IEA Heat Pump CENTRE NEWSLETTER

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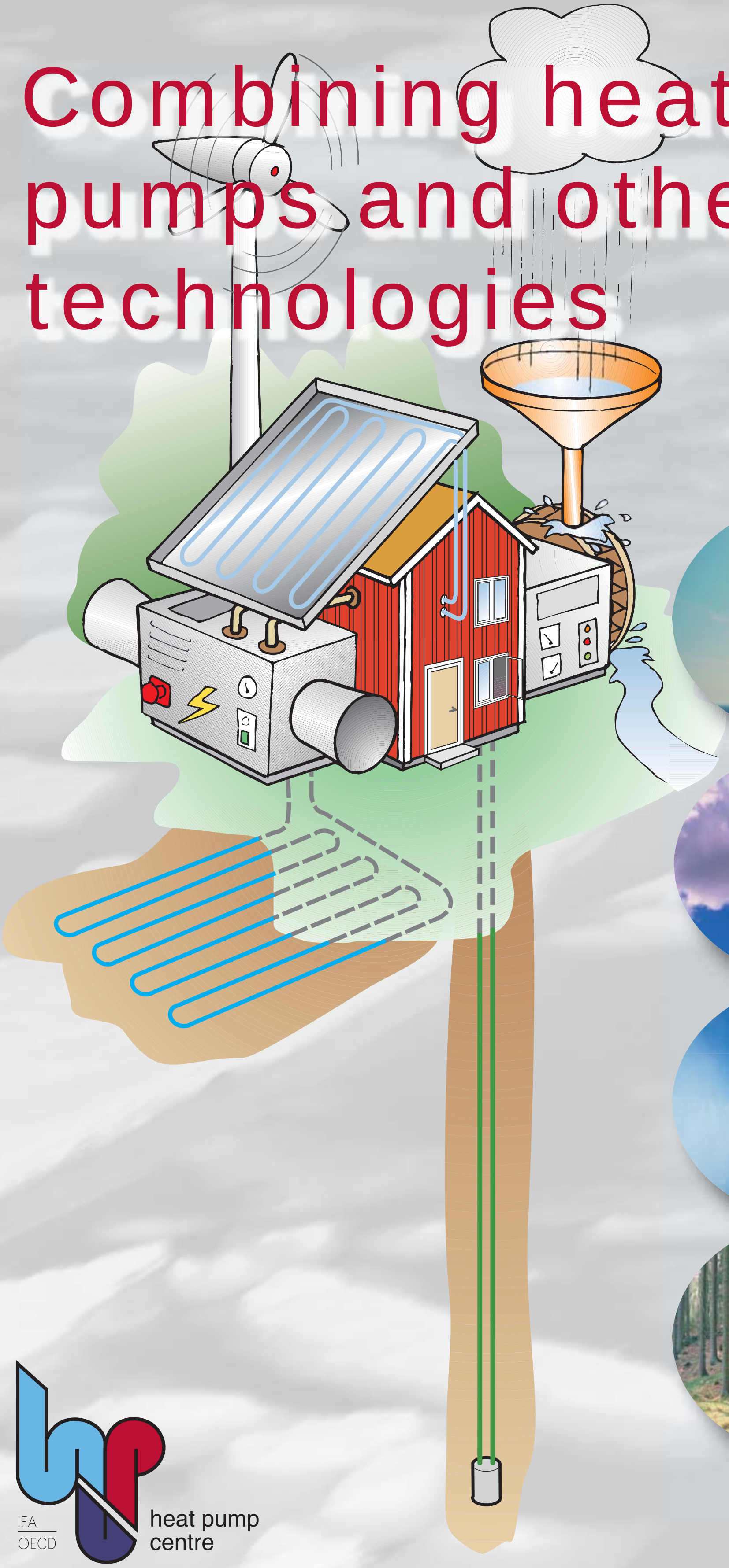
Combining heat pumps and other technologies



Use of Solar Heat in systems with Ground-Source Heat Pump

Biomass driven small-capacity ammonia / water absorption heat pump for heating and cooling

A Sewage Source Heat Pump System

IEA OECD heat pump centre

Merry Christmas!

