pumps. However, neither consumers nor utilities will pursue heat pumps unless it is economically attractive to each of them.
- Governments, and utilities as a second party, have a long-vested interest in the market penetration of heat pumps and should play a leading role in creating a heat pump market.
- The knowledge of the position of heat pumps in the present energy system should be improved, including the knowledge of their environmental benefits as part of the total energy system.
- The comparison of energy consumption and emissions of various heating technologies should, however, be based on the same fuel and the same technology standard.
- The temperature lift of the heat pump has to be as small as possible.
- There is a large potential for increasing the heat pump SPF – e.g. by a factor of 1.5 – and improving the efficiency of electricity generation, which both add to the benefits of heat pumps. In contrast, condensing boilers can only become a few percent more efficient.



▲ *Figure 1: Preconditions for a successful heat pump market development.*

2000: Emission reductions

We now have two issues to deal with, the new oil price crisis and the reduction of greenhouse gas emissions. To reduce the latter requires a significant reduction in the use of fossil fuels. This can be realised in the sector of primary energy transformation and/or in the end-use energy sector. Within the end-use energy sector, as in 1980, the building sector is identified as a sector that can contribute significantly to a rapid solution. The Kyoto Protocol requires a short time frame, as reductions have to be achieved by 2010. In Austria, this means a reduction by 13% based on the emissions of 1990, which is equivalent to a reduction of 17 to 18% of current emissions.

Unlike the 1980s, the electricity market is just beginning to become deregulated; utilities can play an active role in developing an electricity market in which energy efficiency and environmental benefits are recognised. Heat pumps can be one tool to achieve this goal.

As in the 1980s, Central and Northern Europe are still characterised by hydronic heat distribution systems in buildings. Today, heat pumps have to be integrated into extremely different systems: old systems with radiators designed for maximum supply temperatures of 90°C; new systems with floor heating designed for maximum supply temperatures as low as 35°C; radiator systems in renovated buildings with improved building envelopes with maximum supply temperatures of 55 and 45°C, respectively.

Retrofit with heat pumps

Heat pumps can be integrated directly – the outside air-dependent supply temperature control has to be replaced by an outside air-dependent return temperature control in order to guarantee sufficient running time for the heat pump. Especially with outside air heat pumps, heating capacity as well as the COP drop significantly with decreasing heat source temperature. This means that at moderate temperatures, excess heat production results in heat pump outlet temperatures that exceed the supply temperature required by the system. With ground-source heat pumps, this effect is much smaller; ground water as a heat source gives the best results. To reduce these effects, various solutions can be implemented:

- using a thermal storage tank for de-coupling the flow rates through the heat pump and the heat distribution system. By increasing the flow rate through the heat pump, excess temperatures can be reduced;
- using a heat pump with a two-speed

compressor or a unit with two parallel compressors. An excellent solution is an inverter-driven unit with a variable speed compressor; its heating capacity can be adjusted to the heat load required over a wider outside air temperature range.

Expanding the market

While growing numbers of heat pump and air-conditioners are operating in some countries, the advantages of reversible and heating-only heat pumps do not yet appear to be fully realised. In addition to utilising ambient heat, the heat pump offers the option of utilising waste heat, in other words the recycling of thermal energy. Both ambient heat and waste heat are CO_2-free and contribute to reducing global warming.

The following is important for market expansion:

- to succeed commercially, a heat pump must satisfy requirements regarding comfort, safety and reliability, as well as performance and economy;
- utilities and governments must both play a role in helping to reach the critical market volume needed to achieve more favourable system prices;
- lack of uniformity in standards for equipment design and safety among countries with relatively small market volumes (as in Europe) results in higher production costs. Governments of EU countries should adopt uniform design, safety, rating and labelling standards as quickly as possible.

Outlook

The key to sustainable development and a rational policy of energy management is to avoid destroying our environment. Already in 1824, Sadi Carnot discovered the thermodynamic rules for heat pumping technologies. He also more or less prepared the way for the first and the second law of thermodynamics, which were formulated in 1842 by Robert Mayer and in 1850 by Clausius. To judge from the energy discussion taking place today, one would think that Carnot and Clausius had never existed.

The Kyoto Protocol and the present oil price shock require measures such as regulation, taxes and subsidies for promoting energy-saving technologies in order to reduce greenhouse gas emissions. Heat pumps are one of the key technologies to achieve this goal.

Success on the market is not a phenomenon; it is the result of research, excellent products, skilled installers, the support of the utilities and a political target. If we do not forget these preconditions, if governments accept the importance of this technology, and if there is a real need for the reduction of CO_2 emissions by international agreements, then the heat pump will also succeed in Europe and contribute to a better future.

References

A list of references on this topic is available from the IEA Heat Pump Centre.

Hermann Halozan
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The gas-fired residential diffusion-absorption heat pump

Jan Blom, The Netherlands

In 1999, extensive field-testing was carried out of a prototype for a residential gas-fired diffusion-absorption heat pump supplemented with additional peak boiler capacity (bivalent operation). The tests demonstrated that the primary energy ratio (PER) of the bivalent heat pump was 20-40% higher than that of a traditional boiler unit alone. Gas consumption was reduced by 15-27%. A survey conducted among residents and installers involved in the project showed a high degree of satisfaction, and the manufacturer now plans to introduce the bivalent heat pump onto the market in 2001.

Introduction

Nefit Buderus BV, a major Dutch manufacturer of central heating boilers, presented the test results for a prototype of a bivalent heat pump, a combined heat pump-boiler unit, at the Amsterdam BouwRAI (a trade show for project development, building, living and working) in April 2000. The company plans to introduce the combined unit onto the market in 2001. It anticipates that its first customers are likely to be more innovative and energy-conscious project developers, housing corporations and consumers.

The combined unit consists of a gas-fired diffusion-absorption heat pump supplemented by a Nefit high-efficiency (HE) boiler and an indirectly fuelled hot water boiler to guarantee the continuous availability of space heating and hot water under conditions of peak demand. The combined unit can generate a maximum output of 4 kW; the gas-fired heat pump component alone is capable of delivering a constant output of 1.2 kW. For most of the year, this 1.2 kW suffices for the central heating and warm water supply in an average home. Supplementary heating from the HE boiler is required only for peaks in the heating demand and to heat tap water to 60°C. The heat pump itself actually pre-heats the tap water to over 50°C before the supplementary boiler raises the temperature further to 60°C.

