IEA Heat Pump CENTRE
NEWSLETTER
VOLUME 20
NO. 1/2002

Alternative working fluids in practice

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Natural working fluids in Norwegian heat pump systems

An energy efficient CO_2-based heat pump water heater

IEA
OECD
heat pump
centre

In this issue

Alternative refrigerants in practice /refrigerant conservation

This Newsletter focuses on alternative refrigerants in new and promising applications, as well as on refrigerant (CFC/HCFC/HFC) recovery, recycling and reclamation. It covers the application of HFCs, HCs, NH_3, CO_2 and other alternative refrigerants, as well as operational experience with alternative refrigerants and secondary fluids in refrigeration systems.

Front cover: CO_2-based heat pump water heater (Frostmann AS)

COLOPHON

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Raymond Beuken, IEA Heat Pump Centre;
Eli Birnbaum, Jac. Janssen, Derix**Hamerslag*
Production: Novem Support Group
de Vormgeverij, Meerssen

Frequency: quarterly

HEAT PUMP NEWS

TOPICAL ARTICLES

NON-TOPICAL ARTICLE

Newsletter transitional phase

Adapting to a fast changing world is often the key to continued success. This is certainly true for the international heat pump and related sectors. With a wide range of different stakeholders and modern communication media enabling everyone to take part in the information process, it is essential to meet stakeholder needs using modern communication mechanisms in a global network.

The Heat Pump Newsletter has been and will continue to be one of the main information vehicles of the IEA Heat Pump Centre. This issue of the Newsletter is the first one in a transitional year for the Heat Pump Centre. The biggest change for the moment is the electronic appearance of the Newsletter and the reduction of the number of pages. What additional changes may be introduced later has not yet been decided. However, it is our intention to put more emphasis on News and at the same time make increased use of the Internet for information.

These changes are part of an ongoing restructuring of the IEA Heat Pump Programme. The term of the Programme will end in December 2002, and the prospects of continuation for another 5 years are promising. That should come as no surprise, as the work on heat pumps is not yet complete. There is still an important mission to be fulfilled and objectives to be achieved. Several ideas for new international activities (Annexes) have emerged and are being worked out in proposals. These new activities are crucial to the future of the Programme and will hopefully attract new members as well.

The Heat Pump Centre has been playing a central role in the Programme since its inception in 1982. This role and position will become stronger and more significant from now on, as the Centre has been anchored in the Programme serving all of its 15 member countries in different parts of the world. This is a major improvement and it will provide a solid basis for the new style Heat Pump Centre to continue in the future as the leading information centre on heat pumps and air conditioning. We trust that we will provide you with high quality news and information on the fascinating features of thermodynamic heating and cooling, from different parts of the world.

Jos W.J. Bouma
Manager Heat Pump Centre

Heat pump news

General

ASHRAE publishes refrigeration safety standard

USA – One of ASHRAE's oldest standards has a new title. The title and scope of ANSI/ASHRAE standard 15-2001, Safety Standard for Refrigerating Systems, was changed to include absorption refrigeration machines and water as a refrigerant.

The standard establishes procedures for operating equipment and systems to assure the safety of building occupants and system technicians. In recent years, water/lithium bromide absorption chillers have gained a foothold into the commercial building cooling market. Such equipment was previously excluded from the scope of the standard. That has been corrected in the new version.

Standard 15 was first published in 1919 as Tentative Code for the Regulation of Refrigerating Machines and Refrigerants in recognition of the need for cities and states to enact safety regulations.

Source: ASHRAE
Information: http://www.ashrae.org

Heat pump and drilling technology – 2 in 1?

Germany/Austria – The demand for heat pumps for heating applications in combination with a vertical ground probe has risen strongly in Germany and Austria. Farsighted heat pump manufacturers therefore see the need to provide drilling services for potential clients. Such an arrangement means that building owners who wish to order such heating systems only have to deal with one company and that only one warranty is involved.

According to the German and Austrian industry, there is a shortage of certified drilling companies for installing vertical ground probes for heat pumps. One reason for this is the ban on CFCs, which has caused a shift from split unit heat pumps to compact, wired, ready-for-connection heat pumps.

Recently, one company took the initiative to start operating in a part of Austria and Germany with two modern double-rotor drilling machines. This company aims to enter into an alliance with companies that professionally offer ground probes. Such alliances can reduce installation costs for building owners wanting to install ground-coupled heat pump systems.

Source: Luft- und Kältetechnik, 11/2001

Now available from the HPC:

Hands-on experience with heat pumps in buildings (CD-ROM)

The proceedings of the international workshop, held on 10-11 October 2001 in Arnhem (the Netherlands), by the HPC and the International Power Utility Heat Pump Committee (IPUHPC).
Publication date: 01 April 2002; Full price: EUR 90; Order no. HPC-WR-23.
Discount of 67% possible: see for more information: http://www.heatpumpcentre.org.

Technology and applications

European heat pump systems may need fixed leak detectors

UK – New EU regulations which require the installation of refrigerant leak detectors in occupied spaces as well as machine rooms became mandatory in October 2000 but have yet to make an impact on refrigerating and air conditioning (RAC) equipment suppliers and users. Very few people realise the far-reaching implications of this legislation, says Dr Lorcan J Maher writing in RAC magazine (UK).

European standard EN378 requires fixed leak detectors, not only in machine rooms but in all Category A buildings – which includes dwellings and public buildings such as theatres, restaurants and supermarkets – where potential refrigerant leaks may exceed specified MAC values. All systems could be affected by this legislation.

Source: JARN, December 25, 2001

"Out of box" idea for heating, cooling

USA – A 0.5 km^2 medical campus served by the largest lake-coupled system in the United States has been recognised for technological innovation by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).

The system at Great River Medical Center in West Burlington, Iowa, is also one of the first applications of such technology in a hospital. The 5,300 kW ground-coupled system uses a 60,000 m^2 manmade lake that also serves as a storm retention basin and as the heat source and heat sink for the system.

The system includes 105 coil banks, each with 1,280 m of piping near the bottom of the 4 m deep lake, which act as heat exchangers. Two 112 kW pumps move water from the bottom of the lake through plastic piping into the buildings. The pumps move more than 19 m^3 of water per minute through a re-circulating piping system. The water passes through more than 800 heat pumps that provide individual climate control in office rooms and patient treatment rooms.

The facility consumes 31 percent less energy than comparable facilities of this size and type while maintaining a comfortable and safe environment.

Source: ASHRAE
Information: http://www.ashrae.org

Heat from the swamp

Germany – The heating system for the head office of Dywidag, a construction company in Munich, was retrofitted at a cost of over EUR 250,000. The building (**see Figure 1**), constructed in 1978, has a useful surface of 26,000 m^2. It literally stands in the water of the 'Erdinger' swamp. The 22-year-old outdated and over-dimensioned steam boiler system was replaced by four heat pumps, using ground water as a source (**see Figure 2**). The power output of 840 kW is used to cool down the water volume by 4 K and to realise a supply temperature of 70°C.

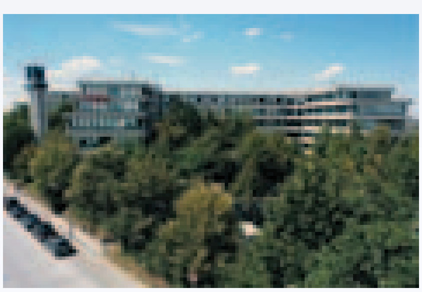

Figure 1: Dywidag office building.

Figure 2: The four heat pumps.

In addition to the heat pumps, a natural-gas-fired peak load boiler is installed, which supplies the kitchen with steam.

The installed heating capacity is now 1,740 kW, compared to 3,720 kW before the retrofitting. The electrically driven heat pumps are switched on and off, depending on heat demand. To reduce electricity demand peaks and overall demand, a 100 m^2 thermal buffer is available, apart from the boiler. The air-conditioning system also benefits from the retrofitting. By means of a heat exchanger, over 500 kW of cooling capacity is extracted from the ground water.

The cold water supply temperature of is 16°C. This water is supplied to the existing heating surfaces and an additional 6,250 m^2 installed cooling ceiling in the offices.

Before the retrofitting operation, the yearly energy costs for the whole building were over EUR 100,000. In future, these costs should not exceed EUR 66,000, which would lead to a payback period of five years. The next heating period should confirm these calculations.

Source: Luft- und Kältetechnik, 1/2002

Working Fluids

CO_2 heat pump water heaters

Japan – As a result of criticism that HFC refrigerants contribute to global warming, research on refrigeration systems using CO_2 as refrigerant is underway.

In the past two years, several Japanese companies including Denso, Mitsubishi, Daikin, Sanyo, Hitachi and Matsushita have announced the development of CO_2 heat pump water heaters. Most of these models will be released in the spring of 2002.

Features common to all these CO_2 water heaters are high efficiency (year-round average COP higher than 3.0) and the ability to heat water to 90°C in a short time. They are environmentally friendly and safe due to the use of natural refrigerant CO_2, which has zero effect on the ozone layer and is non- toxic and non-flammable.

The Japanese market for hot water systems using electricity, gas or kerosene as a heat source is currently estimated at 4 million units/year. According to one manufacturer, the market share of heat pump water heaters using CO_2 as refrigerant will reach 10% within several years.

Source: JARN, December 25, 2001

CO_2 as refrigerant in heat pumps

Denmark – Denmark is one of the few countries with a specific tax on potential greenhouse gases such as HFC. This makes the application of CO_2 refrigeration systems economically feasible and attractive. Three Danish companies, Vesttherm, Lodam and the Danish Technological Institute are involved in developing heat pumps with CO_2 as refrigerant, which will be marketed by Vesttherm. The project started on 1 September 2000 and will be completed on 1 July 2002.

