IEA Heat Pump CENTRE NEWSLETTER
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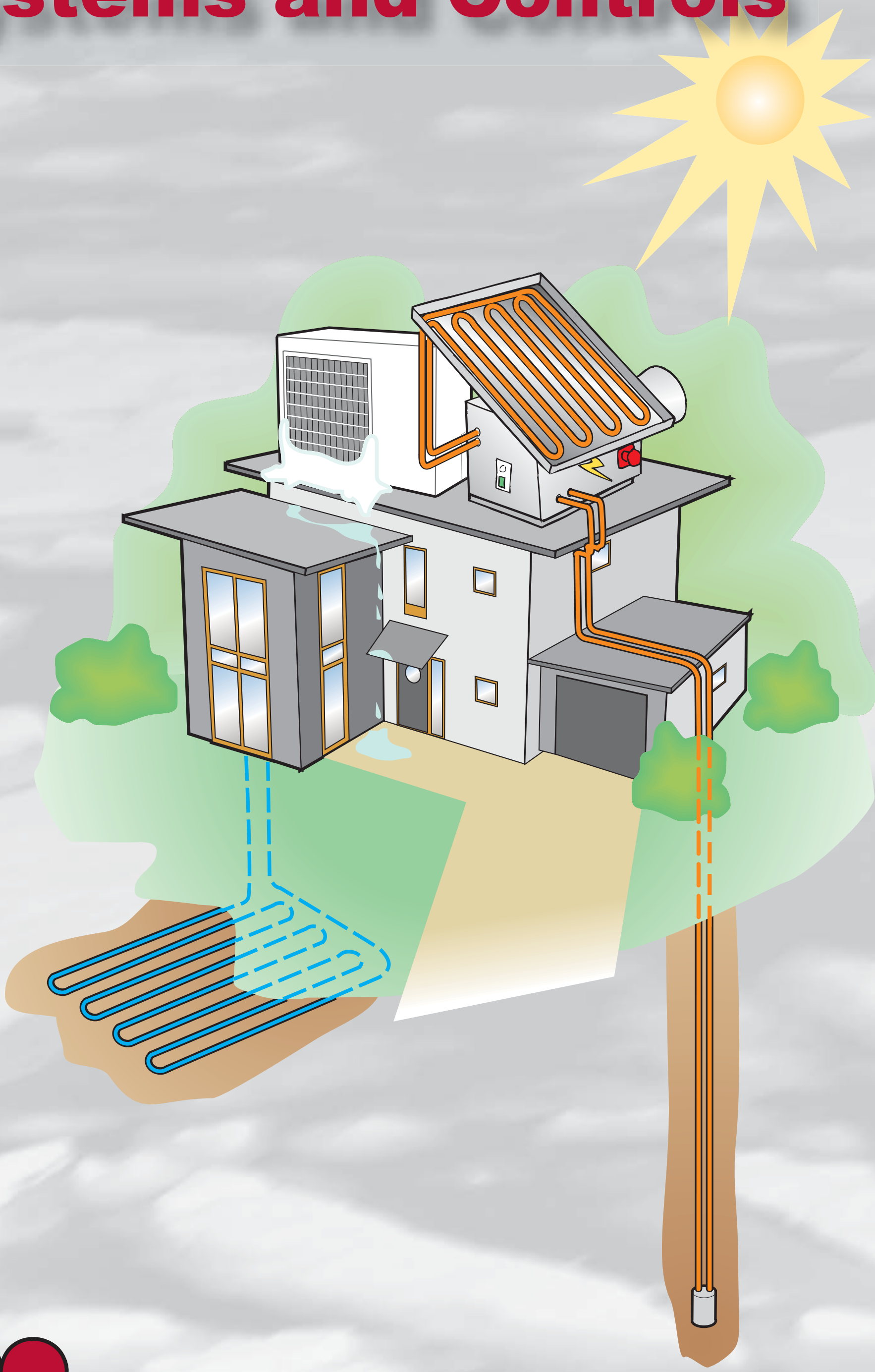
Systems and Controls



Combination of solar collectors and ground-source heat pump

The frost-less heat pump

Gas-fuelled heat pumps for existing buildings and renovations - energy transition substantiated

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heat pump
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IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 23 - No. 1/2005

In this issue

Systems and controls

In order to achieve a highly efficient heating or cooling system, it is necessary to analyse the entire system, and not just the heat pump or refrigerating machine. A very important area in this analysis is that of control of the system and components in the interests of efficiency. This issue of the HPC Newsletter features interesting articles on system analysis, improved control and efficient components.

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Publisher:
IEA Heat Pump Centre
PO Box 857, S-501 15 BORAS
SWEDEN
Tel: +46-33-16 50 00, Fax: +46-33-13 19 79
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

Editor in chief: Monica Axell
Technical editing: Fredrik Karlsson,
Ulf Mårtensson - IEA Heat Pump Centre
Language editing: Neil Muir, Angloscan Ltd
Illustration, page 1: Lars Fransson, illustration och information

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www.heatpumpcentre.org

New chairperson of the Heat Pump Programme

Sophie Hosatte
Chairperson – IEA Heat Pump Programme
Natural Resources Canada

By the time this issue is published, the Kyoto Protocol will have entered into force. February 16 will mark a commitment by many countries to reducing their greenhouse gas emissions and combating climate change. By providing opportunities to reduce energy consumption and peak loads, heat pumping technologies (heat upgrading, air conditioning and refrigeration) can play a key role in helping to meet these objectives. These technologies are used in buildings for heating and air conditioning; in industrial processes for refrigeration and waste heat recovery; and in transport for vehicle air conditioning and the transportation of chilled and frozen products.

To support the sustained implementation of the technologies in this environmental framework, it is important to cut down on synthetic refrigerants, which have a severe adverse effect on climate change. The long-term solution probably lies in using natural refrigerants such as ammonia, carbon dioxide and propane. In refrigeration systems, the use of secondary loops with environmentally friendly heat transfer fluids constitutes a short term alternative that would facilitate the adoption of natural refrigerants that can pose a safety problem in large quantities.

Improving the technologies is the other key element, which must be attacked on several fronts. In terms of equipment, for example, developing more efficient heat exchangers would reduce the temperature difference between fluids and thus enhance performance; in terms of systems, progress must be made in the integration of heat pumps with other building services systems or, in the case of industry, with processes. This integration calls for the use of optimization techniques as well as for the development of highly efficient hot and cold storage systems that are tailored to operating temperatures, in order to meet the building heating and cooling loads that are not always simultaneous.

This newsletter focuses on systems and controls—a critical field. In most facilities, performance too often falls short of expectations due to poor system operation. Rapid advances in information technology and micro-electronics, and the development of artificial intelligence (AI) techniques are creating a new environment that is conducive to a profound change in the way the equipment and systems are operated and controlled. New methods to detect and diagnose faults and constantly to optimize equipment and system operation, as well as cutting-edge control strategies, must be applied to heat pumping technologies and systems.

In addition to overcoming these technical challenges, efforts must be made to remove economic and market barriers. It is a matter of disseminating information and developing competences by creating tools and guides to support designers, installers and end users. Developing standards is one important way of guaranteeing the quality and performance of equipment and systems, and also of progressively ridding the market of obsolete or less efficient systems.

The role of the IEA Heat Pump Programme is to stimulate efforts in this area and encourage international collaboration to support and stimulate the implementation of heat pumping technologies. Several collaborative projects (Annexes) in this vein are in place or in preparation. The May 2005 Las Vegas Conference will also give participants a unique opportunity to discover new technologies and the most recent developments in this domain.

Enjoy the newsletter!

Sophie Hosatte

Columnist

New Director of the IIR

Didier Coulomb
Director of the IIR

After a career in the French administration in the environmental and food sectors, and then supporting research and technology transfer in general, I was appointed Secretary-General of CIRAD, a research organization specializing in tropical countries, and subsequently elected Director of the International Institute of Refrigeration, taking up my duties on October 1, 2004.

One of the first decisions I took was to participate in the Conference of the Parties on Climate Change in Buenos Aires in December and to present the IIR's position. In my opinion, this represents exactly the type of role the IIR will have to play in the future.

The IIR is an intergovernmental organization bringing together developed countries and developing countries from all continents, and in which both public research centres and industry participate. This involves constraints as well as specific assets: a specific intergovernmental position, which the IEA also has, a large variety of needs at stakeholder level, and a capacity for seeing the overall picture in complex issues which, at first sight, often imply diverging interests.

The IIR is positioned in a sector – refrigeration in all its variations - that is vital for humanity, and which is constantly growing, but not very visible to the general public or even to many decision-makers. This sector needs to be better recognized and taken into account, which means that the IIR needs to communicate. Who knows, for example — and this was one of the points of my presentation in Buenos Aires — that refrigeration consumes nearly 15% of worldwide electricity?

Great challenges await the IIR, with regard to health of course (food safety, use of refrigeration in hospitals, safety of refrigeration plants...), and also increasingly with regard to the environment: the impact of refrigerants concerned by the Montreal and Kyoto Protocols and energy consumption of the equipment used.

Concerning this last point, heat pump technology is a wonderful asset that should be promoted. The IIR is already working in this domain and must cooperate as closely as possible with the IEA Heat Pump Centre. One month after my arrival I organized, with Dr Monica Axell, a meeting of the IIR-Heat Pump Centre Liaison Committee and participated in a workshop of the HPC: the partnership between us must be constant and efficient.

Controlling energy consumption in all countries is an increasingly recognised requirement, which implies great research efforts over a long period, and excellent information exchange. The IIR, together with the IEA HPC, will be actively involved.

Didier Coulomb

General

2005 AHR Expo innovation awards

USA – At the AHR Expo in Orlando, Florida, the AHR Expo innovation awards were presented in eight categories: building automation, cooling, heating, indoor air quality, refrigeration, software, tools and ventilation. The submitted applications for the award were judged by a panel consisting of ASHRAE members, selected for their exceptional knowledge of the industry and its products. The products were judged for innovation, application, value to user and market impact. The winners are:

Building Automation: Invisible Service Technicians – IST Monitor. Combines advanced microprocessor, sensors and the Internet to provide contractors with data for remote analysis and diagnosis of a customer's system.

Cooling: Copeland Corp. – next generation Copeland scroll. With 20 major design improvements, the next generation of Copeland scroll delivers breakthrough in performance.

Heating: Trs Systems Inc. – RC2100 wireless hydronic controller. Combines wireless sensors, a wireless energy management interface and an intelligent control algorithm into one product.

Indoor Air Quality: Munters – H2O LiquidAire. By treating humid outside air, this product generates pure drinking water.

Refrigeration: Danfoss – ICV Control Valve. Features a weld-in mild steel body with no internal wear surfaces, less than half the weight of iron valves and with a quarter of the leak potential.

Several thousand of the 45,000 or so attendees filled the aisles at the 2005 AHR Expo in Orlando, Fla. Feb. 7-9. (source: www.ahrexpo.com)

Software: Wrightsoft Corp. – Right-Radiant Plus™. Wide-scale improvements in radiant systems is possible due to this software. It reduces the design labour and provides an increase in design quality.

Tools and Instruments: Goodway Technologies Corp. – Cooling Tower Vacuum. Traditionally, cooling tower basins are completely drained and debris shovelled out by hand, exposing workers to dangerous contaminants. With the vacuum, workers are protected from contact.

Ventilation: Hardcast – FLEXGRIP 550. This is the first spray-grade water-based duct sealant, which can save a lot of labour-intensive work.

Source: Koldfax, January 2005

French foundation for energy in buildings

France – Encouraged to do so by ADEME, the French Environment and Energy Management Agency, the four large companies of Arcelor, Lafarge, Gaz de France and EDF have together established the Bâtiment-Energie Foundation. The aim of the foundation is to finance research and ongoing projects to reduce greenhouse gas emissions from the building sector. The promotion of renewable energy sources in new construction is one example where the foundation could contribute. The foundation has a budget of 8 million Euros, and the first projects will start at the beginning of 2005.

Source: Die Kälte & Klimatechnik, no1, 2005

Conference advances efforts to adapt to climate change

Argentina – A "Buenos Aires programme of work on adaptation and response measures" was adopted at the tenth anniversary UN conference on climate change. The programme was adopted as a response measure to the growing evidence that climate change impacts can already be detected. The programme includes further scientific assessment of vulnerabilities and options for change, support for national action plans for least developed countries, new workshops and technical papers on various aspects of climate change risk and support for mainstream integration with sustainable development planning.

The conference also asked the Climate Change Convention secretariat to arrange a seminar of governmental experts next May in Bonn, Germany. The seminar will promote an informal exchange on

a) actions relating to mitigation and change to assist Parties to continue to develop effective and appropriate response to climate change, and
b) policies and measures adopted by their respective governments that support implementation of their existing commitments under the UN Framework Convention on Climate Change and the Kyoto Protocol.