Field-testing

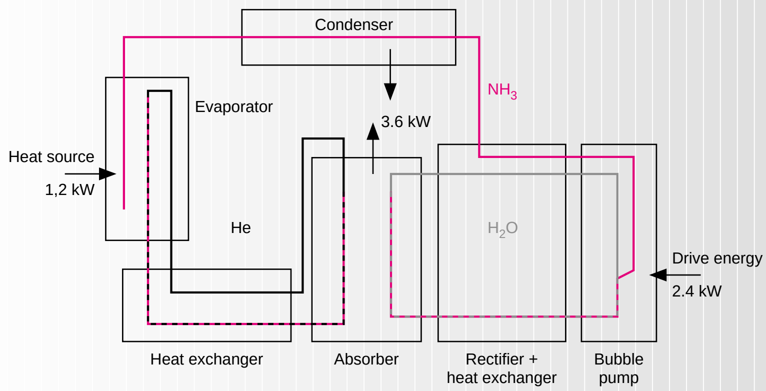
The first combined units were installed in January 1999 as part of an extensive pilot project conducted by Enercom (a co-operative of energy companies), Nederlandse Gasunie BV (gas supplier to domestic and international markets) and Nefit Buderus. The units were hooked up to the existing gas piping systems in different types of housing throughout the Netherlands. The geographical spread was a key condition for achieving valid test results. Over 60 heat pumps were installed in 7 freestanding houses, 27 corner or end houses, and 29 terraced houses. Half of these buildings were equipped with radiators designed for a 50/70°C heating system, whereas radiators for 70/90°C systems were found in about twenty houses. Six houses had both radiators and floor heating; in one house, the system consisted solely of floor and wall heating.

Five different types of outside heat sources were tested for use with the heat pumps in order to provide data on a wide range of options. For most of the houses outside air collectors were installed, but horizontal and vertical ground collectors as well as one specially designed heat collector which extracts heat from surface water and one which extracts heat from the mechanical ventilation system were also tested. In all but a few cases, an energy withdrawal of 1.2 kW proved to be adequate.

The gas companies delivering gas to the houses involved in the field-test monitored the 67 test installations. They measured the following parameters:

- gas consumption of the combined heat pump-boiler unit;
- number of starts;
- hours of operation of the heat pump and of the supplementary boiler.

In seven systems, all the heat flows to and from the heat pump system were continuously measured as well. Each day, the collected data were sent in, providing direct information on the heating efficiency during the preceding day.



How does the diffusion-absorption heat pump work?

In the bubble pump, ammonia (NH_3) is evaporated and driven off from the NH_3-water solution at 160°C. The dilute ammonia-water solution (light blue lines) left behind is transported by the bubbles to a height of 1 m and then to the rectifier and subsequently to the absorber, from where it returns to the bubble pump after being enriched with NH_3 vapour. The NH_3 vapour driven off in the bubble pump (red lines) travels to the rectifier where it is enriched and heat is reclaimed, after which the vapour travels further to the condenser, where heat is given off. The liquid ammonia from the condenser is then brought into an atmosphere of Helium (He) (blue lines), where it evaporates as a result of the low local partial pressure of ammonia. The heat required for the evaporation is supplied by the heat source of the heat pump (air, ground). The resulting NH_3-He vapour, which is heavier than He, moves down towards the absorber, where the ammonia is absorbed by H_2O again and heat is given off to the heat exchanger. The ammonia-water solution then travels to the bubble pump and the process can begin anew. The equipment has no moving parts and is therefore very silent.

Results

The PER (primary energy ratio), or energetic efficiency, of the combined unit is defined as the amount of energy generated divided by the amount of primary energy consumed, in this case as gas. The PER realised by the combined unit varied between ca 1.25-1.5, depending on the type of heat source used, type of space heating radiators used, outside conditions etc. An average long-term PER of 1.28 proved feasible. This compares very favourably with the energetic efficiency of the HE type of condensing boilers currently in use, which realise a PER of 1.06.

For the combined systems that were fitted with an outside air heat collector and 50/70°C radiators, the consumption of primary energy decreased by 15% when compared to a present-day HE boiler with an indirectly fuelled hot-water boiler. If the air collector is replaced by a ground collector, the savings in gas consumption increase from 15 to 22%. If floor heating is used instead of radiators, the savings increase another 5% to 27%. The heat pump component of the unit operated about six times as many hours as the supplementary boiler unless the system was fitted with radiators requiring relatively large quantities of heat within short periods.

Electric heat pump or gas-fired heat pump

For gas-fired heat pumps, a PER is attainable of 1.4 or more, which is comparable to the PER of an electric heat pump. However, when retrofitting existing buildings, the electric infrastructure often proves inadequate for the installation of electric heat pumps, whereas the gas piping system in the Netherlands is always adequate for a gas-fired system. The gas-fired variant also has other advantages for both the consumer and the fitter. Because the gas-fired heat pump itself does not have any moving parts, it is 100% noise-free, hardly shows wear and tear and therefore needs only limited maintenance. It also requires a smaller ground collector than the electric variant.

Optimising the system

As mentioned above, short-term peak heat demand could not always be met by the gas-fired heat pump component of the unit. Adjustments to the process control parameters for the radiators are expected to help solve this problem. In this regard, the daily adjustments that need to be made in room temperature can best be automated. From the perspective of energetic efficiency, the combined unit discussed in this paper can actually best be left at room temperature around the clock, although the economical Dutch may need some time to grow accustomed to this idea. As mentioned earlier, the other parameters which can be expected to yield the most benefits to the system when optimised are those involving the outside heat source (ground collector) and the space heating system used (floor heating).

Reactions of consumers and installers

A survey among 50 households showed that half of the users were highly satisfied and all but one or two of the others were reasonably satisfied. The major reason for this success was the high degree of comfort provided by both the heating and the hot-water systems. Eighty percent of the residents were satisfied with regard to ease of operation, noise level and reliability of the equipment. The main complaint concerned the large space required for the equipment. This aspect will be dealt with in the development of the commercial product, when the heat pump, central heating boiler and hot-water boiler will all be integrated into a single unit.

▲ *Photo 1: The gas-fired heat pump (right) was supplemented by the HE central heating boiler (left) in the pilot project.*

The pilot project gave twelve different installation companies the opportunity to gain practical experience with the gas-fired heat pump. They too found the equipment to be unwieldy and heavy, especially for installation in attics, and the piping was considered very extensive. These aspects will also be dealt with in developing the commercial model. The technology of the heat pump and the installation of the outside heat source presented little or no problem to 80% of the installers. Until now, the operation and performance of the prototype system was the main focus of attention. The focus will now shift to more practical aspects. The improved and integrated commercial model will be far more user-friendly.

▲ *Photo 2: The air coils on the roof supplied "free" energy to the heat pump*

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Propane as refrigerant for heat pump applications in southern Europe

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This article describes the work carried out by AEDIE, Spain; Alfa Laval Artec SpA, Italy; CIATESA, Spain; ENEA, Italy; Kungl Tekniska Högskolan, Sweden, and the Polytechnic University of Valencia, Spain, over a period of two years in a project funded in part by the European Commission within the framework of the Non-Nuclear Energy Research and Technological Development Programme.