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 25 - No. 4/2007

In this issue

Combining heat pumps and other technologies

In this issue, we explore the opportunities for combining heat pumps with other types of renewable energy, such as (for example) solar energy. Such combined operation can not only better supply heating needs, it can also improve the heat pump operation characteristics over time. Additionally, we present a non-topical article on heat pumps in industry, and one article on MAC. Sit back, have a gingerbread biscuit, and enjoy this Christmas issue.

Next year, the HPC Santa will bring you four new, interesting topics, about which you can read more on the IEA HPP page.

Merry Christmas and a Happy New Year
The HPC staff, including Roger Nordman
Editor, HPC Newsletter

Heat pump news

Features

Topical article

Non-Topical article

COLOPHON

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Foreword

9th International Energy Agency

HEAT PUMP CONFERENCE 2008

Thomas J. Kopp
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Mandated to Swiss Federal Office of Energy as Head of R&D-program 'Heat Pumping Technologies, Cogeneration, Refrigeration'

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CH-8640 Rapperswil
Switzerland
www.hpc2008.org

With this final Newsletter of 2007, I wish to take the opportunity to draw your attention to the most interesting event of 2008 in the field of heat pumping technologies: the 9th IEA Heat Pump Conference in Zürich, Switzerland, on 20 – 22 May 2008.
As Chairman of the National Organizing Committee, I invite you to join this conference and would like to tell you about some key elements of it. In addition to the opening session, there will be seven topic sessions, each with a keynote introduction, and five to six oral presentations followed by a poster session. In response to our calls for papers, we received more than 200 abstracts from all over the world. Our International Organizing Committee on behalf of the IEA Heat Pump Programme, and our Regional Coordinators, grouped your proposals into a very interesting and well-balanced conference programme. The session titles are as follows

- Heat Pumps for a Sustainable Society
- Heat Pump Application to Low-Energy Buildings
- Ground- and Water-Source Heat Pumps
- Heat Pump Application (General)
- Market and Application Studies
- Technology Advancements (focus on components)
- Technology Advancements (focus on systems)

The conference is co-sponsored by IIR, ASHRAE, EHPA and all member countries of the IEA Heat Pump Programme (Implementing Agreement on Heat Pumping Technologies), as well as by many corporate sponsors. Detailed information on the conference programme can be found on the conference website www.hpc2008.org.

On Monday May 19th (pre-conference), on Friday May 23rd (post-conference), and during the conference, several half-day workshops have been organized, the majority of which are based on topics found in the Annex working groups of the Heat Pump Programme of the IEA. One full-day workshop is focused on ground-source heat pumps and will be led by GROUND REACH, a group from the EHPA (European Heat Pump Association). Workshop topics are

- Ground Source Heat Pumps – Overcoming Market and Technical Barriers (IEA-HPP Annex 29, final workshop)
- Retrofit Heat Pumps for Buildings (IEA-HPP Annex 30, final workshop)
- Advanced Modelling and Tools for Analysis of Energy in Supermarkets (IEA-HPP Annex 31, workshop)
- Economical Heating and Cooling Systems for Low-Energy Houses (IEA-HPP Annex 32, workshop)
- Compact Heat Exchangers in Heat Pumping Equipment (IEA-HPP Annex 33, workshop)
- Thermally Driven Heat Pumps for Heating and Cooling (IEA-HPP Annex 34, kick-off workshop)
- GROUND-REACH-workshop (GROUND-REACH project 'Reaching the Kyoto Targets by Means of a Wide Introduction of Ground-Coupled Heat Pumps in the Built Environment' is supported by the Intelligent Energy for Europe Programme of the European Commission. The consortium consists of 21 organizations across Europe)

9th International Energy Agency

HEAT PUMP CONFERENCE 2008

On Wednesday afternoon, we will offer technical and non-technical tours so as to break up the intensive thematic discussions and invite the participants from all over the world to meet each other.
The conference dinner will take place on Wednesday evening, and is intended to be both a formal and a social event. We also expect the Ritter-von-Rittinger award and the conference award for the best poster presentation to be announced.
The conference will include an exhibition of products, and sponsors will have booths to display their offers. This areas will also host the coffee breaks and lunches, thus providing opportunities for fruitful and interesting conversations among the attendees.
The conference location is the Swisshôtel in Zürich, which is situated between Zürich airport and Zürich City, and can be reached from the airport with a short railway trip of about 10 minutes. Connections towards the City are by streetcar or by railway, and take only 15 to 20 mins. Our National Organizing Committee has made several reservations in different hotels in Zürich, ranging from one-star to five-star categories. All hotels are within easy reach by streetcar (20 to 30 mins). Special rates could be negotiated for reservations made by February 28th 2008.
You can register on www.hpc2008.org, where you may also register for workshops and tours, and also book your hotel.

