IEA Heat Pump CENTRE
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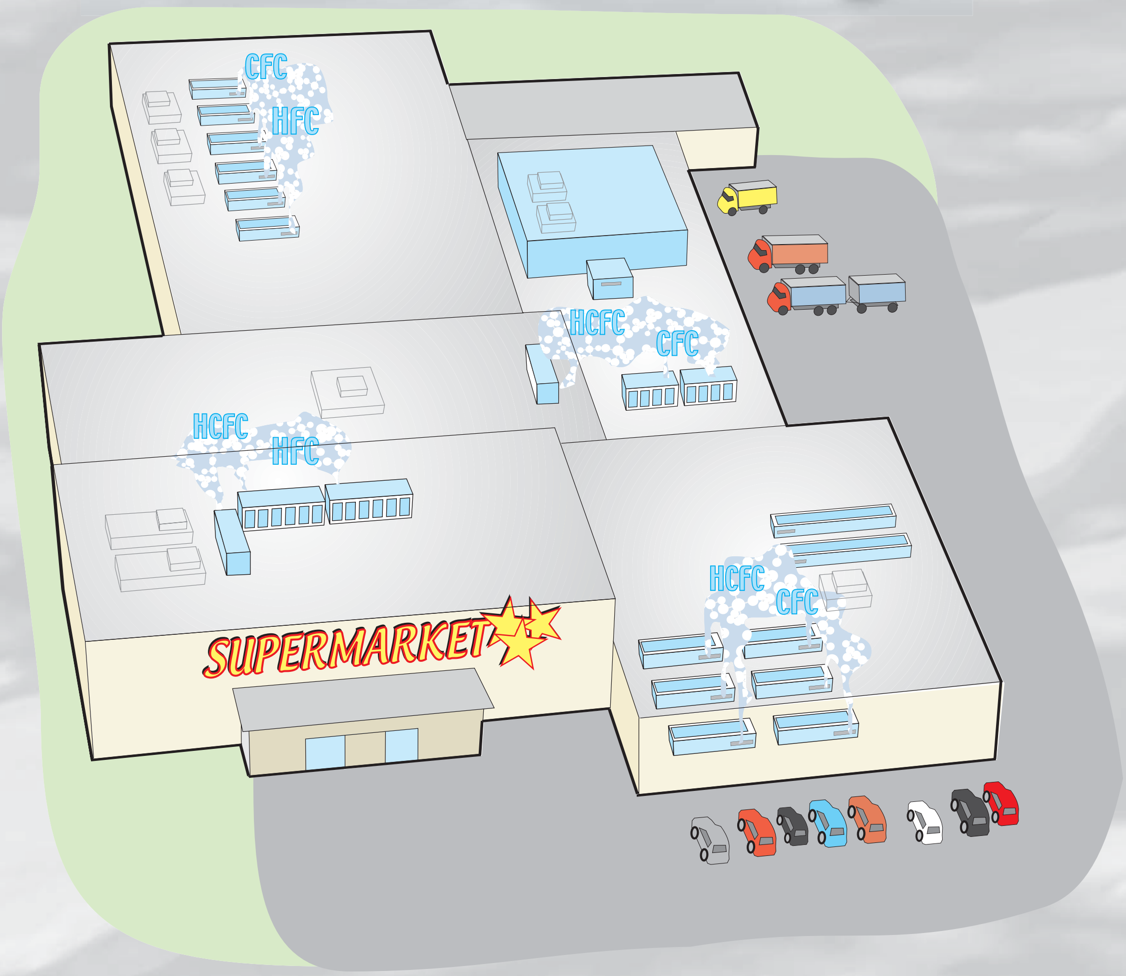
Zero Leakage, Minimum Charge



Designing a heat pump for minimum refrigerant charge

Mitigation of greenhouse gases in refrigeration

Heat pumps in Romania - a general overview

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IEA **Heat Pump** CENTRE
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In this issue

Zero Leakage, Minimum Charge

As the considerations about global warming and climate change is increasing so does the efforts to reduce the environmental impacts from heat pumping equipment. The impact from heat pumping technologies originates from direct (refrigerant leakage) and indirect emissions (from power production). In order to reduce the environmental impact both these effects must be considered. Which of these effects that is most important will depend on the system and the application. This issue of the HPC Newsletter addresses means and methods for reducing the refrigerant charge and keeping the leakages to a minimum. However this should be done without deteriorating the energy efficiency.

Heat pump news

Features

Topical article

Non-Topical article

COLOPHON

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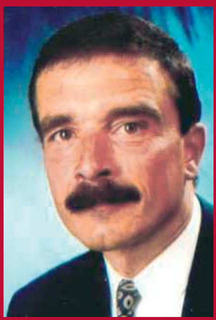
IEA OECD heat pump centre

The IPCC/TEAP Special Report on Ozone and Climate; issues related to HFCs and PFCs



Dr Lambert Kuijpers
UNEP TEAP Co-chair, UNEP Refrigeration TOC Co-chair, UNEP Replenishment Task Force Co-chair Member of Steering Committee, IPCC TEAP Report, Lead Author IPCC 4th Assessment Report, CA Ozone Assessment 2006

It has long been understood that stratospheric ozone depletion and climate change are inter-linked. With other gases, both ODSs and their alternatives contribute to climate change. The issue is that ODSs and their emissions are not addressed under the UNFCCC and its Kyoto Protocol. In recognition of this fact, the 8th Conference of the Parties to the UNFCCC took Decision X/CP.8 in November 2002, inviting the Intergovernmental Panel on Climate Change (IPCC) and the Technology and Economic Assessment Panel (TEAP) to develop a balanced scientific technical and policy-relevant special report. Parties to the Montreal Protocol took a similar decision in 2002. The IPCC/TEAP Special Report has now been finalised.

The primary opportunity suggested in the Special Report as it relates to ODS and protection of the ozone layer is to address emissions from banks of ODS through improved containment of substances, reduced charge of substances in equipment (i.e., it is directly related to *zero leakage, minimum charge*), end-of-life recovery and recycling or destruction, and increased use of alternatives with a low or negligible GWP or by the use of not-in-kind technologies. Banked material is defined in the report as including substances that have been produced but not yet released to the atmosphere, including CFCs stored in existing equipment as a pure chemical, and distributed in foams.

The Special Report includes quantitative estimates of the impact that the proposals would have on climate change, based upon a bottom-up estimation method. The IPCC/TEAP Special Report estimates that under a business-as-usual scenario, the total direct emissions of CFCs are expected to decrease significantly over the period 2002 to 2015. On the other hand, HCFC emissions are assumed to increase by almost a factor of two, mainly due to growth in the developing countries up to 2015. HFC emissions are also assumed to increase, i.e. by a factor of three here.

The report estimates that in a mitigation scenario (with global utilisation of best practices in containment (i.e., *zero leakage, minimum charge*), use of low GWP substances etc.), related direct GHG emissions of CFCs, HCFCs and HFCs could be reduced by about 50 % compared to the business-as-usual scenario. The mitigation scenario demonstrates that emissions of F-gases can be kept within reasonable limits over the next decades, but only provided that high-quality containment and appropriate end-of-life measures are applied globally.

The report notes that there is a wide range of policies, measures and instruments that can reduce related emissions. These include:
a. Regulations (e.g.: mandatory technology and performance standards; production restrictions);
b. Financial incentives (e.g.: taxes on emissions, production, import or consumption; subsidies and direct government spending and investment; deposit refund systems and tradable and non-tradable permits), and,
c. Voluntary agreements.

The Parties to the UNFCCC and to the Montreal Protocol will further address the impact of the emissions of ODSs and their replacements in meetings this year. This issue will also be further addressed in the Fourth IPCC Assessment Report, which is due at the end of 2007.

Dr. Lambert Kuijpers

Columnist

Rich banks and high stocks! ... but a bleak future for our climate

Rajendra Shende
Head OzonAction Branch,
UNEP DTIE, Paris

The world is well on its way to eliminate production and consumption of CFCs and other ozone-depleting substances (ODS). Only a few tens of thousands of tonnes of CFCs, for example, are being consumed each year, mainly in developing countries. Considering that some millions of tonnes were being consumed about two decades ago, this is quite an achievement. Drastic reduction in consumption of CFCs has certainly helped to reduce atmospheric chlorine loading and put the ozone layer on the path to recovery.

Now consider the following:
Actions taken under the Montreal Protocol have led to the replacements of CFCs with HCFCs and HFCs, as well as others. The refrigeration, heat pump and air conditioning industry has undergone considerable transformation. However, CFCs and their replacements (HFCs & HCFCs) have global warming potential (GWP). The GWP of CFCs is higher than that of HFCs and HCFCs. As a result of this replacement of CFCs, in a decade starting from 1990, the combined CO2 equivalent annual direct emissions of CFCs, HCFCs and HFCs has decreased by nearly 30 % to 2.5 Gt, which is equivalent to 10 % of total CO2 emissions from fossil fuels in the year 2000. So far so good.

Consider further:
Current and future emissions of CFCs, HCFCs and HFCs will mainly come from banks. Banks are substances that have been produced but not yet released into the atmosphere, as they are stored in equipment, stockpiles, captured in foams etc. Worse, there are no regulatory obligations to restrict their emissions, either under the - so far successful - Montreal Protocol, or the Kyoto Protocol, which has just entered into force. How serious are these current and potential emissions?

Current banks of CFCs, HCFCs and HFCs are estimated to amount to the equivalent of 21 Gt of CO2. This is about the same as the annual emission of CO_2 in the year 2000! The share of refrigeration, air-conditioning and heat pump applications in the banks represent 50 % of banks and 80 % of emissions. It is clear that, while the global community world-wide is on the right track to safeguard the ozone layer, the same cannot be said about the climate system, considering these *'rich' banks, 'high stocks' and global warming emissions.*

Take action now:
- Improved containment of substances.
- Reduced charge of substances in equipment.
- End-of-life recovery and recycling and/or destruction of substances.
- Increased use of alternative substances with a lower or zero global warming potential.
- Not-in-kind technologies.

Informal decisions based on Life Cycle Climate Performance (LCCP) are needed for technology options to be deployed. Improved energy-efficient technologies could give economic benefits. Recovery, recycling and destruction have associated costs, but the environmental benefits could outweigh these costs.

Through its OzonAction Programme, UNEP will be assisting developing countries through regulation, financial incentives and voluntary agreements to reduce the impact of these banks on global warming.

Rajendra Shende

General

State of demand-side management and energy efficiency in the world

A report from the IEA Demand-Side Management (DSM) Implementing Agreement provides an overview of the environment in which DSM and Energy Efficiency (EE) programmes and measures will need to operate in the next five years. The information was gathered during a meeting in October 2004, where Executive Committee delegates summarized their countries' top energy concerns, new trends in the energy market sector and new policies that will affect DSM and EE in their country. The participating countries were:

Australia	
Austria	Japan
Belgium	Norway
Finland	Spain
France	Sweden
Italy	United Kingdom
South Korea	United States

The top energy concerns for the countries include:
- Security and reliability of energy supply
- Environmental protection
- Market efficiency

New market trends identified were:
- Tradable white certificates (Italy, France)
- Energy efficiency in the building sector (Austria, Norway)
- A growing presence of renewable energy (Spain, US, Australia, Belgium, Sweden)
- Distributed generation (Austria, Finland, Belgium)
- New coal and nuclear power plants in some countries (Finland, US)
- Continued phase-out of nuclear power in other countries (Sweden, Belgium)

A large number of policies related to DSM and EE were reported, and can be categorised as:
- Financial (tax reductions, tax incentives)
- Targets and trading (carbon targets, emissions trading)
- Standards/labels and information programmes (voluntary efficiency standards, energy audits, labels, standards etc.)
- Research and development (R&D important tool for climate change technologies).

The above is a brief introduction. The report also contains a section for each country.

Source: State of DSM and EE in the world. The report can be downloaded at dsm.iea.org

Top ten in Switzerland

Switzerland – A web site providing potential customers with information on energy use and other information on products has been set up in Switzerland. The site, called 'top ten' (www.topten.ch), is an initiative of the Schweizeriche Agentur für Energieeffizienz, S.A.F.E., Consuprint and Oerlikon Journalisten AG, and is supported and promoted by WWF Switzerland. It has been running for four years, receiving 550 000 visitors in 2004, a 50 % increase since 2003. Current product categories are: office, lighting, recreation, house, transport, electrical appliances and green power. Among the products are heat pumps and heat pump water heaters. The green power products are all labelled according to the Swiss green energy label, 'naturemade Star'.

The concept of the top ten web site is now extended to France and Austria, and a new web site (www.topten.info) will be set up to connect the national top ten web sites.

Source: www.eugenestandard.org

Commercial refrigeration efficiency standards

USA – Commercial refrigeration manufacturers and energy efficiency advocates have reached an agreement on efficiency standards for federal equipment. The standard relates to refrigerators, freezers and refrigerator freezers used in restaurants, convenience stores, grocery stores and other commercial buildings. The agreement has now been submitted to both the US Department of Energy and to members of Congress for anticipated inclusion in the new energy efficiency legislation.

Currently, there are no federal minimum efficiency standards for refrigerators, freezers or refrigerator freezers. In the agreement, the signatories recommend Congress a minimum efficiency standard for such equipment. If the agreement comes into force, it is estimated that, by 2020, it will reduce peak power demand by about 530 MW, and reduce the emissions of carbon dioxide by 1.6 million metric tons, which is equivalent to taking about 300 000 average passenger vehicles off the road that year.

The agreement was negotiated between the Air-Conditioning and Refrigeration Institute (ARI) and the American Council for an Energy-Efficient Economy (ACEEE). Other signatories to the agreement are nine commercial refrigeration manufacturers, the California Energy Commission, the Natural Resources Defence Council, the Alliance to Save Energy, the Northeast Energy Efficiency Partnerships, the Environment Northeast, and the Appliance Standards Awareness Project.

Source: www.ari.org

US efforts for clean and renewable energy

USA – Many news items and press releases have been issued during this spring regarding initiatives for energy efficiency, green energy and clean air in the United States. Two initiatives are coordinated by the Environmental Protection Agency (EPA). The EPA State Energy Efficiency and Renewable Energy (EERE) Projects have participants from utility regulators from six states. State utility regulators work together with EPA in these projects to explore approaches for reducing the cost of consumer electricity and gas bills through cost-effective energy efficiency, renewable energy and clean distributed generation. The project will build upon the experience from the ENERGY STAR program, run for the past decades.

In the second project, Clean Energy/Environment State Partnership Program, EPA will assist states as they develop and implement action plans to improve air quality, decrease energy use, reduce greenhouse gas emissions, and enhance economic development. This program brings together ten states. The background for the project is that the demand for energy is expected to climb by 40 % by the year 2025, and that 126 million people are living in counties where the air is unhealthy at one time or more during the year. Many states are therefore trying to integrate energy and environmental policies to protect public health while addressing concerns such as electricity reliability, energy security and economic development.

Other initiatives are:

- USD 100 million over the next five years for energy efficiency efforts in the northwest states of Idaho, Montana, Oregon and Washington.
- Incentives for increased use of wind power, hydrogen and alternative fuel technologies in North Dakota.
- USD 20 million in bonds for financing energy efficiency and renewable energy improvements in public buildings in New Mexico. The bonds will be applied to state buildings and school district buildings, and the projects will include energy efficiency measures and any types of renewable energy systems, as well as systems for energy recovery and combined heat and power generation.
- In Pennsylvania, the Department of Environmental Protection announced USD 10 million available for grants, loans and loan guarantees for projects and research involving solar, wind, geothermal, biomass, fuel cells and low-impact hydro power. The funds could also be used for energy efficiency projects and energy recovery and load management systems.
- Connecticut and New Jersey are launching new Green Power Programs to encourage customers to buy green power – electricity generated from renewable energy sources.