Market potential for propane

Propane is one of the substances being studied worldwide as a substitute for HCFCs. Its advantages over the latter include zero contribution to the destruction of the ozone layer and almost zero contribution to the greenhouse effect. Its disadvantage is its flammability, and until recently safety standards in this regard significantly restricted its use. European standard EN378:2000 *(Refrigerating systems and heat pumps – safety and environmental requirements)* was recently accepted. The informative annex of this standard specifies maximum charge criteria for all refrigerants, including hydrocarbons such as propane, depending on type of occupancy and location of the heat pump. Within Category "A" [strictest area], the annex allows 5.0 kg of propane above ground, located in a special machinery room or in the open air. The standard states that the use of hydrocarbons is not allowed in direct, indirect open, or indirect vented open systems for air-conditioning and heating. It thus permits their use in the remaining common systems (indirect closed, indirect vented closed and double indirect systems). EN378 takes precedence over the corresponding national standards.

At present, propane is being used in heat pumps only in some countries in western and northern Europe. However, these heat pumps are not suitable for the climatic conditions of the Mediterranean countries. As a result, Asian and American manufacturers, whose climates are very similar to that of southern Europe, have gained a major share of southern European markets. These manufacturers of reversible heat pumps tend to replace CFCs and HCFCs by HFCs. The substances involved, R-32, R-134a, R-143a, R-125, etc., are not environmentally neutral (zero ODP but significant GWP), in contrast to natural refrigerants like propane and ammonia. In light of the above, the participants in this project pooled their resources to develop a heat pump that uses propane as refrigerant and that is suitable for the southern European climate.

It was decided to make use of an existing commercially available heat pump of approximately 20 kW that uses R-22 as refrigerant and to modify it as necessary.

Goals of the project

Improving the energy efficiency of existing appliances is one of the cornerstones of current European energy policy as it results in lower contributions to the greenhouse effect. In view of this policy and with the aim of improving the commercial viability of the product to be developed, the participants set themselves the goal of improving the energy efficiency of the existing unit by 10%.

As propane is a flammable substance, any reduction in the amount needed would increase the safety of the system. With this in mind, an additional objective was set: achieving a reduction of 40% in the amount of propane needed.

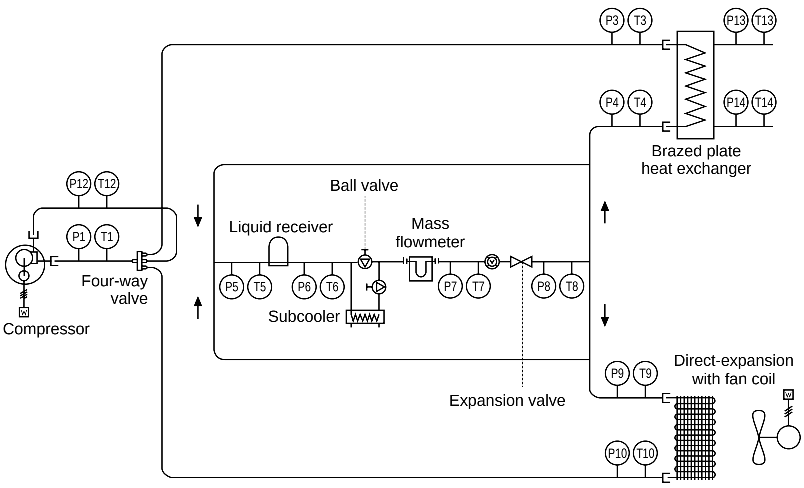
The requirements that had to be met by the new heat pump in order to meet the above goals were first evaluated. Next, a commercially available heat pump was chosen in light of these requirements. The choice fell on the CIATESA IWA 95 air-to-water heat pump, with a heating capacity of 21.1 kW ($COP_{heating}$ = 2.8) and a cooling capacity of 19.2 kW ($COP_{cooling}$ = 2.5).

Methods and materials

The heat pump and its components (plate heat exchanger, heat exchanger coil, compressor and expansion valve) had to be characterised in order to evaluate their performance with propane and R-22; the characterisation phase. Test benches have been constructed specifically designed for each component and for the heat pump itself. **Figure 1** shows the set-up of the heat pump test bench. Temperature and pressure sensors were installed at 12 points, which were the most significant points in the thermodynamic cycle.

This heat pump was tested in an installation consisting of a climate chamber in which the air temperature was controlled by use of the heat pump itself. Once the predetermined temperature was reached, the test was carried out and the conditions in the chamber were maintained by a device that mixed return air with outside air in the necessary ratio.

Separately, different compressors were tested in a compressor test bench specifically designed to that end. It was



▲ *Figure 1: Reference heat pump tests.*

used to measure cooling capacities and COPs under a full range of conditions in order to determine the size of the replacement compressor for use with propane. To test the air and plate heat exchangers, a test bench was built consisting of three circuits: air, water and refrigerant. The air circuit was a wind tunnel equipped with an air-treatment unit. The water circuit consisted of a metered circuit connected to the plate heat exchanger to provide the thermal loads. The refrigeration circuit was a heat pump made by CIATESA, connected to the heat exchangers. A large set of sensors was used to measure temperature, flow and pressure at all points of interest in the three circuits.

A special mathematical model was developed for each of the main components as well as for the heat pump assembly. These models were adjusted using the data obtained in the characterisation phase. Subsequently, the components were optimised by using the mathematical models to perform several parametric studies. A set of possible modifications of every component was proposed and its effect on the system output was checked. This procedure resulted in a final design for the components and the heat pump.

The optimised components were subjected to the necessary testing to confirm the improvements achieved by the modifications. The optimised heat pump was also subjected to testing to determine to what degree it met the goals defined for the project.

Prototype and results

About halfway through the project, the first prototype heat pump was built: the advanced heat pump unit AHPU. This improved design incorporated all the changes that had been identified and included improved heat exchangers.

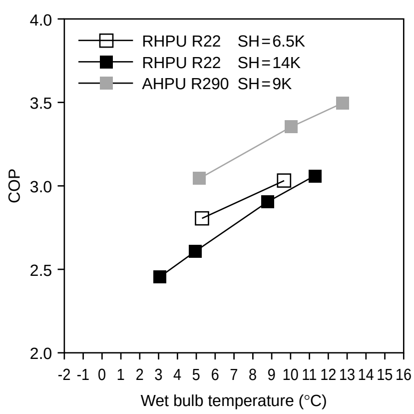
Figures 2 and **3** show a comparison of the energy efficiencies achieved with the intermediate prototype using propane (in red) and the efficiencies achieved with the reference heat pump (RHPU) using R-22, for different levels of super-heating (SH).