Dear Heat-Pump Friend
I wish you all the best for the remainder of 2007, a wonderful Christmas and a happy New Year.
My last piece of personal advice to you for 2007 is - try to convince your boss that attendance at the 9th International Heat Pump Conference is an absolute MUST for the progressive development of your company, and includes a significant discount if you register as soon as possible.
I'm looking forward to seeing you in Zürich!

Thomas Kopp
Chairman of the National Organizing Committee

IEA HPP Newsletter
The United Nations Climate Change Conference

The 13th Conference of the Parties on Climate Change, which was also the 3rd meeting of the Parties to the Kyoto Protocol, took place in Bali, Indonesia, on December 3-14, 2007. It was the 10th Anniversary of the Kyoto Protocol and this was celebrated.

Progress has been made since the last Conference of the Parties, which took place in Nairobi in 2006 (Newsletter N°4/2006). First, the Adaptation Fund has been created and many discussions, during the high-level segment and during the side-events, emphasized the importance of actions on adaptation. Even if we obtain a reduction of 50% in the emissions of Greenhouse gases in 2050 (which is optimistic), we will have a 2°C increase in the global temperature and this will have important consequences, in coastal areas (floods…), …

However, the main challenge of this Conference was the definition of a procedure for negotiations for the "post-Kyoto" period, i.e. after 2012. The new factor was the decision of the newly elected Australian Prime Minister to ratify the Kyoto Protocol: Australia was, with the USA, one of the last countries to refuse to ratify the Protocol. However, the USA still did not want any commitment, and the developing countries (including countries like China which will become the most important emitter of CO_2 this year) did not want any constraints; some developed countries which have ratified the Kyoto Protocol (e.g. Canada) had considerably increased their emissions instead of reducing them. An agreement was difficult to reach with such conditions.

The European Union did not totally respect its engagements but it had taken measures and certainly was the region which did its best to obtain a new agreement. The declarations, during the high-level segment, of the European Commission, the European Presidency and the European countries were really determined, both for 2020 (intermediary period) and for 2050 (final period as reference). It seemed to be open to other targets for 2020 than the 20 % or 30% reduction rate initially proposed (the GIEC report proposed 25% to 40 % for developed countries).

After difficult negotiations, it was finally announced that the procedure to define new commitments after 2012 will begin next April and end in 2009.
In between, we will have a G8 meeting but first of all the next United Nations Conference on Climate Change which will take place in Poznan, Poland on December 1-12, 2008. It will be held after the election of a new President of the USA and important declarations could take place on that occasion. However, we can only hope to obtain an agreement in Copenhagen, Denmark, where the 2009 United Nations Conference on Climate Change will take place.

The number of attendees of such Conferences is increasing, with the presence of numerous non-governmental organizations, including trade associations, which try to be more present through stands and side-events. There were more than 10 000 attendees.

The International Institute of Refrigeration made three contributions to the conference:

- As an intergovernmental organization, it was able to deliver a statement (hereafter) during the high-level segment, with the presence of the delegations of all the countries (as the IEA also did);
- It ran a booth, where it disseminated various IIR documents and had discussions with people who attended the Conference;
- It organized a side-event, focused on energy savings in refrigeration, air conditioning and heat pumps. We had just published a new guide and thus were able to promote it (see www.iiifiir.org). We of course also presented the refrigeration sector more broadly, and its various environmental challenges and possible solutions, including both refrigerant emissions and energy consumption, with a target of a reduction rate from 20% to 30% in 2020 of CO_2 emissions. It was much more practical than the other side-events, and it was thus really appreciated.

In conclusion, even if no precise engagements have been made during the Conference, it is likely that now four dates are important:

– 2009: beginning of an agreement for the post-Kyoto period;

– 2013: beginning of a post-Kyoto agreement, with differentiated obligations for developed and developing countries;

– 2020: date of reference for the achievement of the first new engagements

– 2050: date of reference for the achievement of long-term engagements.