Source: EERE Network News, April 13 and April 27
www.epa.gov/newsroom
www.nwalliance.org

Four new EU projects

EU – Four newly started collaborative EU projects concentrating on heat pumping technologies have been reported.

Groundhit: Aims at improving cost-effectiveness, competitiveness and market penetration of ground-source heat pumps. The project is investigating the following topics:

- Development of a prefabricated borehole heat exchanger with improved heat transfer.
- Increasing the efficiency of ground-source heat pumps (GSHP). The aim is to increase the seasonal performance factor from 3.9 to over 4.5.
- Developing GSHP which can deliver hot water at 80 °C.
- Increasing the efficiency of GSHPs using hot groundwater at 40 °C as the heat source.

Three prototype installations, demonstrating the above technologies, will be made in Greece, Portugal and Austria.

The project is coordinated by the Centre for Renewable Energy Sources (CRES) in Greece, with partners from France, Germany, Austria, Portugal, Romania and Poland.

Auditac: The background to this project is that a large part of the European AC equipment will be more than 15 years old in 2010. A SAVE study (EECCAC) shows that it should be possible to reduce the energy used for air conditioning by 50 %. In addition, the Energy Performance of Buildings Directive (EPBD) stipulates that AC equipment with a capacity over 12 kW must be regularly inspected.

The objective of this project is to help the European air-conditioning (AC) market to reach higher efficiencies through good inspection routines and other measures. The results from the project should be information on the EPBD, a guideline for inspection of AC equipment with information on best practice etc, training material, and benchmark analysis and case studies.

The project is a collaboration between Austria, Belgium, France, Italy, Portugal, Slovenia, the UK and also Eurovent. More information is available from the web site, www.energyagency.at/projekte/auditac.htm

Keep Cool: This project intends to reduce the use of air conditioning. The current trend in Europe is that the need for air conditioning is increasing. Even in countries like Sweden, the use of mechanical air conditioning is increasing, although there are several ways to reduce the need for air conditioning. The objective of the project is to stimulate cooperation and to help companies that manufacture and sell products that can reduce the heat load, and thus the need for air conditioning, in other ways.

The participating countries include Sweden, Portugal and Italy.

Compfreeze: The objective of this project is to increase the competitiveness of small and medium sized enterprises (SMEs) in the frozen food industry by developing low-temperature freezing equipment. The aim is to improve knowledge of the connection between rapid freezing processes and the quality of the product, using various types of freezers. The project also focuses on using carbon dioxide as a refrigerant.

Denmark and The Netherlands are taking part in this project, which is operated within EU's CRAFT-programme which aims to assist SMEs.

Source: www.geothermie.de/groundhit, Eurovent/Cecomaf Review, March 2005, Energi & miljö no. 4, 2005 (in Swedish), Scandinavian Refrigeration, no. 2, 2005 (in Danish)

Energy label on circulation pumps

EU – The European Association of Pump Manufacturers, Europump, has launched an energy efficiency labelling scheme for circulation pumps. It is a voluntary scheme, developed by the four companies of Grundfos (Denmark), Wilo (Germany), CP (UK) and Smedegaard (Denmark), who together have more than 80 % of the European circulation pump market. The scheme resembles the EU energy label scheme, and Europump wants the EU and its member states to support and endorse the scheme. It is open for all circulation pump manufacturers to join.

The scheme has been developed in order to promote competition between manufacturers by encouraging the development of more energy-efficient circulation pumps. A traditional pump in a hydronic heating system is a Category D pump: by changing to a Category A pump, about USD 40 per year can be saved. The pumps are said to be an anonymous energy consumer, using up to 15 % of the electricity of a European household.

Source: Europump and www.grundfos.se

European Certified Heat Pump Installer

EU - EU-CERT-HP (EU Certified Heat Pump Installer) is a project part-funded by the European Commission and involving partners from Austria, Germany, Italy, Ireland, UK, Sweden, France, Czech Republic and Slovenia, with Raphaela Boeswarth of Arsenal Research – Austria being the project co-ordinator. The aims of the project are to have a common training methodology and certification scheme for heat pump installers in Europe. This is to ensure that the quality of heat pump installations is maintained at a high level. The EU Certified Heat Pump Installer, a trade mark for highly qualified and reliable installers in the field of heat pump technology, would be created. This certification will, on the one hand, help qualified and committed installers to stand out from competitors, and on the other hand give customers the necessary information to make an informed choice for selecting a quality installation.

The training and certification methodology for this project involves the following tasks:

- Identifying the key competences for an EU Certified Heat Pump Installer.
- The publishing of a training manual which details the knowledge and requirements to become an EU Certified Heat Pump Installer.
- Setting the standards for the training facilities and the equipment needed in an approved training laboratory.
- Setting the extent of the practical learning experience.
- Implement the required training infrastructure in national training institutions in the participating countries.
- Realisation of pilot training courses in the participating countries followed by an evaluation and revision procedure of the training materials and training organisation.
- Defining a European certification scheme for Heat Pump Installers which enables continuous quality control in the field of heat pump planning and installation. A regular check of the competence of the EU Certified Heat Pump Installers would maintain the quality of heat pump planning and installation on a high level.
- The setting up of a European Certification Committee to validate the proceedings whilst ensuring that the consistency and quality of the certification scheme and the training courses undertaken in all participating countries is maintained. This Certification Committee will continue after the end of the project and will ensure the advancement of the training and certification program in the future.
- After the revision process of the training program, non-participating countries are invited to join the training and certification activities and to join the Certification Committee, thus extending the influence of the EU-CERT.HP project on the quality of heat pump systems to more countries.

The project commenced in March 2004 and the running of the pilot training courses in each of the project countries is due to start at the beginning of 2006, with the final dissemination activities due to be completed by the end of 2006 (see the EU-CERT website at www.ehpa.org)

Research has been undertaken in all partner countries to investigate the status of current training available, how it is applied and the target groups for such training (for example, electricians, plumbers, technicians). This research was then co-ordinated to produce the first draft of a training manual and the minimum requirements for a heat pump training laboratory. A preliminary version of an English training manual will be finished in June 2005.

Source: Raphaela Böswarth, Arsenal Research, Austria
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EU Certified HEAT PUMP INSTALLER

Mitigation of emissions of greenhouse gases in refrigeration - A new IIR Working Party

A new IIF/IIR working party entitled "Mitigation of Emissions of Greenhouse Gases in Refrigeration" has been set up in order to address these broad issues further. The working party will involve Commissions B1, B2, D1, D2, E1 and E2[1]
The objectives of the working party are:

- To exchange views on reduction of emissions of greenhouse gases in refrigeration.
- To collect information and figures on the subject and disseminate them amongst members of the working party. This clearing house will be prepared with the participation of the Information Resources Department of the IIF/IIR.
- To prepare statements, position papers and Informatory Notes on behalf of the Scientific Council.
- To represent the IIF/IIR at events dealing with global warming.

The IIF/IIR has been particularly active with regard to the global warming issue in the field of refrigeration (refrigeration as such, air conditioning and heat pumps), and has attended most of the Conferences of Parties to the UN Framework Convention on Climate Change. Several statements and Informatory Notes were prepared and presented at these events.

IIF/IIR firmly believes that reduction of emissions of greenhouse gases (GHGs) will increasingly become an issue of paramount importance. It will drive the development and operation of new equipment. All countries, with or without ratification of the Kyoto Protocol, will undoubtedly also develop measures to reduce emissions of GHGs. The new working party is based on the assumption that possible measures are numerous and will be based on a design, operation and end of life life-cycle analysis of the refrigerating equipment.

The following hot list of measures will be addressed (more or less):

1. Design
Gastight systems
Maximised energy efficiency
Minimised refrigerant charge
Use of the appropriate refrigerant depending on the application (non-HFC and HFC refrigerants)
2. Operation
Commissioning of the refrigerating system
The importance of training, qualification and certification of refrigeration personnel in the proper handling of refrigerants
Raising the awareness of stakeholders
Minimised leakage
Regular inspection of containment
Recover, recycle, reclaim or destroy refrigerants
Monitoring the handling of refrigerants (log book)
3. End of life
Minimised end-of-life emissions

The members of the working party will be commission members of the IIR and experts whose knowledge of the subject will benefit the working party. Members of the working party are expected to be either private members or representatives of corporate members of the IIR.

The work will be led by the undersigned, who has been appointed by agreement between the Presidents of Commissions and Sections involved, the President of the Scientific Council and the Director. The working party will hold at least one meeting per year. Minutes will be taken at each meeting and posted on the working party's web site.

The following deliverables are planned

- One statement, position paper or Informatory Note per year.
- One workshop or conference per year, with publication of proceedings in CD-ROM form.

The working party will start its work during early autumn 2005, as soon as the report "IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues related to Hydrofluorocarbons and Perfluorocarbons" has been published. Interested IIF/IIR members or experts should contact me or the IIF/IIR office in Paris as soon as possible.

[1]For information on the working areas of commissions within the IIF/IIR, see the www.iifiir.org web site.

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7th IIR-Gustav Lorentzen Conference – Call for papers

Norway – The main objectives of this conference, which will occur May 29 – 31 2006, is to discuss the latest research results and advances related to the use of natural working fluids in different types of systems and application areas. Conference sessions are planned and papers are requested on subjects related to the basic engineering science, design and application of refrigeration, air-conditioning and heat pump systems based on natural working fluids, including:

- Fundamentals
- Properties, lubrication, chemistry
- Process, cycle, system and components development
- Vapour compression systems: NH_3, hydrocarbons, CO_2 and water
- Gas cycle and sorption systems
- Safety with respect to flammable, toxic and high-pressure fluids
- Secondary systems
- Heat transfer and heat exchangers, compressors and machinery
- Energy efficiency, operational experience and economy
- Applications of systems based on natural fluids

Deadline for titles and abstracts is September 1st 2005. Authors notified about acceptance of abstract: November 1st 2005. Papers due: February 1st 2006; authors notified about acceptance of papers: March 1st 2006.

Source and more information: www.energy.sintef.no/arr/GL2006/

Technology & Applications

Solar-assisted air conditioning

For six years, experts from twelve countries of the IEA Solar Heating and Cooling Implementing Agreement have jointly worked on the 'Solar-assisted air conditioning of buildings' project. The aim of the project is to improve conditions for the market introduction of solar-assisted cooling systems. The project participants identified three key barriers to an increased market share:

- A lack of common design and construction practices
- Limited understanding of the market availability of the technology and its environmental benefits
- Absence of field data and experience of solar air conditioning technology in buildings.

Two major niche markets were also identified:

- 'Solar combi-plus systems' (domestic hot water heating, space heating plus cooling) for residential and small commercial buildings
- Applications with added values besides energy savings, such as concern for the environment, green businesses etc.

There are two major types of systems where the solar-assisted technology may be used:

- Desiccant cooling systems
- Thermally driven chillers.

The following work has been carried out in order to begin to remove market barriers:

- Defining performance criteria of solar-assisted cooling systems – both energy and economic performance. This work is detailed in the book 'Solar-assisted air conditioning in buildings – a handbook for planners and the design tool 'SOLAC'.
- Identifying and further developing promising solar-assisted cooling technologies.
- Optimising the integration of solar-assisted cooling systems into buildings and HVAC systems
- Monitoring eleven demonstration projects in six countries.

The situation for solar-assisted cooling has made remarkable progress over the last five years. Far more systems are in operation today than five years ago, and there is thus lot more experience of their operation. Combined with the developments of thermally-powered cooling technology, the potential for solar-assisted cooling applications is growing.

Source: SHC Solar Update, vol. 43, March 2005.

New efficient air source heat pump

Austria - Ochsner Heat Pumps has come up with a new air source heat pump, claimed to be more efficient than other units on the market. The AIR-STATION heat pump provides both space heating and domestic hot water heating, and is intended for bivalent operation. It is available in five different sizes and is suitable for homes with living areas from 100 to 350 m². It is available for indoor or outdoor installation, and can also be used as a climate control heat pump, i.e. providing space heating in winter and cooling in summer.

Technology improvements

The "O-Tronic" controller provides hot-gas defrost on demand. A new design of evaporator is about 30 % larger than evaporators in other units on the market. The third highlight is a particularly efficient fan. These three improvements are claimed to increase the coefficient of performance (COP) above the current market level: where other air heat pumps on the market have COPs from 2.9 to 3.2, the new AIR-STATION heat pump achieves COPs from 3.4 to 3.6.

Quiet operation

The new design has other advantages. In order to ensure adequate protection for outdoor installation, the housing is specially designed for optimal weather resistance. The side covers not only improve protection against rain, but also reduce emission of noise. Noise is further reduced by the use of special sound insulation in the casing and the use of an adequately sized, slow-rotating fan. With these features, the noise emitted from the AIR-STATION unit is comparable to that from a freezer. This represents a significant reduction of noise emissions.

Source: OCHSNER WÄRMEPUMPEN GmbH

Recovering sewage water heat

Germany - Using the waste heat in a sewer system as a sustainable heat source has not been seriously considered up to now, although it makes a lot of sense from an ecological point of view. Fossil fuels are becoming increasingly expensive, which makes renewable energy technologies more competitive. The recovery of waste heat from sewer systems represents a new alternative heat source. Japan has been the first to exploit it, followed by Switzerland and Germany.

The average year-round temperature in thousands of kilometres of municipal sewerage systems, accepting waste water from a mix of urban housing and industry, is about 12-16 °C: in some countries, it can reach about 20 °C or more. In addition, the whole network of buried pipes represents a huge shallow ground heat collector system, with the additional benefit of providing an excellent infrastructure from which all buildings can be reached.

Japanese estimates indicate that 40 % of the waste heat discharged by urban communities is carried away in the sewage. Cooling the entire sewage waste water production in Germany, estimated to amount to approximately 11 thousand million m3/year, by 5 °C would provide a theoretical heat source of 65 million MWh, equivalent to a saving of 5,59 million tonnes of fossil fuels and a reduction of 11 thousand million tons of CO2 emissions per year.

Sewerage systems therefore represent a large sustainable heat source, with a huge future potential for every community in the world. This energy could be a perfect source for modern heat pump systems, preferably supplying heat to district heating systems, or for use in combination with conventional heating systems.

Against this background, TEC MANAGEMENT, a small engineering and consulting firm in Germany, has recently developed a basic concept for modification of conventional sewer pipes for use as heat exchangers for the collection of both sewage waste heat and shallow ground heat. The design is basically a coaxial double-wall sewer pipe made of ductile cast iron, stainless steel or HDPE, with two tangentially arranged supply and return connections. The inner pipe carries the waste water flow as usual, while the outer pipe forms an annular chamber through which the heat exchanger fluid (water) is pumped. The pipes can be laid conventionally from one sewer manhole to the next. Each pipe can have a maximum length of six meters. Where possible, two separate pipelines should be laid above the sewer pipe, acting as supply and return pipes for the heat exchangers, and connected to the heat pumps. It is planned to offer a full range of sizes and connection systems, designed for delivery ex works and ready for conventional laying in a trench.