A final prototype, the HEAHP (high-efficiency advanced heat pump) was built by CIATESA using heat exchangers specially manufactured in Italy by Alfa Laval Artec, a scroll type commercial compressor from Maneurop and a Danfoss standard expansion valve. The scroll type compressor has a higher volumetric capacity than other types, which compensates for the lower capacities resulting from the lower density of propane compared to R-22 at the compressor inlet.

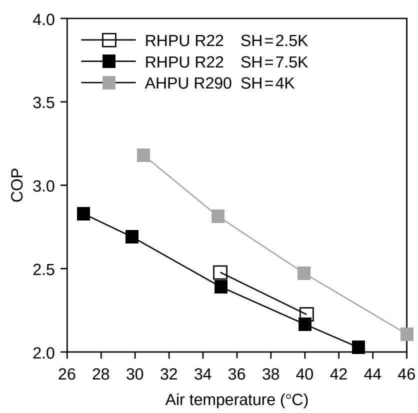
Tests at CIATESA and certification measurements at CEIS (official Spanish certification lab) showed that the HEAHP is able to work properly with 66% less charge than the R-22 RHPU for the same output. This is a very important result in terms of safety concerns and cost savings. This charge reduction was achieved in spite of the lower density of propane compared to R-22 (with a volumetric latent heat slightly lower than R-22).

Conclusion

The main result of the project was the development of a high-efficiency advanced heat pump which uses propane as a refrigerant instead of R-22. The test results indicate that the project goals of reducing the amount of



▲ *Figure 2: COP as a function of the wet bulb temperature - heating mode.*



▲ *Figure 3: COP as a function of dry air temperature - cooling mode.*

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refrigerant by 40% and improving the energy efficiency by 10% have been met and amply exceeded.

The HEAHP cooling capacity lies within ±5% of the R-22 RHPU figures, but the compressor energy consumption for the HEAHP is 9-13% lower. The increase in COP in cooling mode is between 10-19%.

In heating mode, COP results are even better, being 15-20% higher for the HEAHP compared to the R-22 RHPU. The way this was realised was different than in the cooling mode: a significant increase in heating capacity (between 11-23%) was realised with the same (or even slightly lower) compressor energy consumption.

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Annex 24 finalised: “Ab-sorption machines for heating and cooling in future energy systems”

Robert Tozer, UK

The work of Annex 24 has been concluded with the publication of the final report “Ab-sorption machines for heating and cooling in future energy systems”. The report summarises the work done and describes sorption technology, potential applications, experience, technical development, country-specific issues, and gives an outlook to the future. This article summarises the Annex 24 final report.

The title of Annex 24 focuses attention on the technology of the known absorption cycles. However, the splitting of the word “absorption” into “ab-sorption” (with a hyphen), emphasises that a broader view is taken, embracing all sorption technologies. The title also spells out the prime functions of the machine (to cool and heat), and of the Annex (to look into the future of this technology). Furthermore, the objectives of the Annex state that an understanding of actual systems is needed to appreciate the market barriers to the adoption of sorption technologies, and when they benefit the environment. Finally, recommendations are made regarding policies and R&D, to enable these technologies to be better assisted by market pull, especially when they offer environmental benefits.

Applications

The work on Annex 24 considered the highly important residential and commercial/institutional markets, mostly concerned with air-conditioning of buildings. In addition, applications are identified and discussed for the industrial market, including refrigeration, food-storage cooling, process cooling and process heating at various temperature ranges.

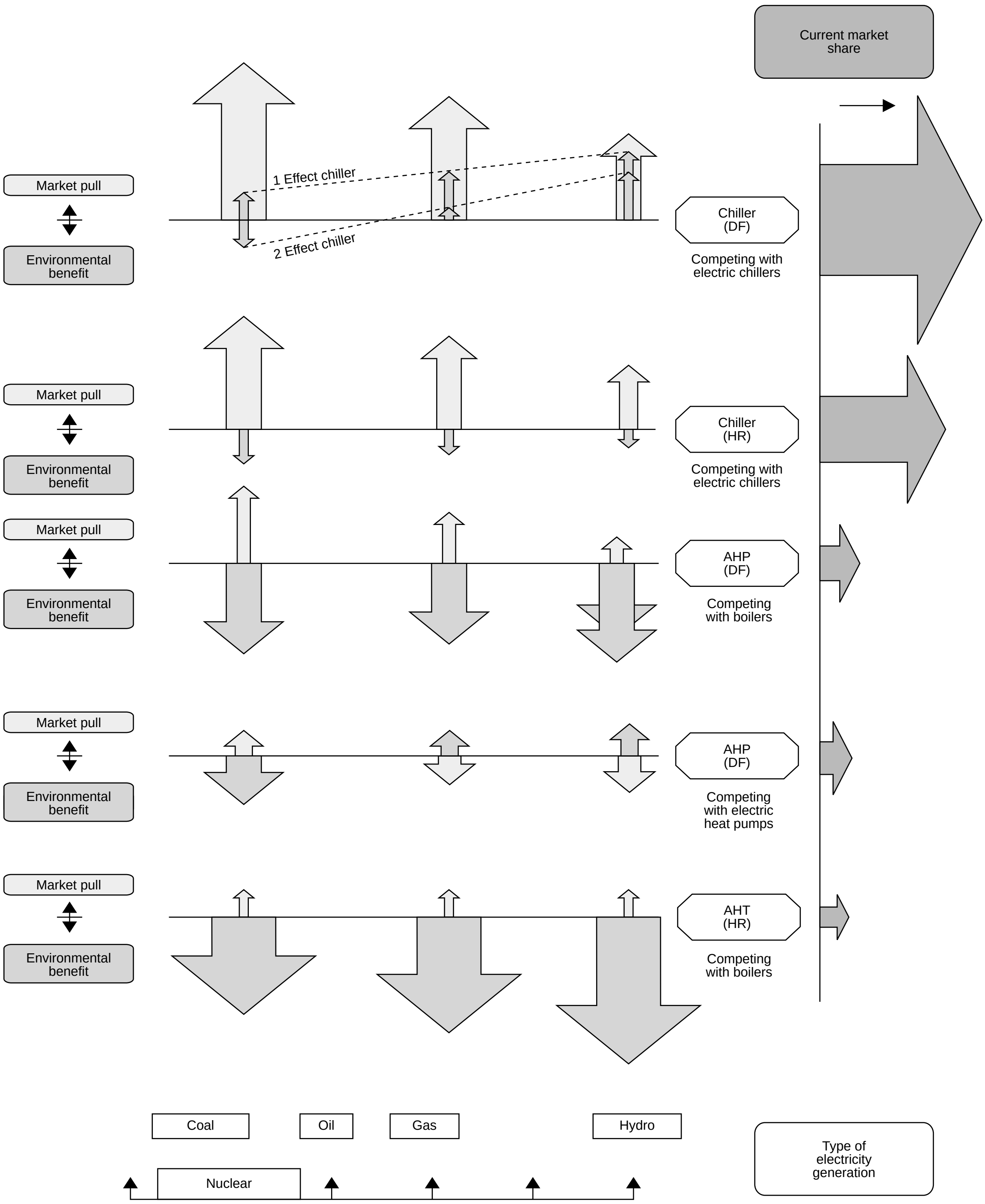
Waste heat is important for driving absorption chillers, if a suitable cooling demand has to be met. Flue-gas cleaning (which is generally mandatory) is the simplest and most direct method of recovering what would otherwise be waste heat, mostly vented to the atmosphere via cooling towers. Cooling tower water is a source of lower-temperature waste heat that may also be of interest.