Other highlights of the conference included the submissions by Brazil and China of their first national communications outlining their strategies for addressing climate change.

Source: UNEP press release, December 2004, www.unep.org

Industrial refrigeration consensus

Denmark – On the initiative of Danfoss, a two-day workshop on industrial refrigeration with 60 invited guests from all over the world, was held near Nordborg in the south of Denmark. The event was called IR Consensus 2004, and the idea was to point out what the future holds for the industrial refrigeration business. The statements below are the essence of the discussions.

Ammonia in industrial refrigeration

- Ammonia will continue to be the main refrigerant
- Work will continue towards lower charges and tighter systems
- Public affairs work, based on facts, will be needed to improve the perception of ammonia

Carbon dioxide in industrial refrigeration

- Carbon dioxide will be used in low-temperature applications
- There is no general driver for transcritical carbon dioxide systems
- If demand arises for transcritical components, heavy investments will be needed

Other refrigerants in industrial refrigeration

- R723 will not be a significant refrigerant
- HCFCs do not have a future, and HFCs will be reduced wherever possible

Systems in industrial refrigeration

- First cost is clearly most important today, but life cycle cost will become more important
- The price of energy is too low to drive significant work on energy efficiency
- Significant problems prevent the use of DX plate heat exchangers as a solution for reducing refrigerant charges and cost
- There is a need for innovative pump design, i.e. speed, flow regulation, head.

Regulation in the industrial refrigeration business

- Stay ahead of regulations – it is more expensive and inconvenient to adjust to regulations than to develop business according to political trends.

Source: Scandinavian Refrigeration, No. 1 February, 2005

The management method for Chinese energy labels published

China – On December 12, 2004, the "Energy label and implementing regulation for air conditioning equipment and refrigerators" was published in China. From 1st March, 2005, all air conditioners and refrigerators will be required to display energy labels, showing the name of the manufacturer, product specifications and model, energy efficiency level and national standards number. Air conditioners must also display the EER, refrigeration output and input power. The organisation issuing the energy label must publish the label information of the products on its web site and also in another news media, at least every quarter.

The energy label is compulsory and is an initiative from the Chinese Government. It is intended to encourage manufacturers to improve the technical level of the equipment and to strengthen the consumer's awareness of energy conservation.

Source: JARN, January 2005

Research within ECBCS

The latest issue of the ECBCS News reports on two issues which relate to heat pumping technologies. ECBCS is an abbreviation for Energy Conservation in Buildings and Community Systems, and is an implementing agreement within the International Energy Agency. See the web page for more information www.ecbcs.org

Annex 40: Commissioning of building HVAC systems for improved energy performance

The demands for reduced environmental impact causes the HVAC industry to develop products intended for efficient and flexible integration into larger systems. Unfortunately, this leads to a higher level of complexity for the building owner, the designer and the installer. The management of this complexity demands new approaches, skills and tools. Commissioning is one of these new tools which Annex 40 has been working on since 2001. The achievements of the Annex can be divided into the following four categories:

1. **Tools to manage the commissioning process**
   It is essential that the commissioning process is well managed. A central document should define the actions to be performed. Three types of tools were developed or used in the Annex work: standard model commissioning plans, checklists and matrices. Examples of these will be available on the final Annex CD.

2. **Manual commissioning tools**
   Functional performance tests are the core of commissioning. They are devoted to detection of possible malfunctions and their diagnosis. A standard format for these tests was defined to describe these tests, and procedures were developed and applied.

3. **Approaches using building energy management systems (BEMS) for building commissioning.**
   BEMS are seen by some players as the future key tool for efficient commissioning. The Annex has reviewed the state of the art of BEMS in Japan, Canada, the USA and France. Four main techniques for automatic commissioning were studied:
   - Model-based
   - Rule-based
   - Performance index-based
   - Controller logic tracer-based

4. **Approaches for the use of components as well as whole building models to improve commissioning,**
   Two main uses of models in the commissioning were studied:
   - Using models to perform functional performance tests
   - Using models to design tests in order to optimise the func tional performance tests

The results from the Annex will be available on a CD and a report during spring 2005.

ECBCS building retrofit initiative
This article describes the importance of retrofitting existing buildings and thus reducing their energy use if global warming is to be reduced.
Several opportunities for IEA building-related R&D-programmes are identified:

- Advanced insulation technologies for envelope and openings
- New roof systems with integrated solar systems
- Integrated energy systems
  Heat pumps will be more important than gas- and oil-fired boilers in the future. They are ideal for waste heat recovery and as a source for combined heating and cooling. The focus will be on integrated systems using renewable energies to provide heating, ventilation, hot water and cooling.
- New concepts for district heating and cooling
- Risk management for advanced technologies

Source: ECBCS News, October 2004

Technology & Applications

Small pumps - large potential

Germany – The pumps used for circulating the water in hydronic heating systems for domestic use are small (< 250 W), and one may not think of them as large energy users. However, as there are approximately 87 million such units in Europe, their total energy consumption amounts to 41 TWh of electricity per year. In an IEA report, the estimated energy use for these pumps in 2030 will reach 45 TWh. As development is towards finding efficient system solutions, the efficiency of these pumps must also start to be of concern in connection with cooling systems, heat pump systems and solar heating systems.

The energy use of today's most efficient pump is only 18 % of the energy used in the 1960s. This is due to several improvements, both in design and controls. In the 60s, the pumps were constant-speed pumps. In the 70s, the pumps gained stepped speed control, with variable speed control appearing in the 1980s. The 1990 saw feed-back control loop technology, and this was followed after 2000 by the introduction of higher efficiency pumps with permanent magnet rotors instead of the traditional asynchronous motors.

These newly developed pumps have been developed by Wilo, a large German manufacturer, in response to demands for reduced energy use originating from the Kyoto Protocol, an increased use of the Life Cycle Cost concept instead of first cost, and (finally) clear signals on coming directives for the energy labelling of pumps.

Source: CCI Print no. 2, 2005 and Norsk VVS, no.1, 2005 (in Norwegian)

New Japanese RAC models for 2005

Japan – New products for 2005 have been announced by several room air conditioner (RAC) manufacturers in Japan. The trends are towards more energy-efficient units, improved ventilation power and slimmer and more compact design. The new models also come with eye-catching functions or features, such as flat panels, more colour variations and automatic filter cleaning mechanisms. One important trend, in terms of energy efficiency, is that since October 2003 it has become virtually impossible to sell the "orange"-marked models which have the poorest efficiency. Energy-saving performance is one of the most important points of consideration for the customers.

After having carried out a survey among its customers and found that filter cleaning was insufficient (for more than 90 % of the units) and considered troublesome, Matsushita has developed a RAC with an automatic filter cleaning mechanism.

Hitachi H&L focuses on energy saving, and launches a new product with top class energy-saving performance utilizing a newly developed high-efficiency compressor.

Daikin aims at improved comfort and increases the top ventilating flow by 15 %, from 28 to 32 m3/h. The new models also features functions such as skin moisturising operation and prevention of skin irritations in winter by adding hyaluronic acid to the air supply filter, which discharges Vitamin C with antioxidant action.

Sanyo takes the approach of considering the RAC as part of the room interior, by preparing seven colour variations, allowing the user to change the front panel colour as they like.

Source: JARN, January 2005

Air-to-air heat pumps evaluated

Sweden, Norway – The market for air-to-air heat pumps has increased rapidly in both Sweden and Norway. As a response to this, the Swedish Consumer Agency and the Norwegian magazine Forbrugerrapporten ordered a test on eight air-to-air heat pumps which were available on both the Swedish and the Norwegian markets. All of the heat pumps were equipped with variable-speed compressors. The performance of the heat pumps in heating mode was tested in accordance with standards EN 14511 and CEN/TS 14825, which specify test requirements for heat pumps at full and partial load.

The prices of these heat pumps have fallen since 2001, when a similar test was performed. Prices in 2001 ranged from SEK 24 000 to SEK 35 000 (SEK 1 000 ~ USD 141), to which must be added SEK 5 000-10 0000 for installation. In the 2004 test, the prices ranged from SEK 14 000 to 27 000 (installed). Despite the lower price, the performances of the heat pumps have increased. The coefficient of performance (COP) is generally higher, and they also maintain a good performance down to –18 °C. At –15 °C the COP for the heat pumps ranged from 1.4 to 2.3, and the rejected heat power ranged from 1.3 to 3.2 kW.

However, the tests showed that there were quite considerable variations in performance between the different brands. Also, the test showed the importance of testing the heat pumps at more than one operating point. How well-tuned the variable speed control and the defrost strategy are will influence the results, and a heat pump showing good performance at +7 °C may show quite poor performance at –7 °C.

Source: Råd & Rön, no. 10 December 2004 (in Swedish), and SP Swedish National Testing and Research Institute

Ground-source pilot plant in Korea

South Korea – Starting from a co-operation in the International Energy Agency's energy storage program, a fruitful partnership has been established between German and South Korean companies working in the ground-source heat pumps sector. A pilot plant with borehole heat exchangers (BHE) at the premises of KEPRI (Korean Electric Power Research Institute) in Daejon was completed in 2003. The plant consists of four boreholes, in which three different BHEs have been tested and evaluated. A heat pump designed by the Korean company HP System Tech was connected to the BHEs. The heat pump supplies a hot water storage for heating and an ice storage for cooling.

The cooperation on this pilot plant turned out successfully and now there are plans for a large plant in the south-east part of Seoul. The plant will provide both heating (500 kW) and cooling (700 kW) for an office building. Preliminary calculations indicate that more than 60 boreholes, 150 meters deep, must be drilled and BHEs installed under the building.

Source: Geotermische Energie, no. 44 October 2004

Algebraic spiral scroll compressor

Japan – Hitachi H&L has developed a new series of scroll compressors for refrigeration and freezing applications. The company has changed the shape of the spiral wall in the compressor from the conventional round involute curve to an algebraic spiral curve. This new shape is claimed to improve the compressor efficiency at low suction pressures and to reduce internal leakage. The efficiency is improved by 15-25 % compared to the previous compressors used for refrigerating and freezing applications.

Source: JARN, January 2005

Automobile air conditioning

A super lightweight external variable-displacement compressor for automobile air conditioning has been developed by Toyota. The compressor, which uses R134a, is 25 % lighter than current fixed displacement compressors. According to Toyota, the compressor makes it possible to reduce the fuel consumption by 60 % and allows a 30 % faster acceleration.

Valeo has developed an air conditioning system which meets future EU regulations. The regulations could lead to a ban on using R134a in automotive air conditioning systems, and so Valeo's system uses carbon dioxide as the refrigerant. Valeo expects to market this system in 2009.

Source: IIR Newsletter, no. 21, January 2005

Markets

Japanese companies aims for Europe

Japan – Triggered by the intense heat waves in Europe during the summer of 2003, the air conditioning market in Europe has increased substantially. Now, major Japanese air conditioner manufacturers intend to strengthen their situations in Europe. Sanyo Electric will invest approximately 1 billion yen to construct a new factory for household ACs in China, thus doubling their total production capacity in China to 1.2 million units. The additional units will be supplied to the European market. Sanyo will also establish a commercial AC factory in Hungary.

Daikin will open a small residential AC factory in September, in Pilzen, Czech Republic, as well as a compressor factory in December, which will also be in the Czech Republic.

Mitsubishi Electric Corp. will replace the current household AC sales via agents in eight European countries by direct sales.

Matsushita Electric Industrial Co. will open a commercial AC supply centre in Germany and increase the production capacity of its Malaysian facilities to the uppermost limit.

Source: JARN, December 2004

The South Korean air conditioning market

South Korea – Korea has two main manufacturers, LG Electronics and Samsung Electronics, while other companies, such as Winia Mando, Carrier Korea, Daewoo and Century are also active. In 2004, LG achieved great results with sales exceeding 10 million units. Samsung is also doing well with its VRF systems as high-end models. The recent trend is as follows:

- The appearance of indoor units is being constantly improved, with reduced size and smooth surfaces.
- The Korean products are increasingly penetrating major markets in the USA, Europe, China and the Middle East.

The domestic market for room and packaged air conditioners (RAC/PAC) in 2004 is estimated as 1.4-1.5 million units. Of these, split type RACs make up 45 %, split type PACs 35 % and multi VRFs etc make up the rest. The major domestic trends are systems with two indoor units and one outdoor unit, VRF systems, flat and thin indoor units, more built-in cassette indoor units and air purification functions.