Source:
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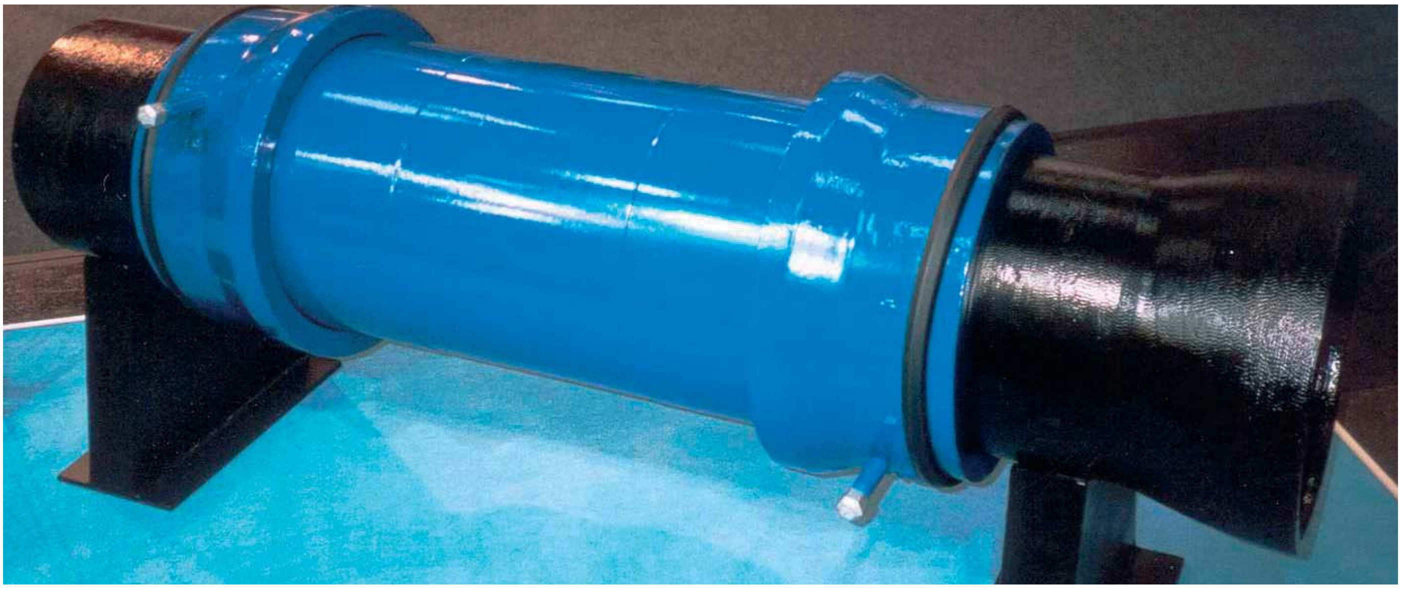
The first 20 SEER residential air conditioner

USA – Lennox Industries, USA, have introduced what is claimed to be the world's first residential air conditioner rated at over 20 SEER (Seasonal Energy Efficiency Rating). The air conditioner, XC21, has a two-stage scroll compressor with two levels of operation; one high level for hot summer days and one low level for cooler days. The low level will be enough for approximately 80 % of the time. The XC21 also uses R410A and is designed for low sound level. It is claimed to be 13 times quieter than a standard air conditioner. The low sound level is achieved by a new fan design, a vibration insulator for the compressor and a sound-dampening fan grille.

Source: ASHRAE HVAC&R Industry, March 31, 2005



CO2 heat pump for hydronic heating systems

Sweden – The first CO_2 heat pump for the Swedish market has now been released by the Swedish company Ahlsell. It is an air source heat pump for hydronic heating systems, developed by Sanyo, and which provides both space heating and domestic hot water (DHW) heating. The outdoor unit is connected to a specially designed storage tank, where the DHW is circulated in two coils placed inside the storage tank. The heat pump, which is capacity-controlled by a variable-speed control (inverter), is claimed to deliver 4.5 kW heat power down to an outdoor air temperature of -15 °C and to be able to heat the water up to +70 °C.

Source: www.kcc.se

Markets

Strong development of the French air conditioning market

France – The market for air conditioning equipment in France boomed in 2004. The market for mobile air conditioners increased by 96 %, even though these units have quite low capacity and is not particularly energy-efficient. They benefit from the fact that they do not need to bear the cost of an installation. Even more impressive is the increase of mono and multi-split air conditioners with a capacity less than 17.5 kW. Sales of mono units increased by 141 %, and of multi units by 109 %. The only fall in this category was that of window units, which fell by 18 %. It is also interesting to note that 80 % of the split units were reversible, compared to 68 % in 2002. Inverter units constituted 40 % of the split units, which is an increase of 210 % over last year.

Source: Die Kälte&Klimatechnik, no.2, 2005

Heat pump water heater market expands

Japan – The market for heat pump water heaters is expanding steadily in Japan. Sales for 2004 are expected to have reached 120 000 units, which is an increase of about 50 % from 2003. In particular, demand for the ECO CUTE units using natural refrigerants is increasing rapidly. The great interest for the ECO CUTE technology is said to be due to a steady penetration of the all-electric homes market, low running costs and environmental considerations.

Source: JARN, February, 2005

Almost 10 000 units sold in Switzerland

Switzerland – Despite a new sales record, the magic number of 10 000 sold units was not quite reached. In 2004, 9,872 units were sold, which is an increase of 13 % since 2003. The following activities will be in focus for FWS during this year and in the years to come:

- Increasing the share of heat pumps in the retrofit market
- Increasing the number of large heat pump units in both new builds and retrofits
- Maintaining and further strengthening quality assurance
- Strengthening the technological and sales skills of the association's members.

Source: Mitgliederinformation Fördergemeinschaft Wärmepumpen Schweiz, FWS, no. 1, 2005

Developments on the Dutch heat pump market

Netherlands - The Dutch Heat Pump Association has 15 members, being producers and importers of heat pumps. The Association has welcomed Nibe as a new member in 2004.

At the end of 2004, about 5000 heat pumps were in use in the Netherlands: about 1500 were sold in 2004.

A very successful subsidy scheme on sustainable energy systems was abolished at the end of 2003 due to the budget being exhausted. Domestic heat pumps were subsidised by EUR 700, which assisted the market for heat pumps to remain about the same in 2004 as in the previous year.

The Kwaliteitskeur Warmtepompen (Quality Seal Heat Pumps) scheme has become more important: it requires heat pumps to be tested for performance aspects such as COP and noise production, with the results stated on certificates accompanying the heat pumps.

New developments
Two new initiatives were started in the Netherlands in 2004, making use of heat pumps in an ingenious way.

The first initiative consists of a project to use sewage effluent from a sewage plant to provide heat to up to 10 000 residences through district heating. Sewage effluent, at a temperature between 11 °C and 23 °C, will provide the heat source for the heat supply. A pilot project for 150 to 200 residences in The Hague will be started by Eneco, one of the large energy companies in the Netherlands.

A second initiative uses sea water as the heat source. In this project, also in The Hague (Duindorp), heat is extracted from sea water at an average temperature of 11 °C. This heat is rejected to a primary heat transfer media circulated to 749 buildings, where local heat pumps use this as a heat source to produce higher temperatures for space heating and domestic hot water heating. From 2006 onwards, these homes should receive their heat from sea water as a worldwide first using this concept.

Opportunities for the future
The Dutch Building Directive incorporates an energy performance standard for calculation of the dimensionless Energy Performance Coefficient (EPC), which is a measure of the energy a house or building needs under standard conditions. The calculation sums all the heating requirements (including hot water and lighting) of a building, divided by a weighted measure of the surface of all floors plus a weighted measure of the external area of the building (and a correction factor for backward compatibility with previous versions of the standard).

The standard provides opportunities for heat pumps, as the new version of the standard (which is expected to come into effect from 2006) also includes the cooling requirements of a residential building. The standard will be tightened up in 2006 or 2007, which will make it virtually impossible to obtain a building permit without incorporating a sustainable energy source and/or making use of heat recovery systems.

Source: Gerald Huijzendveld, Inventum BV
Member of the Dutch Heat Pump Association
info@stichtingwarmtepompen.nl

Yet another record year for China

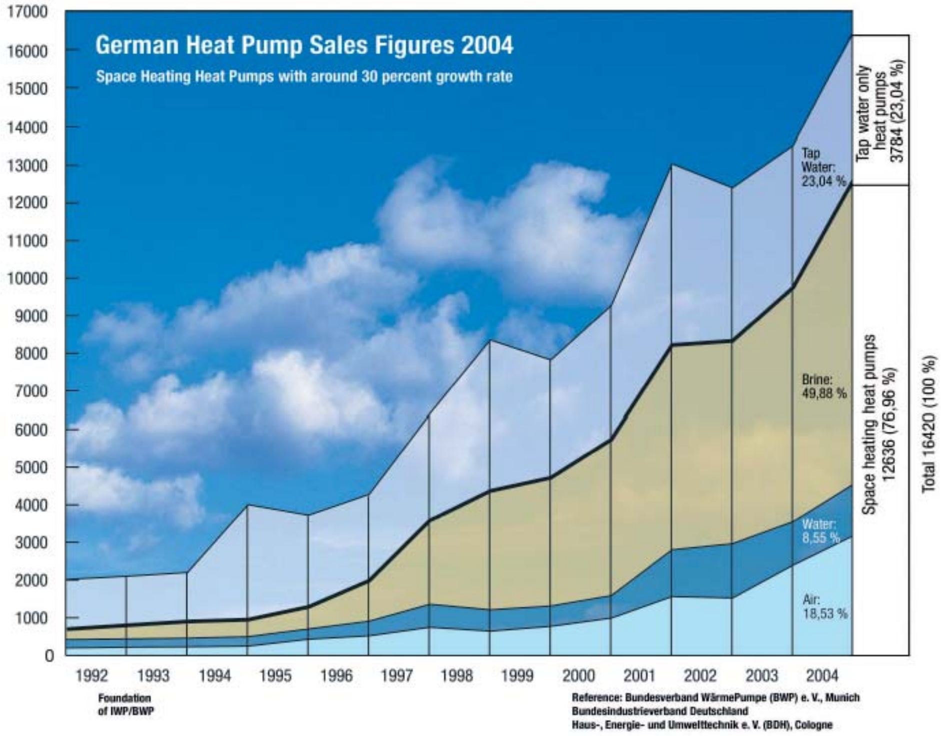
China – Both domestic and overseas sales of Chinese air conditioners (AC) set new records during the 2004 refrigeration year (RY) (September 2003 – August 2004). In the domestic market, sales reached 26 million units, and exports reached 25 million units. The export figures represented an increase of 52 % since 2003, mainly due to increased production in China by foreign enterprises. These figures were reached even though 2004 saw an increase in raw material prices, shortage of compressors and environmentally friendly refrigerants, power crisis, export rebate reductions, and the Chinese state's macro-control policies used to cool down the overheated economy.

Many of the above obstacles arise from the rapid expansion of the production rate of ACs. Even though the production of compressors reached 43 million units in China during RY 2004 (an increase of 50 % over 2003), there was a shortage of compressors for the AC manufacturers. The increasing exports to the European market caused a shortage of environmentally friendly refrigerants. Both these effects caused some companies to suspend production. Another problem faced was a power crisis, which was also due to the high production rate. Many production lines in Shanghai, Zhejiang and Guangdong had to be stopped due to power supply shortage. The intense competition also caused the price of steel to rise, which had the effect of making many AC manufacturers form allies with raw material providers.

From 2003 to 2004, the value of sales on the domestic market increased by 11 %, even though the average price for a household AC fell by 10 % during the period. The increase in sales is explained by an increase in household incomes and the development of real estate. Of the units sold, only 5 % are inverter ACs, which are still considered too expensive. The dominating manufacturers for the domestic market are Gree, Midea and Haier, which all sold more than 3 million units. More than 1 million units were also sold by Kelon, Aux, Chigo, LG, Matsushita, Shinco and Hisense. Worth noting is that there were 96 air conditioner brands on the Chinese market in 2004. Even though this must be considered a large number, it is a decrease from 150 brands in 2003.

Source: JARN, February, 2005

German heat pump market continues on successful course, with around 30 % growth rate for heat pumps in 2004



Germany - The German heat pump market has recorded continuous growth for more than ten years. 12 636 heat pump heating systems were sold last year, together with 3 784 hot water heat pumps for reliable and environmentally friendly heating of non-potable water, to give a total of 16 420 units. This is confirmed by the figures of the joint heat pump sales statistics issued by the Bundesverband WärmePumpe eV. (BWP – Federal Heat Pump Association) in Munich and the Bundesindustrieverband Deutschland Haus-, Energie- und Umwelttechnik eV. (BDH – Federal Association of Building Services, Energy and Environmental Engineering) in Cologne. These figures do not take into account heat pumps integrated in building ventilation systems with heat recovery. Around 50 % of the heating heat pumps sold are used for ground heat sources. This is followed in second place by air source heat pumps, the sales of which continue to grow. The proportion of heat pumps installed in new buildings (single and multi-family buildings) was around 8 %. More than 90 000 heat pump heating systems are currently installed in Germany. Conservatively estimated, these reduce CO_2 emissions by about 170 000 tonnes/year, compared to a modern low-temperature oil-fired boiler.

Heat pump grants

Since 6 April 2005, the Ministry of the Environment and Transport of the German state of Baden-Württemberg has subsidised the construction of ground heat collectors as part of its "Klimaschutz-Plus" scheme. The target groups are home owners and the builders of detached and semi-detached houses, as well as small and medium-sized enterprises. The funding is issued in the form of a grant and amounts to 14 euros per meter of ground heat collector installed, with a maximum of EUR 3 500 per house. EUR 2 million of funding is available for 2005 and 2006.

What is the reason for the increasing success?

Several factors are responsible for the growing popularity of heat pumps. On the one hand, new generation heat pumps not only produce heat and hot water reliably, but also, with an appropriate design, they can also ventilate and cool. In addition to this, compact units are now on offer, in which all this is achieved by only one device. Further technical development has meant that for around the past three years high inlet and return temperatures can be produced, as are necessary for the modernisation of old buildings. Rising oil and gas prices have of course also made home owners more sensitive to heating costs. The uncertainty of future fossil fuel prices and the fact that with a correctly dimensioned and professionally installed heat pump heating system the heating costs can be virtually halved certainly also influences purchase decisions.

Source: Joachim Ogorek
Pressestelle Bundesverband
WärmePumpe (BWP) e. V.
Germany
joachim.ogorek@fp-werbung.com

Heat pumps on the increase in Austria

Austria - In 2004, an increasing number of developers decided on a modern heating system for low heating costs and reduced CO2 emissions. Today, heat pumps are among the most environmentally friendly and efficient heating technologies available.

Market development
Information on the development of the heat pump market in Austria from 1977 to the end of 2001 was compiled by the heat pump manufacturers and distributors active in Austria, in collaboration with the Environmental Energy Consortium of the Austrian Federal Economic Chamber. Sales statistics for 2001, 2002 and 2003 (partly) have been supplied by the members of the National Austrian Heat Pump Association (BWP), of the Austrian Federal Economic Chamber. Market statistics for 2003/2004 have been compiled on a new basis, as a result of cooperation between the BWP and the Austrian Heat Pump Promotion Association (LGWA). 22 firms from BWP-Austria and LGWA, which represent nearly 100 % of the market, are accounted for in the statistics. The sales figures for 2003 and 2004, compiled under contract with the National Ministry for Transportation, Innovation and Technology, with considerable support from both BWP and LGWA, speak for themselves. There are clear indications of positive growth rates in the heating heat pump and controlled dwelling ventilation segments of the market.