Other interesting industrial applications are absorption cooling or heating combined with co-generation, desiccant cooling, gas turbine inlet air cooling, combining absorption chillers with district heating systems, direct-fired absorption heat pumps (AHPs), and a closed greenhouse concept (under development). In all such applications of sorption – or any other – technology, it is emphasised that proper system design is essential to reap real benefits.

System suitability

Most of the sorption market at this time comprises direct-fired absorption chillers, or hot water or steam absorption chillers indirectly driven by direct-fired boilers. In addition, the report covers absorption (reversible) heat pumps, absorption heat transformers, compression-absorption heat pumps, and *ad*sorption chillers and heat pumps. *Ad*sorption systems together with desiccant systems are also addressed.

After the review of systems and markets in the earlier chapters, the report chapter “Factors affecting the market” considers economic, environmental and policy issues. The geographical make-up of the world sorption market is then reviewed, followed by a number of practical operating and control considerations. These include vacuum



▲ *Figure 1: Sorption market and environment.**

* *The area of the arrows (current market share, market pull, environmental benefit) indicate the relative magnitude of the variables. The length and width of the arrows does not provide any additional information. DF = direct fired, HR = heat recovery.*

requirements, crystallisation, corrosion, maintenance, health and safety etc. Possible crystallisation and corrosion problems are still major concerns of some users, but are shown not to be problematic in practice with proper attention by producers, system designers, installers and maintainers. The lack of trained maintenance people is a major concern.

The following chapter in the report gives a brief survey of R&D activities.

Future opportunities

An analysis of the market factors shows that the market pull favours sorption technologies in different ways. Direct-fired absorption chillers are installed in areas where there is lack of mains electricity, or restrictions on using it to power electric-driven mechanical compression chillers. A chart (see **Figure 1**) illustrates the different market pull factors. It shows the following technologies, in decreasing order of market pull:

- direct-fired or boiler-driven absorption chillers; and
- absorption chillers driven by waste heat, heat recovery or combined heat and power (CHP) systems.

Far less prominent are:
- absorption heat pumps;
- absorption heat transformers; and finally
- *ad*sorption chillers.

The chart shows that *environmental benefit is inversely proportional to the market pull and share of sorption technologies.* Although the lack of knowledge of sorption technology by technicians, engineers, and professionals is an important barrier, the main market barrier is considered to be the relatively high first cost of the sorption plant.

In practice, different technologies are found to be most suitable for different countries, mainly depending on their energy infrastructure and particularly on how the country's electricity is produced. An energy infrastructure based mainly on coal-fired generation should favour sorption or other non-electric systems over compression systems. On the other side of the spectrum are countries that have a more renewable energy basis, which should favour electric-driven systems. The history of generation shows that energy production generally improves over time, which affects the benefits sorption technology can offer. Recommendations are made regarding policies to promote sorption technology (where it is environmentally beneficial), and with regard to future R&D.

Conclusions

The work of the Annex showed that the application of sorption technology cannot always be claimed as the best choice for the environment.

Detailed conclusions are that:
- Encouragement should be given to absorption and *ad*sorption chillers using waste heat, heat recovery or applied heat.
- Sorption chillers applied to CHP systems have an existing market pull and benefit the environment. However, the overall efficiency has to be relatively high with respect to each nation's power production, throughout the life of the system.
- Absorption heat pumps (including reversible heat pumps) will be available on the market in the short term. Due to their environmental benefits, they should be strongly supported, unless electric heat pumps are more beneficial, as occurs in countries with a high proportion of hydroelectricity and even gas energy.
- Absorption heat transformers and compression-absorption heat pumps offer excellent environmental benefits for industry. However, the latter are likely to have more market pull in the medium or long term.
- Direct-fired chillers should be phased out whenever they do not prove to be environmentally beneficial.

Recommendations

Technically, it is suggested that the main emphasis of future work could be on sorption applications of waste heat / heat recovery and process heat, but other factors need equal or greater attention. These other factors include the study of the effect of existing taxes and economic incentives, and formulation of recommendation for such measures. Attention should furthermore be paid to: system capital cost reduction studies, a more thorough study of environmental benefits and new potential markets, and the need to assemble a representative portfolio of Case Studies and Demonstration Projects. A new Annex proposal was discussed at the Heat Pump Programme Executive Committee Meeting, November 2000. Results of this discussion were not known at the time of writing.

Other work and ordering

The final report can be ordered from the IEA Heat Pump Centre for NLG 300 (NLG 100 in Annex member countries); for address, see back cover. The Annex also published its third workshop proceedings, with information from the San Francisco and Turin working meetings (NLG 180 or NLG 60 in Annex member countries). An order form is stapled in this Newsletter.

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Electrical compression cooling versus absorption cooling - a comparison

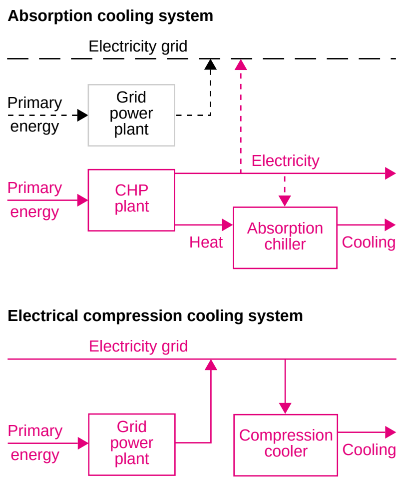
Harry Hondeman, The Netherlands

Within the context of Annex 24, a comparison is presented between two types of cooling systems: one using an electrical compression chiller and the other using an absorption chiller. The absorption chillers considered are all driven by heat from CHP (Combined Heat and Power) units. The comparison focuses on the relative levels of primary energy consumption and CO_2 emission. A spreadsheet program is used to calculate these relative levels.