The overall purpose of the project is to promote the use of CO_2 as a substitute for HFCs, which are potential greenhouse gases. Particularly in indoor systems such as domestic hot water heat pumps, CO_2 is an outstanding substitute for HCFCs and HFCs. CO_2 can be used in a large number of applications in the Danish market. Particularly in small systems with capacities below 10 kW, CO_2 is promising. In addition to the domestic market, there is a potential export market, e.g. in third-world countries wishing to switch directly to natural refrigerants. A large part of the Danish heat pump shipment is exported to neighbouring countries. Germany, Switzerland and the Netherlands are major markets for Danish producers.

An important area where CO_2 can be used as a refrigerant is in domestic hot water heat pumps, where it is possible to make good use of the temperature glide in the gas cooler. Calculations show that it should be possible to increase the total annual efficiency of such systems by up to 50%. In Denmark, about 16,000 domestic hot water heat pumps have been installed, with an estimated total energy consumption of 28,000 MWh. The use of CO_2 in these systems could save 9,300 MWh per year, corresponding to a reduction in CO_2 emission of 7,280 tonnes per year. In recent years, the sales of domestic hot water heat pumps in Denmark has stagnated and now amounts to about 600 units per year, while the total production is currently 3,000 per year. In the coming years, a steep increase is expected both in the export and in the domestic shipment of hot water heat pumps in Denmark. The total sales of domestic hot water heat pumps are expected to reach 5,000 per year in 2002.

The use of CO_2 as refrigerant is not confined to domestic hot water heat pumps. In the long term, CO_2 is also of interest for other types of heat pump installations. One possibility that will be investigated is the use of CO_2 in combined systems, in which heat pumps provide part of the heat demand of a house. Such combined systems are widely used in Sweden, but they all use HFCs.

Source: Luft- und Kältetechnik, 1/2002
More information: http://www.uk.teknologisk.dk
Contact: Mr Claus S. Poulsen, Project manager
E-mail: claus.s.poulsen@teknologisk.dk

Markets

Trends in refrigerant sales

France – Figures published by the French environment ministry show that CFCs accounted for less than 5% of the total 10,000 tonnes of refrigerants sold in 2000. Just over half of these were HCFCs and 44% HFCs. Compared with the preceding year, CFCs consumption fell by half, HCFCs remained virtually constant and the share of HFCs grew slightly.

Results for the early part of 2001 show that total demand was somewhat reduced and HFCs (notably R-404A and R-507) had gained ground over R-22. The greatest gain was for R-134a, mainly through its extensive use in automotive systems.

Source: JARN, December 25, 2001
E-mail: info@pyc.fr

New data on Spanish room AC market

Spain – A recently published survey by BSRIA shows that half the European market for room air conditioners is centred in Spain and Italy, being shared almost 50:50 between the two countries.

In 2000, Spain's total market for room air conditioners, worth USD 548 million, was made up predominantly of single splits (USD 418 million). An increase to about USD 582 million for all types of room air conditioners is expected for 2001 – primarily through the expansion of the single split market. In the next few years, the market for such units will continue to increase, with an increase of over 50% expected by 2005 compared to the present level – according to BSRIA.

Source: JARN, December 25, 2001

HVAC Shipment forecast for 2002

Canada – The Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI) published the annual statistics forecast for the year 2002, indicating that HVAC shipments will show a small increase over year 2001. Residential air-conditioning system shipments are expected to increase by 6%, commercial air conditioning by 4% and residential furnace shipments by 1%.

"Residential air conditioning" means split system air conditioning and heat pumps up to 5 tons; "commercial air conditioning" means rooftops (combination heat/cool), packaged cooling and packaged heat pumps; "furnace" means residential forced air furnaces of all types (gas, oil, electric and combination).

The 2000 actual, projected 2001 and forecasted 2002 figures are as follows.

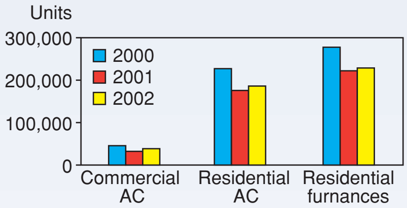

Figure 1: Canadian HVAC shipment forecast for 2002

Source: JARN, January 25, 2002

Chinese AC market no. 1

China – BSRIA has just launched a major new study of the Chinese air-conditioning market, predicting that it will become the number one market by 2005.

The Chinese market has increased dramatically to a gigantic USD 6.2 billion and 11 million units in 2001. It is now the second largest market in the world behind the USA, and is poised to become the world number one by 2005. The market is still immature with residential urban penetration of air conditioning at only 25% and less than 5% for the rural population. In particular, very strong growth is expected in large and medium-sized cities in the eastern and central regions and in the prosperous towns around the Pearl and Yangtze River deltas.

The enormous and rapidly increasing RAC (room air conditioning) minisplits market is changing with prices falling dramatically at the same time as a significant upgrade in products with very sharp increases in the proportion of heat pumps and the use of filters and inverters. By volume, the Chinese chiller market is now the largest market in the world with sales of 34,000 units in 2001. The pattern of chiller sales is changing significantly. Over half of all chiller sales are now heat pumps, with a trend towards installations of several similar chillers instead of one large chiller, so that part loading is more efficient.

Source: BSRIA
Information: www.bsria.co.uk,
fax: +44 (0) 1344 487575

Natural working fluids in Norwegian heat pump systems

Jørn Stene, Norway

Various naturally occurring substances have been proposed as working fluids in heat pumps as alternatives to HFCs. Several of these alternative fluids – such as ammonia, hydrocarbons and CO_2 – have found practical use in different heat pump installations in Norway, often with promising results.

Introduction

Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) have long been widely used as working fluids in heat pumping systems. Unfortunately, these substances contribute to ozone depletion as well as global warming. During the past decade, extensive international efforts have therefore been devoted to developing acceptable alternatives. One of the options considered was the use of hydrofluorocarbons (HFCs), which do not deplete the ozone layer but which still contribute to global warming. A more long-term strategy has been the use of naturally occurring and ecologically safe substances such as ammonia, hydrocarbons and carbon dioxide, which do not contribute to ozone depletion or global warming. Due to the considerable technological strides made in recent years, these natural working fluids are now considered viable long-term alternatives to the HFCs now used in many heat pump applications. This article reports on the use of various natural working fluids in several Norwegian heat pump systems, on the issues and technical designs involved and on some of the results achieved.

Ammonia as working fluid

Ammonia is the best-proven alternative among the natural working fluids, as it has been extensively used in industrial refrigerating plants for over a century. However, it has the disadvantage of being toxic. The strict standards and regulations for the construction and operation of ammonia-based heat pump systems have hampered their commercial application. In recent years, great efforts have been made to develop simple, automated, low-charge and more reasonably priced ammonia-based heat pump systems, which can be safely used in buildings situated in densely populated areas. The result has been a renewed interest in ammonia-based technology, particularly in Europe.

In order to ensure the safety of operating personnel as well as people inside and outside the building, the heat pump units and the machine room must be carefully designed and equipped with adequate safety equipment. Safety measures include the use of low-charge heat pump units (0.05 to 0.2 kg ammonia per kW), gas-tight machinery rooms or containers located on top of the building, fail-safe (emergency) ventilation systems with two-speed fans, leak detectors, alarm systems, ammonia absorption systems (scrubbers) and sprinkler (water spray) systems.

Norway has a long history of working with ammonia-based refrigerating plants. Due to its excellent thermo-physical properties, ammonia is also regarded as an important alternative for use in medium and large-capacity heat pump systems. Examples include the use of heat pumps in district heating and cooling systems, in heating and cooling commercial buildings, in fish farming plants, and the use of supercharged heat pumps in industrial applications. At present, more than 50 ammonia-based heat pumps are in operation in Norway, with heating capacities from a few hundred kW up to 8 MW.

In 1994, a large-capacity ammonia-based heat pump for space conditioning and hot water heating was installed at the Statoil Research Centre (with about 500 employees) in Trondheim, Norway. The heating and cooling demands at design conditions are 1.5 and 1.35 MW, respectively. The nominal heating capacity of the bivalent seawater heat pump is about 900 kW, and two identical units of 450 kW each were installed to achieve a high COP even at partial load operation (see **Figure 1**).

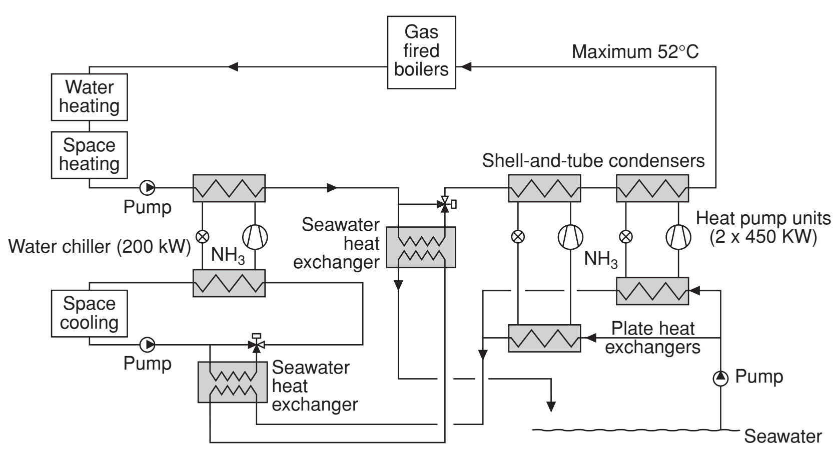

Figure 1: Example of an ammonia-based heat pump system for a commercial building.