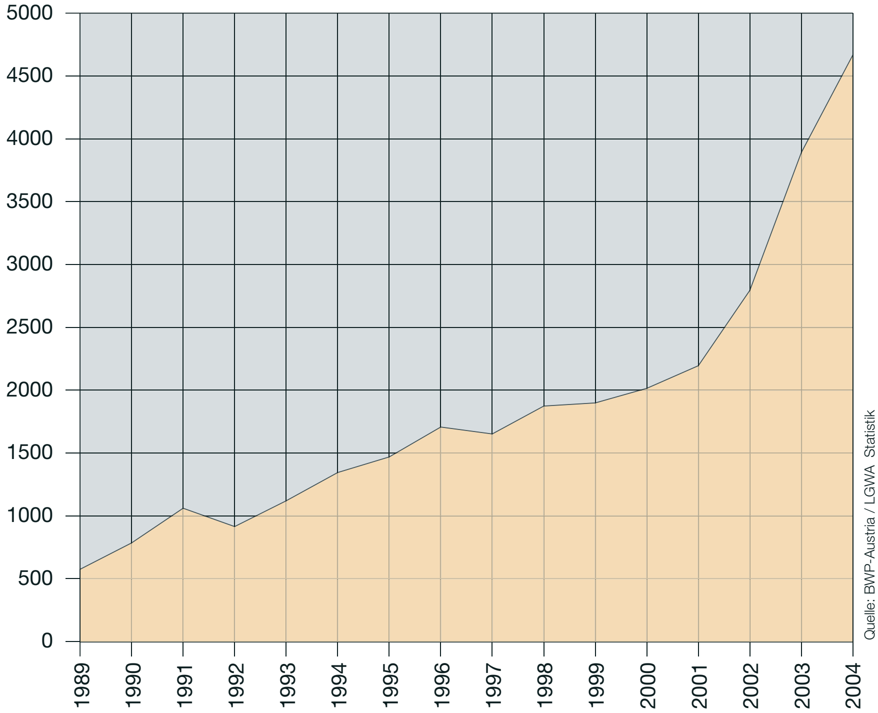
Market share
Sales of heat pumps for heating have risen by 18.4 % to 4700 units sold annually. With regard to the heat sources utilised, the following developments are to be seen: with a share of 50 %, the brine/water heat pumps are the most popular systems in Austria, followed by direct vaporisation with 26 %, water/water with 14 % and air/water with 10 %. The largest growth rates in the sector were for air/water heat pumps, with 45.9 %, and for brine/water heat pumps, with 25.9 %.

Positive trend
Preliminary data for 2005 indicates a continuation of the positive trend for heat pumps. "The BWP goal of 10 000 heating heat pumps in 2010 is already within reach," declares Dipl. Ing. Karl Ochsner, Chairman of the National Austrian Heat Pump Association (BWP). The growing popularity of heat pumps can be attributed to high quality, reliability, ease of operation, environmental friendliness and cost-effectiveness.

Source: Karl Ochsner, chairman of BWP
Tel.: +43 7434 42451-0

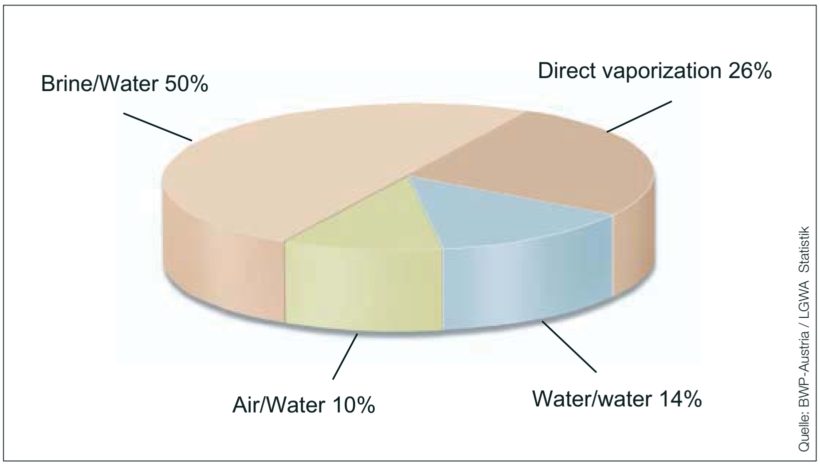
Austrian Heating Heat Pump market

1989 - 2004



The demand for heat pumps in Austria has grown significantly in the last five years.

2004 Heating Heat Pump System Breakdown



The breakdown of heat pump systems sold shows that brine/water systems are currently the most commonly sold systems.

Working Fluids

C-dig meeting in Finland

Finland – The carbon dioxide interest group (c-dig) held a seminar in Uusikaupunki in Finland on 14-15th April. The event was hosted by the Finnish plate-and-shell heat exchanger manufacturer Vahterus. The seminar was attended by approximately 60 persons, mainly from Europe and from the industrial and supermarket refrigeration sector. During the two days, eight presentations were held, together with three plant visits.

The visits were made to the manufacturing plant of Vahterus, where the visitors were welcomed by Mr M Kontu, president of Vahterus, and also to a fish plant with a refrigeration system consisting of a cascade system with R404A and CO2. The third visit was to a newly built skiing and walking/running track in Uusikaupunki, where the chairman of c-dig, Mr Andy Pearson, took the chance to try the track. The 1 km long track is cooled by a 400 kW indirect CO2 refrigeration system. The snow is cooled both from underneath, by pipes in the floor, and from air coolers in the roof. The track is divided into two parts: the cold part provides the opportunity to ski throughout the year, and the other part, which is heated, provides a track for all-year roller skating.

The seminars were dominated by presentations from Finland. Professor Aittomaki from Tampere University gave an overview of the development of CO2 as a refrigerant in Finland. Professor Aittomaki has held information seminars, introducing the CO2-technology, but so far progress has been slow. However, two systems have been built recently (the fish-plant system and the ski track), and hopefully a new refrigeration laboratory will be built and ready to use at the beginning of 2007 in Uusikaupunki. The focus of the laboratory would be natural refrigerants and indirect refrigeration systems. Other presentations from Finland were an ice storage system from Tankki Oy, the ski track, and air coolers from Fincoil.

The other presentations featured valves from Danfoss, a new approach for a defrost system by TNO, transcritical gas coolers from Lu-Ve, and experience with pumps for CO2 by Mr Wijbenga. The defrost system proposed by TNO would make use of the fact that the adhesion force between the ice and the heat exchanger disappears when the surface temperature goes below -80 °C. By using an extra defrost compressor, the evaporation pressure can be decreased such that the temperature drops below 80 °C and the ice releases from the surface. The seminars were ended by a problem/solution session where problems such ammonia leakage into the CO2 circuit, problems with pump bearings and valve malfunctions at defrost were discussed and possible solutions proposed.

C-dig is an interest group for the use of carbon dioxide as a refrigerant. The aim is to enhance information exchange, which is done by arranging two seminars each year and by producing a newsletter. More information is available at www.c-dig.org.

Source: Heat Pump Centre

China to phase out CFCs by 2010

China – The State Environmental Protection Administration of China has announced that China will totally phase out CFC production by 2010. China has cut down production of ozone-depleting substances (ODS) by 90 000 tonnes/year. A national plan for ODS curtailment has been worked out together with the Montreal Protocol Multilateral Fund. The fund has recently donated USD 25.41 million to China for producing 10 000 tonnes of CFC alternatives per year.

There are also initiatives for an earlier phase-out of CFCs at various places in China. Shenzhen City will ban production and use of CFCs by the end of 2005. The Jilin province has also started a CFC phase-out plan. With effect from May 1, 2005, it is forbidden in two pilot cities to sell or store CFC refrigerants or refrigerating equipment using CFCs. By the end of 2005, CFCs will not be allowed in the entire province. CFCs will be phased out in the city of Wenzhou, too, by the end of 2005.

Source: JARN, no. 3, 2005

IEA Heat Pump Programme

New information service on the HPC web site

Information on ideas for new research areas (not yet annexes) is now available on the Heat Pump Centre web site, together with contact information for the person currently working on the project proposal. This information has been added to the web site in order further to stimulate collaborative research. To find the project proposals, visit the web site at www.heatpumpcentre.org, click on "Projects" and then on "Proposals". Current proposals are:

- Compact Heat Exchangers in Heat Pumping Equipment
- Tools for Performance Analysis of HVAC&AR Systems in Supermarkets
- Replacing Direct Electric Heating by Air-water Distribution
- Air-conditioning Systems in Large Commercial Buildings
- Heat Pumps in Low and Ultra-low Energy Houses
- Heat Pumps with Combined Heat and Power Systems (and Distributed Energy)
- Commissioning Tools
- Standardisation Development, Seasonal Energy Efficiency of Heat Pumps
- Long-term Performance of Heat Pumps (Heat Pump Systems – Troubleshooting)
- Heat Pump Water Heaters

Source: Heat Pump Centre

The annual report is now available

The promotional Annual Report of the Heat Pump Programme, describing the activities of the programme in 2004, is now available and can be downloaded or ordered from the web site, www.heatpumpcentre.org.

Events of interest in 2004 include the transfer of the Heat Pump Centre from Novem to SP Swedish National Testing and Research Institute, a national teams meeting in Borås, Sweden, and the publications from the finalised Annex 27 "Selected issues on CO_2 as a working fluid in compression systems".

Source: Heat Pump Centre

Ongoing Annexes

Bold text indicates Operating Agent.

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
Annex 30 Retrofit heat pumps for buildings	30	**GE**, FR

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.

Designing a heat pump for minimum refrigerant charge

Björn Palm, K. Andersson, P. Lundqvist, O. Samoteeva, Sweden

This paper reports results from a project aiming at reducing the refrigerant charge in a 5 kW liquid-to-liquid heat pump (heating only) to 150 g of propane. The work started by determining the fluid inventory in each part of the heat pump, with the result that the main effort has been on redesigning the heat exchangers using mini-channel tubes. At present, the system operates with about 200 g of propane. It should be possible further to decrease the charge by redesigning the condenser and by reducing the amount of propane in the compressor, either by using oils in which propane is not soluble or by using compressors with a low charge of oil. The resulting designs may open the way to safe use of flammable refrigerants with high energy efficiencies, such as R152a, R32, R290 or R600a.

Introduction

Today, it seems highly probable that the increase in global temperatures is a result of human activities causing an increase in the concentration of carbon dioxide and other greenhouse gases in the atmosphere. Among these other gases recognized in the Kyoto protocol as being of importance, are found most of the chemical compounds used as refrigerants in heat pumps and refrigeration equipment, i.e. hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs). For this reason, many have advocated the use of natural refrigerants with low global warming potential (GWP) as a means of reducing the contribution to global warming caused by gases released from refrigeration equipment and heat pumps. However, a change to natural refrigerants is not without its problems, as they are either flammable (NH3, HC) or poisonous (NH3), or have a substantially different pressure level than the refrigerants used today and thus require different system design (CO2, H2O).

From an environmental point of view, it is not only the direct effect caused by release of refrigerant into the atmosphere that should be considered. Equally important is the secondary effect, i.e. the release of carbon dioxide due to the generation of the electricity necessary for operation of the system. Whereas the direct effect is measured by the global warming potential (GWP) of the fluid, the total contribution to global warming is measured by the Total Equivalent Warming Impact (TEWI). For systems with low refrigerant losses, the indirect effect will be dominant, while for systems with large losses, the direct effect will make the largest contribution to global warming. In any case, the TEWI concept points to the importance of designing systems with high COP. Of the natural refrigerants, hydrocarbons and ammonia seem to have the potential of giving (at least) as high COP as the HFC and HCFC refrigerants. Hydrocarbons can be introduced with only minor changes to present technology.

Baseline heat pump design

Regardless of the refrigerant used, there are incentives to seek to reduce the charge in the system, whether for safety reasons or for concern for the environment.

A Government-sponsored project has been running for some years at the Royal Institute of Technology in Stockholm, aiming to demonstrate how charge minimization may be achieved without reduction of COP. The focus of the project has been on single-family heat pumps as they are normally designed for the Swedish market, i.e. designed for heating only (i.e. not cooling), using a secondary loop for absorbing heat from the ground or from a lake. The heat pumps are connected to the hydronic heating system of the house and to a tank for domestic hot water. This type of system is already from the start quite compact, with all refrigerant-containing parts housed within a small volume. The evaporators and condensers used are almost exclusively brazed plate heat exchangers, which have a quite small internal volume. The total refrigerant inventory for heat pumps in the 4-10 kW (heating) range varies between 1 and 2.5 kg HFC (R407C, R134a).

Aim of project description of test rig

The aim of the project has been to design a heat pump system for a single family house (at least 5 kW heating) using less than 150 g of propane. The reason for choosing this level is that such a small amount is considered safe according to preliminary European standards, and so the necessary safety requirements are therefore less demanding below this level. As the density of propane is about half of that of the HFCs, the target charge expressed in terms of volume is 1/3 to 1/8th of that of an ordinary compact system. In a first phase of the project, a model heat pump was built in the laboratory using standard components: a hermetic scroll compressor, two brazed plate heat exchangers and a thermostatic expansion valve. No receiver was used. All components were mounted to achieve as short interconnecting lines and as small internal volume as possible. Apart from the standard components, the system was supplied with four quick-closing valves which could be closed simultaneously while the system was running. The purpose of these valves was to allow measurement of the mass of refrigerant in the different parts of the system under operation. The valves were placed as shown in Figure 1.

Test procedure

The tests were performed as follows. The operating conditions of the system were fixed by choosing the volume flow and inlet temperatures of the heat source fluid (glycol solution) and the heat sink fluid (water). When the system had been operating stably for some time, the quick-closing valves were closed and the compressor was stopped. Each of the four sections was then evacuated of all refrigerant by connecting them one at a time to an empty cylinder immersed in liquid nitrogen. Due to the low temperature, all refrigerant in the section was condensed into the cylinder, which could then be disconnected and weighed. Knowing the initial weight, the mass of refrigerant in the section was thus determined.

Baseline system

Tests were run with different total amount of refrigerant in the system, and the performance was determined for each charge. Figure 2a shows some of the results. As shown, for the selected set of running conditions, (t2 = -9 °C, t1 = +40 °C), there is a specific charge for which the performance is the highest. For the type of systems studied, the evaporation temperature varies a few degrees over the heating season. In a commercial system, a small receiver should be included to take up the variations in optimum charge. However, the volume of this receiver is quite small.