Introduction

This article focuses on the Dutch situation. In the Netherlands, Combined Heat and Power units (CHPs) are a popular method for generating heat and electricity. The heat generated can be used to drive an absorption chiller and provide cooling. This article compares absorption chillers driven by heat supplied by a CHP with electrically-powered chillers. In order to compare the overall effect of cooling on fossil fuel consumption and on CO_2 emissions, it is necessary to consider the total process. **Figure 1** is an overall representation of both cooling systems.

In both systems, fossil fuel is converted into heat and/or electricity after which heat or electricity is used to provide cooling. As the CHP plays a central role in determining the efficiency of the overall absorption cooling process, it is important to understand how CHPs work. There are two basic types of CHPs: the “heat-focused” type and the “electricity-focused” type.



▲ *Figure 1: Schematic overview of absorption cooling and electrical cooling.*

The heat-focused CHP is meant primarily to supply heat, and the electricity generated is a high-value by-product that can be fed to the national power grid. Such CHPs are, for example, used for farming under glass to heat greenhouses. The operation of such a CHP is determined primarily by the demand for heat. Typically, such units are powered by gas engines.

The electricity-focused CHP is meant primarily to supply electricity, and the heat generated is a by-product that can be used for various purposes - for example powering an absorption chiller. It is typically a combined cycle CHP, which consists of a gas-fired turbine in combination with an exhaust-gas-driven steam generator. The heat contained in the exhaust gases from the turbine is used to produce high-pressure steam in the steam generator. If the system does not need to supply heat, the temperature in the condenser unit of the steam generator is generally only 5-10°C above ambient temperature, which is too little to allow much practical use of the waste heat. State-of-the-art combined cycle power plants have an electrical efficiency of 55% when operation is optimised for the production of electricity. However, if the CHP also has to supply heat for driving an absorption chiller, the heat from the steam cycle must be drawn off at a higher pressure so that it can be condensed at a higher temperature (for example 120°C). As a result, the electrical efficiency of the CHP unit falls to 52%.

Calculation method

A spreadsheet program is used to calculate the overall energy efficiencies and CO_2 emissions of the two systems depicted in Figure 1. In order to use the spreadsheet program, one must first enter values for the energy conversion efficiencies and energy losses associated with the various processes in Figure 1, as well as for the CO_2 emissions generated per unit of fossil fuel used. The spreadsheet will be added to the HPC website shortly, allowing interested parties to enter their own data on efficiencies, losses and CO_2 emission, and to calculate results for their own particular situation. Data for the Dutch situation, as used in this paper, are presented in **Tables 1** and **2**.

Table 1 presents three reference efficiency scenarios with which fossil fuel is converted into electricity by the grid power plant depicted in Figure 1. The spreadsheet program is used to make calculations for all three scenarios.

In order to make the calculations, the following assumptions were made:

- when using a heat-focused CHP to produce heat for driving an absorption chiller: The electricity production by the CHP leads to the elimination of an equivalent amount of public grid electricity production capacity. The electrical efficiency of the CHP (36%) is lower than that of the public power plants in the various reference scenarios. An extra amount of fossil fuel is needed to compensate for the lower electrical efficiency of the CHP unit in comparison to the public grid. This extra amount of fossil fuel is the energy cost of generating the useful heat supplied by the CHP unit, and is used as such in the calculations. For CO_2 emissions, the same procedure is applied. However, the power plants in two reference scenarios emit *more* CO_2 than the CHP unit. Therefore, a *reduction* of CO_2 emissions is the cost of the generated heat in these cases;

- when using an electricity-focused CHP to produce heat for an absorption chiller: Heat is the by-product. Eliminating some potential production capacity at the "electricity-focused" CHP plant in order to produce heat necessitates an equivalent amount of electricity production elsewhere in the grid. The amount of extra fossil fuel needed to compensate for this lowering of the electrical output by generating the electricity by another plant in the grid is the energy cost of generating the useful heat supplied by the CHP unit, and is used as such in the calculations. For CO_2 emissions, a similar procedure is applied.

Table 1: Efficiency of electricity generation in three "standardised" types of public power plants in the Netherlands

	code	fuel	efficiency %	CO_2 emission kg/GJ
Best available technology	BAT	gas	55.0	56
Average national grid	ANG	mix	42.0	73
Phase-out power plant	POP	coal	37.0	98

Table 2: Energy conversion efficiencies and energy losses for the various steps in Figure 1

Heat-focused CHP:		
CHP elect. eff.	36	%
CHP overall eff.	85	%
Electricity-focused CHP with heat drawn off:		
CHP elec. eff.	52	%
CHP overall eff.	85	%
Absorption cooling COP_{th}*	0.70	-
Absorption cooling R_{el} **	40	-
Distribution loss electricity grid	5	%
Distribution loss heat distribution	10	%

** COP_{th} = cooling capacity/thermal energy input*
*** R_{el} = cooling capacity/auxiliary electrical input*

The remaining data in Table 2 are needed to calculate the conversion efficiencies of the two cooling systems in Figure 1 and the energy distribution losses in the system.

Results and discussion

Heat-focused CHPs

The results calculated for the energy comparison of compression cooling and absorption cooling driven by a heat-focused CHP are presented in **Figure 2**.

The solid curve passes through those points at which the energy efficiency of both cooling systems is equal. At these points, the values for the efficiency of the power plant used as a reference and for the COP (Coefficient Of Performance = cooling capacity/ electrical input) of the compression chiller are such that both cooling systems are equally efficient. The red area above and to the right of the solid line represents those combinations of values in which compression cooling is more efficient. The blue area below and to the left of the solid line defines the range of values in which absorption cooling is more efficient.

Modern technologies make it possible to achieve a COP of 5 for electrical compression cooling. Modern cooling plants used in the food industry and for cooling buildings can even achieve a COP higher than 5. Assuming a COP of 5 or higher, Figure 2 shows that if the efficiency of the reference power plant exceeds 42%, then the energy efficiency of electrical compression cooling is higher than that of absorption cooling.

The efficiency of most power plants in the Netherlands is 42% or more. Modern gas-fired power plants can achieve an efficiency of 54%. In future, the average efficiency of power plants is expected to increase further. At present, the useful life span of an absorption cooling plant is almost 15 years. Decisions on whether or not to install absorption chillers for cooling should be based on energy efficiencies at present as well as in the future.