Each of the two Sabroe-type units are equipped with two 25 bar single-stage, six cylinder reciprocating compressors, a titanium plate heat exchanger as evaporator and a shell-and-tube condenser. The ammonia charge is less than 0.2 kg per kW heating capacity. Auxiliary heating and back-up is provided by gas-fired boilers which are located in the same machinery room as the heat pump units. Since the machinery room is located inside the building on the ground floor, the room is gas-tight with self-closing doors. Other safety measures include leak detectors located above each heat pump unit, an alarm system, a fail-safe ventilation system, and an ammonia scrubber.

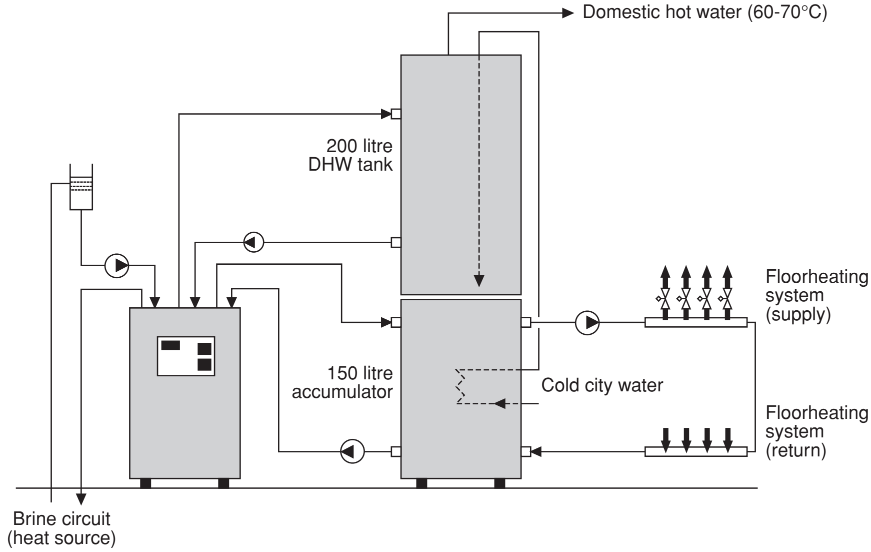

Figure 2: Example of a residential propane-based brine-to-water heat pump system.

Although the COP of the heat pump units is above four at design conditions, the Seasonal Performance Factor of the entire heating system is less than 2.5. This relatively poor performance is mainly caused by the gas-fired peak load system, which covers the entire heating load at low ambient temperatures, since the return temperature in the hydronic heat distribution system at these operating conditions is higher than the maximum supply temperature of the ammonia heat pump. As a consequence, the heat pump unit itself supplies less than 80% of the total annual heating demand of the building. This problem could have been resolved by using 40 bar reciprocating compressors or designing the hydronic heating system for a lower return temperature.

Hydrocarbon working fluids

Hydrocarbons are environmentally benign working fluids with excellent thermo-physical properties, which have been widely used in large refrigerating plants in the petrochemical industry. Due to technological developments and the establishment of new refrigeration standards for flammable working fluids, hydrocarbons are now regarded as safe and energy-efficient alternatives in low-charge systems such as beverage coolers, household refrigerators, brine/water-to-water heat pumps, water chillers and unitary air conditioning split-units. The hydrocarbons most commonly used in heat pumps are propane and propylene as well as binary blends of propane, iso-butane and ethane.

The use of hydrocarbon heat pumps in Norway is still quite rare, but a few heat pump suppliers are now offering residential propane-based brine-to-water units that provide space heating and domestic water heating. One supplier offers units with heating capacities ranging from about 4 kW to 11 kW at 0/45°C. The heat pumps are equipped with a scroll compressor, plate heat exchangers as evaporator, condenser and desuperheater (optional), a thermostatic expansion valve, and a sub-cooler (see **Figure 2**).

The sub-cooler utilises the cold brine to sub-cool the propane working fluid before throttling, which in turn increases the inlet brine temperature to the evaporator and ensures stable operation of the throttling valve. In accordance with prevailing safety standards, only soldered joints are used inside the cabinet, the pressostats are explosion proof, and the electrical connections and controller are sealed according to IP65. The propane charge for the various units on offer ranges from about 350 to 800 grams. For installations above ground level, the cabinet has a pipeline to the ambient air for draining of propane in case of leakage. For installations below ground level, an explosion proof fan, which is activated by a leak detector in the cabinet, is also required.

Water from the urban water supply is preheated in a finned coil in the accumulator tank for the floor heating system, and further heated to the desired domestic hot water temperature in a single-shell hot water tank by the desuperheater. A heat pump system with desuperheater will achieve a higher COP than a system that only preheats hot water for space heating, since such a heat pump unit can be used to satisfy the demand for both space heating and domestic hot water without an increase of the condensing temperature. In combination with a ground-coupled heat source and a low-temperature floor heating system, such a bivalent heat pump system will typically achieve a Seasonal Performance Factor of 3.0 to 3.5. This factor takes into account the energy needed for the circulation pumps and the electrical peak load.

Carbon Dioxide as working fluid

From an environmental and safety point of view, carbon dioxide (CO_2) is considered an ideal working fluid. It is non-toxic, non-flammable and does not contribute to ozone depletion or global warming. Ever since the first CO_2-based prototype heat pump system was constructed and monitored by NTNU-SINTEF in Norway in the early 1990's, considerable international research activity has been carried out in order to develop CO_2-based systems for the most promising application areas. In addition to feasibility studies, system analysis and monitoring of prototype plants, the development of different types of compressors, evaporators, gas coolers and throttling devices has been critical for the realisation of commercial products.

The most striking property of CO_2 as a working fluid is its low critical temperature (31.1°C). Most CO_2-based heat pumps will therefore reject heat at a supercritical pressure. Moreover, the heat is not rejected by condensation of the fluid at a constant temperature but by removal of sensible heat from the compressed gas at a gliding temperature. The temperature glide of the CO_2 gas in the gas cooler will typically range from 20 to 50°C, depending on the type of application. Although the theoretical COP of a simple transcritical CO_2 cycle is poor, it does have excellent thermo-physical properties. Due to the use of new and optimised component and system designs, the practical performance of various CO_2-based heat pump systems has become fully competitive and in some cases even superior when compared to state-of-the-art HFC-based systems. The supercritical CO_2-based heat pump process is particularly favourable for use in heat pump water heaters. The heating of water involves a large temperature glide, which leads to small heat transfer losses in the gas cooler. Since the efficiency of CO_2 compressors is higher than that of compressors for conventional working fluids, these systems can achieve a very competitive COP.

The worlds' first commercial prototype CO_2-based heat pump water heater was installed by the Norwegian company Frostmann/Finsam AS at the Norwegian food factory Eggprodukter AS in Larvik in 1999 (see **Figure 3**). The 22 kW heat pump unit utilises excess heat from a refrigerating plant as the heat source and supplies hot water of 70 to 80°C. The plant comprises a semi-hermetic, two-cylinder, single-stage reciprocating Dorin compressor, a counter flow tube-in-tube gas cooler, and a shell-and-tube evaporator. Due to the relatively high heat source temperature, the measured COP of the heat pump is as high as 5.5. The unit has been running for more than 500 hours without any operational problems.

Due to the superior performance and good operational characteristics of the above unit, Frostmann/Finsam is about to install a second such system in a block of flats in Norway. This system will extract heat from the exhaust air in the common ventilation system and satisfy the entire hot water demand for the flats.

Figure 3: The CO_2-based heat pump water heater (Photo by Frostmann AS).

Figure 4: Energy Award logo.

In December 2001, the CO_2-based heat pump water heater technology developed by NTNU-SINTEF was one of the finalists for the Financial Times Global Energy Awards (see **Figure 4**) – a clear indication that the technology has now achieved international recognition.

A Japanese connection

In 1999, the Japanese company Denso Corporation Ltd. signed an agreement with Pronova/Hydro from Norway to use the CO_2 technology developed at NTNU-SINTEF in a new generation of hot water heat pumps for the residential market. Denso has now developed a 4.5 kW CO_2-based unit for the Japanese market that utilises ambient air as the heat source and supplies hot water at 85°C. The Seasonal Performance Factor measured for the system is above three in the Tokyo climate. Serial production of the high-quality air-to-water CO_2-based heat pump water heater was started in May 2001, and the technology has become a great success in Japan. For more information about this Japanese project, see the article on page 10.

References

Stene, J., 1999: Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids". Final report from Annex 22 of the IEA Heat Pump Programme, report No. HPP-AN22-4. ISBN 90-73741-31-9.

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An energy efficient CO_2-based heat pump water heater

Kazutoshi Kusakari, Japan

A new system has been developed and is being marketed in Japan for providing domestic hot water. The system is based on a heat pump using CO_2 as working fluid; it extracts heat from ambient air during the night and is very cost-effective and energy efficient. Its widespread use could significantly decrease greenhouse gas emissions and their impact on global warming.

Summary

As the issue of global warming becomes increasingly important, so does the need to limit the production of greenhouse gases by reducing the use of fossil fuels via alternative, more energy-efficient technologies. About one third of end user residential energy consumption is used to provide domestic hot water, and most of this energy is presently generated by direct combustion of fossil fuels. Increased efficiencies and/or alternative technologies in this sector could therefore lead to significant reductions in greenhouse gas emissions. The Tokyo Electric Power Co., DENSO CORP., and the Central Research Institute of Electric Power Industry have jointly developed a heat pump water heater for residential use which uses a natural refrigerant, CO_2, as working fluid. The system extracts heat from ambient air and boasts a very high Coefficient Of Performance (COP), thus helping reduce fossil fuel consumption and the resultant impact on global warming. A test unit was successfully developed and tested in the field, and commercial models are now being marketed.