Source: JARN, January 2005

The domestic market in Japan

Japan – Domestic shipments in Japan for the RY 2004 (October 2003-September 2004) show a small decrease for room air conditioners (RACs) and an increase for packaged air conditioners (PACs). The sales of RACs totalled 6 723 072 units, which is a decrease of 0.8 % compared to RY 2003. Heat pump units decreased by only 0.7 %, while units of cooling-only type decreased by 6.2 %. The Japanese market for RACs is totally dominated by the heat pump type (98.7 %).

Domestic shipments for PACs went up by 11 % from RY 2003 to RY 2004, with a total of 731 795 units being shipped. Ice thermal storage PACs numbered 6915 units, which is about 11 % lower than RY 2003.

Source: JARN, December 2004

Record year for air conditioners and heat pumps in the US

USA – 2004 set yet another record for shipments of air-source heat pumps and unitary air-conditioners in the US. Shipments passed 7 million units for the first time ever, and the year ended with 7,401,067 units shipped. This was 9 % more than 2003, which also was a record year. Heat pumps increased by 16 % from the level in 2003.

Source: ARI Statistical Release, 1 February, 2005

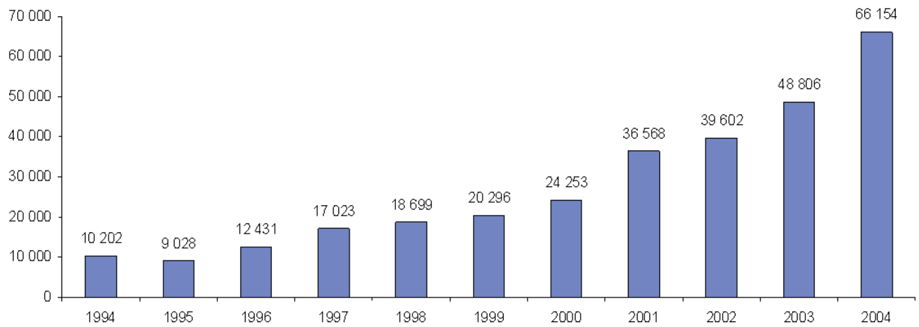
The Swedish heat pump market

Sweden - The Swedish market for domestic heat pumps has gone through enormous development during the last ten years. The technology has evolved from being an interesting curiosity to become the natural choice in new construction as well as in refurbishment. The compiled sales statistics for 2004 revealed total sales of 66 000 units. That figure excludes the sales of the major part of all reversible air-air units, which are estimated to somewhere around 40 000 units in 2004. Altogether, more than 100 000 heat pumps were sold in Sweden 2004. The market still has a strong focus on the single-family house segment, of which there are a total number of approximately 1.6 million. The market has been profiting from recent increases in energy prices and favourable energy price ratios between electricity and oil. There are no subsidies offered for installation of heat pumps in Sweden.

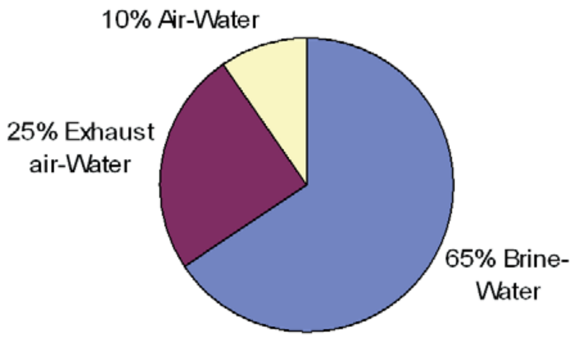
Markets

The sales of small air-air heat pumps have shown a dramatic increase during 2004. This type of installation is the most cost-effective alternative in dwellings heated by direct electricity and in dwellings with low heating load. The competition on this market segment is fierce, which has led to substantial price cuts. Exhaust air heat pumps are installed in more than 90% of all new single-family houses. The reason for this is that strict building regulations raise the demand for mechanical ventilation. Brine/water heat pumps, of which the ground source heat pumps are dominating, accounted for nearly 40 000 units 2004. Interest in air/water heat pumps is increasing, much owing to new actors on the market offering high-performance products. The pie chart below shows the present market share for each type of heat pump that can be categorised as the dominant heat source. Air/air heat pumps are excluded, as they are regarded as supplementary heat sources.

Source: Martin Forsén, Swedish Heat Pump Association



Swedish heat pump sales statistics compiled by The Swedish Heat Pump Association



Market share for different types of heat pumps serving as dominating heat source

Working Fluids

HFC emissions account for 1 % of total GHG emissions in Europe

EU – The "Analysis of greenhouse gas emission trends and projections in Europe in 2003" report, published by the European Environmental Agency (EEA), states that "despite a sharp increase in F-gas emissions between 1992 and 1998, HFCs still account for only 1 % of the total greenhouse gas emissions". HFC emissions increased by 11 % between 1995 and 2001 and, according to EEA, the global increase of HFC emissions is due to the continuing replacement of ozone-depleting substances (ODS) such as CFCs. The report concludes that, despite the continuing replacement of ODS, total EU HFC emissions will remain small.

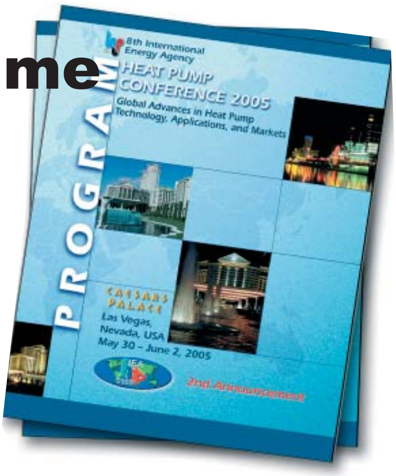
Source: IIR Newsletter, no. 21, January 2005

New natural refrigerant blend

R723 is a new natural refrigerant, and is a blend of 60 % ammonia and 40 % dimethyl ether. It is classed as a B2 refrigerant. It has a high specific evaporation heat and insignificant GWP (global warming potential), just as ammonia. Further benefits are that it can be used in copper systems and offers full mineral oil solubility. It is also reported to have a slightly higher volumetric cooling performance than ammonia.

Source: IIR Newsletter, no. 21, January 2005

IEA Heat Pump Programme



The 8th IEA heat pump conference

USA – The 8th IEA heat pump conference will be held in Las Vegas on May 30 to June 2, 2005. On the 30th there will be workshops for two of the ongoing annexes, Annex 28 "Test procedures and seasonal performance calculations for residential heat pumps with combined space heating and domestic hot water heating", and Annex 29 "Ground-source heat pumps - Overcoming market and technical barriers". More information about these worksops will be published at the conference web site and at the Heat Pump Centre's web site, www.heatpumpcentre.org.

The second announcement with general information, technical programme and registration information is available from the conference web site at http://www.ornl.gov/hp2005/

Source: Heat Pump Centre

Ongoing Annexes

Bold text indicates Operating Agent.

Annex 25 Year-round residential space conditioning and comfort control using heat pumps	25	**FR**, NL, UK, SE, US
Annex 28 Test Procedure and seasonal performance calculation for residential heat pumps with combined space heating and domestic water heating	28	AT, CA, **CH**, DE, FR, JP, NO, SE, US, UK
Annex 29 Ground-Source Heat Pumps - Overcoming Market and Technical Barriers	29	**AT**, CA, JP, NL, NO, ES, SE, CH, UK, US

IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), France (FR), Germany (DE), Japan (JP), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US). All countries are member of the IEA Heat Pump Centre (HPC). Sweden is Operating Agent of the HPC.

High-efficiency, multi-split air conditioners for buildings in a global market

Eiji Kuwahara, Nobuo Murase, Makoto Ueno, Katsuaki Nagamatsu, Japan

In recent years, there has been a growing need for high-efficiency air conditioners as a means of preventing global warming. In response to this need, we have developed very high efficiency multi-split air conditioners for use in office buildings by using R410A refrigerant, which is suitable for higher efficiency, and by improving the efficiency of main components such as compressors, controllers, fans and heat exchangers. In addition, we have improved the partial load efficiency by using variable-speed compressors and inverter drives for their motors. As a result of this improvement, the annual energy consumption of this air conditioner is reduced by half compared to conventional models.

Introduction

Demand in Japan for multi-split air conditioners for use in office buildings is approximately 70,000 units annually. Although the market is currently stable, domestic demand for such units is expected to increase in the next few years, as the air conditioning facilities installed in the many office buildings constructed during the economic boom period in the late 1980s and early 1990s begin to deteriorate and need to be replaced, and as the need for individual multi-split type air conditioning system suited to working environments in office buildings rises. At the same time, there is a growing social need to reduce maximum electric power demand, and recent revisions to the Law Concerning the Rational Use of Energy (the Energy-Saving Law) require products to be made more efficient.

This paper explains the key energy-saving technologies and other features of Toshiba Carrier multi-split air conditioners for building use, which provide the highest efficiency multi-split air conditioners in order to respond to these needs. The 28.0 kW (equivalent to 10 HP) and 56.0 kW (equivalent to 20 HP) class air conditioners described in this paper were developed jointly by Chubu Electric Power Co., Inc. and Toshiba Carrier Corporation. The same demands for greater energy saving as in Japan can also be seen in global markets, particularly in Europe. We also expect that pressure for energy saving will increase dramatically in China in the future. These products will be marketed globally, with a focus on the European, Chinese, Asian, and Australian markets.

Summary of the system

Figure 1 shows an overview of a multi-split air conditioning system for use in an office building. Multiple indoor units are connected to one to four outdoor units with refrigeration pipes and control wires in order to form the whole system.

Figure 1. System overview

1. Lineup of outdoor units
Toshiba Carrier has a lineup of five types of outdoor units, with power ratings of 5HP, 6 HP, 8 HP, 10 HP and 12 HP. By combining up to a maximum of four of these individual units, systems with total capacities ranging from 5HP and 6 HP to 48 HP, in increments of 2 HP, can be created. Table 1 provides additional details concerning the lineup of outdoor units.

2. Lineup of indoor units
Toshiba Carrier has a wide range of indoor units that can be selected according to the application and installation conditions. Those indoor units include the 4-way air discharge cassette, 2-way air discharge cassette, 1-way air discharge cassette, concealed standard-type duct, concealed high static pressure type duct, high wall type, floor standing cabinet type, floor-standing concealed type, floor-standing type, and under-ceiling type.

Table 1. Lineup of individual outdoor units and unit combinations

	Heating capacity (kW)	Equiv. HP	Combined units (Equiv. HP of combined units)	Power rating (cooling capacity) (kW)	Heating capacity (kW)	Equiv. HP	Combined units (Equiv. HP of combined units)
14.0	16.0	5	-	73.0	81.5	26	10 + 8 + 8
16.0	18.0	6	-	78.5	88.0	28	10 + 10 + 8
22.4	25.0	8	-	84.0	95.0	30	10 + 10 + 10
28.0	31.5	10	-	90.0	100.0	32	8 + 8 + 8 + 8 or 12 + 10 + 10
33.5	37.5	12	-	96.0	108.0	34	10 + 8 + 8 + 8 or 12 + 12 + 10
38.4	43.0	14	8 + 6	101.0	113.0	36	10 + 10 + 8 + 8 or 12 + 12 + 12
45.0	50.0	16	8 + 8	106.5	119.5	38	10 + 10 + 10 + 8
50.4	56.5	18	10 + 8	112.0	126.5	40	10 + 10 + 10 + 10
56.0	63.0	20	10 + 10	118.0	132.0	42	12 + 10 + 10 + 10
61.5	69.0	22	8 + 8 + 6 or 12 + 10	123.5	138.0	44	12 + 12 + 10 + 10
68.0	76.5	24	8 + 8 + 8 or 12 + 12	130.0	145.0	46	12 + 12 + 12 + 10
				135.0	150.0	48	12 + 12 + 12 + 12

Energy-saving technologies

1. Efficiency improvement of components

In order to improve the efficiency of the system, we adopted R410A refrigerant, suitable for high efficiency, and made improvements in the efficiency of each system component. Figure 2 shows the energy-saving technologies incorporated into each of the outdoor unit components.

(2) Outdoor air management and fan motor

The outer diameter of the fan propeller is 13 % larger than the propellers used on conventional models, and the blade trailing edge, which serves as the air bleed part during operation, has a reverse arc shape to reduce noise and vibration and to increase efficiency. The reverse arc shape increases the distance between blades, which reduces the fluctuation in air pressure resulting from interference, thereby improving efficiency. Also, the corner radius dimension of the air intake portion of the bell mouth has been optimized to rectify the outward air flow and increase flow rate. In place of the AC motors previously used, a new DC motor was developed. Efficiency at the rating points has increased from 60 % to 81 %, and the power input has decreased.