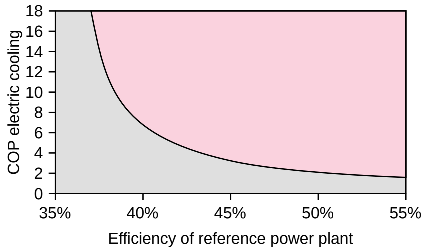
Figure 3 presents the results of the calculated relative CO_2 emissions for the two cooling systems.

The amount of CO_2 emissions depends not only on the energy efficiency of the power plant but also on the type of fuel used (see Table 1). As different types of fuel are used in the reference scenarios, the results are given separately for each scenario. As expected, the CO_2 emissions per unit of cooling capacity for electrical compression cooling decrease as the COP of the cooling system increases. For absorption cooling, two scenarios (POP, ANG) result in negative CO_2 emissions. The reason is that the gas-fired CHP unit produces less CO_2 than the coal- or oil-fired reference power plants in these cases. This causes negative "CO_2 emission cost" for the heat to drive the absorption chiller, and therefore negative CO_2 emissions for absorption cooling. Figure 3 shows that in the POP reference scenario this reduction would be considerable. In the BAT scenario all power plants are gas-fired. As a matter of fact, if the COP of the electrical chiller is greater than 1.6, compression cooling produces less CO_2 emissions than absorption cooling in this scenario.

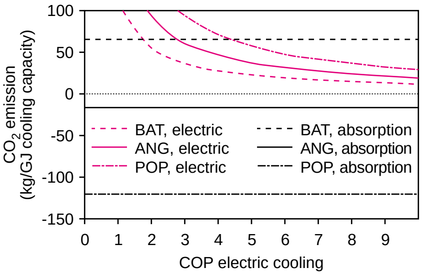
Electricity-focused CHPs

Figure 4 summarises the spreadsheet calculations for the energy comparison when the absorption chiller is driven by heat from an electricity-focused CHP.

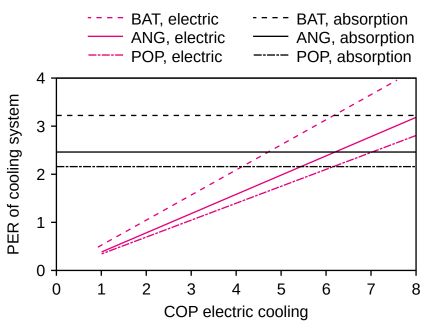
The PER (Primary Energy Ratio) on the Y-axis is equal to the cooling capacity delivered by the system per unit of primary energy input to the system.



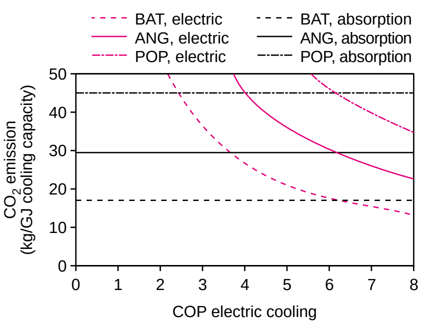
▲ *Figure 2: Comparison of energy efficiency of electrical compression cooling and absorption cooling driven by heat-focused CHP.*



▲ *Figure 3: Comparison of CO_2 emissions for electrical compression cooling and absorption cooling driven by heat-focused CHP.*



▲ *Figure 4: Comparison of energy efficiency of electrical compression cooling and absorption cooling driven by electricity-focused CHP.*



▲ *Figure 5: Comparison of CO_2 emissions for electrical compression cooling and absorption cooling driven by electricity-focused CHP.*

Again, results are presented for each reference scenario. Figure 4 shows that, regardless of the scenario chosen, if the COP for the compression chiller is greater than 6.1, then compression cooling is more favourable from an energy perspective. The reason why the reference scenario, and therefore the efficiency of the power grid, has no influence on the "break-even" point when comparing the two systems can be explained as follows.

As explained earlier, the energy cost of the power delivered by the CHP to the absorption cooler is defined as the extra amount of fossil fuel needed to compensate for the reduced electricity generation capacity. This extra amount is proportional to the efficiency of the reference power plant used to generate the compensating electricity. For the compression cooling system, the efficiency is also proportional to the efficiency of the reference power plant and to the COP of the compression cooler. When the efficiencies for the two cooling systems are assumed to be equal, the efficiency of the reference power plant drops out of the equation, as it is present on both sides. Therefore, there is only one COP of the compression cooler where the efficiencies of both cooling systems are equal, regardless of the efficiency of the reference power plant.

From Figure 4 it is clear that, from an energy perspective, compression cooling is more favourable than absorption cooling driven by an electricity-focused CHP only if the COP for the compression cooler is greater than 6.1. In other words, the break-even point is a COP of 6.1.

The results calculated for CO_2 emissions are summarised in **Figure 5**.

Figure 5 shows a comparable result for CO_2 emissions as for energy efficiency. The break-even point, regardless of the scenario chosen, is a COP of 6.1. At COP values higher than 6.1, compression cooling becomes more favourable. The reasoning here is the same as in the energy comparison presented above.

Conclusion

If electrical compression cooling is compared to absorption cooling driven by heat-focused CHPs, compression cooling is more favourable from an energy efficiency point of view if the COP of the compression chiller is greater than 5 (which is technically quite feasible nowadays) and the electrical efficiency of the power grid is 42% or greater. From the perspective of CO_2 emissions, compression cooling is shown to be more favourable only if the reference grid is of the BAT (Best Available Technology) type and the COP of the electrical chiller is greater than 1.6. Otherwise, absorption cooling is more favourable.

If electrical compression cooling is compared to absorption cooling driven by electricity-focused CHPs, then electrical compression cooling is more favourable if the COP of the electrical chiller is greater than 6.1. If the COP is less than 6.1, absorption cooling is more favourable. This is true from the perspective of energy efficiency as well as CO_2 emissions and regardless of which reference scenario is chosen for the electricity grid.

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Commercial/Institutional Heat Pump Systems in Cold Climates

Doug Cane and Jeremy Garnett, August 2000, 120 pages. Available from: Caddet Energy Efficiency, PO Box 17, 6130 AA Sittard, the Netherlands. Fax: +31-46-4510389. E-mail: caddet@caddet-ee.org. Price: depending on country.

This publication provides the reader with guidance on heat pump system selection, taking into account factors such as cost, requirements for and advantages and disadvantages of various types of systems. The conclusions are based on the analysis of 15 case studies, of which six involved ground heat exchanger systems, five had groundwater wells and two involved surface water. The demonstration projects were located in Canada, United States, Norway, the Netherlands and Japan. The Analysis Report (no. 27) concludes with a Technology Trends section.