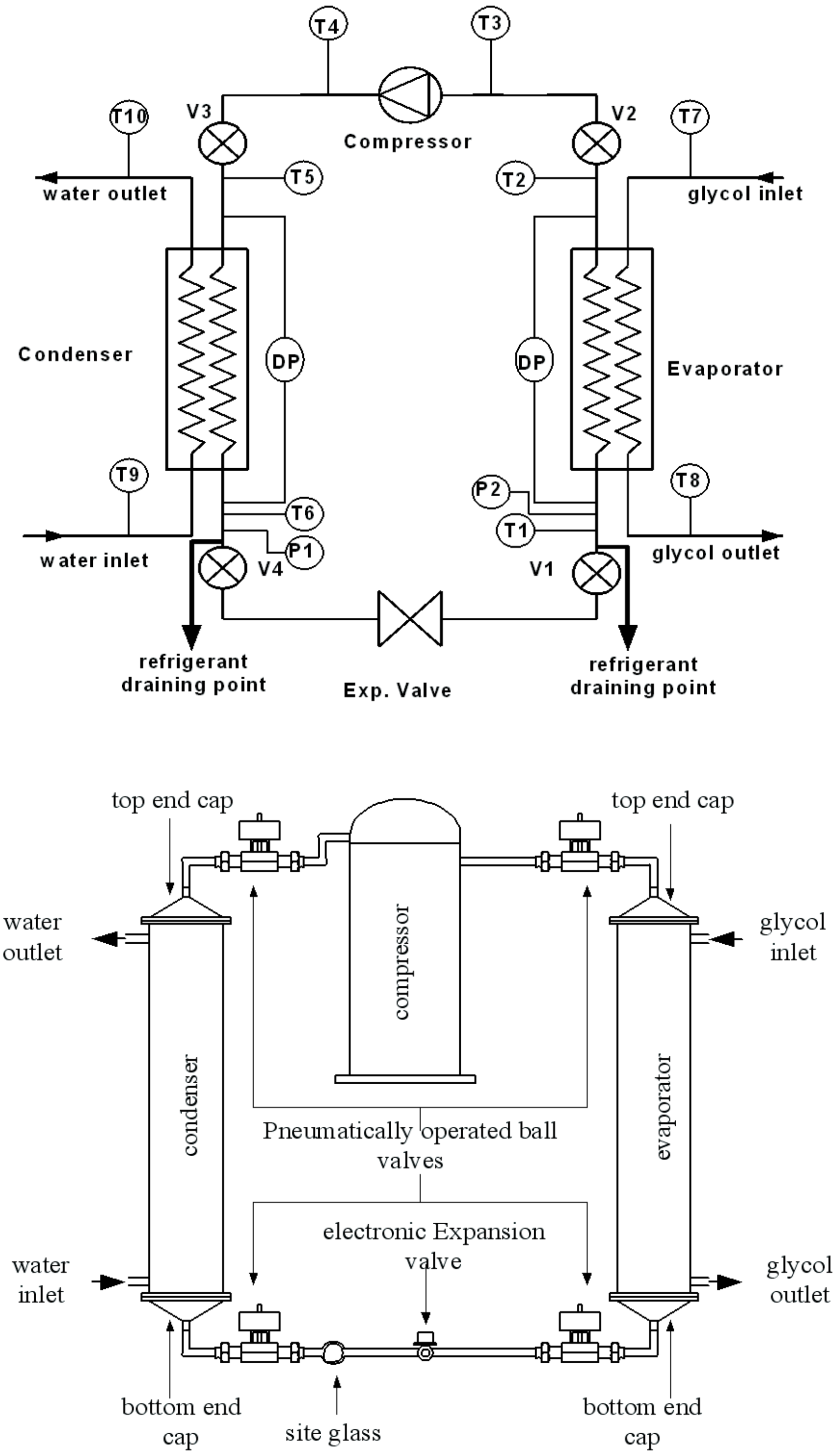


Fig. 1: Schematic drawings of test setup [1]

Fig. 2b shows the distribution of the charge. Charging the system above the optimum level increases the refrigerant mass in the condenser while the charges in the other parts remain constant. It is clear that 300 g of propane is sufficient to operate this system, built from only standard components. Even 250 g would be enough, giving slightly lower COP and lower heating capacity of the system. Fig. 2b shows that the two heat exchangers are the parts containing the largest mass of refrigerant.

System with flat copper tube heat exchangers

In a first effort to reduce the charge, a heat exchanger based on flat copper tubes was tested. These mini-channelled flat tube heat exchangers were made from sections consisting of 60 parallel flat rectangular-shaped copper tubes in two rows connected at each end by headers. The distance between two tubes is 1 mm. The length of a tube is 0.4 m and the internal hydraulic diameter is 1.096 mm (cross-section 0.6 x 6.3 mm2). The total tube area of the refrigerant side is 0.331 m2 and the total internal tube volume is only 90.7 ml. The tube package is enclosed in a shell with baffles and the brine/water flows back and forth between the flat tubes. Two packages were connected in series as a condenser and two in parallel as an evaporator. Test results with these heat exchangers are shown in Fig. 3 in terms of COP1 vs. refrigerant charge at different evaporation temperatures. The dependence of the optimum charge on the evaporation temperature is quite obvious.

Comparing the optimum charge to that with the plate heat exchangers (at an evaporation temp of -8 °C), it is clear that the flat copper tube heat exchangers have enabled the charge to be reduced by about 100 g. Not shown is the fact that the temperature differences in both the evaporator and the condenser were larger with the flat tube heat exchangers. In an actual installation, this would have resulted in a considerable decrease in the performance.

Aluminium multichannel heat exchanger

Having difficulties finding a sufficiently compact heat exchanger on the market, it was decided to develop a new prototype based on extruded aluminium multi-channel tubes. A cross section of the tubes used in the

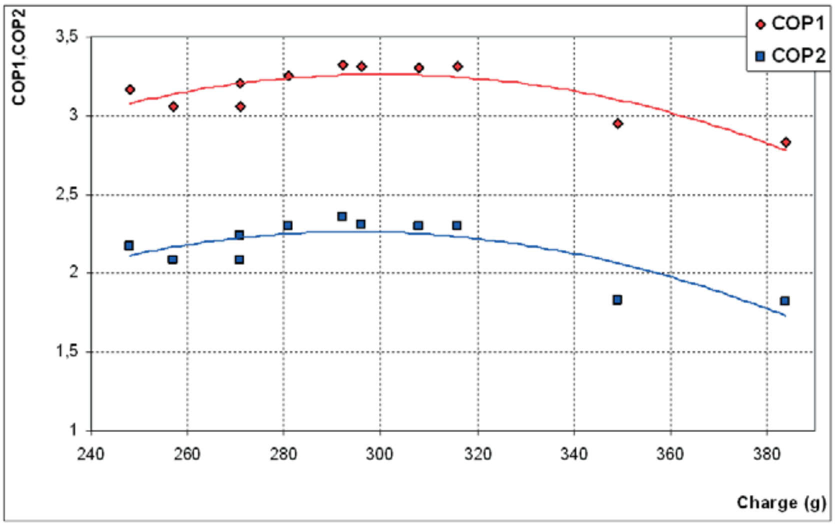


Fig. 2a: COP of baseline system vs refrigerant charge [1]

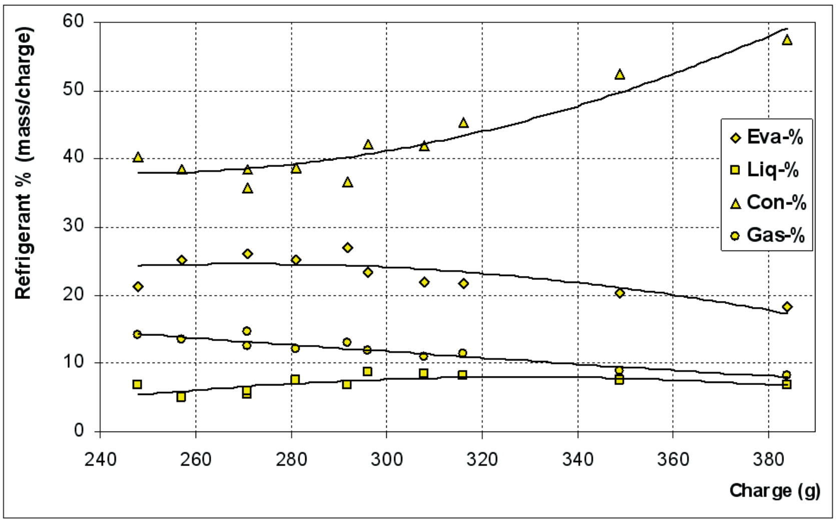


Fig. 2b: Refrigerant distribution between the four sections in the baseline system [1]

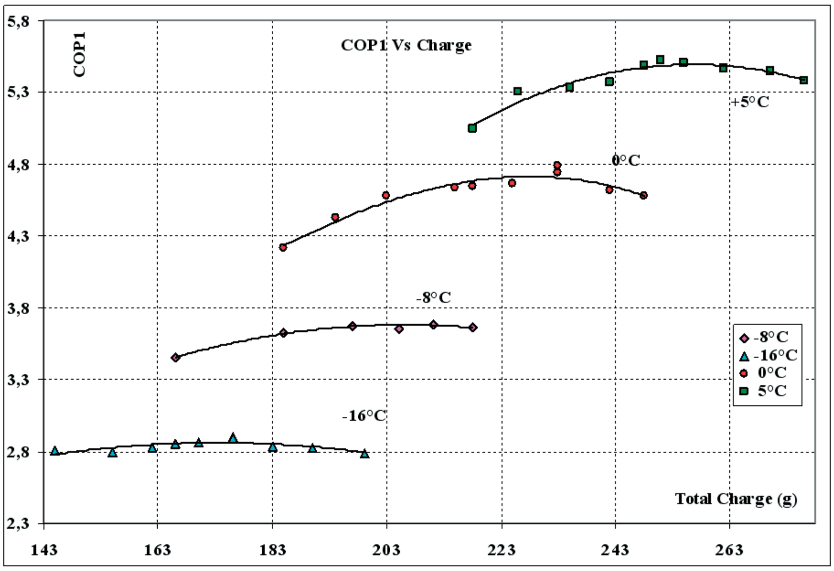


Fig. 3: Variations in coefficient of performance (COP1) with the total amount of refrigerant charge in the test rig with flat copper tube heat exchangers, at evaporation temperatures -16°C, -8°C, 0°C & +5°C with constant condenser cooling water outlet temperature (39-40 °C) [2]

first design is shown in Fig. 4. Two heat exchangers were manufactured from these tubes. The evaporator consisted of 30 tubes, and the condenser of 36 tubes. The tubes were fixed into a shell with 31 baffle plates, the tubes forming 2 mm high channels. The heat pump was tested with these heat exchangers as described above. Fig. 5 shows the measured COP1s for different charges. The data for -2/+40 corresponds to the evaporation/condensing temperatures -9/+40. The optimum charge is about 200 g, and even at 185 g the COP1 is very close to the maximum.

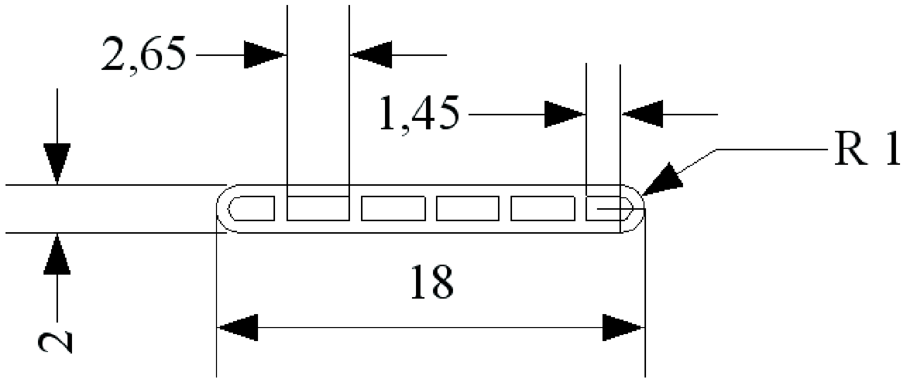


Fig. 4: Profile of aluminum multi-channel tube [4]

Table 1 shows the refrigerant distribution at the charge giving the highest COP1. As shown, the section around the condenser still contains the largest part of the refrigerant at the two lower temperatures. However, at higher temperatures, the compressor alone contains more than 100 g of propane and thus accounts for most of the charge. The evaporator, on the other hand, contains only about 25 grams of propane, which must be considered quite satisfactory.

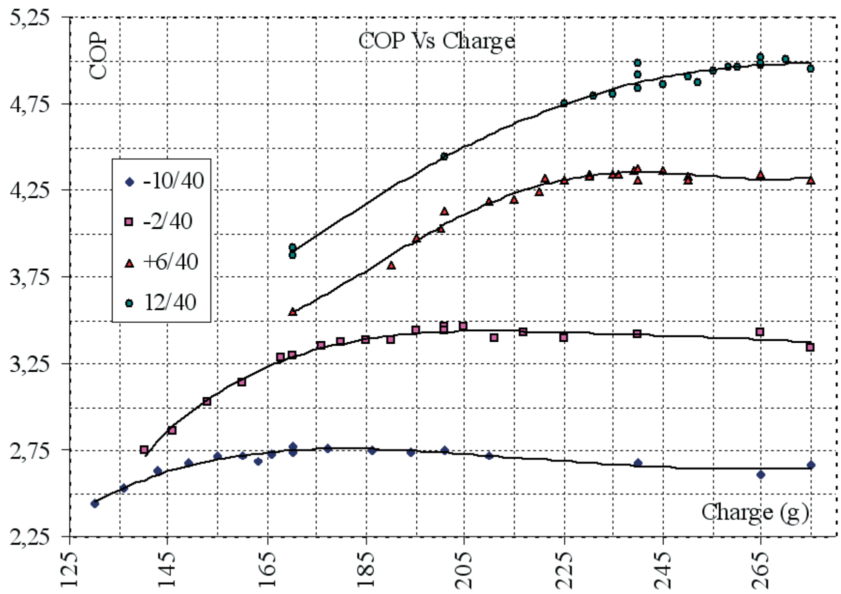


Fig. 5: COP1 vs. charge using prototype aluminum heat exchangers. Temperatures indicated are heat source and heat sink temperatures [4]

Reducing the charge in the compressor

The reason for the large charge in the compressor is mainly the absorption of propane in the compressor oil. It would be possible to reduce this amount by using an oil in which propane is less soluble. In fact, the solubility in some PAG oils is very low.

Another way of reducing the amount of refrigerant in the compressor would be to use compressors with smaller internal volumes and lower oil charges: consider, for example, the types of compressors (scroll or swashplate) used in the automotive industry. Compressors of this type supplied with an electric motor, designed for use in hybrid cars, are already on the market. It is expected that the oil charge in the compressor could be reduced to less than 20 g with this type.

Heat source/heat sink temperatures (°C)	−10.22/40.77	−2.09/40.67	6.93/40.77	12.64/40.74
Evaporation/condensing temp. (°C)	−16.49/39.73	−8.79/40.44	−0.51/41.44	4.55/39.95
Evaporator/condenser capacity (kW)	2.67/4.00	3.66/5.01	4.90/6.31	5.89/7.23
Super heat/sub cool (K)	4.66/3.91	5.30/4.76	5.18/4.56	5.77/3.82
Optimum refrigerant charge (g)	170	201	240	265
Measured in evaporator (g)	27	23	25	26
Measured in condenser (g)	69	80	90	93
Measured in liquid line (g)	24	24	23	24
Measured in compressor (g)	50	74	102	122

Table 1. Test conditions and refrigerant charge distribution with aluminum multiport heat exchangers

Conclusions

Up to now, charge reduction has not been an important goal for the heat pump industry. With new legislation concerning the use of fluids with high GWP, and with the introduction of flammable refrigerants, this may be an important factor in the future. This paper has shown that there is a considerable potential for charge reduction by using compact heat exchangers and short interconnections between the components of the system. It has also been shown that a substantial amount of refrigerant may be contained in the compressor, mainly dissolved in the oil. This amount may be reduced by using compressors with small internal volumes, small amounts of oil and/or by using oils which are not miscible with the refrigerant.

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Mitigation of greenhouse gases in refrigeration

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Mitigation of greenhouse gas emissions from refrigeration is a challenge for the future. In order to understand what is involved it is useful to divide the emissions into direct, caused by release of refrigerants to the atmosphere, and indirect, caused by the release of CO_2 in power production plants. The most important sectors are commercial refrigeration and mobile air conditioning, which together represent about 70% of the total contribution from the refrigeration sector. However, the relation between the direct and indirect effect varies considerably with factors such as type and quantity of refrigerant, leakage rates and the regional power mix. It is therefore difficult to generalise the characteristics of a certain application; for example, a supermarket. It is also important to note that minimizing charge and leakage does not necessarily lead to a higher energy consumption if systems are properly designed, which thus suggests that the direct and the indirect effects are best treated as separate issues.

Background

Refrigeration in all its forms, air conditioning, process cooling and food preservation, today use somewhere between 15 and 20 % of the electricity in the world, with the higher figure being attributed to developed regions in warmer climates. For certain regions, this figure might be as high as 30 %. There is thus no doubt that refrigeration contributes to global warming through the required driving energy and the associated release of carbon dioxide to the atmosphere. There are also still huge yearly releases of refrigerants to the atmosphere, although significant improvements have been made regionally in the last few years. Most of our common refrigerants, such as R404A, R407C or R134a, are strong climate gases. Within certain sectors the release of these HFCs - and in many regions CFCs and HCFCs (mainly R22) - may be as high as 25 to 30 % of the installed stock on a yearly basis. Notable sectors with high leakage rates are commercial refrigeration and mobile air conditioning. Other sectors, such as domestic refrigeration, are already in transition to an extensive use of the natural refrigerant iso-butane, while for R134a-based systems the contribution is rather from service or decommissioning, i.e. related to field practices.