Characteristics of CO_2-based heat pump water heater

The system (**Figure 1**) works by using an electrically driven compressor to repeatedly compress the working fluid, followed by expansion, thereby extracting heat from ambient air and releasing it into the water. It has a higher Coefficient Of Performance (COP) than that of conventional combustion type water heaters using fossil fuel. By using a storage tank to store the hot water, it can be run at night on inexpensive nighttime electricity.

Previously, a fluorocarbon refrigerant (HCFC-22) was mainly used as the working fluid in the heat pump water heater. We switched to the natural refrigerant, CO_2, for two reasons. First, CO_2 is preferable from an environmental perspective, as it is a naturally occurring substance. Second, CO_2 is well suited for use with heating processes that have a wide range of temperature climb such as are used in a storage type water heater.

The characteristics of CO_2 as a working fluid are:

- CO_2 has little environmental impact, as its ozone depletion potential (ODP) is 0 and its global warming potential (GWP) is 1;
- CO_2 is inexpensive and safe as it is not toxic and not flammable;
- CO_2's critical temperature is low (31°C), and it can be used in a transcritical cycle where the high-pressure side of the cycle becomes supercritical for use in air conditioning and domestic hot water supply;
- in the case of a simple cycle, a high COP can be expected for a heating process with a wide range of temperature climb, such as once-through heating, but COP will be low for use in air conditioning;
- as CO_2 has a large heating capacity per refrigerant mass unit, the system can be compact;
- as CO_2 has a high heat transfer coefficient , the heat exchanger can be compact;
- as CO_2 refrigerant does not need to be recovered, no recovery costs are involved;
- as CO_2 works under high pressure, the equipment has to be specifically designed; CO_2 operates at a low

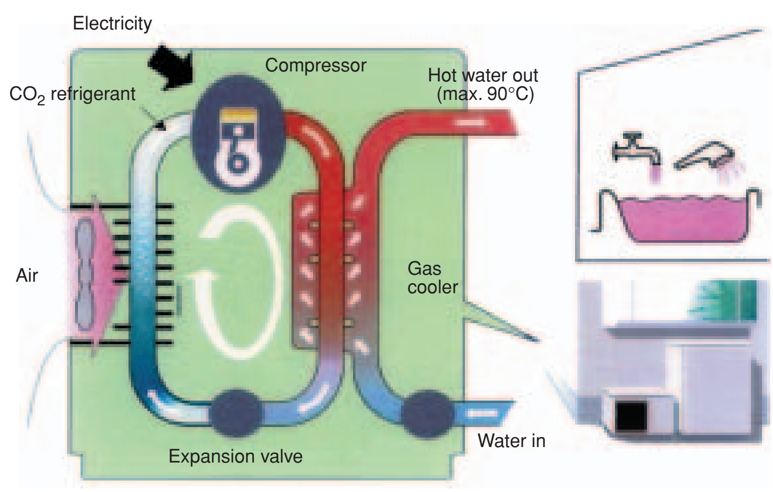


Figure 1: The CO_2-based heat pump water heater, scheme.

system pressure of 3 MPa and a high system pressure of about 10 MPa;

- CO_2 requires a compressor of low compression ratio and high differential pressure.

Development of field test unit

In September 1998, The Tokyo Electric Power Co., the Central Research Institute of Electric Power Industry, and DENSO CORP. started the joint development of the CO_2-based heat pump water heater. **Figure 2** and **Table 1** show the dimensions and specifications of the field test machine developed with a view to establishing the final specifications for commercial application.

The test unit uses a simple cycle with a vapour-liquid separator and a rated heat capacity of 4.5 kW. Its heating capacity is comparable to that of a conventional electric water heater (370 litres and 4.4 kW for a four-member family).

The compressor is inverter-motor-driven and is of the full-hermetic scroll type. The hot water supply capacity is variable. The evaporator (air-to-refrigerant heat exchanger) is fin and tube type that is typically used in air conditioners. The water heat exchanger (gas cooler) is counterflow type. The noise performance is 45 dB (A) under winter conditions. The unit is designed to be quiet enough to avoid complaints about noise, even if the heat pump is operated at night in an area where houses are densely built.

The system has two 150 litres tanks for a total of 300 litres of hot water storage. Taking into account Japan's housing

Table 1: Specifications of the field test machine.

Item		Specifications
Power supply unit		Single-phase AC200V 30A
Heat pump unit	Compressor	Configuration: Scroll + DC brushless motor
	Inverter (for the compressor)	Controlled speed: 600 - 9,000 rpm. Permissible current: 25A RMS
	Water heat exchanger	Type: Multi-tube. Capacity: 4.5 kW
	Air heat exchanger	Type: Fin-tube. Size: 650 x 480 x 52
	Electric control valve	Drive system: Step motor
	Accumulator	Type: Impact type
	Outdoor fan	Fan diam.: 400. Shroud: Made of resin
Tank unit	Hot water tank	Capacity: 150 l x 2 (300 l). Material: Equivalent to YUS 190
	Heat insulating material	Molded foam polystyrene
	Pressure reducing valve	Set pressure: 0.15 MPa
	Relief valve	Set pressure: 0.17 MPa
	Mixing valve	Step motor-driven three-way
	Bath solenoid valve	Solenoid valve integrated with an atmospheric
	Bathwater circulating solenoid valve	Electric two-way valve
	Bathwater circulating pump	AC200V single-phase induction type
	Water level sensor	Measuring range: -49 - +49 KPa
	Temperature-retaining heater	AC200V 1000W
Additional water heating function	Automatic control mode	The system learns the maximum calorific value as divided into a whole-day value and an after-17:00-value from data for the last one week and calculates the temperatures of stored hot water and the additional volume of water to be heated
	Night-only service mode	Limiting heat pump operation to the midnight hours
	Full-tank mode	Heating additional water to fill up the hot water storage tank whenever the water level falls below 250 liters
	Forced heating mode	Heating additional water, whenever necessary, with the control unit set in the full-tank mode until 23:00 every day
Bathwater supply function	Automatic bathtub filling	Set bathwater temperature: Approx. 35°C-48°C (adjustable to 14 positions by every degree Celsius). Bathwater level setting: 10 positions approximately 3 cm apart
	Automatic temperature retaining	Holding the bathwater temperature at the set level for selected hours of automatic operation [0 - 10 hours (the initial set time being 4 hours)] from the start of automatic bathtub filling
	Automatic refilling	Keeping the bathtub refilled to the set level for selected hours of automatic operation [0 - 10 hours (the initial set time being 4 hours)] from the start of automatic bathtub filling
	High-temperature water supply	Adding high-temperature water at approximately 60°C to the bathtub in such a quantity that the bathwater temperature will rise about 2°C
	Hot water adding	Supplying the bathtub with some 20 litres of additional hot water at the set temperature
	Cold water injection	Injecting cold water into the bathtub in such a quantity that the bathwater temperature will fall about 1°C
	Pipes for bathtub cleaning	Washing the bathtub with some 20 litres of water

conditions, where houses are often built on small narrow sites, the unit is quite thin for easy installation (Figure 2).

In Japan, large amounts of domestic hot water are used, as Japanese people love taking baths. In the case of a hot water storage type water heater, the storage volume of hot water is generally set at 370 - 460 litres (temperature of storage hot water is up to 85°C) for a four-member family. In our test unit, it is possible to reduce the volume of hot water in storage through improved control and intelligent management of water heating. To this end, the water heater memorises the maximum heat energy used in the past week, forecasts the volume of hot water to be used the next day, and determines the storage temperature of the hot water. Moreover, if a large amount of hot water is used during the daytime, the water heater again forecasts the volume of hot water to be used and automatically controls the volume of hot water so as not to run out of hot water.

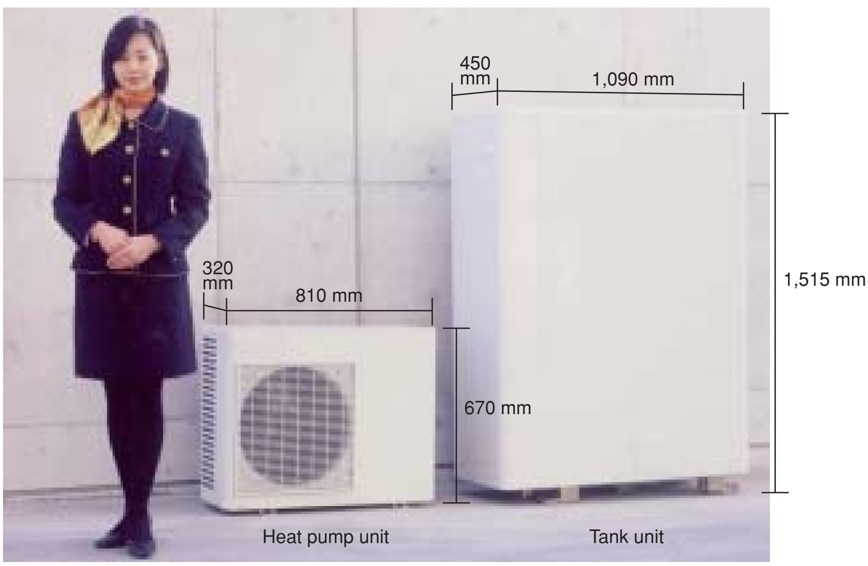
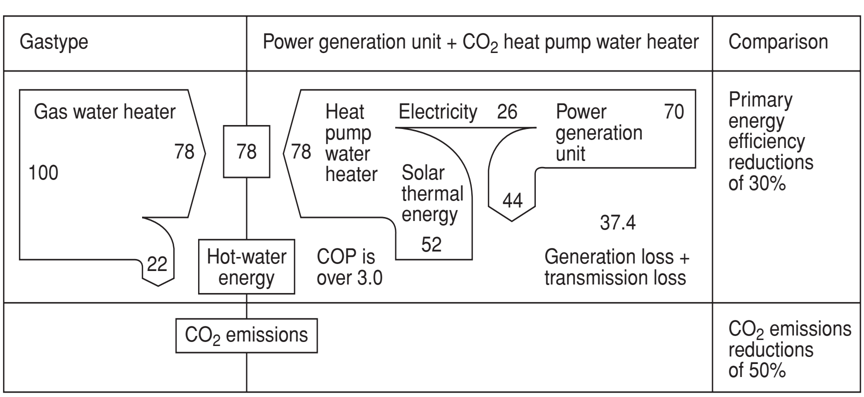


Figure 2: The field test machine.