High-Temperature Underground Thermal Energy Storage

B. Sanner (ed.), Giessener Geologische Schriften Nr 67, Lenz-Verlag Giessen, Germany, 158 pp, Price DEM 36 (~USD 17.50) ISSN 0340-0654

This publication discusses experiences from experiments, pilot and demonstration plants with high-temperature (50-150ºC) underground thermal energy storage. It treats economic, thermal and energetic, chemical and environmental aspects and deals with site investigation and design. The publication is the result of Phase 1 of Annex 12 of the IEA Implementing Agreement “Energy Conservation through Energy Storage (ECES)”. See for more information http://cevre.cu.edu.tr/eces/a12.html.

A New Method for Determining the Thermal Properties of Soil Formations from In-Situ Field Tests

J.A. Shonder, J.V. Beck, available for download from the FEMP (US Federal Energy Management Program) Internet site at: http://www.eren.doe.gov/femp/financing/ghpresources.html. For more information contact John Shonder at shonderja@ornl.gov.

In order to design cost-effective systems, designers of GHP systems with vertical ground heat exchangers need reliable data on the thermal properties of the soil/rock formation. This report presents a new method for determining thermal properties from short-term in situ tests using a parameter estimation technique. Unlike other analysis methods, this new method is not affected by short-term variations in heat input during the test. It can accurately determine properties from short-term in-situ field tests. The method has been laboratory and field-tested. A Windows-based program incorporating the Geothermal Properties Measurement model has been developed and is being distributed free of charge via the web site indicated above.

Generic Guide Specification for GHP [geothermal heat pump] Installation

Available for download from the FEMP (US Federal Energy Management Program) Internet site at: http://www.eren.doe.gov/femp/financing/ghpresources.html. For more information contact Warren Thomas at thomaswk@ornl.gov.

These guide specifications were developed by Oak Ridge National Laboratory (ORNL), USA under the US Department of Energy’s Federal Energy Management Program, to assist federal agency sites and engineers in the preparation of construction specifications for geothermal heat pump (GHP) projects. The guide specifications are in the industry-standard Construction Specification Institute (CSI) format and cover several of the most popular members of the family of GHP systems. These guide specifications are applicable to all GHP projects.

Guidelines for Recovery and Recycling Systems – Refrigeration Sector

Released by UNEP DTIE OzonAction Programme. Available from SMI Ltd, PO Box 119 Stevenage, Hertfordshire SG1 4TP, UK. Fax +44 (1438) 748 844. Price: USD 75. ISBN 92-807-1691-3. Online orders: http://www.earthprint.com.

Recovery and recycling of ozone depleting refrigerants is a key strategic element for protecting the ozone layer. UNEP DTIE’s OzonAction Programme is releasing the recovery and recycling systems guidelines – refrigeration sector. The objective of the Guidelines is to help governments and industry in developing countries to design and establish recovery and recycling systems for CFC refrigerants and to operate such systems efficiently. This will make recovered or recycled refrigerant available for re-use, thus reducing the need for virgin CFC refrigerants. The Guidelines will be particularly useful in light of the first control measure applicable to developing countries: the freeze in consumption of Annex A CFCs by July 1999. The Guidelines will be translated into Chinese, Arabic, Spanish and French.

The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana: Final Report.

Authors: P.J. Hughes and J.A. Shonder, ORNL/CON-460. For further information contact: Patrick Hughes at mailto:hughespj1@ornl.gov. For a complimentary copy of this report, while supplies last, contact Susan Rider at hyperlink mailto:ridersl@ornl.gov or Fax: +1-865-574-9329.

This report documents an Oak Ridge National Laboratory evaluation of an energy retrofit of 4003 family housing units at Fort Polk, Louisiana, under an energy savings performance contract. Replacement of the heating, cooling, and water heating systems in these housing units with geothermal heat pumps (GHPs) anchored the retrofit; low-flow shower heads and compact fluorescent lighting were also installed, as well as attic insulation where needed. Statistically valid findings indicate that the project will save 2.5 million kWh, or 32.5% of the pre-retrofit whole-community electrical consumption, and 100% of the whole-community gas previously used for space conditioning and water heating in a typical meteorological year.

Available from the HPC

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Annex 24 final report, October 2000
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Residential heat pumps and energy-efficient heat and cold distribution and ventilation systems
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Natural Working Fluids – a challenge for the future
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International Heat Pump Status and Policy Review: 1993-1996
Analysis Study, August 1999
Order no. HPC-AR-7, NLG 480 or
NLG 160 in HPC member countries

Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids
Final Report, December 1998
Order No. HPP-AN22-4, NLG 100 in CA, CH, DK, JP, NL, NO, UK and US.
(Not available for other countries until 5 June 2001)

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

2001

ASHRAE Winter Meeting
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Atlanta, GA 30329, USA
Fax: +1-404-3215478
E-mail: jyoung@ashrae.org

Arab-African Conference for Refrigeration and Air Conditioning
29 April-1 May 2001
Co-sponsored by IIR, Commission B2, E1, E2
Contact: Prof. Dr M. Nagi Shatla
The American University in Cairo
PO Box 2511, Cairo, Egypt
Fax: +20-2-7957565
E-mail: Counslor@aucegypt.edu

ASHRAE Annual meeting, including symposium "Experiences with Alternative Refrigerants in Unitary Split Systems"
23-27 June 2001 / Cincinnati, USA
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E-mail: jyoung@ashrae.org

2nd International Heat Powered Cycles Conference – Cooling, Heating and Power Generation Systems
5-7 September 2001 / Paris, France
Contact: Dr Pierre Neveu, CNAM, Paris
E-mail: neveupi@cnam.fr
Information: http://www2.cnam.fr/iffi/hpc.htm

10th International Stirling Engine Conference (ISEC)
24-28 September 2001 / Osnabrück, Germany
Contact: Mrs Dr Eleni Konstantinidou
VDI-Society of Energy Technology
PO Box 101139, D-40002 Düsseldorf, Germany
Fax: +49-211-6214161
E-mail: konstantinidou@vdi.de

Thermophysical Properties and Transfer Processes of New Refrigerants
3-5 October 2001 / Paderborn, Germany
Co-sponsored by IIR, Commission B1
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Symposium on the Analysis and Applications of Heat Pump and Refrigeration Systems
(2 Sessions of) ASME Congress
11-16 November 2001 / New York, USA
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2002

International Sorption Conference 2002
24-27 September 2002 / Shanghai, China
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5th Gustav Lorentzen Conference on Natural Working Fluids
5-8 October 2002 / Guangzhou, China
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IEA Heat Pump Programme events

7th IEA Heat Pump Conference
tentatively 20-22 May 2002 / Beijing, China
Host: China Academy of Building Research
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Experiences from operating heat pump systems

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International Energy Agency

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

IEA Heat Pump Programme

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

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

Novem

Netherlands agency for energy and the environment

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