Today, the combined effect on global warming from the refrigeration sector of (i) the *direct effect* caused by leakage, service or poor end of life recovery and (ii) the *indirect effect* caused by power production based on coal, oil or gas is so significant that there is an international consensus that something must be done.

Several initiatives are on their way

The European Commission is currently in the process of adopting the *F-gas Directive* regulating the use of HFC gases in various applications in the European Union, such as mobile air conditioning. Over the last few years, the Intergovernmental Panel of Climate Change, IPCC, has performed several studies, and the latest - entitled *"IPCC/TEAP Special Report on Safeguarding the Ozone Layer and the Global Climate System: Issues related to Hydrofluorocarbons and Perfluorocarbons"* - is currently in the publication phase[1]. The report considers replacements of ozone-depleting substances such as CFC and HCFCs and their applications in technologies that have either already been demonstrated, or (in the view of the authors) have significant market potential by 2015, and that could make a significant contribution to global warming. The effects of total emissions of ozone-depleting substances and their substitutes (mainly HFCs) on the climate system and on the ozone layer are assessed. The aim is to show how the replacement options affect global warming. Technical performance, potential assessment methodologies and indirect emissions related to energy use are considered, as well as costs, human health and safety, implications for air quality, and future availability issues.

Another important recent initiative has been taken by the International Institute of Refrigeration, IIF/IIR. In the second part of 2005, the Institute will start a working party with the theme *"Mitigation of greenhouse gases in refrigeration"*, which is mentioned elsewhere in this issue. The idea of the working party is to present guidelines for a route towards more sustainable refrigeration and heat pump systems by arranging expert meetings, state of the art reports and informatory notes on special issues for its member all over the world.

Measures to reduce greenhouse gas emissions

There are several possible ways of improving the environmental performance of refrigeration systems:

- improved containment of substances (zero leakage);
- reduced charge of substances in equipment and products;
- end-of-life recovery and recycling or destruction of substances;
- increased use of alternative substances with a lower or zero global warming potential; and
- Not-in-kind[2] technologies.
- Significantly improved energy efficiency of systems (as a whole).

Reductions of indirect GHG emissions can be achieved by improving the energy efficiency of products and processes (and by reducing the specific GHG emissions of the energy system). In determining which technology option has the highest GHG emission reduction potential, both direct and indirect emissions have to be assessed. Comparison of technology options is not a straightforward exercise, as significant variations in direct and indirect emissions may occur even within one technological application. A few examples will be given to illustrate the point.

All the above measures must be addressed in order to harvest the full potential of global warming mitigation. It is thus encouraging to see the formulations selected for the F-gas Directive[3] within the EU, although only the life cycle of the refrigerants is considered: the directive does not address the energy usage issues.

The energy mix dilemma

The indirect effect is strongly dependent on the energy mix in power production, in which there are notable regional differences. This effect complicates the analysis, and it may also hamper the generality of results and conclusions. Space here does not allow for a lengthy discussion, but recommendation and default values for regions are given in the IPCC report.

A thorough discussion of refrigerant emissions, with valuable data can be found in an IPCC report, partly based on the publications by Palandre et. al [1], which describes databases for worldwide refrigeration and air conditioning systems and refrigerants including refrigerant sales, system refrigerant inventories, and refrigerant emissions expressed in units of mass and carbon dioxide-equivalents.

The sub-sectors are different

In the category of commercial refrigeration, supermarket refrigeration systems represent the major share of GHG emissions. Recent findings suggest a global annualised refrigerant emission rate of 30 % from commercial refrigeration for the systems inventory in 2002. This represents 41 % of total emissions on a carbon dioxide equivalent basis. This data has partly been supported by other references, whereas several reports indicate leakage rates between 14 and 20 % in Europe and the USA. The second most important category is mobile A/C, with a global share of 35 %. The carbon dioxide-equivalent emission data for each sector can be found in Table 1. Since commercial refrigeration has the largest carbon dioxide-equivalent refrigerant emissions of all the air conditioning and refrigeration sectors, studies of emission reduction for this sector are an important step toward lower climate change impact. A more thorough discussion can be found in references [2-3]. These publications also present regional leakage rates for supermarkets. Additional data on refrigerant stocks and emission for the sectors will be published in the aforementioned IPCC report.

Table 1. Sector shares of refrigerant emissions expressed in CO2 equivalents

Sector	% Share of Emissions
Commercial refrigeration	41
Mobile A/C	35
Stationary A/C	13
Industrial refrigeration	6
Domestic refrigeration	4
Transport refrigeration	1

How to compare and evaluate the direct and indirect effect

Two measures have been suggested for comparing the direct and indirect effects from various systems: TEWI and LCCP. TEWI stands for "Total Equivalent Warming Impact", and LCCP for "Life Cycle Climate Performance". The idea is to sum the direct and indirect effects over a project lifetime as a support for decision-making for system design, refrigerant choice or other measures. TEWI and LCCP are similar, but LCCP is the (slightly) wider concept, taking manufacturing and decommissioning into account as well. However, results from a TEWI analysis do not differ significantly from an LCCP analysis.

In this paper, we suggest an "extended" TEWI analysis, taking end-of-life recovery of the refrigerant into account by assigning a share of the end-of-life release of refrigerants to each year of the project lifetime. This assumption is justified if similar systems exist with overlapping life. The analysis is performed by calculating the direct emissions from leakage during operation, including servicing, and from eventual decommissioning and disposal of the system. The total mass in kg of emissions of each greenhouse gas component is converted to CO_2 equivalent emissions using the GWP-value[4] and a suitable conversion factor (see, for example, literature by IEA or the IPCC). These are then added to the emissions of carbon dioxide arising from production of the necessary electricity for operation to give a TEWI value expressed as CO_2 equivalent emissions per year. Examples of analysed equipment could include refrigeration or air conditioning systems, although even an entire building could be used as the basis for comparison. A better (environmental) performance can often be achieved through a combination of measures, with energy conservation, and thus significantly lower cooling demand, being an often neglected option.

The TEWI-value is expressed in several ways in the literature. One possible formulation is:

$$TEWI_{s,y} = m_r \cdot GWP_r \cdot (\eta_{leak} + (1-\eta_{rec}) / years) + \dot{Q}_2 / COP_2 \cdot hours \cdot CO2_{reg}$$

Where: $TEWI_{s,y}$ is the total equivalent warming impact from system S for one year y (for example, a particular refrigeration system or a building installation), expressed as the mass of CO2 equivalent per year. m_r is the refrigerant charge in kg, GWP_r is the specific CO_2 equivalent value for the refrigerant, η_{leak} is the leakage in percent /100 and η_{rec} is the end of life recovery in percent / 100. Q_2 is the refrigeration effect in Watt, COP_2 is the coefficient of performance, and $CO2_{reg}$ is the regional conversion factor for electricity. The term $\dot{Q}_2 / COP_2 \cdot hours$ is easily changed to the yearly energy consumption in kWh, E_{year}, if this is known.

It is important to note that a TEWI value calculated for one system by one methodology and one set of assumptions, equations, procedures and source data, is not comparable with a TEWI value calculated for another system using another methodology, and TEWI has no meaning if used in this way. It is therefore crucial to state the assumptions made. If a TEWI value for the entire project lifetime is selected as a basis for comparison, it is important to note that a comparison between systems with different lifetimes may appear strange.

Is the trade-off between direct and indirect necessary?

If a measure is directed towards minimising the direct contribution, it should not result in higher energy consumption, and the concepts of TEWI and LCCP give us an opportunity to express this. Different sectors in refrigeration are very different, and leakage in some sectors such as domestic refrigeration are practically non-existent except for service and decommissioning, whereas supermarket refrigeration and mobile air conditioning have been inherently leaky, although great improvements have been achieved during the last five years in some parts of the world. Typical relations between direct and indirect effect are given in Table 2.

Table 2 Typical share of direct emissions of total greenhouse gas emissions

Application	Percentage direct emissions	Characteristics and assumptions
Mobile air conditioning	40 – 60%	Passenger car, HFC-134a, Seville
Commercial refrigeration	20 – 50%	Direct expansion, supermarket 1000 m2, HFC404A, Germany
Domestic refrigeration	10%	Standard refrigerator, HFC134a, European energy mix, 100 g charge, no eol recovery

tems in three fundamentally different energy systems[5] : an average European power system (0.51 kg CO_2/kWh), Norway (0 kg CO_2/kWh) and Denmark (0.84 kg CO_2/kWh). The first example is a very "leaky" supermarket with direct expansion (DX), R404A as refrigerant and no end-of-life recovery. The second example is an indirect system, with lower charge and leakage (see the text under the figure for assumptions).

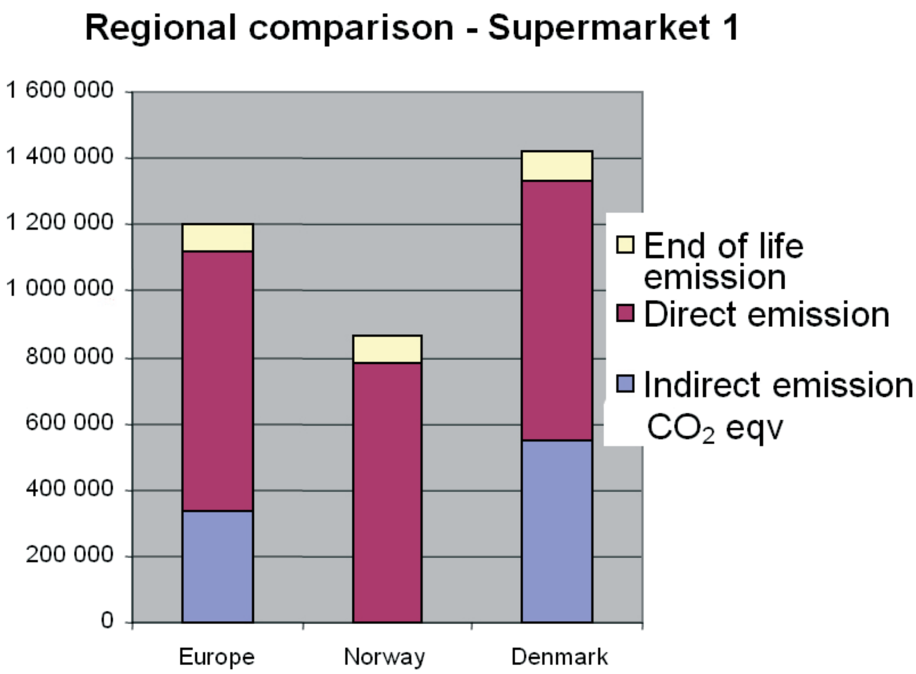

Figure 1. Total yearly CO_2 emission for Supermarket 1, charge 600 kg HFC404A, yearly leakage 30%, end of life recovery 50%, COP of refrigeration machinery 2.5 and a yearly operation time of 75 % with a nominal capacity of 250 kW.

Generalised data of the type given in Table 2 must be used carefully. The following sections illustrate the influence on the results from different assumptions for refrigerant leakage, charge and regional conversion factor for a supermarket. All data given in the following example are realistic [4].

Figures 1 and 2 present absolute values (CO_2 – eqv./year) for the combined direct and indirect effect for two supermarket refrigeration sys-

Figures 1 and 2 shows the absolute values of yearly TEWI for the systems. Figures 3 and 4 show the relative importance of the indirect and the direct contributions for the "European" energy system. System 1 is dominated by the direct effect, and System 2 is dominated by the indirect effect.

It is therefore easy to be misled by the information in Figures 3 and 4. The energy consumption and the associated CO2 emissions are exactly the same in the two examples, and the potential for improvements should therefore be the same with respects to the energy efficiency. Figure 1 shows that the total yearly emissions are three times higher for System 1 due to excessive leakage (and a big charge). The examples chosen here illustrate the importance of the assumptions when performing a TEWI or LCCP analysis. Absolute values should always be used for comparisons/benchmarking, along with the ratio between direct and indirect effects. It is obvious that great care must be taken, and one should avoid taking decisions based on generalised statements such as those given in Table 2.

Footnotes

1 The summary for policy makers can be downloaded from www.ipcc.ch/press/spm.pdf

2 "Not-in-kind technologies" is often used in the literature to bundle all kind of technologies not yet fully on the market but with a potential to mitigate global warming through the use of alterative energy sources (solar cooling for example), or completely different cycles such as the Stirling cycle. This category may also include information on free cooling using ground or sea water, although these technologies are commercial today.

3 http://europa.eu.int/scadplus/leg/en/lvb/l28138.htm

4 A list of updated GWP values will be available in the forthcoming IPCC report.

5 These figures are changing from year to year, and are also dependant on system boundary selections. The purpose here is merely to illustrate the principles, rather than to report on the current status of electric power production.

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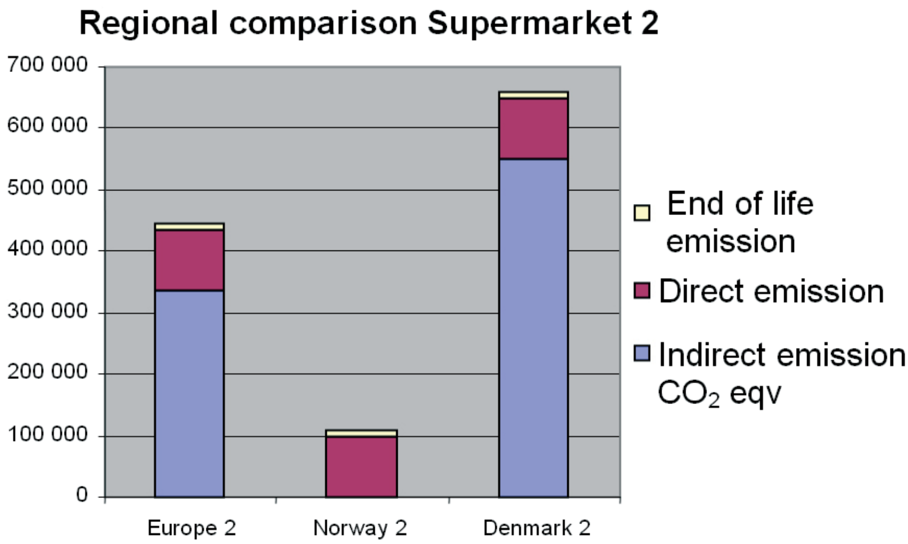

Figure 2. Total yearly CO2 emission for Supermarket 2, charge 150 kg HFC404A, yearly leakage 15%, end of life recovery 75%, COP of refrigeration machinery 2,5 and a yearly operation time of 75 % with a nominal capacity of 250 kW.