(3) Outdoor heat exchanger

In order to increase the performance of the finned-tube heat exchanger, we used a tube that has many spiral grooves in the inner surface, raising the heat transfer coefficient by 35 % to 40 %. In addition, by using a section of the heat exchanger as a subcooler, the coefficient of performance in cooling mood is improved by 5 %. We have also introduced a four-sided air intake heat exchanger (see Figure 3). Most of the conventional models take the air from three sides, and the air velocity at the lower section of the

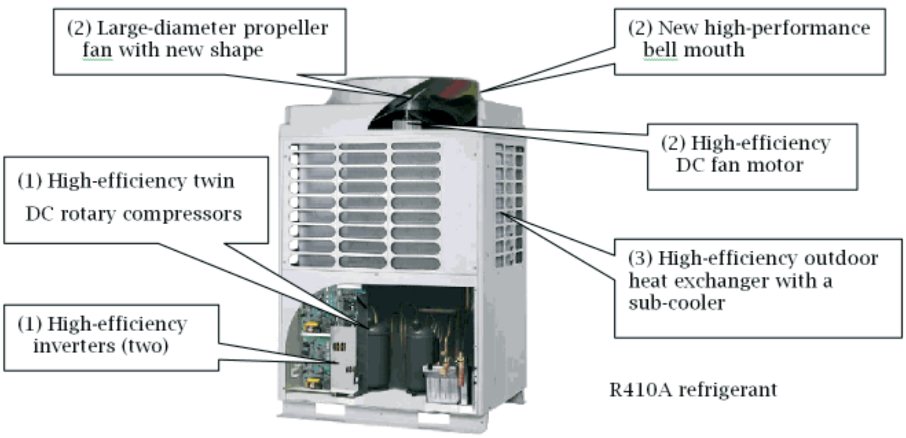


Figure 2. Outdoor unit components and energy-saving technologies

(1) Compressor and inverter(variable-speed driver)

For the compressor motor, we replaced a distributed-winding AC motor with a concentrated-winding DC motor, and adopted compact, high-power rare earth magnets, thereby greatly improving the efficiency. In addition, the inverter that drives the DC motor uses a low-loss IGBT device and a high-speed, reduced instruction set computer (RISC) to improve efficiency further.

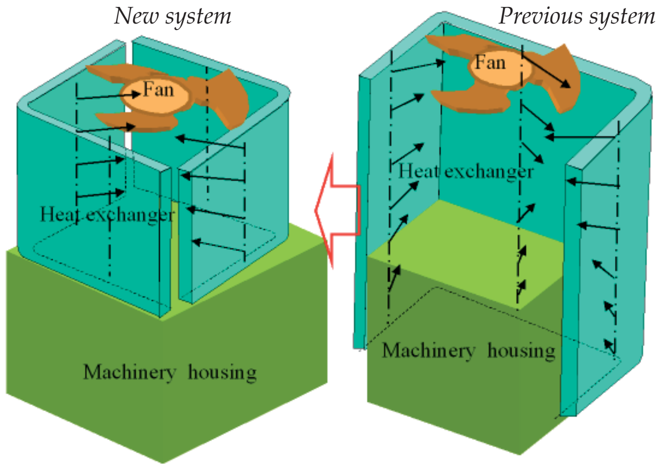


Figure 3. Chassis structure and outdoor heat exchanger

heat exchanger would drop, making it difficult to increase the heat transfer coefficient. The four-sided intake improves the air velocity distribution and achieves higher efficiency, despite the compact size.

2. Efficiency improvement by system control

The efficiency of multi-split air conditioners varies greatly, depending on the operating conditions, and in order to reduce the annual electric energy consumption it is necessary to improve efficiency not only at the rated condition but also at part load, because the actual operating conditions are almost part-load conditions, especially in cooling mode. Consequently, we developed the AI Dual Inverter System, the world's first system to use inverter-driven variable-speed compressors in all outdoor units, which features higher part-load operation performance. As shown in Figure 4, each outdoor unit has two inverters and two variable-speed compressors. Figure 5 shows a system control block diagram for one outdoor unit. The system control board controls the outdoor unit and also controls the entire system in coordination with other outdoor units.

Compared to conventional systems that combine a single variable-speed compressor with some constant-speed compressors, the new system is more efficient under part-load conditions because of the reduction of On/Off losses and of the prevention of concentration of the load on a single variable-speed compressor. In addition, using only variable-speed compressors increases the operating pattern options, such as the number of outdoor units, the number of compressors in each outdoor unit and the operating frequency of each compressor. This allows for optimal selection of the operating pattern according to the air conditioning load, outdoor conditions and so on, which serves to raise the part-load operation performance.

For example, when a 20 horsepower (56 kW) system, such as that shown in Figure 3, operates at half load or less, only one unit of a conventional model would operate, but both units of the new model would operate. Therefore, the new model uses two outdoor heat exchangers and becomes more efficient than a conventional model.

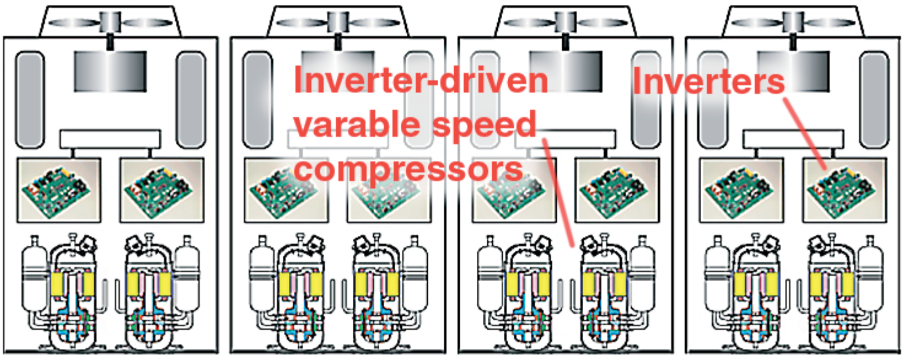


Figure 4. AI dual inverter system

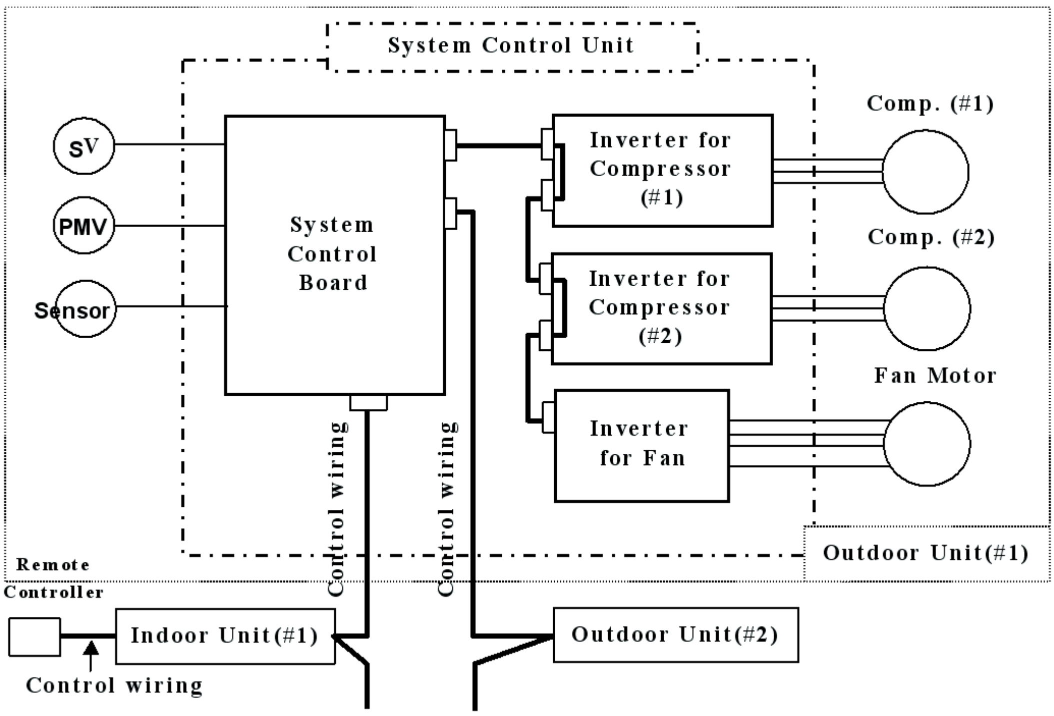


Figure 5. Control system block diagram

3. Improving efficiency and reducing annual electric energy consumption

Table 2 shows a comparison of the rated COP and annual electric energy consumption of a new system and a conventional system. Compared to a conventional system, the new system achieves improvements in average cooling and heating COP of 64 % at 8 HP (22.4 kW), 56 % at 10 HP (28 kW), and 39 % at 20 HP (56 kW). These results greatly exceed the standards in Japan's revised Energy Saving Law (COP of 3.07 at 10 HP and under), achieving 130 % of the standard at 8 HP and 121 % at 10 HP, and are at the industry's highest levels. The new standards will come into effect in 2007. The new system also achieves substantial reductions in annual electric energy consumption compared to the conventional system—approximately 50 % for 8 and 10 HP and 52 % for 20 HP.

The annual electric energy consumption figures were calculated using the Electric Power Consumption Calculation Standards (JRA4055: 2003) adopted by the Japan Refrigeration and Air Conditioning Industry Association. This method determines annual electric energy consumption based on the operating performances at different outdoor temperatures and the frequency at which the outdoor temperatures occur, and takes into account not only the efficiency during rated operation but also the efficiency during part-load operation (see Figure 7).

With regard to energy saving effects, if the multi-split air conditioning systems currently in operation in Japanese office buildings were replaced by high-efficiency multi-split systems, the amount of carbon dioxide produced during electricity generation would decrease by 2.1 million tons per year. This is equal to 2.8% of the reduction goal in the Kyoto Protocol (approximately 76 million tons).

Table 2. Comparison of the COP and annual electric energy consumption of the new system and the conventional system (including outdoor and indoor inputs)

System capacity	8 HP		10 HP		20 HP	
	New	Old	New	Old	New	Old
Rated cooling COP	3.86	2.26	3.54	2.30	3.37	2.30
Rated heating COP	4.15	2.63	3.85	2.50	3.73	2.50
Average rated heating and cooling COP	4.00	2.45	3.70	2.40	3.55	2.40
Intermediate cooling COP	5.34	2.41	5.22	2.59	5.02	2.30
Intermediate heating COP	6.08	2.76	5.89	2.71	5.60	2.50
Heating low-temperature COP	2.94	2.17	2.89	2.03	2.85	2.44
Annual electric energy consumption (kWh)	3,855	7,663	4,962	9,716	10,362	21,371
Reduction in electricity consumption	50%	-	49%	-	52%	-

**1. Indoor units of the 4-way air discharge cassette type are used for the performance test*
**2. Annual electric energy consumption is calculated for an office building in Tokyo under JRA4055 standard.*

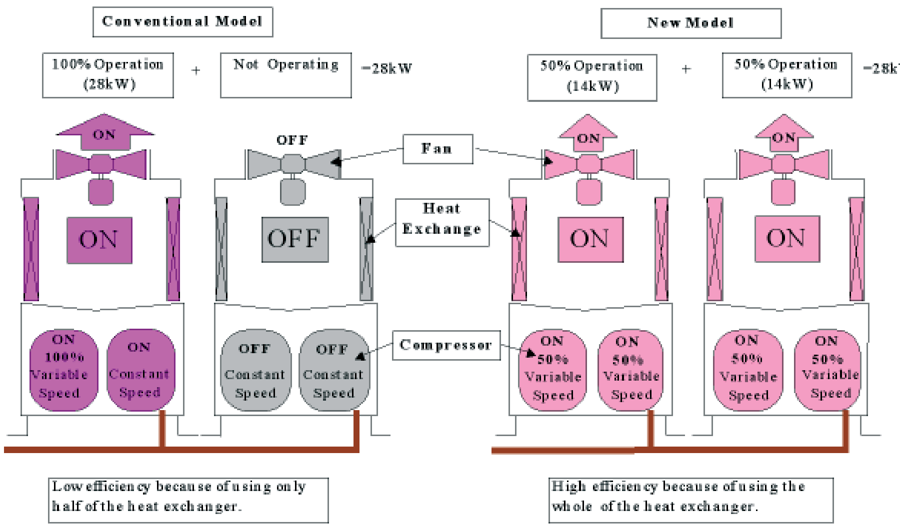


Figure 6. Control example of the AI dual inverter system

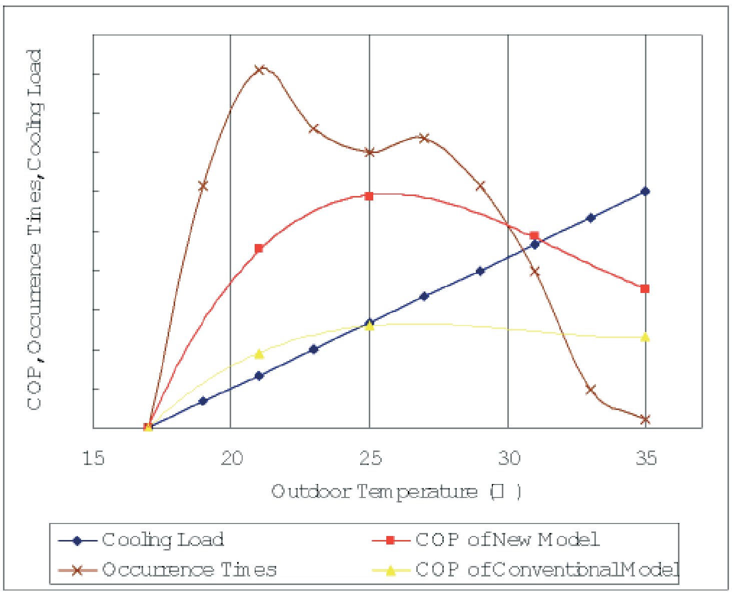


Figure 7. Performance, occurrence times and cooling loads vs. outdoor temperature

Other features

High reliability

The AI dual inverter system can operate the two variable-speed compressors in an outdoor unit in rotation, and also multiple outdoor units in rotation to. This ensures that the operating time of each compressor and each outdoor unit is equalized and the number of on/off cycles is minimized. Therefore, the reliability is improved. Also, since all the compressors are variable-speed compressors, it is easy to maintain the compressor oil at uniform volumes, greatly reducing the risk of compressor failure due to a lack of oil.
Actual effects were confirmed through testing under various temperature conditions and by performing high head tests in a 50-meter tower test room.