- Power generation efficiency (0.37 = 860/2,300) is based on the energy equivalent nightly available electricity purchase of 2,300 kcal/kWh under the Energy Conservation Law.
- CO_2 emission coefficient and intensity: electricity = 0.357 kg CO_2/kWh; utilty gas = 2.360 kg CO_2/m^3 (Environment Agency, 2000).

Figure 3: Comparison of energy efficiencies and CO_2 emissions.

Calculation of annual average system COP

Based on the data obtained from the field test unit, we calculated, for trial purposes, the average annual system COP for Tokyo. The ambient air temperature used for the calculation was the average value of the late night period (from 11:00 p.m. to 7:00 a.m.), and the hot water supply load was set at the average value for a four-member family. In calculating the COP of the hot water system, we also took into account the power consumption of the air fan motor on the endothermic side and of the feed pump (30W). The total power consumption of the system was then used to calculate the average annual system COP for trial purposes.

The average annual system COP obtained in the trial calculation is about 3.4. Even if the heat loss (about 10%) of the storage tanks is taken into consideration, the COP should still be higher than 3.0.

Comparison of energy efficiency of CO_2-based heat pump water heater with conventional system

We compared the energy efficiency of the CO_2-based heat pump water heater, having an average annual system COP of 3.0, with that of a combustion type water heater on a primary energy basis. The results are shown in **Figure 3**.

If the primary energy efficiency of the combustion type water heater is 0.78, then that of the CO_2-based heat pump water heater is calculated as:

Power generation efficiency
0.37 x COP 3.0 ≈ 1.1

This shows that the CO_2-based heat pump water heater saves energy by about 30% compared with the combustion type water heater.

The CO_2-based heat pump water heater also reduces CO_2 emissions by about

50% compared with the combustion type water heater.

At present, combustion type water heaters account for 95% of Japan's water heater market. Replacement of combustion type water heaters by the CO_2-based heat pump water heater can make a large contribution to reducing CO_2 emissions.

Conclusion and future prospects

Although system COP changes slightly with various conditions such as ambient air temperature, water supply temperature, and hot water supply load, we believe that we can still achieve our initial overall target of an average annual COP of higher than 3.0 in Tokyo.

The research and development stage has been completed, and the CO_2-based heat pump water heater for residential use is now available. It is being marketed by six home electrical products and electric water heater manufacturers.

The "Report on Ideal Measures for Energy Conservation in Future: Energy Conservation Subcommittee of Advisory Committee for Resources and Energy," which was announced by the Ministry of Economy, Trade and Industry in June 2001, said: "The outcome of recent technology development has reached a stage where highly efficient equipment has been developed and commercialised," introducing our water heater. This report further said: "The energy-saving effect of the new water heater is about 30% higher than that of a combustion type water heater. ”

The CO_2-based heat pump water heater is highly efficient, and its market is worldwide, as it can produce high-temperature hot water even at low ambient air temperature. It also has growth potential for applications such as hot water supply for business use and for air conditioning in cars. The system has great potential for saving energy and reducing fossil fuel consumption.

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A small oil-free CO_2-based compressor for heat pumps

Dr Martin Zogg, Switzerland

A working prototype of an oil-free compressor has been successfully developed. Commercial introduction of this prototype should make it easier to develop heat pump technology based on CO_2 as the working fluid.

Introduction

Carbon dioxide is a non-flammable, naturally occurring substance with certain thermodynamic properties that make it particularly interesting for replacing synthetic hydrofluorocarbons (HFCs) as the working fluid in heat pumps used for domestic water heating applications. However, the compression of carbon dioxide to supercritical pressures in conventional oil-lubricated compressors is problematic, due to the mutual solubility of the carbon dioxide and the lubricating oil. An oil-free compressor would overcome this problem, but such compressors are not yet available on the market.

The project ‘*Small semi-hermetic oil-free CO_2 compressor*’ has led to the successful development of a functional model of an oil-free compressor that is suitable for use in CO_2-based heat pumps. This project is the Swiss contribution to the efforts aimed at developing CO_2-based heat pumps for supercritical heat pump applications over large temperature spans – with a focus on domestic water heating applications. The project was carried out under the framework of the IEA Heat Pump Programme Annex 27.

Compressor characteristics and performance

The key elements of the compressor (see **Figure 1**) are based on experience with the small high-pressure compressors used in natural gas refuelling appliances.

The new compressor has a highly efficient, suction-gas-cooled, permanent magnet synchronous motor working on four cylinders (bore 10 mm, stroke 16 mm). It has dry running clearance seal piston cylinders with a clearance gap of a few microns, and flat sealing plastic plate valves with flat springs.

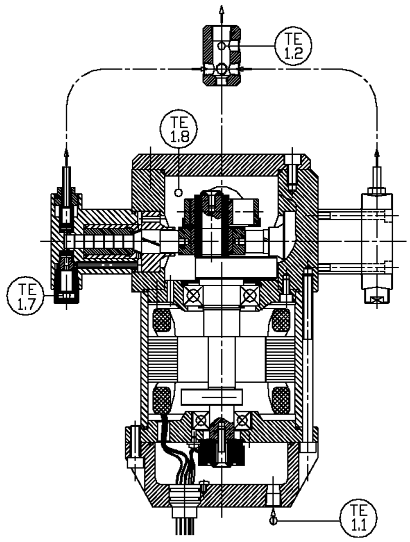

Figure 1: Cross section of the functional model of the new, oil-free CO_2 compressor. TE = Temperature measuring points on the compressor.

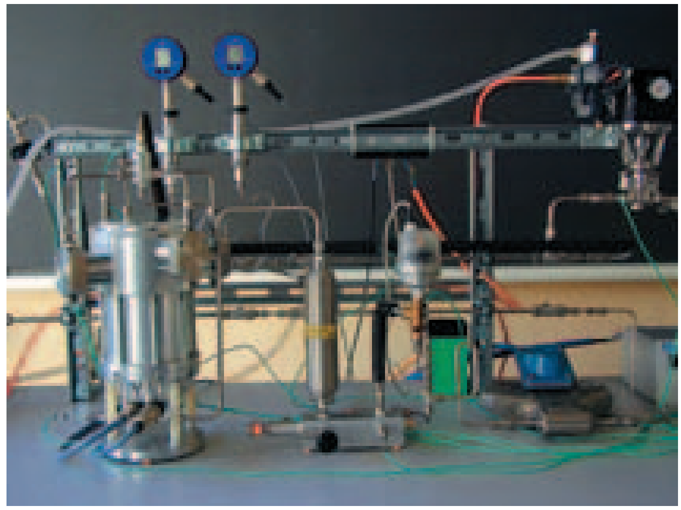

Figure 2: Functional model (left) on the test bench at the Zurich University of Applied Sciences (ZHW), Winterthur.

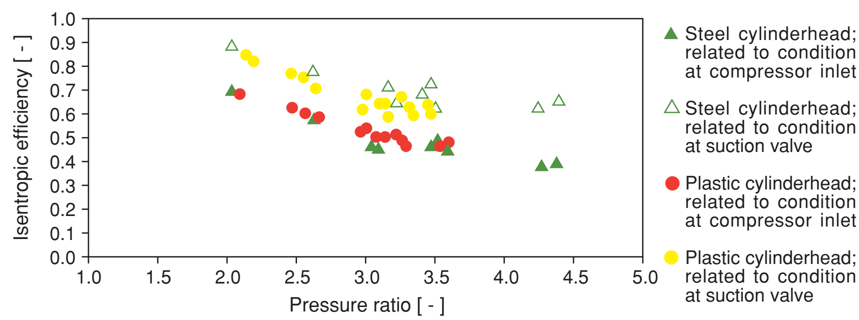

Figure 3: Isentropic compressor efficiency of the functional model in relation to the pressure ratio, at a suction pressure of 35 bar, for steel cylinder heads and reinforced plastic cylinder heads, without losses of motor and frequency converter.

The performance of the functional model was evaluated on a test bench (see **Figure 2**).

At cylinder speeds from 750 to 2900 RPM and electrical power consumptions from 150 to 950 W, the CO_2 gas was compressed from 35 bar (boiling temperature approximately 0.3°C) to supercritical pressures of 80 to 150 bar and temperatures up to 190°C. The critical point of CO_2 is at 73.8 bar and 31.1°C. **Figure 3** shows the isentropic efficiencies measured at various pressure ratios. The pressure ratio is the ratio between the supercritical pressure and the initial pressure of 35 bar. The isentropic efficiency is a measure of the deviation from the thermodynamically ideal compression.

The efficiency values measured are in the same range as those found for conventional oil-lubricated compressors. The fact that the new functional model, despite the absence of a lubricating sealing film between piston and cylinder, displays energetic efficiencies similar to those of more conventional compressors, demonstrates the remarkable success of the model. Further development of a commercial model will hopefully result in suitable oil-free compressors. This means that a small oil-free compressor suitable for CO_2-based heat pump technology could soon become available.