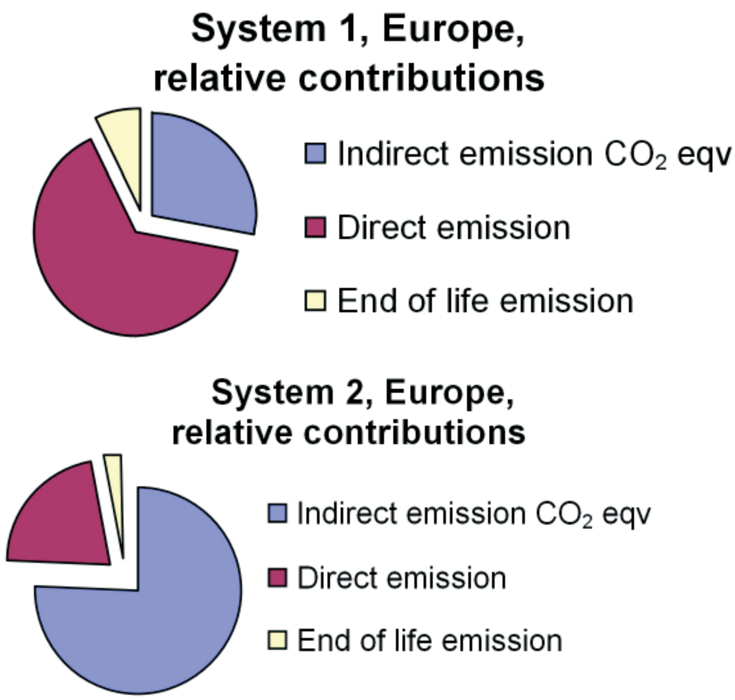

Figure 3 and 4. Relative contributions from indirect emissions, direct emission and end of life recovery for Systems 1 and 2 in Europe.

Potential for lower refrigerant charge in conventional and advanced heat pump systems

Keith Rice, John Tomlinson, USA

Lower charge heat pump systems can reduce the direct contribution to global warming as measured by the Total Equivalent Warming Impact (TEWI) as well as to mitigate flammability risks associated with hydrocarbon (HC) refrigerants. The DOE/ORNL Heat Pump Model was used to optimize a residential heat pump with several working fluids (replacements to HCFC-22) and conventional fin-tube heat exchangers [1]. The study found that the required refrigerant charge for optimal heat pump designs with HCFC-22 replacements can be somewhat lower than for the baseline heat pump system. Microchannel heat exchangers have the potential for even more significant reductions that can significantly reduce the TEWI of HFCs and possibly make flammable refrigerants more acceptable in residential equipment.

Findings for conventional and advanced heat pumps

Most of the U.S. domestic heat pump market is based around split system, air-to-air heat pumps. This type of heat pump has an indoor unit comprised of a fan, air-to-refrigerant heat exchanger (HX), backup electric resistance heaters and controls, and an outdoor unit comprised of the compressor, outdoor heat exchanger and reversing valve. Both heat exchangers are typically of round-tube-and-fin (RTF) construction using round expanded copper tubes and aluminium fins. A line set (suction and liquid lines) that is field-installed at the time of initial heat pump installation, connects the outdoor and indoor units. The two heat exchangers in the heat pump in addition to the liquid line between the two account for 90% of the total refrigerant charge.

Microchannel heat exchangers (MC) are typically flat, multiport aluminum tubes that are made by extrusion processes and finned together to form an effective, refrigerant-to-air heat exchanger. These tubes can have a number of ports (parallel passages) per circuit and a range of port sizes. The result is that the internal volume of such heat exchangers is about 30 to 50% less than with RTF HXs while the refrigerant-side areas are larger by a factor of 5 or more [2a, 2b]. (The air-side resistance of the MC HX is also reduced due to the flattened tubes.) While the number of circuits and tube sizes is rather limited for conventional HXs, microchannel HXs have an added degree of freedom in balancing heat exchanger and pressure drop considerations. As such, MC HXs have more potential for reducing refrigerant charge while maintaining an optimal balance of refrigerant-side heat transfer and pressure drop [2a].

However, even with the limitations on tube sizes and number of circuits, heat pump systems with conventional RTF heat exchangers can be optimized for lower operating charge depending on the refrigerant used. This finding was revealed in an analysis of air-to-air heat pumps using the DOE/ORNL Heat Pump Design Model in which the performance of a 9.4-kW cooling heat pump operating with several refrigerants was studied. In this work, HCFC-22 was compared to three non-chlorine-containing alternatives: HFC-134a, R-410A and R-290 (propane) with each system optimized for performance. Design conditions for this optimization were considered to be at the DOE test point for high temperature cooling condition shown in col. 5 of Table 1. Off-design conditions considered were for the low-temperature cooling (col. 4) and high- and low-temperature heating test points (col. 3 and col 2.) of Table 1.

Table 1. Basic Steady-State Rating Conditions for Air-to-Air Heat Pumps

Rating conditions	Heating mode		Cooling Mode	
	Low temp DB/WB*, °C	High temp DB/WB*, °C	Low temp DB/WB*, °C	High temp DB/WB*, °C
Outdoor coil	-8.3/-9.4	8.3/6.1	27.8	35
Indoor coil	21.1	21.1	26.7/19.4	26.7/19.4

**WB given for evaporating cases only*

Under these conditions and for the refrigerants noted, the outdoor and indoor coil tube sizes and numbers of circuits were optimized for the best balance of heating and cooling performance for the case of smooth tubes on both coils. Condenser subcooling (directly affected by charge among other parameters) was optimized at each of the design and off-design conditions given in Table 1. The total heat exchanger finned area, tube spacings, and fan power were held constant for all of the heat pump cases at the values of the original baseline configuration. The optimal tube o.d. sizes, numbers of circuits, and required refrigerant charge levels for expanded tubes that were determined are shown in Table 2.

Table 2. Heat Exchanger Configurations and Charge Requirements for Refrigerant-side Optimized Heat Pump Designs (predicted from the DOE/ORNL Heat Pump Design Model)

Refrigerant	Indoor coil		Outdoor coil		Refrigerant charge (kg)
	Tube o.d.[2] (mm)	No. of parallel circuits	Tube o.d.[2] (mm)	No. of parallel circuits	
HCFC-22[1]	7.9	6	9.5	3	3.5
HCFC-22	7.9	5	9.5	3	3.4
HFC-134a[3]	7.9	6	9.5	3	3.1
HFC-410A	6.4	5	7.9 6.4	3 4	2.7 2.2
HC-290 (propane)	6.4	6	7.9 6.4	4 5	1.1 0.67[4]

All units have 9.4 kW design cooling capacity
[1] Original 10.5 SEER HCFC-22 split system
[2] Tube o.d.'s are nominal before expansion
[3] Suction lines increased from 19 to 22 mm
[4] No accumulator, smaller connecting tubes, reduced subcooling

For HCFC-22, the original design is given first (with the model predicted conditions and pressure drops calibrated to actual system performance) and is seen to compare closely with the optimal design listed second. For HFC-134a, slightly more circuits were needed in the indoor coil. A 6% reduction in charge was predicted with R-134a (the suction line had to be increased by one tube size to avoid excessive pressure drop). As shown, the tube sizes for HFC-410A and HC-290 were smaller resulting in a charge reduction of 21-35% in the case of the former and 68% in the case of the latter. For the flammable refrigerant (propane), additional measures were taken to see how low the charge could be taken. To accomplish this, all line sizes and subcooling levels were reduced and the accumulator was eliminated. A lower level of 0.67 kg (0.071 kg/kW) was realized, giving an 80% reduction from the optimum R-22 charge.

Smaller refrigerant tubes have the added benefits of reduced copper requirements and increased strength. With copper prices trending ever higher and the residential and light commercial HVAC industry transitioning to R-410A, a move to the smallest possible tube sizes is to be expected. An added advantage for heat pumps in moving to the smallest possible tube size in the outdoor coil is that this reduces the excess charge that needs to be dealt with in the heating mode, when the indoor coil must store the refrigerant previously held in the outdoor coil. It should also be noted that an AC-only design can be designed for higher pressure drop in the condenser, which suggests that an even smaller tube size with slightly higher circuits would also be possible for the outdoor coil for R-410A and propane, reducing charge even further.

A similar optimization analysis for conventional tubes with rifled or grooved surfaces would be expected to show similar relative charge results, while the numbers of circuits may need to be increased to accommodate the higher pressure drop of such enhanced surfaces.

The quantity of refrigerant required per unit capacity is of interest in assessing the risk of propane designs in residential-size heat pump applications. Grob [3] showed sample flammability calculations which indicated that levels less than 0.051 kg/kW would be needed before propane might be considered non-flammable in certain scenarios. From the above analysis for residential heat pump equipment, the charge requirements of conventional fin tube heat exchangers can start to approach this level for propane and other hydrocarbons; however new design approaches based on microchannel or other low refrigerant volume heat exchangers will be needed to drop below this level in conventional vapor compression equipment.

From recent testing in prototype rooftop AC units, it was reported by TIAX [4] that the R-410A refrigerant charge requirement was reduced 40% using a microchannel condenser, with 50% reductions estimated previously by TIAX [5] if both heat exchangers were microchannel. Applying similar results to the above residential case would yield a possible propane level of 0.043 kg/kW with a microchannel condenser and 0.036 kg/kW if both heat exchangers were replaced with microchannel. Previously Goslovich and Bullard [6] showed that the charge per unit delivered capacity for a refrigerator was reduced by 42% when using microchannel HXs for both coils.

Microchannel heat exchangers are the subject of active investigation in the U.S. in reaching higher performance levels with the same or smaller cabinet sizes. Charge reduction is one added benefit of this technology in achieving higher performance levels while also reducing the refrigerant charge requirement/cost. As the cost of copper relative to aluminium increases and manufacturing costs of such heat exchangers are reduced, the economics of microchannel heat exchangers should become more competitive.

It has been noted by TIAX [5,7] that the recommended "next steps" in technology development for microchannel HXs are:

1) development of publicly-available performance prediction tools,
2) cost reduction of microchannel HX fabrication, and
3) development of fabrication techniques allowing greater design flexibility

Additions to the DOE/ORNL Heat Pump Design Model [8] and/or other publicly available vapor compression design models are recommended to allow further evaluation of microchannel heat exchangers and their impact on heat pump performance and charge reduction with HFCs and hydrocarbon alternatives. Recent research by Jacobi et al [9] has provided a good basis for the development of such performance prediction tools for microchannel heat exchangers.

Conclusions

Conventional fin-tube heat exchangers can be optimized for performance with new HFC or HC refrigerants while minimizing refrigerant charge. An analysis of the performance of refrigerants HFC-410A and HC-290 as alternatives to HCFC-22 in a residential heat pump with smooth tubes showed that the optimal refrigerant charge could be 21 to 80% less than for the baseline HCFC-22 system. Microchannel heat exchangers have the potential reduce the optimal charge by another 40 to 50%. Efforts to extend publicly-available heat pump design models to include microchannel analysis capability are recommended based on the need to reduce the TEWI of HFCs and the degree of risk for flammable refrigerants while increasing equipment performance levels.

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Heat pumps in Romania – a general overview

Robert Gavriliuc, Romania

This paper describes the past, present and future perspectives of heat pump technology in Romania. It also emphasises the important development possibilities of heat pump technology in connection with Romania's EU accession.

Introduction

It is well known that heat pumps can contribute to substantial fossil fuels savings and thus to the protection of the environment. These reasons are even more important for a developing country such as Romania, which does not possess significant fossil fuels energy sources and which is in a process of fundamental economical change towards a market-orientated economy. The need to build up a competitive economy involves the acquisition of competitive technologies, all of which are based on low energy consumption. Statistics show that energy consumption per product unit is 3 to 4 times higher in Romania than in the developed countries. This high energy consumption leads to high production costs and, ultimately, to low living standards.

Economic and political background, climate information

For about three decades, Romania followed a process of forced development, with its benefits and shortcomings. Many industrial sites have been built and, together with them, cities developed and grew up. To provide energy both for industry and for dwellings, many power stations were built, almost always of the co-generation type. Hot water is used as heat transfer media in district heating systems.

The Romanian climate has strong continental features, with severe winters when the temperature may drop to -20 °C or even -25 °C, and with hot and dry summers, when the temperature may rise to +35°C or even +40°C. The main problems occurred in winter time, when the district heating or other heat supply systems for homes or important civil facilities (such as hospitals) was unable to meet the heat load of the buildings and to ensure proper indoor conditions for the inhabitants. The situation became quite dramatic at times, with indoor temperatures falling to 12 °C, or sometimes even lower, depending on the thermal standards of the buildings.

However, the periods of time with favourable outdoor temperatures that allow the use of heat pumps are considerable, so that heat pump technology is very attractive.

Past history of heat pump technology in Romania

In the 1970s, the Tehnofrig Company in Cluj-Napoca manufactured a range of large compression heat pumps working with R12, but the company was re-structured due to the economic changes and it abandoned the production of such equipment. The compressors of these heat pumps were manufactured under licence from the ex-German Democratic Republic.

Technical Room for WSHP - water to water - SKODA Dealer Bucuresti

In Romania, ammonia is the most widely used refrigerant in the chemical and food industries. Ammonia/ water absorption machines were first built in 1955, reaching a present installed refrigeration capacity of over 100 MW. The chemical industry had imported several Borsig and Linde systems from Germany, and others from Poland. As experience was accumulated in the field, ammonia/ water absorption systems of this type began to be built entirely in Romania. Starting in 1975, the Refrigeration Research team from the T.U. of Civil Engineering, Bucharest, under the supervision of Prof. Dr. Eng. Florea Chiriac, has investigated and built several types of refrigeration machines and heat pumps based on

ammonia absorption in an ammonia/water solution. These machines have been mainly of the resorption type, in order to reduce the high pressure in the system.
Some examples of such ammonia/water absorption-based heat pumps are:
- The absorption - resorption heat pump from "Danubiana" Tires Company, Bucharest;
- The compression - re-sorption heat pump from "Faur" Company, Bucharest;
- The compression – re-sorption heat pump from the student campus of the T.U. of Civil Engineering, Bucharest;
- The heat transformer from Sânnicolaul Mare.

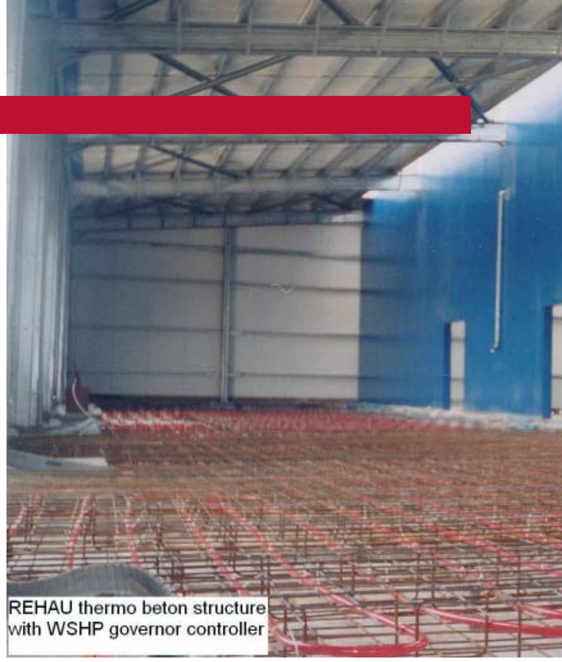
The absorption-re-sorption heat pump from "Danubiana" Tires Company Bucharest is characterised by the following technical features:
- thermal capacity: 5 MW;
- thermal capacity of the vapour generator: 3 MW;
- COP: 2.33 (including the water cooling effect in the desorber)
- heat source: industrial cooling water, cooled in the desorber from 25 °C down to 20°C:
- drive energy: low pressure steam:
- heated water: 147 m^3/h flow rate, from an inlet temperature of 35 °C to an outlet temperature of 70 °C, the heat being collected in the resorber, reflux condenser and absorber;
- equipment: vertical film vapour generator, provided with rectification column; horizontal film absorber and resorber.