Realization of comfort

Conventional systems use a combination of a variable-speed compressor and several constant-speed compressors, and differences in capacity occur as a result of the constant-speed compressors cycling on and off, causing large fluctuations in room temperatures. The AI Dual Inverter System uses only variable-speed compressors, which enables smooth capacity control, resulting in less room temperature fluctuation and enhanced comfort.

Excellent communications system

A communication system that links remote controllers with indoor and outdoor units is essential for controlling a multi-split air conditioning system for buildings. The new system uses an excellent communication system for setting the functions of indoor units via remote controllers, and for remote monitoring and control from a building management office.

Conclusion

We have developed a high-efficiency variable refrigerant flow multi-split air conditioning system for office buildings that features low electric power consumption, high reliability and enhanced comfort. But further improvements in the efficiency of office building air conditioning systems are needed, and so we will continue to make every effort to meet this demand for greater energy savings. We shall also continue to improve reliability and ease of installation, and to develop and provide products that satisfy our customers.

Katsuaki NAGAMATSU
Energy Applications R&D Center,
Chubu Electric Power Co., INC.,
20-1, Kitasekiyama, Ohdaka-cho, Midori-ku, Nagoya, 459-8522, Japan
TEL: +81-52-621-6101
FAX: +81-52-624-9234
E-mail: Nagamatsu.Katsuaki@chuden.co.jp

Combination of solar collectors and ground-source heat pump

Elisabeth Kjellsson, Sweden

The combination of solar heat and ground-source heat pumps for residential buildings provides opportunities for optimising the use of renewable energy sources and minimising the amount of bought energy. Solar collectors in the system may improve the operational conditions of both the solar collectors and the heat pump. A project is in progress at Lund University in Sweden: the first part of the work has been reported [1]. In the project, TRNSYS simulations have been made for different components, systems and energy balances for the Swedish climate and building conditions.

Introduction

In Sweden, interest in both ground-source heat pumps and solar collectors has steadily increased in the dwelling sector over the last decade. In 1999, there were about 100 000 ground-source heat pumps installed, a figure that had reached about 250 000 at the end of 2004. The present rate of installation is running at about 30 000 ground-source heat pumps per year. Several systems from different contractors are already on the Swedish market.

The combination of ground-source heat pumps and solar collectors can be arranged in many ways, with different components and designs. An example is shown in Figure 1. The benefit of the system may therefore vary considerably, and detailed analyses have not yet been undertaken

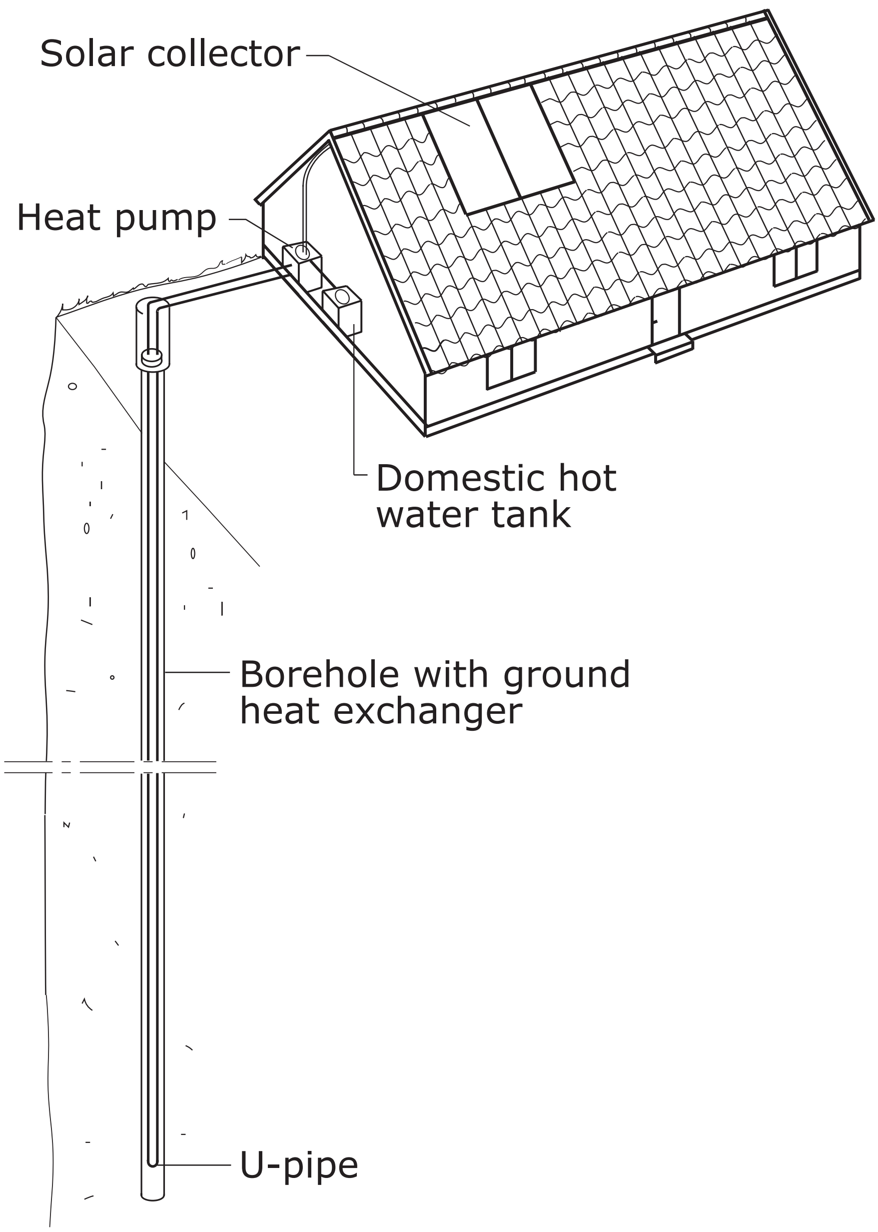


Figure 1. Single-family dwelling with solar collectors and ground-source heat pump.

Background

Ground-source heat pumps, in combination with solar heat, have been tested with different system designs in several countries over the last 25 years. In Sweden, the performance of small solar-assisted ground-source heat pump systems was tested by the Swedish State Power Board. Experience from 1984/85 from operation of 14 heat pump plants, including equipment such as simple solar collectors or air collectors to recharge heat into the ground, was reported.

The system performance was considered to be satisfactory as far as operating time, energy performance, coefficient of performance (COP) etc. were concerned. However, it was concluded that it would be more cost-effective with a higher source temperature, and thus an improvement in performance by drilling a deeper borehole. The source temperature increase, due to recharging, only reached about 2 °C.

The differences since these projects were realised are that the components have improved in performance and costs have decreased. The heat pumps have a higher COP and the manufacture of solar collectors is more industrialised. With the introduction of microprocessors, control systems can incorporate completely new control strategies, and systems can be designed and optimised for different applications, depending on solar radiation and heat demand. The drawback is that the complexity of these systems may cause difficulties in optimisation and operational control. Economic conditions have also changed. In the late 1980s, the cost of alternative energy forms, with which heat pumps and solar energy were competing, was about 0.30 SEK/kWh (SEK 1 ~ USD 0.14) for electricity and about the same for oil. Today, these prices are more than three times higher.

The advantages of recharging the borehole include:

- increased seasonal performance factor of the heat pump
- reduction in the depth of the borehole
- possibility of higher heat extraction from the borehole
- reduction of the thermal interaction of neighbouring boreholes with heat extraction
- solar collectors and boreholes may be designed for seasonal heat storage in a system with a group of houses with a common heat distribution network.

The reduction of the thermal interaction is of special interest in densely populated dwelling areas, where concern for long-term thermal influence between adjacent boreholes might lead to restrictions on the use of ground heat sources.

Solar recharging can also be used to:

- increase the evaporator temperature when the active borehole depth is undersized e.g. because of
  - higher heat demand than as sumed
  - lower ground thermal conduc tivity than was assumed
  - lower ground water level than was assumed
- counteract freezing of boreholes.

Ground-source heat pump

The heat to a conventional ground-source heat pump is taken from boreholes. For single family dwellings, one borehole is normally sufficient but, for higher demand, several boreholes can be linked together. The depth of the borehole varies from 60 to 180 m.

In the borehole there is normally a collector consisting of a U-tube heat exchanger with a circulating heat carrier fluid. In ground-source heat pump systems without solar collectors, the heat carrier fluid is normally an antifreeze solution of ethanol/water. This antifreeze liquid cannot be used if the system is connected to solar collectors with high temperatures, due to explosion risks, and a glycol-based rapeseed oil is normally used instead.

Unglazed and glazed solar collectors

Depending on the type of solar collectors used in the system, the solar heat can be used in several ways. For unglazed solar collectors, the heat can be used either to increase the temperature to the evaporator or for recharging the borehole. The simplest way is to connect the solar collector to the return pipe from the evaporator back to the borehole. Figure 3 shows one system available on the market.

Components and systems

The solar heat may be used in different ways in systems with ground-source heat pumps, depending on the choice of components and system. In the most flexible systems, solar heat can be used in several ways, depending on demand and temperature levels.

- directly to the domestic hot water
- directly for heating the building
- heating the evaporator in the heat pump
- recharging the borehole.