Ordering detailed report

For the detailed final report of this SFOE-research project: H. Baumann: Small oil-free CO_2-compressor, Final report, Swiss Federal Office of Energy 2001. Heinz Baumann, project manager, can be reached at hpbaumann@bluewin.ch.
Download from www.waermepumpe.ch/fe category "Berichte / English"

You can order the written report, project number 37570, in German or English, at ENET, Egnacherstrasse 69, CH-9320 Arbon, Tel. ++41 71 440 02 55, enet@temas.ch

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Research consortium for the utilisation of low-temperature waste heat in Japan

Bidyut Baran Saha, Japan

Objectives

The low-temperature waste heat utilization research consortium was launched in October 1998 under the umbrella of the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ). The objectives of the research consortium are to collect R&D information in Japan and other countries, to develop innovative sorption (absorption, adsorption and desiccant) and chemical heat pump (CHP) technologies, to evaluate the performance of these technologies and to provide industrial partners with useful guidelines for sustainable sorption systems.

Members

At its inception, the consortium consisted of eleven companies – Osaka Gas Co. Ltd., Kubota Corp., Sanyo Electric Co. Ltd., Shin Nippon Air Technologies Co. Ltd., Daikin Ltd., Tokyo Gas Co. Ltd., Toho Gas Co. Ltd., Nichimen Engine Sales Co. Ltd., Hitachi Zosen Corp., Hitachi Ltd., and Mayekawa Mfg. Co. Ltd. – as well as two research institutions, Japan Co-generation Center and HPTCJ, and the Tokyo University of Agriculture and Technology (TUAT). Prof. T. Kashiwagi of TUAT has been directing the consortium. The consortium meets four times a year, usually at the HPTCJ. Suga Kogyo Ltd., Taisei Corp., Kumamoto University and Kyushu University are new members.

Research interests

The consortium members have been working on innovative sorption systems development, heat exchanger design, selection of natural refrigerants and life cycle assessment. In order to stimulate the utilization of low-temperature waste heat, the consortium members are working on the development of environmentally friendly, highly efficient sorption systems in three working groups (WGs): absorption working group (AbWG), adsorption working group (AdWG) and chemical heat pump working group (CHPWG).

The AbWG develops a LCA (life cycle analysis) database and reviews contemporary R&D on absorption cycles. It singled out:

- an ejector absorption refrigerator introduced by Dr. I.W. Eames and his co-workers at the University of Nottingham, U.K.;
- load leveling hyper energy converting and utilisation systems (LHECUS) proposed by Drs. T. Kashiwagi and Y. Kunugi of TUAT together with their colleagues from Waseda University and other Japanese manufacturers.

The ejector absorption cycle is a single-effect cycle utilising water/lithium bromide as working pair. The system performance is as high as that of the double-effect water/lithium bromide absorption cycle. The LHECUS is a combination of hybrid and absorption cycles, and will contribute significantly to energy conservation and demand side management.

The AdWG analyses various adsorption and desiccant cycles in terms of their temperature suitability, performance, merits and demerits and market potential. It singled out the following emerging adsorption technologies:

- two-stage adsorption chiller developed by Drs. B.B. Saha, A. Akisawa and T. Kashiwagi of TUAT;
- direct contact adsorption chiller developed by Dr. Y. Yanagi and his colleagues from Mayekawa Mfg. Co. Ltd., Japan;
- 4-wheel desiccant cooling system developed by A. Kodama, T. Hirose and their co-workers of Kumamoto University.

The two-stage adsorption chiller can be powered effectively by waste-heat sources of 45°C to 65°C with a cooling source of 30°C. In the direct contact adsorption chiller, water vapour evaporates directly from the surface of the water jet spray and is adsorbed by the adsorber, while the desorbed water vapour from the desorber is condensed on to the sprayed water in the condenser. This results in a compact system without refrigeration valves and yields high performance. The advantage of the 4-wheel desiccant cycle is that it can produce effective cooling energy at ambient air humidities of 20 g/kg and above. Another attractive feature of the system is that the required regeneration temperature is between 50°C and 60°C under moderate ambient humidity conditions.

The CHPWG has reviewed various chemical heat pumps using water, ammonia and hydrogen as refrigerants from the viewpoints of regeneration temperature, coefficient of performance, global warming impact and LCA. It has singled out the following as promising technologies:

- the lithium chlorate-water CHP developed by Mr. C. Lange of GASTEC, the Center of Gas Technology, the Netherlands;
- the combined magnesium oxide-water CHP and diesel engine cogeneration system developed by Drs. Y. Kato and Y. Yoshizawa of the Tokyo Institute of Technology.

The main advantages of the lithium chlorate-water CHP are high efficiency, high heat rejection temperature and fewer crystallisation and corrosion problems. The combined CHP-diesel engine system can provide up to 200% more thermal output than the diesel engine by storing waste heat from the diesel engine during periods of low demand. Further information regarding CHP R&D can be obtained from Mr. K. Yonemoto of Daikin Ltd.

The research consortium has led next-generation sorption research, development and marketing in Japan. At present, the consortium members are working intensively on the environmental impacts of air-conditioning machinery and co-generation systems. Some of the aspects being considered are energy conservation and energy cascading and re-circulation of material. This work should provide essential guidelines for sorption R&D.

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The international heat pump market from a business development perspective

Alain Serge Schilli, Switzerland

Long-term trends such as the need to reduce the dependence of the world economy on fossil fuels and the risk of adverse climate change, are driving interest in sustainable and renewable energy technologies. The financial and business markets are also showing increased interest in this sector. Heat pump technology is in principle well positioned to benefit from these developments. This article discusses some preliminary requirements and challenges for the successful business development of the international heat pump market.

Introduction

New market entrants to the renewable energy sector typically have highly developed technologies but less well-developed business and management solutions available. But it is the level of these business and management skills that will ultimately determine whether they are able to attract the investment capital needed to profit from their technologies. Potential investors and market partners must of course manage and limit their risk with regard to new investments. To do so, they must have access to reliable and relevant market data. The recent negative investment experience in the 'new economy' and the current uncertainty reigning over the world economy are increasing the pressure on both businesses and investors to address and manage their financial risks. This leads to a more demanding entrance level for new players to the marketplace.

This article discusses some of the challenges, requirements and opportunities for the successful business development of the international heat pump market:

- challenges facing companies wishing to evolve from technology management to successful long-term business development;
- requirements regarding the quality of market information and data available, notably concerning the data on market potential for heating and cooling in residential, commercial and industrial buildings;
- trends and opportunities relevant to the heat pump market, particularly in the real estate sector.

The communication challenge

Perception, understanding and conviction of technology value

Although a heat pump is a proven technology and is positioned as a sustainable and energy-efficient source of energy, the heat pump market has not yet lived up to its potential. Potential investors have access to large amounts of technical information, such as coefficients of performance (COPs), characteristics of working fluids etc., but this type of information in itself is insufficient to convince the investor of the value this business can provide. The technical information must be translated into the business community's language. Valuation indicators of interest to key business facilitators, such as financial markets and analysts, are often not available for companies operating in the international heat pump

arena. It should be noted, however, that other sustainable technologies including those for fuel and photovoltaic cells, which are no less technologically complex than heat pumps, have succeeded better in gaining the attention of these business facilitators.
One reason for this communication gap is the traditional technological focus in reporting company performance figures. COPs, for example, are all too rarely expressed in terms of the investment performance of the entire heat pump system – a key requirement of professional information for the investment community. Therefore, financial comparisons with more conventional as well as other alternative energy systems are rendered more difficult.

The further development of international labelling schemes as a guarantee of quality and energy efficiency performance, not only for heat pumps, but for energy systems as a whole, will certainly help the process of linking COPs to investment performance, and hence bridge the gap to the demands of potential investors and decision makers. Such measures could accelerate the acceptance of heat pumps as a sustainable technology and increase their market share. Ideally, such labelling schemes should cover the entire business value chain and set standards from manufacturing through to installation.

The information challenge

Availability, reliability and credibility of heat pump market information

Decisions by market players on strategy and investments must be based on reliable and accurate market data. Data for the heat pump sector can be obtained by using a bottom-up or top-down approach (see **Figure 1)**. The top-down approach makes use of data on numbers of units produced, installed etc. whereas the bottom-up approach uses more general data on real estate units built or renovated and related demand for heating and/or cooling.

The main sources of heat pump market data are currently: the World Energy Council, the IEA Heat Pump Centre reports[1] & Newsletters, the European Heat Pump Association (EHPA) newsletters, and official national real estate and energy statistics. The quality of the data varies considerably. The bottom-up approach mentioned above has proven to be unreliable and inconsistent for a variety of reasons. The real estate market data needed is often available for the residential sector but rarely for the commercial and industrial sectors. Data on energy demand for heating buildings are often incomplete and even more difficult to obtain for cooling. Different countries use different system boundaries and definitions (notably for surface area figures) for compiling real estate statistics. By combining the bottom-up and the top-down approach, it might eventually be possible to obtain more accurate data on the heat pump market and its potential.

PricewaterhouseCoopers has developed an alternative model, the Energy Demand MF model, for calculating the heat pump market potential based on the thermal energy demand of new buildings and of retrofitting existing buildings. The model uses the most accurate data available from a reference country and extrapolates the data to the other target countries. In this case the reference country is Switzerland, and the data are based on the Swiss Minergie-Standard[2] (a quality label for new and retrofitted buildings) and the official Swiss national real estate figures. Extrapolation to the other European countries was carried out using additional real estate figures from various national and European sources and factors for climatic differences calculated from an empirical study report[3]. **Figure 2** presents the 'demand-side' figures estimated with the above model for various European countries and compares them to the 'supply-side' estimates of heat pump thermal energy based on EHPA figures.