Another project that finally came to life dealt with a *compression-re-sorption heat pump from "Faur" Company, Bucharest*, to produce domestic hot water for 8000 apartments. The most important technical features of this heat pump are as follows:
- overall thermal capacity: 8700 kW, out of which 5800 kW are produced by the heat pump itself, and 2900 kW by the direct recovery heat exchanger;
- electric power input: 1730 kW (compressors - 1620 kW, pumps - 110 kW);
- COP ≈ 3 (considering only the heating power)
- heat source: 30–50 °C cooling water from an air compressor station located in a factory;
- water flow rate: 1300 m^3/h at an average temperature of 30-35 °C (800 m3/h are used to heat up the evaporator, while 500 m^3/h pass through a heat exchanger with direct recovery);
- secondary water circuit: 125 m^3/h flow rate, heated from 10 °C to 30 °C in the recovery heat exchanger, and then up to 70 °C in the heat exchanger that takes the heat from the resorber;
- equipment: horizontal cylinder reciprocating dry compressor, 1000 m^3 storage tank.

The compression – re-sorption heat pump from the student campus of the T.U. of Civil Engineering, Bucharest uses the return circuit of the district heating system as its heat source. Its main technical features are:
- thermal capacity: 600 kW;
- secondary water circuit: inlet temperature 40 °C, outlet temperature 70 – 80 °C;
- COP varies between 3 and 3.5.

The Sânnicolaul Mare heat transformer (near Oradea, in the western part of Romania) uses geothermal water as its heat source, and has been designed to function in a very flexible configuration:
- single stage absorption – when the temperature of the geothermal water reaches 120 °C;
- double stage absorption - when the temperature of the geothermal water below 100 °C;
- compression-absorption system, by introducing a booster compressor in front of the absorption machine when the outdoor temperature drops below +10 °C.

Some technical data for this heat transformer are:


REHAU thermo beton structure with WSHP governor controller

- design temperature of the geothermal water: 40-50 °C and a heat input of 630 kW;
- heating capacity 320 kW, with the temperature of the delivered hot water in the range of 60-80 °C (the heat transformer was designed especially for a radiator heating system);
- low temperature heat capacity 310 kW, with the brine temperature in the range 0-10 °C (ice production also possible for high temperature geothermal water input); COP≈0.5

Analysis of the technical and economical information for these heat pumps provides the following conclusions:
- Although the initial idea was good, there was only a few research projects performed at small scale, and the projects were directly implemented at megawatt scale.
- The equipment was old-fashioned (no imports were allowed at the time), with large metal consumption and low energy efficiency, as for example: reciprocating and lubricated compressors, shell and tube heat exchangers.
- The projects were meant to fulfil political objectives, rather than complying with technical and economical requirements.

The present situation for heat pump technology in Romania

Nowadays, heat pump technology in Romania is not sufficiently widely spread to meet the social and economic demand. The first obstacle is the poor knowledge of heat pump technology, and the mistrust of people to new (and risky, they say!) technical solutions.

However, many companies have started to promote heat pumps. These companies are involved in the delivery of either heating equipment or refrigeration and air conditioning equipment, or they have specialised simply in heat pump equipment. Among them can be mentioned the GEOEXCHANGE SOCIETY Bucharest. The company holds agencies for Trane and Water Furnace equipment, and has supplied several large heat pumps abstracting heat from underground water. Their reference list comprises:

- 32 water/water and water/air heat pumps for the MIDOCAR (Volkswagen and Audi dealer) showroom in Bucharest, supplying the (underfloor) heating and cooling needs for 4000 m2 of offices and workshops. The overall installed capacity is 390 kW, with an underground water storage capacity of 350 m³. Running and maintenance costs for this facility are in the range 4.5 – 7 Euro/(m², year), on the basis of an increase in electricity costs from 50 to 100 Euro / MWh in the years before Romania's accession to the EU.
- The Avia Motors (Skoda dealer) showroom in Bucharest has a floor area of over 3000 m2, very similar to the Midocar showroom. The overall heat pump capacity is 270 kW, and the groundwater storage tank has a volume of 400 m³. There are a total number of six water/water heat pumps, and another six water/air heat pumps, installed in two heat pump stations.

Another Romanian company very much involved in heat pump distribution and installation is the Ost-West Company Timisoara, representing the Austrian Ochsner company. It has sold over 13 reversible heat pump systems, with heating capacities between 2.4 and 17 kW, and with various heat sources (groundwater, ground-coupled systems).

The Viessman Romania company has advertised its own products by installing a water/water compression heat pump system at its headquarters in Brasov, with a thermal capacity of 36 kW and a drive power input of 9.8 kW. The heat source is groundwater, with a flow rate of 1 l/s and a temperature difference of about 8 K. The nominal temperature of the heating system is 35 °C, with a maximum temperature of 55 °C. The company has also exported five other 26 kW heat pumps to Bulgaria, most of them being of the ground-coupled type.

The Alfabit company in Bu charest specialises in sustainable energy technologies: wind, solar and heat pumps. The company has several projects in progress, using either underground water (as the one in Otopeni, near Bucharest), or surface water (as the one in Giurgiu by the Danube, and in th e Danube delta).

Future perspectives and strategies

Analysis of information on the heat pump development in Romania shows that the past belonged mainly to the large ammonia/water absorption systems coupled with high temperature heating systems (classic radiators), while the present is characterised by smaller (but flexible) and reversible compression systems, connected to low-temperature heating systems. The opening of the Romanian market to western products has been beneficial for the growth of business in the heat pump sector.

The present conditions in Romania allow even bigger growth, considering the permanent rise in energy costs and the awareness of potential clients of the benefits that heat pumps can bring. An event that is positive for heat pumps are that the Geological Institute of the Romanian Academy of Sciences and the Romanian Hydrogeologists' Association have investigated Romania's geological and hydrogeological potential. Further is that heat pump technology is being taught in technical universities, so that graduates can apply the knowledge in their future projects and spread it among potential users in Romania.

The marketing and training aspects should be awarded special attention, by adopting the following measures:

- Identification of Romanian potential customers for heat pump technology;
- Installation of pilot heat pumps to prove the validity of heat pump technology to the Romanian authorents.
- The training of specialists for evaluation of local heat sources and for implementation of various heat pump systems.

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4. Design prescriptions for heat pump systems, Viessman Company, 2002

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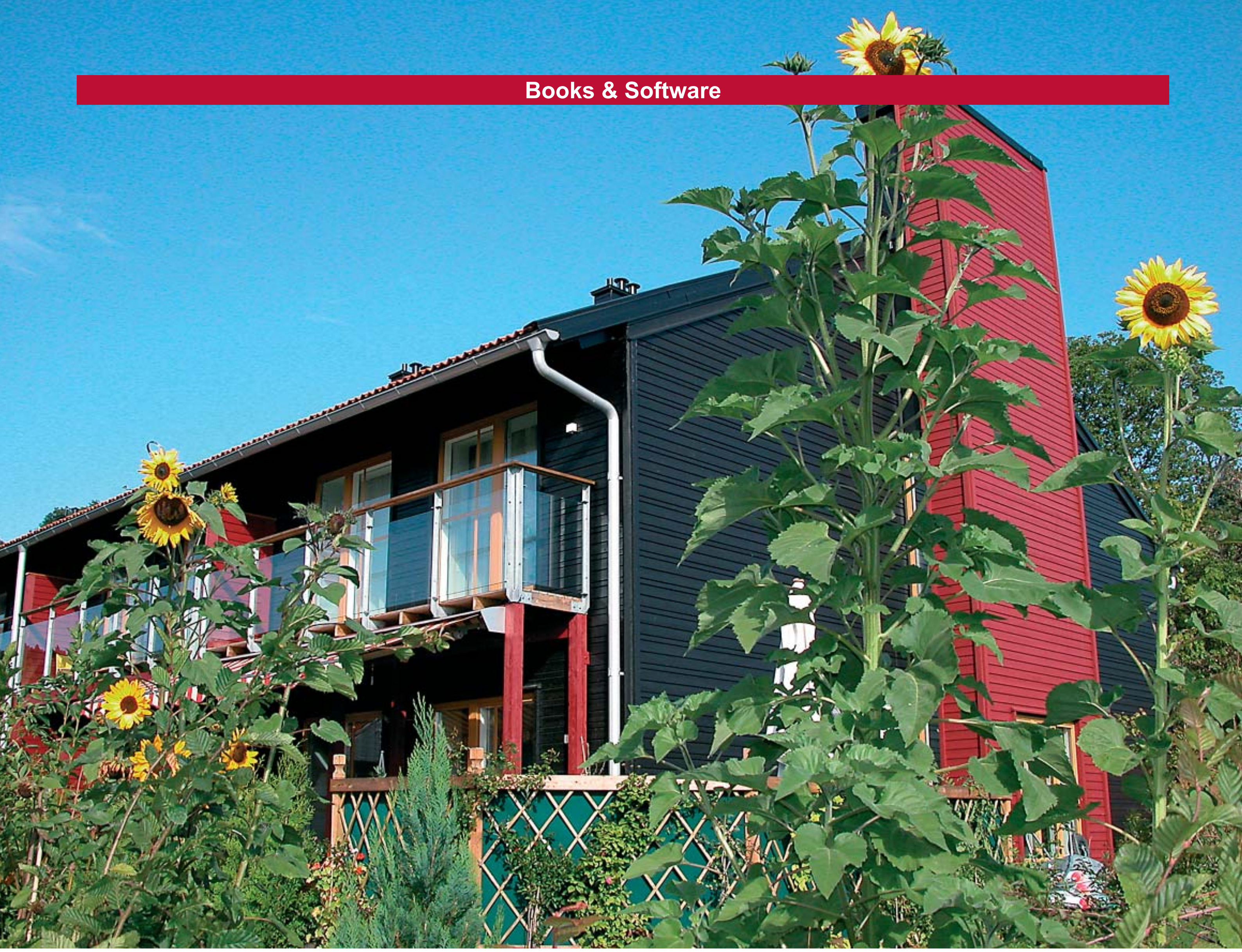

Small HVAC system design guide

The California Energy Commission has developed this guide to help engineers, designers and contractors design small packaged rooftop systems for commercial building applications that reduce energy use by 25-35 %. The guide covers building design practices to minimise HVAC loads, unit selection and sizing, distribution and control system design, commissioning, and operation and maintenance.

The guide can be ordered from http://www.energy.ca.gov/reports/2003-11-17_500-03-082_A-12.PDF

Indirect refrigeration systems

The Institute for Energy and Process Engineering at Tampere University of Technology in Finland has developed a handbook for designing indirect brine refrigeration systems. The handbook deals with corrosion, pipe dimensions, different brines and controls etc.

Solar-assisted air conditioning

The possibilities of using the sun as a source for air conditioning have been investigated by the IEA Solar Heating and Cooling implementing agreement. Some of the work has been devoted to defining performance criteria of solar-assisted cooling systems – both energy and economic performance. This work is detailed in the book 'Solar assisted air-conditioning in buildings – a handbook for planners'.
The book is edited by Hans Martin Henning, ISE, Freiburg.

The book can be ordered at www.springer.at

2004 ASHRAE handbook – HVAC systems & equipments

This handbook describes the equipment and components or assemblies that perform a particular function, either individually or in combination. The information helps system designers select and operate HVAC&R equipment. Chapters cover system selection and analysis, air distribution, panel heating and cooling, cogeneration, heat pumps and heat recovery, steam, district heating and cooling, hydronic heating and cooling and infrared radiant heating.

The handbook is available both in printed format and as a CD, and can be ordered at www.ashrae.org

2005

6th Workshop on Ice Slurries
15 – 17 June, 2005
Yverdon-les-Bains, Switzerland
Contact: Michael Kauffeld
Fax: +49 721 925 1915
Tel: +49 721 925 1843
E-mail: michael.kauffeld@fh-karlsruhe.de
http://iir.eivd.ch

International Sorption Heat Pump Conference
22 – 24 June, 2005
Broomfield, Colorado, USA
Contact: Mrs. Lori C. Puente
University of Maryland
Tel: (301) 405 5439
Fax: (301) 405 2025
E-mail: lpuente@umd.edu
www.enme.umd.edu/ceee/ishpc

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
Tel: +86 29 8266 3785
Fax: +86 29 8266 8724
E-mail: xypeng@mail.xjtu.edu.cn

ASHRAE Annual Meeting
25 – 29 June, 2005
Denver, Colorado, USA
www.ashrae.org

Commercial Refrigeration
30 - 31 August 2005
Vicenza (Padua), Italy
Contact: Alberto Cavallini
Fax: +390 49 827 6896
Tel: +390 49 827 6890
E-mail: alcav@unipd.it

Thermophysical Properties and Transfer Processes of New Refrigerants
31 August – 2 September 2005
Vicenza (Padua), Italy
Contact: Alberto Cavallini
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Tel: +390 49 827 6890
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International Conference on Compressors and their Systems
4 – 7 September, 2005
London, United Kingdom
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E-mail: m_willis@imeche.org.uk
www.imeche.org.uk

Heat Transfer and Fluid Flow in Microscale
25 – 30 September, 2005
Castelvecchio Pascoli, Tuscany, Italy
http://www.engconfintl.org/5ah.html

The 2005 World Sustainable Building Conference, SB05 Tokyo
27 – 29 September, 2005
Tokyo, Japan
Conference Secretariat of SB05 Tokyo
c/o Institute of International Harmonization for Building (iibh)
#30 Mori Building 3-2-2, Toranomon, Minato-ku, Tokyo, 105-0001 Japan
E-mail: info@sb05.com
http://www.sb05.com

Clima 2005
9- 12 October 2005
Lausanne, Switzerland
Tel: +41 (0)31 852 13 00
Fax +41 (0)31 852 13 01
E-mail: info@swki.ch
http://www.clima2005.ch/

3 Forum Wärmepumpe
13- 14 October 2005
Berlin, Germany
Contact: Tina Barosso
Tel: +49 (0)30 726 296 301
Fax +49 (0)30 726 296 309
E-mail: forum@solarpraxis.de
http://www.solarpraxis.de

2006

ASHRAE Winter Meeting
21 – 25 January, 2006
E-mail: jyoung@ashrae.org
http://www.ashrae.org

ACREX 2006 International Exposition on Building Services
22 – 25 January, 2006
New Delhi, India
ACREX Secretariat
K-43, Basement, Kailash Colony
New Delhi- 110048
India
Tel: +91 11 516 356 55
Fax: +91 11 264 249 25
E-mail: acrex@touchtelindia.net
www.acrex.org.in

5th International Conference on Cold Climate Heating, Ventilation and Air-Conditioning
21 – 24 May, 2006
Moscow, Russia
Contact: Andrey Golovin
Tel: +7 095 921 6031
E-mail: golovin@abok.ru
http://www.abok.ru/CC2006

Natural Working Fluids 2006: 7th IIR-Gustav Lorentzen Conference
29 – 31 May, 2006
Trondheim, Norway
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Tel: +47 7359 3750
Fax: +47 7359 3950
E-mail: Trygve.M.Eikevik@sintef.no
http://www.energy.sintef.no/arr/GL2006/

18th International Compressor Engineering Conference and 11th International Refrigeration and Air Conditioning Conference at Purdue
17 – 20 July, 2006
Purdue University, West Lafayette, USA
Contact: Virginia Freeman
Tel: +1 765 494 6078
Fax: +1 765 494 0787
E-mail: herlconf@ecn.purdue.edu

6th International Conference on Compressors and Coolants – Compressors 2006
27 – 29 September, 2006
Casta Papiernicka, Slovak Republic
Contact: Peter Tomlein
Tel: +421 2 4564 6971
Fax: +421 2 4564 6971
E-mail: zvazchkt@isternet.sk
http://www.isternet.sk/szchkt/

2007

22nd IIR International Congress of Refrigeration
21 – 26 August 2007
Beijing, China
http://www.iifiir.org

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

In the next Issue

Global Advances in Heat Pump Technology, Applications and Markets

Volume 23 - No. 3/2005

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

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.

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IEA OECD heat pump centre

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