Figure 2. Drilling a borehole for a single family dwelling

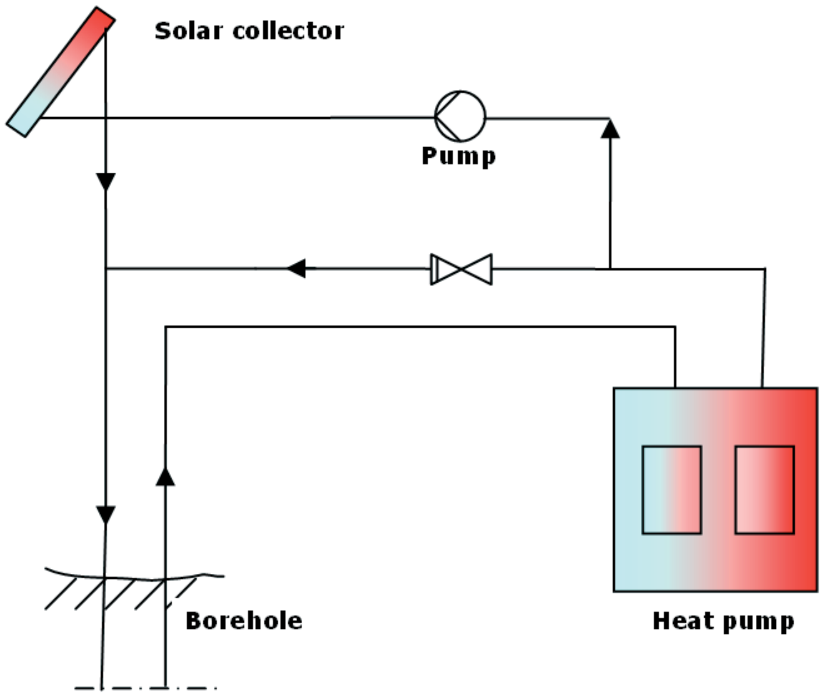


Figure 3. Unglazed solar collector recharging the borehole

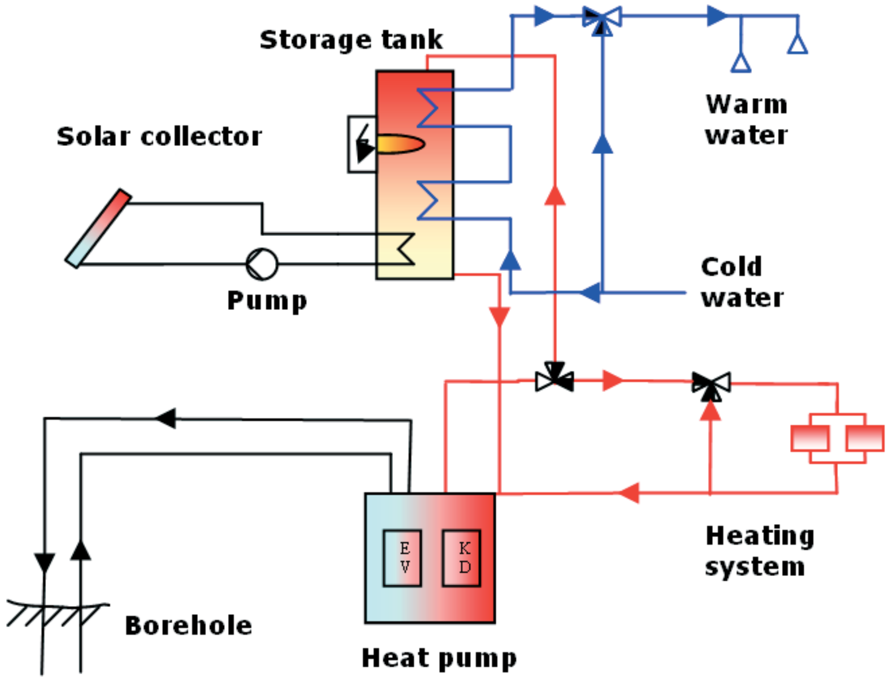


Figure 4. System with a heat pump and glazed solar collectors, used only for heating domestic hot water.

When using glazed solar collectors, one possible system is to use the solar collectors only for domestic hot water. See Figure 4.

In the system in Figure 4, the heat pump is used for all of the space heating and as auxiliary heating for the domestic hot water, when the solar collector is not able to meet the total demand. The operating time of the heat pump decreases, as the solar collector produces the hot water during the summer and the heat pump can be shut off. This gives the borehole a natural recharge and may extend the life of the heat pump, as summer operation with many starts and stops is reduced to a minimum. The seasonal performance factor (SPF) of the system also increases, as the heat pump has a shorter operation time and because the temperature in the borehole is higher than it would be in a conventional system without solar collectors.

System with flexibility

With glazed solar collectors, the solar heat can be used also for more than heating domestic hot water, either when there is no demand for hot water, or when the irradiation is not high enough to reach the needed temperature. With a system as in Figure 5, solar heat can be used to heat the building, the evaporator or the borehole.

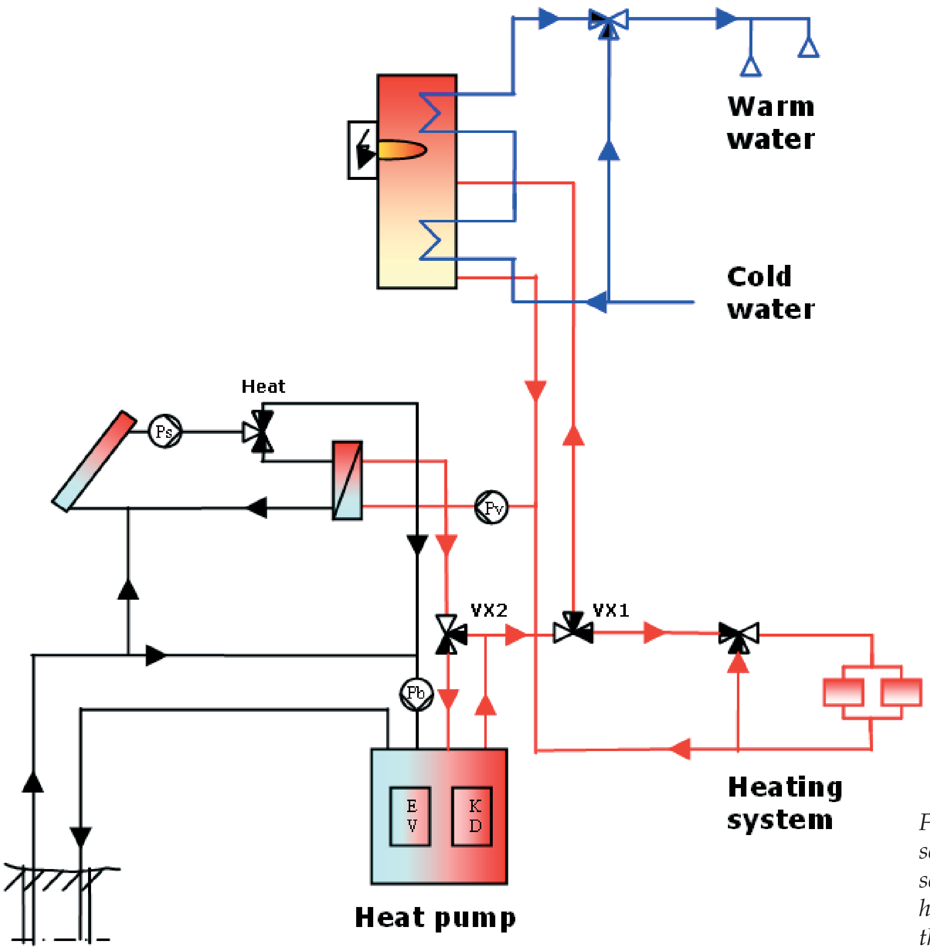


Figure 5. System with a heat pump and glazed solar collectors. This arrangement can deliver solar heat for heating domestic hot water, the heating system in the building, the evaporator in the heat pump or for recharging the borehole.

The solar collector circuit and the borehole circuit in the system in Figure 5 are linked together with an antifreeze liquid, with an external heat exchanger for the water in the heating system.

Compared to conventional solar collector systems, mainly used for domestic hot water, the solar collectors used in combination with heat pumps can be used with lower system temperatures. The advantages are that the solar collectors can produce more heat, due to longer operating times and reduced heat losses because of the lower temperature in the collectors and the system. If the solar collectors are used for increasing the temperature to the evaporator, the collector efficiency is improved, as is the coefficient of performance (COP) of the heat pump.

The disadvantage with the combination of solar collectors and ground-source heat pump is primarily the investment costs, which increases with the complexity. Also the cost for operating the circulation pumps increases, as the operating time is extended. The conventional circulation pumps in both the solar collector circuit and the borehole circuit have a low investment cost, but also a low efficiency. This means that control of the pumps must be optimised for the overall system performance.

Simulations

Simulations for the combination of solar collectors and ground-source heat pump have been performed for a single-family dwelling. The solar collector area varied between 0 and 14 m2 and borehole depths between 100-160 m.

One objective was to investigate the benefits for the heat pump operation of solar recharging of the borehole. If all the collected solar heat is delivered to the borehole circuit, the maximum increase of the inlet evaporator temperature is achieved. The result from the simulation, with a system as shown in Figure 6, shows that the energy-weighted temperature to the evaporator for the whole year during the time when the heat pump is in operation, will increase by about 2.5 – 3.5 °C with a 14 m2 solar collector, as compared to a system without solar collectors. The greatest increase is for the shallowest boreholes, which have a lower temperature, compared to deeper boreholes, for the same load. This possibility can be used for undersized boreholes to compensate for an increased load.

For the type of heat pump used in conventional systems, the increase in temperature to the evaporator gives a corresponding increase of the coefficient of performance (COP) for the heat pump, of about 1.5 %/°C or about 3.5 %/°C for the thermal output. Figure 6 shows the corresponding increase in the seasonal performance factor (SPF).

The seasonal performance factor in Figure 6 is calculated as the ratio between the heat produced over the year and the electricity used by the compressor. This means that electricity for circulation pumps and auxiliary heat is not included. For the simulated systems, the increase in SPF is about 0.1 – 0.2, depending on different depths of the boreholes.

Calculations including the electricity use for the pumps and auxiliary equipment show that the total use of electricity may exceed the advantage from recharging, and give a lower total system seasonal performance (SPF) as compared to systems without solar collectors.

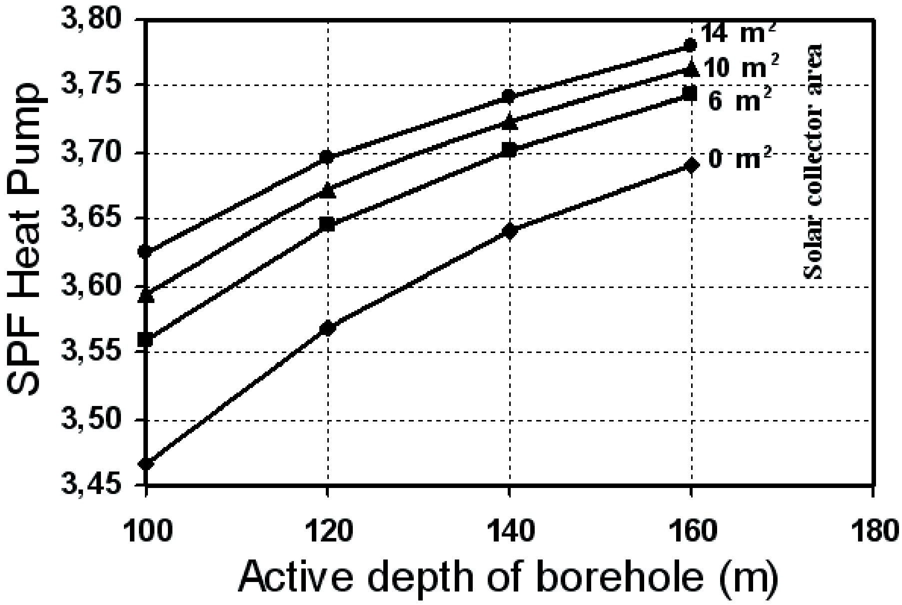


Figure 6. Seasonal performance factor (SPF) for the heat pump, with and without solar heat (glazed solar collectors, m2 collector area) for recharging the borehole, for different depth of boreholes (m), but the same load. The SPF does not include the use of electricity for circulation pumps and auxiliary heat.

Conclusions

Recharging with solar heat is a way of increasing the temperature to the evaporator in a system with a ground-source heat pump, especially when the system is undersized with too shallow active borehole. Recharging may also be necessary in areas where the ground-source heat pumps are so close together that they influence each other.

With the systems available on the market today, it is important to optimise the energy flows for the whole system, as otherwise there are risks that the use of electricity for the circulation pumps will exceed the benefit of the recharging. Further simulations will be made, but it is already clear that the more efficient circulation pumps that are now being introduced into the market, would be definitely profitable after a few years in operation.

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[1] Kjellsson, E., 2004. "Solar Heating in Dwellings with Analysis of Combined Solar Collectors and Ground-source Heat Pump" (in Swedish), Report TVBH 3047, Dept. of Building Physics, Lund University, Sweden, 2004. (Can be downloaded in pdf format from: www.byfy.lth.se/Publikationer/3000.htm)

Elisabeth Kjellsson
Dept. of Building Physics
Lund University
P.O. Box 118
SE-221 00 Lund
SWEDEN
Tel: +46 414 70677
Fax: +46 46 222 4535
E-mail: Elisabeth.Kjellsson@byggtek.lth.se

The frost-less heat pump: new method of controlling the wintertime performance of air-to-air heat pumps

V. C. Mei, Z. Gao, and J.J. Tomlinson, USA

A new frost-less heat pump technology has been developed at Oak Ridge National Laboratory. If a moderate amount of heat is added to the refrigerant stream in the accumulator, the suction pressure and temperature can be raised. As a result, frost accumulation on the outdoor coil is retarded.

Introduction

There are two major concerns associated with space heating heat pumps. One is that periodic defrosting of the outdoor coil below 4.4°C (40˚F), and the other is the "cold blow" effect (delivery of air at less than body temperature) that compromises indoor thermal comfort. Conventional defrosting by cycle reversing has an inherent energy penalty because it absorbs heat from the indoor air during the defrosting period.