For some countries (Switzerland, Germany, France, Denmark, and Greece), there appears to be a clear gap between market potential and supply. The estimates for other countries (Italy, Spain, Austria, Sweden), where supply would seem to exceed demand, are anomalous and are an indication that the heat pump statistics and/or real estate data used are not very reliable. Interestingly enough, when all the countries are lumped together, the estimates of the overall market demand for heat pump energy and the overall heat pump energy supplied by the market compare rather well: 38 TWh per year versus 41 TWh per year (EHPA production figures).

An accurate and reliable dataset on the market potential for heat pumps is essential for business development and

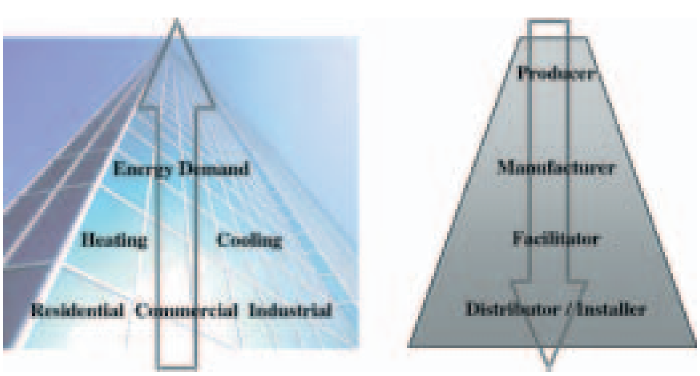

Figure 1: Two different approaches to obtaining heat pump market data.

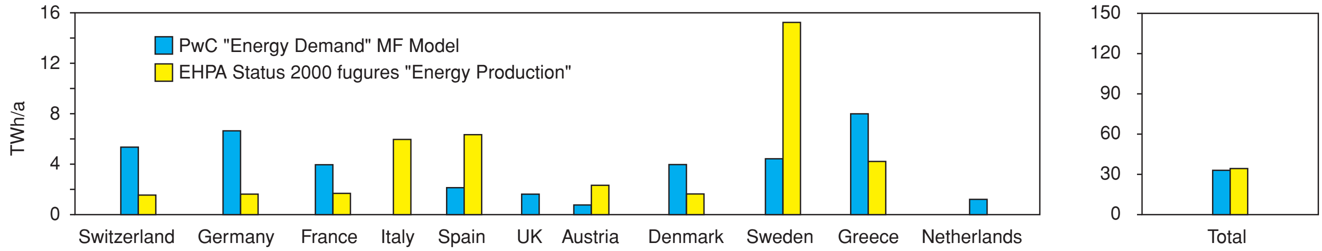

Figure 2: Residential thermal energy by heat pumps: the gap between energy demand (estimation based on CH reference situation) and production (from EHPA data).

for fundraising purposes. The examples given above demonstrate that there are still many problems to overcome in this respect.

Capitalising on trends and opportunities in the market

The current sustainability-driven trends in the energy market should provide an impetus to the heat pump sector. The 18th Congress of the World Energy Council, recently held in Buenos Aires, advocated the search for a balance between economic, social and environmental interests in the future development of the world energy market. Reversing economic dependence on fossil fuels and reducing the risk of global warming are long-term goals that should drive the heat pump market.

Real estate standards are also improving from the point of view of energy efficiency. At the same time, consumer patterns are changing and people are becoming more aware of the environmentally damaging effects of traditional energy sources. Forward-looking companies, be they producers, manufacturers, facilitators or installers are recognising the long-term value of renewable energy sources and their market potential, providing them with the necessary drivers for carefully reviewing current and traditional business strategies. Companies in the conventional heating system markets are increasingly looking to the heat pump sector in their search for higher performance and more sustainable solutions. Utility companies in Europe are reorganising and reconsidering their business priorities and options.

However, for the above drivers to really be able to do their work and for the heat pump market to fulfil its potential, major obstacles need to be overcome. The market and the investment community must become convinced that the heat pump sector offers them long-term economic advantages and is worth investing in. This will happen only if reliable and accurate data become available on the overall economic benefits of heat pumps, in a form which can be understood by the market, and on the market potential of heat pumps.

Favourable national and international energy policies would of course also benefit the heat pump sector. But even more important for the development of the market sector as a whole is the development of an increased professionalism. This includes effective organisation on a national and international scale and the promotion of heat pump technology and intelligent lobbying within the energy industry. Importantly, many of the shortcomings and barriers to market development are also being recognised and communicated by the heat pump associations. The EHPA, in its strategy paper published this year, devotes a chapter to heat pump market barriers – including limited awareness, high initial costs, poor perception and competitive risks due to low energy prices.[4]

Conclusion

One of the major challenges facing the heat pump sector is to improve the perception of the market and the investment community of the economic benefits of heat pump systems. For this to happen, reliable investment-oriented information must become available on the economic advantages of heat pump systems and on their market potential. The heat pump sector also needs to become more effectively organised nationally and internationally and to better promote itself within the energy industry. If these challenges are overcome, the heat pump sector should finally be able to realise its full potential.

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1 IEA Heat Pump Centre (1998) The role of heat pumps in a deregulated energy market, Analysis Report HPC – AR5
IEA Heat Pump Centre (1999) International heat pump status and policy review 1993-1996, Part 1 Analysis & Part 2 National Position Papers, HPC – AR7
2 http://www.minergie.ch
3 JOULE III report. Ref. JOR3-CT96-0034 “Atlas on the potential of retrofitting scenarios for offices”
4 European Heat Pump Association (2001) Strategy for heat pumps – final report, 24 March.

2002 ASHRAE Winter Meeting

Jos Bouma, IEA Heat Pump Centre

The 2002 ASHRAE Winter meeting and AHR Expo were held in Atlantic City, New Jersey (USA) from 12 to 16 January 2002. Several interesting research projects were reported on as well as some developments in the commercial market.

Frost-less heat pump

Frost-less heat pumps without any energy or comfort related penalty may seem like a dream, but recent research has brought them closer to reality. In the past, various attempts have been made to develop air-source heat pumps that need less defrosting or none at all. More recent research in the USA has taken the approach of adding a moderate amount of (electric resistance) heat to the refrigerant in the accumulator, resulting in a higher compressor suction pressure and causing the evaporator coil temperature to rise several degrees. This method delays frost accumulation on the outdoor coil and reduces the number of defrosting cycles. Tests were done on a 7 kW cooling modified heat pump. The concept works as expected. However, if the outside air drops below 0°C, adding a moderate amount of heat will not prevent frost accumulation on the outdoor coil, and the heat input to the accumulator should be stopped.

The research also included an alternative defrosting technology for building applications, which does not rely on heat taken from the conditioned space, but also works by adding heat to the liquid refrigerant in the accumulator. The accumulator basically becomes an evaporator, providing heat for coil defrosting. The system also works as expected.

Absorption heat pump water heater

A gas-fired absorption heat pump for supplying hot water that incorporates a generator-absorber heat exchanger (GAX) has been developed in the USA. The 60-kW prototype delivers water at temperatures above 60°C. The heat pump has a gas PER of 1.54 and provides free cooling with evaporation temperatures as low as -10°C. The economic payback period in the USA would be about 2 years. Field-testing is being prepared.

CO_2 technology

Several prototype cross-flow gas coolers have been developed and tested for use in air conditioning and heat pumps. Trade-offs involved in approaching conventional counter-flow configurations through multi-slab configurations were reported. A side view of the arrangement is given in **Figure 1**. The new design offers better performance than the commonly used multi-pass design. An 11% increase in gas cooler capacity was achieved, and the approach temperature difference (air-refrigerant) for the cooler was reduced by more than 3 K.

In another research project from the USA, a near-counterflow gas cooler for CO_2 air conditioning systems has been modelled and analysed. This configuration uses micro-channel tubes and multi-louver fins. The study demonstrated that a 7-kW gas cooler the size of an automotive air-conditioning system could be transferred into a very small envelope (0.55m/0.41m/0.019m). Small approach temperature differences were achieved here as well.

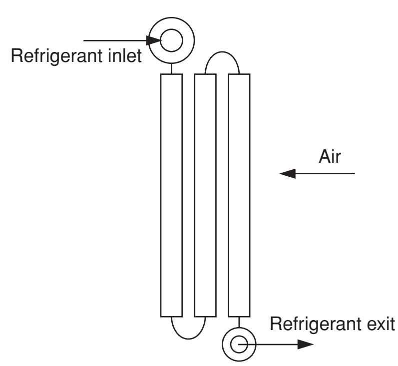

Figure 1: Multi-slab CO_2 gas cooler configuration.

Refrigerants

In North America (and particularly the USA), hydrocarbons for use in air-conditioning and refrigeration equipment have long been and still are looked at sceptically. It was therefore surprising to see a Canadian company at the Expo offering several hydrocarbon-based refrigerant mixtures. The blends were said to be direct replacements for use in installations originally designed for operation with R-12, R-22 and R-502. The company noted that the refrigerant blends are being used in Canada in ice machines, coolers and other closed systems. They are even applied in secondary loop configurations in public buildings in Canada.

ASHRAE literature

"Vapour Compression Heat Pumps with Refrigerant Mixtures" is the tile of a book that offers a comprehensive background and understanding of the thermodynamics of working fluid mixtures and their applications in vapour compression systems.
Author: Y. Hwang, R. Radermacher.
Price USD 69. Code 96765.
Published in 2000, University of Maryland. Order from ASHRAE, Atlanta.