A new frost-less heat pump technology has been developed at Oak Ridge National Laboratory. If a moderate amount of heat is added to the refrigerant stream in the accumulator, the suction pressure and temperature can be raised. As a result, frost accumulation on the outdoor coil is retarded. Most of the heat added to the accumulator will be delivered to the indoors in the form of a higher heat pump supply air temperature, reducing the cold blow effect. The frequency of defrosting cycles can be drastically reduced over the temperature range where frosting is most likely to occur. Further, the higher heating capacity and slowed frost accumulation on the outdoor coil allows the heat pump to operate for a shorter time before defrosting is needed.

The new technology also includes a new energy-efficient defrosting scheme. When the ambient temperature is below 0˚C (32°F), the moderate amount of heat added to the accumulator will not retard frost accumulation entirely. However with the new defrosting method, the indoor fan remains off during the defrosting period. Two-phase refrigerant flowing through the indoor coil remains two-phase, enters the heated accumulator, and boils. Thus the accumulator functions as an evaporator. An obvious advantage is that the heat pump will not produce cold air during the defrosting period. Power for defrosting is modest, around 1 kW, as compared to an average of 7-10 kW for resistance heat used in conventional defrosting designs. Laboratory experiments indicated that the new frost-less concept saves energy: conventional defrosting uses about 10 kW for 10 minutes whereas the frost-less system uses 1 kW for about 12 minutes. The energy savings depends on the number of defrosting cycles needed.

With the participation of the U.S. Department of Energy (DOE) and the Tennessee Valley Authority (TVA), ORNL is completing R&D on the frostless heat pump. A split heat pump system was modified with the new frost-less feature and was tested in a two-room environmental chamber at various simulated outdoor temperatures. The results indicated that frost-less operation retarded frost accumulation on the outdoor coil significantly. The new defrosting concept was also tested and worked as expected. With only 1 kW of power applied to the accumulator, the defrosting time was almost identical to that of the conventional defrosting method. Compared with conventional defrosting technology, which energizes a 7- to 10-kW resistance heating element during the defrosting period, the new defrosting technology is energy-efficient, and it does not take heat from indoor air. DOE-supported field tests of the frost-less heat pump have been initiated with the participation of Parker-Hannifin and the Modern Supply Co., and they will be completed at the end of the 2004-2005 heating season.

Frost-less heat pump concept

Laboratory tests of air-to-air heat pumps have shown that if the outdoor coil temperature is above -2.8°C (27˚F), there will be practically no frost accumulation when the ambient temperature is in the range of 0 to 4.4°C (32 to 40˚F), which is the range over which frost is most likely to accumulate. If a moderate amount of heat is added to the accumulator during winter heating-mode operation as depicted in the schematic shown in Figure 1, the outdoor coil temperature can be increased to around -2.8°C (27˚F). Frost formation on the coil will then be retarded because of the elevated coil temperature. Most of the heat added to the accumulator will be delivered to the inside of the house as higher supply air temperature through more efficient compressor operation with higher suction pressure and mass flow rate. The cleaner outdoor coil with less

frost accumulation increases its heat transfer capability.
Snapshots of the growth of frost on the outdoor coil of a conventional split system heat pump under outdoor conditions of 4.4 to 0°C (40 to 32°F) and 21.1C (70°F)/15.6C (60°F) db/wb, are shown in Figure 2 (a), page 24. The outdoor coil is fully-frosted after 100 minutes. The performance of this heat pump but converted into a frost-less design using the heated accumulator and controls, and under the same conditions as the conventional heat pump is shown in Figure 2 (b), page 24. The duration of time for the coil to become fully frosted was essentially doubled.

It should be noted that "frost-less" is not "frost-free." If the heat pump is operated over a long time at low ambient temperatures, frost will accumulate on the outdoor coil even with heat added to the accumulator. When the ambient temperature is outside the range of 0 to 4.4°C (32 to 40˚F), the heater in the accumulator will be turned off, because above 4.4°C (40˚F) the coil temperature will be warm enough to prevent frost formation, and below 32˚F, the moisture content of the air will be too low for heavy frost accumulation on the coil.

Converting to frost-less

Cycle reversing is the standard heat pump defrosting method. Figure 1 shows the schematic of the frost-less heat pump and Figure 3 shows the schematic of the new accumulator-heater assembly. The new accumulator costs less than $16 (about the same as for a conventional accumulator used in a conventional heat pump), and the accumulator heater costs less than $13. Figures 4 and 5 show the real accumulator and heater used.

Conclusions

The frost-less heat pump concept has addressed the two major concerns about heat pump operation: (1) cold blow during normal operation and particularly during defrosting,

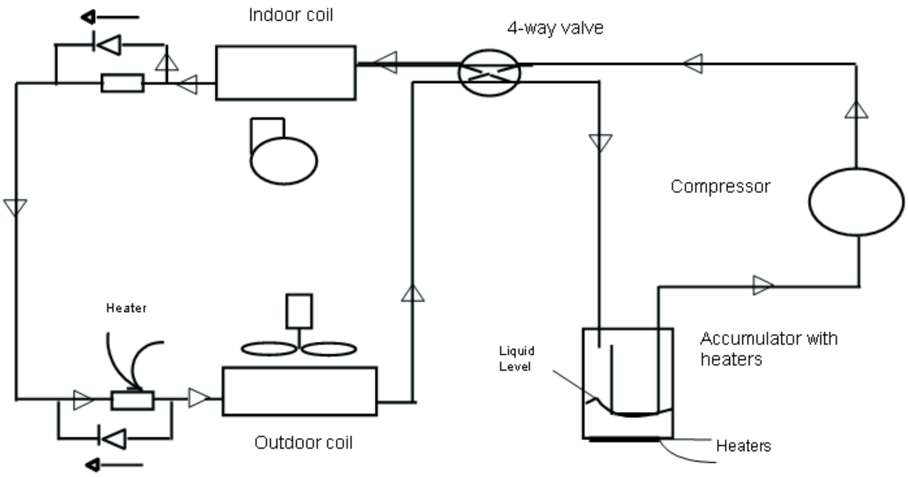

Fig. 1 Refrigerant path in Frost-less heat pump

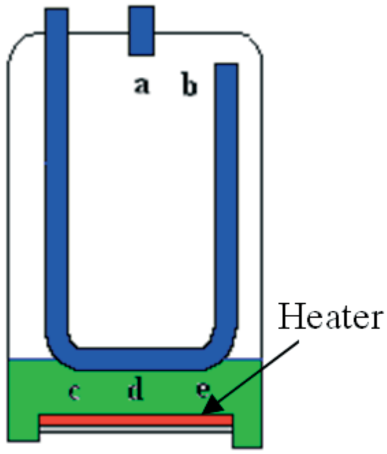

Fig. 3. Flat bottom accumulator heater assembly design


Fig. 4. New flat-bottom accumulator by Parker-Hannifin

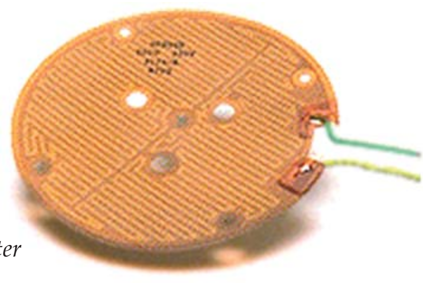
Fig. 5. ThermofoilTM Mica heater from Minco

(2) frequent defrosting cycles. The Frost-less heat pump meets this challenge by increasing the heat pump supply air temperature and reducing the defrosting cycle frequency using a simple technology and controls applied internal to the outdoor unit.

Laboratory test data show the concept works very well. The technology delays the frost accumulation on a 10.5 SEER heat pump unit so that it operated 200 minutes instead of the baseline system of the same capacity that operated for 100 minutes before the defrosting cycle was initiated. Limited field test data on an SEER 13 heat pump also indicated that the accumulator heater worked as expected: During the defrosting cycle, the indoor blower was off and the accumulator heater was energized with 1 kW power input to the heater.

The indoor cold blow during the defrosting period was completely eliminated. This means that indoor thermal comfort was improved. Energy savings were also realized: instead of the conventional 10 kW resistance heater, the frost-less design used only 1 kW of power for a slightly longer period of time during the defrosting period. It is estimated that this technology enables heat pumps in regions above the TVA area to save more energy during the defrosting period, because those regions would require more frequent defrosting cycles.

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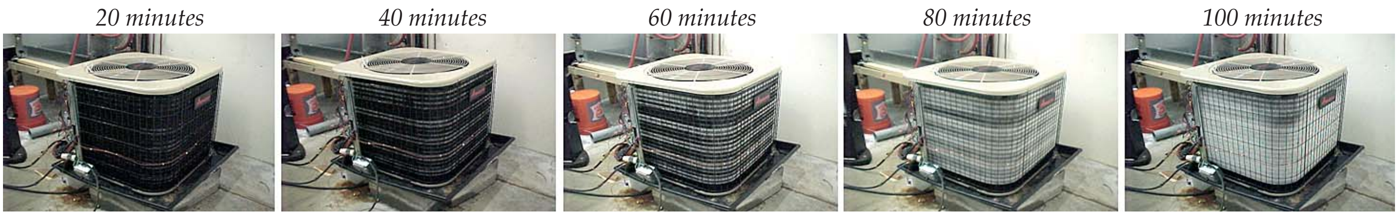
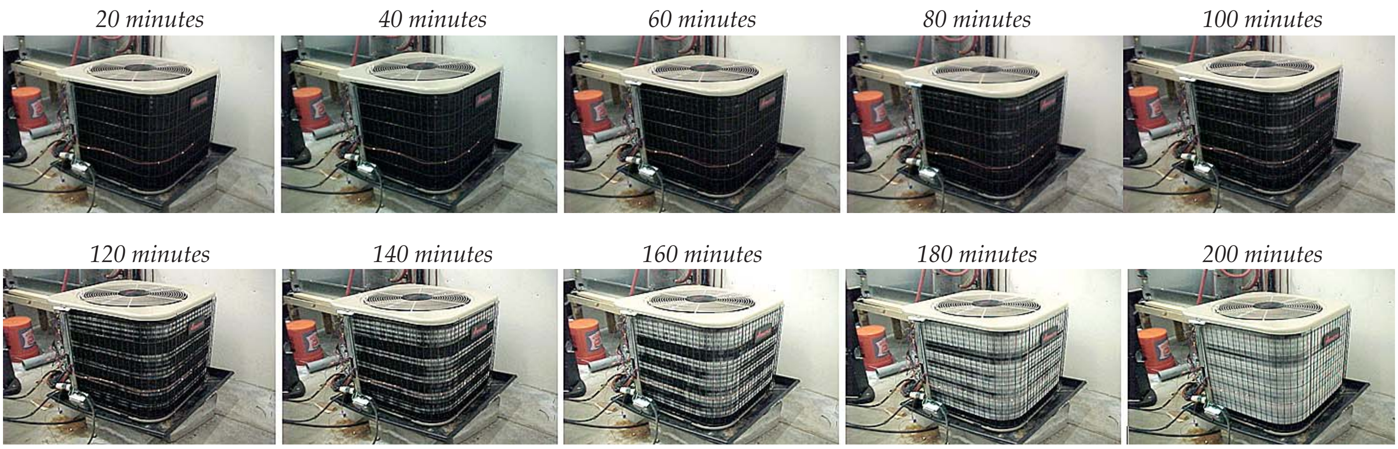
V. C. Mei
Engineering Science and Technology Division
Oak Ridge National Laboratory
USA
E-mail: vcm@ornl.gov



(a) Baseline operation at 1.7 °C (35°F) and 80%RH



(b) Frost-less operation at 1.7 °C (35°F) and 80%RH; 1kw accumulator heating

Fig. 2a & 2b. Transient process of frost formed on the surface of outdoor coil

Gas-fuelled heat pumps for existing buildings and renovations - energy transition substantiated

Peter Oostendorp, Netherlands

Heat pumps are installed mainly in new buildings, while the larger replacement and renovation market remains practically untouched. Within the framework of SenterNovem's 'Support for Transition Coalitions Scheme', TNO and Techneco BV are conducting a project named 'The use of ambient heat for heating existing dwellings' as preparation for transition experiments with gas-fuelled heat pumps in existing dwellings.

Introduction

Until now, heat pumps have been installed chiefly in new buildings. This is only natural, since the situation in new building makes it easiest for us to meet the preconditions which determine the smooth functioning of heat pump systems. Consider, for example, the heat source, the required low-temperature heating systems and the related energy infrastructure. And it is only natural, of course, to introduce a new technology to those market segments first, where complications are (or appear to be) least.