Jos Bouma
IEA Heat Pump Centre
Address: see back cover

Books & software

Three BSRIA press releases
Contact: Ms Karen Runacres, Worldwide Market Intelligence, BSRIA Ltd, Old Bracknell Lane West, Bracknell, Berkshire, UK RG12 7AH. Tel.: +44-1344-426511, Fax: +44-1344-487575, E-mail: karen.runacres@bsria.co.uk

The Australian air conditioning market: 10% growth per annum
BSRIA press release. Contact: see above.

BSRIA Worldwide Market Intelligence has just released a brand new research study into the Australian air-conditioning market (150 pages, 126 tables). It forms part of a study on key countries in Southeast Asia and Oceania *(other countries covered include China, Malaysia, Philippines, Singapore and Thailand).*
This press release gives an overview of new findings regarding:
- the Australian packaged air-conditioning and close control market;
- the Australian central plant market;
- the strong growth and changes in the above markets.

The Australian air-conditioning market has grown to USD 620 million, and despite the economic gloom, it is growing at 11% per annum. About 600,000 units are sold per year, making it one of the world's largest markets. Strong growth is forecast in mini-splits as a result of very strong growth in the residential sector. There is also a major market for retrofitting schools as well as continuing demand in the hotel, commercial and leisure sectors. Although there is significant local production, imports are high and continuing to increase.

The European room and packaged air conditioning market
BSRIA press release. Contact: see above.

This study was published in November 2001 in seven volumes - covering France, Germany, Greece, Italy, Portugal, Spain, and the UK separately, and including an overview report. This is the fifth edition of these reports. The report is 360 pages long and contains 460 tables and 90 figures.

The report shows that the seven largest European countries are moving up quickly in the ranks of the world's biggest air-conditioning markets. Despite the global economic slowdown and the threat of terrorism, Europe remains a safe haven and a market with much potential. Overall growth across the biggest countries is expected to be 12% until 2005.

Mini-splits, which now account for over 80% of all sales, is the fastest growing market, with the strongest growth in Southern Europe and with VRF systems in particular strong throughout Europe. However, the market faces the challenges of continued price erosion and the need to switch to HFCs as the 2004 deadline looms. At the same time, competition from the Far East is set to intensify still further.

The European Central Plant Air Conditioning Market
BSRIA press release. Contact: see above.

This study was published in November 2001 in seven volumes - covering France, Germany, Greece, Italy, Portugal, Spain, and the UK separately, and including an overview report. This is the fifth edition of these reports. The report is 375 pages long and contains 473 tables and 70 figures.

The European central plant market is now worth USD 1.7 billion and continues its robust expansion in the face of a darkening economic outlook. Major shifts in the chiller market to the use of screw and scroll compressors will continue apace, accompanied by a long overdue shift to HFC chillers in Southern Europe. The supply structure has become more concentrated, but several local manufacturers still represent significant competition.

The forces of globalisation have had less impact on airside with only a modest move towards more uniform products and pan-regional companies/brands, although some companies have become truly pan-regional. Fan coils are the fastest growing market, buoyed by a good performance from the key Italian market.

Energy Conservation and Alternative Sources of Energy in Sugar Factories and Distilleries
By Mr P.J. Manohar Rao, Chief Director (Sugar) Rtd.
Contact: P.J. International Group Consultants, A-101, Yamuna Apartments, Alaknanda, New Dehli – 110 019, India.
Tel.: +91-011-6461081, Fax: +91-011-6474514, E-mail: scgtc@vsnl.com, Internet: http://www.sugar_ind.com/pjm.
This book has 780 pages; USD 110.

The book contains a description of the actual energy conservation systems and equipment adopted by some of the progressive sugar factories in different countries. The author visited 60 countries to study the energy conservation measures adopted by the progressive factories and collect volumes of data from energy experts.

Modern technologies like those using heat pumps are explained. In particular, the use of multi-stage thermal vapour recompressors, improved types of falling film tubular and plate evaporators, and continuous vacuum pans and membrane technology are discussed.

How Small and Medium-Sized Enterprises in Developing Countries can protect the Ozone Layer
New publication of the United Nations Environment Programme
Contact: Mr Rajendra M. Shende, Chief, UNEP DTIE Energy and OzonAction Unit, Tour Mirabeau, 39-43 quai André Citroën, Paris 75739 cedex 15, France. Tel.: +33-1-4437-1450, Fax: +33-1-4437-1474, E-mail: ozonaction@unep.fr

This publication provides tools to small and medium-sized enterprises in developing countries to find ways of substantially reducing and eventually eliminating the use of ozone depleting substances (ODS). Each part of the document is designed to address several aspects that apply to specific ODS-using sectors: refrigeration and air conditioning, solvents, coatings and adhesives, foams and aerosols.

The handbook aims to assist owners, operators and employees of such businesses in assessing their present operations. It will help them find options that are available to phase out these dangerous substances. As small and medium-sized enterprises contribute an important share of these dangerous substances in developing countries, this sector remains a challenge to the Montreal Protocol implementation.

2002
International IIR Workshop – Mobile Air Conditioning
20-21 June 2002 / Vienna, Austria
IIR Workshop of Commission E1
Organising secretary: Dominik Bencsics
Faradaygasse 3, Objekt 210
1030 Vienna, Austria
Tel.: +43-50-550-6353
Fax: +43-50-550-6596
E-mail: iir.workshop@arsenal.ac.at
Internet: http://www.arsenal.ac.at

Application of Carbon Dioxide in Unitary Equipment
2002 ASHRAE Summer Meeting (Symposium)
22-26 June 2002, Honolulu (HI), USA
Contact: Dr Piotr Domanski
National Institute of Standards and Technology
1000 Bureau Drive, Stop 8631
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International Compressor Engineering Conference at Purdue
International Refrigeration and Air Conditioning Conference at Purdue
16-19 July 2002 / West Lafayette, USA
Short courses: 14-15 July 2002
Contact: Reena L. Fleischhauer, coordinator
Conference Division, Purdue University
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West Lafayette, IN 47907-1586, US
Tel.: +1-765-494-9499
Fax: +1-765-494-0567
E-mail: rlfleischhauer@purdue.edu
Internet:
http://www.ecn.purdue.edu/Herrick/event/

IIR Conference - New Technologies in Commercial Refrigeration
22-23 July 2002 / Urbana (Illinois), USA
IIR Conference of Commissions B2 and D1
Contact: Ms Tammy Smith
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E-mail: tssmith1@uiuc.edu
Internet: http://acrc.mie.uiuc.edu/

15th International Congress of Chemical and Process Engineering
25-29 August 2002 / Praha, Czech Republic
Contact: Organising Committee
CHISA 2002
Novotného Lávka 5
116 68 Praha 1, Czech Republic
Tel.: +420-2-2108-2333
Fax: +420-2-2108-2366
E-mail: org@chisa.cz
Internet: www.chisa.cz/2002

Zero Leakage - Minimum Charge
26-29 August 2002 / Stockholm, Sweden
Contact: Per Lundqvist
IIR conference
Royal Institute of Technology
Fax: +46-8-20-30-07
E-mail: elksne@egi.kth.se
Internet: http://www.egi.kth.se/zero/

International Sorption Conference 2002
24-27 September 2002 / Shanghai, China
Contact: Dr Wang Wen
Institute of Refrigeration & Cryogenics
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Fax: +86-21-62933250
E-mail: ISHPC@sjtu.edu.cn
Internet: http://www.sorption.sjtu.edu.cn

5th Gustav Lorentzen Conference on Natural Working Fluids
5-8 October 2002 / Guangzhou, China
Contact: Yanhua Liu
Guangdong Association of Refrigeration,
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Tel.: +86-20-87674286
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2003
Thermodynamics Heat and Mass Transfer of Refrigeration Machines and Heat Pumps
31 March – 2 April 2003 / Valencia, Spain
Contact: Prof Rafael Royo
IMST Group, IIE
Departemento de Termodinámica Aplicada
Tel.: +34-9638-77325
Fax: +34-9638-77329
Email: rroyo@ter.upv.es
Internet:
http://www.imst.upv.es/eu_seminar.htm

Cold Climate HVAC 2003, The 4th international Conference on Cold Climate Heating, Ventilation and Air-Conditioning
15-18 June 2003 / Trondheim, Norway
Eurotherm Seminar
Contact: Conference Secretariat
SINTEF Energy Research Refrigeration and Air Conditioning
N-7465 Trondheim, Norway
Tel.: +47-73592511
Fax: +47-73593186
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21st IIR International Congress of Refrigeration
17-22 August 2003 / Washington DC, US
Contact: ICR 2003 Conference Manager,
Nadine George
Hachero Hill, 6220 Montrose Road
Rockville, MD 20852
Tel.: +1-301-984-9450 x11
Fax: +1-301-984-9441
Internet: http://www.icr2003.org

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

Ongoing Annexes

Red text indicates Operating Agent.

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	FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	26	CA, DK, SE, UK, US
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	27	CH, JP, NO, SE, UK, US
Annex 28 Sorption - Heat Recovery Systems Market and Enviromental Impact for cooling and heating	28	NL, NO, ES, SE, others to be confirmed

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).

Next Issue

7th IEA Heat Pump Conference

Volume 20 - No. 2/2002

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

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

The Programme is the foremost world-wide source of independent information & expertise on heat pump, refrigeration and air–conditioning systems for buildings, commerce and industry. Its international collaborative activities to improve energy efficiency and minimise adverse environmental impact are highly valued by stakeholders.

Mission

The Programme serves the needs of policy makers, national and international energy & environmental agencies, utilities, manufacturers, designers & researchers. It also works through national agencies to influence installers and end-users.

The Programme develops and disseminates factual, balanced information to achieve environmental and energy efficiency benefit through deployment of appropriate high quality heat pump, refrigeration & air-conditioning technologies.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC). 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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