This approach has been successful. In new buildings, the electric heat pump has developed into a reliable technology; an increasing number of suppliers are marketing both Dutch and foreign products; successful (hydraulic) system designs have been developed; knowledge is (still) recorded in handbooks and publications; consultants choose the technology as the obvious option; an already sufficient, yet still increasing, number of installers is capable of properly installing the systems and – supported by the fact that a heat pump can also provide cooling in the summer – the technology is on the shortlist of project developers and architects. It is a pity that the Government has abolished the Energy Premium Scheme, but it looks as though this will cause only a temporary setback in the numbers installed. The 'Competition Strength Analysis' [1] has shown that there are sufficient robust and competitive techniques to achieve an EPC reduction of up to 0.8 in housing.

Existing buildings/new house construction

If we confine ourselves to private dwellings in the Netherlands, new housing involves approximately 50,000 dwellings per year. This market is too small to contribute in a substantial way to the goal of reducing CO2 emissions, which our Government has pledged to do. The existing housing stock, with roughly six million units, presents a huge potential. If their heating systems are replaced once every 15 years, this would result in an annual market of roughly 400,000 units, which is ten times more than in new house construction. After considering new house construction, it therefore makes sense and is logical to concentrate on the possibility of heat pumps in existing buildings.

Energy transition

The term 'energy transition' refers to combined developments which, in the long term, must lead to a sustainable and cost-efficient energy policy in the Netherlands. The Ministry of Economic Affairs views the energy transition goal as a means of developing a long-term reliable and efficient energy supply. The energy transition period is also intended to tackle the climate problems caused by burning fossil fuels, and involves structural changes to society. This change is necessary in order to solve our persistent environmental problems and help to move towards a sustainable energy policy.

Since the options available up to now (especially short-term developments) seem to have been unsuccessful, the Government now wants to switch to an innovating process, known as 'energy transition'.

Characteristics of transitions [2] are that they involve (a) development over a longer period, (b) several social sectors, (c) the involvement of a wide range of disciplines and (d) that the solutions will probably involve breaking one or more trends.

Energy transition specifically also entails (e) a new approach to energy and (f) a large energy-saving potential.

The energy transition is one of the four "transitions" described in the National Environmental Policy Plan (NMP, 2001).

Reversal of ideas about energy

A reversal of the commonly held beliefs is necessary to get away from the 'more of the same' approach to energy and environmental problems. A U-turn towards innovation is necessary, away from the existing improvement and optimisation concept.

Terms of transition management

Future visions

Imagine how the desired future might look, (for example, envisage that high-efficiency boilers can be replaced by sorption heat pumps in just a few hours' work, that the entire operation is limited to the site of the original boiler, that the equipment and maintenance is provided by power distribution companies and that users pay only for the system's useful output).

Backtrack from this future vision and deduce which steps are needed now in order to realise it (for example, overcoming barriers, solving problems, filling in gaps). Follow on from this by making a more detailed determination of the ways in which this might be achieved

The goals and approach methods are not fixed in advance and are subject to change. Continuous evaluation of results, processes and (interim) goals, with the entire matter in a constant state of flux.

Consider an example from [1] the transition from combustion engines to electric vehicles. The automobile industry is used to the preferences of consumers, such as affordability, multi-purpose use, high speed and acceleration and large action radius, and therefore takes these points as the basis in development of electric cars. This makes it necessary to design a battery with high capacity and discharge rate, which so far has not yet been achieved. If you look at this in terms of a transition, you would have to try and develop a broader outlook; one in which not just one product would have to meet existing demands, but where changes would be needed in adjacent fields. Imagine that such a change in context would lead to a drastic reduction of the average driving distance of each car trip, that forms of public transport would be created, or that a travel method would be developed, whereby the time used for travelling is no longer considered wasted; then the demands on the battery would come closer to more easily achievable levels.

Transition paths

Several paths have been defined for energy transition. These are possible routes which can be taken in order to achieve the energy transition goal. And within them lie a number of transition experiments. These are (practical) exercises for exploring the paths. In the preparation of a transition experiment, projects were started which should lead to transition groups being formed. To begin with, experiments are designed and conducted with these groups, but they will also play a role later in the transition, when the transition paths are further expanded and subsequently embarked on.

The present project 'The use of ambient heat for heating existing dwellings' is a project that involves input from a wide range of sources, both individual and collective. 'Ambient heat' in this context refers to heat pumps, as the heat extracted from the heat pump from the heat source (environment) is at any rate considered sustainable.

The results of this project are:

1. A group of parties wishing to become engaged in order to contribute their share to the realisation of the transition experiment (use of ambient heat for space heating in existing dwellings), and which is able in particular to carry out the economic, administrative/legal and technical aspects of the transition experiment.
2. Formulating a vision of the respective transition path through a description of the context needed for bringing the respective technology to the market (in this case, gas-fuelled sorption technology).
3. A first description of a transition experiment, which attempts a broad implementation of the technology. 'Broad' means that the experiment is pre-competitive; that products from several suppliers are used; that the experiment is supported by several players and that it interacts on several social levels (micro, meso and macro).

The group

The group in the process of being formed comprises a number of essential sectors, such as the suppliers of gas-fuelled heat pumps (Nefit, Vaillant, Robur/Techneco), the energy sector (Nuon, Eneco, Gasunie), the installation sector (Uneto-VNI and several individual installers wishing to participate in experiments), and various knowledge institutions (ISSO, Saxxion Hogeschool, Gastec, TNO).

An introductory workshop was held to get the participants acquainted with one another and with the project's concept. Business cases were developed to establish the preconditions, both in technical and institutional terms, which must be met in order to get the introduction of gas-fuelled heat pumps in existing buildings off the ground. What comes to mind are issues such as:

- What does energy management look like where ambient heat is used in existing buildings?
- What are the possible exploitation models?
- Which economic and administrative changes are needed?
- Which technological changes and developments are required?
- Which forms of knowledge transfer are necessary for the different players?
- Which vicious circles and 'chicken – egg situations' must be broken?

Of the people currently involved, most will remember a heat pump demonstration programme from the eighties, launched with huge enthusiasm and ambition, in which the quality of the technology and just about everything surrounding it (particularly the implementation aspects) ultimately turned out to be inadequate to justify the scale of the approach. The thing to do is to make maximum use of this (now) free lesson. At any rate, effective securities should be integrated in the practical experiments, regardless of their nature, so that residents can enjoy the comforts that they may well expect of the systems.

Openings in the group

There are, as mentioned earlier, promising contacts with housing corporations. The group, however, would still like further input from a number of additional organisations from that sector. And it is looking for housing corporations or project developers with scheduled renovation or replacement projects between 2005 – 2006, that would be willing to consider, for example, the use of gas-fuelled heat pumps within the framework of SenterNovem's Unique Opportunity Scheme (UKR). The group would also like to establish contact with those departments of municipalities geared towards sustainable energy that would like to promote this type of project.

Further information concerning the group is available from:

Peter Oostendorp
TNO, Refrigeration and Thermal Engineering
Tel. : +31 (0)55-549 37 71
E-mail : peter.oostendorp@mep.tno.nl

References:

[1] Oostendorp et al., The competitive power of heat pumps in the Netherlands [De Concurrentiekracht van warmtepompen in Nederland], TNO report R2004-062, February 2004. Printed version available through: www.mep.tno.nl/wie_we_zijn/organisatie/expertisegebieden/koudetechniek/PDF/Ra2004_062_rapport.pdf

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[3] The Ministry of Economic Affairs maintains a very informative site about energy transition at: http://www.ez.nl/content.jsp?objectid=17725

Books & Software

Proceedings of the IIR compressors 2004 conference

This CD-ROM contains 41 papers from the 2004 conference and an additional 27 papers presented at the previous conference in 2001. Topics addressed are: New trends in the field of compressors; Reciprocating compressors; Scroll compressors; Centrifugal compressors; Improving energy efficiency; Heat pumps; Applications in domestic and commercial refrigeration and air conditioning; Carbon dioxide compressors and Hydrocarbon compressors.

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The proceedings are available from the Ray W Herrick Laboratories, www.adpc.purdue.edu

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E-mail: greth@cea.fr
http://www.greth.fr/heatset2005

Ammonia Refrigeration Systems, Renewal and Improvement
6-8 May, 2005
Ohrid, Republic of Macedonia
Contact: Prof. R Ciconkov
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www.mf.ukim.edu.mk

8th IEA Heat Pump Conference 2005
30 May – 2 June 2005
Las Vegas, Nevada, USA
Contact: The Conference Secretariat
Oak Ridge National Laboratory
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Fax: +1 865 574 9331
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International Sorption Heat Pump Conference
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Broomfield, Colorado, USA
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University of Maryland
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Fax: (301) 405 2025
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5th International Conference on Compressors and Refrigeration
19 – 22 July
Dalian, China
Contact: Xueyuan Peng
School of Energy and Power Engineering
Xi'an Jiaotong University
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Fax: +86 29 8266 8724
E-mail: xypeng@mail.xjtu.edu.cn

ASHRAE Annual Meeting
25 – 29 June, 2005
Denver, Colorado, USA
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Commercial Refrigeration
30 - 31 August 2005
Vicenza (Padua), Italy
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E-mail: alcav@unipd.it

Thermophysical Properties and Transfer Processes of New Refrigerants
31 August – 2 September 2005
Vicenza (Padua), Italy
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International Conference on Compressors and their Systems
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Heat Transfer and Fluid Flow in Microscale
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Castelvecchio Pascoli, Tuscany, Italy
http://www.engconfintl.org/5ah.html

The 2005 World Sustainable Building Conference, SB05 Tokyo
27 – 29 September, 2005
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http://www.clima2005.ch/

3 Forum Wärmepumpe
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In the next Issue

Zero Leakage, Minimum Charge

Volume 23 - No. 2/2005

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

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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.

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SP Swedish National Testing and Research Institute

IEA Heat Pump Centre
SP Swedish National Testing
and Research Institute
P.O. Box 857
SE-501 15 Borås
Sweden
Tel: +46 33 16 50 00
Fax: +46 33 13 19 79
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

IEA OECD heat pump centre

National team contacts

AUSTRIA
Dr Hermann Halozan
Technical University of Graz
Institute of Thermal Engineering
Inffeldgasse 25,
A-8010 Graz
Tel.: +43-316-8737303
E-mail: Halozan@iwt.tu-graz.ac.at

CANADA
Mrs Sophie Hosatte
1615 Lionel-Boulet Blvd
Varennes (Quebec)
Canada J3X 1S6
Tel.: +1 450 652 5331
E-mail: sophie.hosatte@nrcan.gc.ca

FRANCE
Mr Etienne Merlin
ADEME/DIAE
27 rue Louis Vicat
F-75737 PARIS Cedex 15
Tel.: +33-1-47-65-21-01
E-mail: Etienne.Merlin@ademe.fr

GERMANY
Dr Claus Börner
Forschungszentrum Jülich GmbH
PO Box 1913,
D-52425 Jülich
Tel.: +49-2461-613816
E-mail: c.boerner@fz-juelich.de

JAPAN
Mr Takeshi Yoshii
HPTCJ
Kakigara-cho, F Building (6F)
1-28-5 Nihonbashi, Kakigara-cho
Chuo-ku, Tokyo 103-0014
Japan
Tel:+81-3-5643 2404
E-mail: yoshii@hptcj.or.jp

NETHERLANDS
Mr Onno Kleefkens
Novem
P.O. Box 8242
NL-3503 RE Utrecht
Tel.: +31 30 2393 449
E-mail: o.kleefkens@novem.nl

NORWAY
Mrs Trude Tokle
Enova SF
Abelsgatan 5
N-7030 Trondheim
Tel.: +47 73 19 04 54
Fax: +47 73 19 04 31
E-mail: trude.tokle@enova.no

SPAIN
Ms Marta Garcia
ENEBC
Po General Martinez Campos, 11 1o
28010 - Madrid
Tel.: +34 914445904
E-mail: enebc@enebc.org

SWEDEN
Dr Björn Sellberg
FORMAS
PO Box 1206
S-11182 Stockholm
Tel.: +46-8-775 4028
E-mail: Bjorn.Sellberg@formas.se

Dr Peter Rohlin
STEM
Buildings & Community Systems
PO Box 310
S-63104 Eskilstuna
Tel.: +46 16 544 2112
E-mail: Peter.rohlin@stem.se

SWITZERLAND
Dr Thomas Kopp,
Hochschule Rapperswil
On behalf of the Swiss Federal Office of Energy, Energy Renewable Division, CH-8640 Rapperswil
Tel: +41-55-222 4923
E-mail: tkopp@hsr.ch

UK
Mr Roger Hitchin
BRECSU, BRE
Energy Efficiency
Garston, Watford, WD25 9XX
Tel.: +44 1 923 664773
E-mail: HitchinR@bre.co.uk

USA
Mrs Melissa V. Lapsa
Oak Ridge National Laboratory
Building 4500 N, P.O. Box 2008
Oak Ridge, TN 37831-6183
USA
Tel.: 1 865 576 8620
E-mail: lapsamv@ornl.gov