Didier Coulomb
Director of the IIR/Directeur de l'IIF

INTERNATIONAL INSTITUTE OF REFRIGERATION
INSTITUT INTERNATIONAL DU FROID

United Nations Framework Convention on Climate Change, COP 13 and CMP3 Bali, Indonesia, December 3-14, 2007

Statement presented by Didier Coulomb, Director of the International Institute of Refrigeration

Mr President, Dear Delegates,

I am speaking on behalf of the International Institute of Refrigeration IIR, which is the only organization in the field of refrigeration, air conditioning and heat pumps that has an intergovernmental status, with current 61 member states, which represent more than 80% of the world's population and with almost all countries with a manufacturing industry being members of the IIR.

Refrigeration (including air conditioning) is undoubtedly vital technology for the survival and well-being of mankind. Food supply, food safety, health and quality of life cannot be maintained and improved without refrigeration.

However, refrigeration contributes to two major threats to the environment: ozone depletion and climate change. These threats have led to the Montreal and Kyoto Protocols.

Refrigeration contributes to these threats in two ways:

- Refrigeration uses refrigerants, some of which have a negative effect on the environment if released into the atmosphere due to equipment leaks or if refrigerants are not properly recovered when disposal of the equipment takes place:
  - CFCs, and to a lesser extent HCFCs, contribute to the depletion of stratospheric ozone;
  - CFCs, HCFCs and HFCs are potent greenhouse gases which cause global warming.

  However, the natural refrigerants (ammonia, CO8 pkt, hydrocarbons) that are gradually replacing them in many refrigeration units, do not have a significant impact on the environment.
- Refrigeration technologies use energy and thus indirectly contribute to the emission of large amounts of CO_2. Refrigeration and air-conditioning technologies taken together account for about 15% of worldwide electricity use. Improved energy efficiency of refrigeration systems is therefore a priority.

The refrigeration sector, which was using 40% of CFCs in use when the Montreal Protocol entered into force, has played a decisive role in ensuring that the Montreal Protocol has succeeded and has also addressed climate change mitigation. However, refrigeration stakeholders are still facing a lot of challenges.
During the Montreal conference held last September, agreement was reached on accelerated phase-out of HCFCs and this is also good news with respect to mitigation of climate change, provided that the following aspects are taken into account:

- refrigeration is just one part of overall solutions leading to reduced energy consumption in housing and transport;
- plant maintenance and leak tightness and recovery of CFCs and HCFCs refrigerants remain vital issues;
- replacement of refrigerants must also consider energy efficiency and other potential impacts such as safety and cost;
- research must be stepped up in order to optimize alternative technologies that are developed, to enhance the energy efficiency of this equipment and to generally reduce the impact of refrigeration technologies on the climate;
- replacement solutions must take into account the specific contexts in the least developed countries, particularly in terms of cost;
- it is vital to inform and train refrigeration engineers and technicians in order to successfully implement these solutions.

The first problem to be addressed is insufficient information on these technologies.
The International Institute of Refrigeration is a knowledge and research driven global authority with no commercial interest and it is at your disposal to help you in your task of sustainable development.

CHINA Networks of Expertise in Energy Technology (NEET) Workshop Beijing, China 1-2 November 2007

China Coal Research Institute *International Energy Agency* *Ministry of Science and Technology*

"The Chinese Ministry of Science and Technology (MOST) and the International Energy Agency (IEA) have agreed that their experts will work together on the development of advanced technologies for secure, clean and affordable energy supplies. The agreement follows two days of discussions between experts from MOST and the IEA", states the final press statement issued by both the IEA and MOST at the close of the China NEET workshop.

On 1-2 November 2007, the International Energy Agency, in collaboration with the Chinese Ministry of Science and Technology and the China Coal Research Institute (CCRI), held the Networks of Expertise in Energy Technology (NEET) workshop in Beijing, China. Stemming from the G8 request in Gleneagles to increase energy technology collaboration with major emerging economies, the NEET workshop is the second of a series of events in the "Plus-Five", seeking to enhance collaboration with the IEA Technology Network composed of Working Parties and Implementing Agreements, as well as other networks.

At this event, more than 110 high-level Chinese stakeholders, ranging from policy makers, industries, R&D institutions and universities, were invited to discuss their respective activities and identify with the IEA Technology Network where collaboration would be mutually beneficial. Ten IEA Implementing Agreements actively invited targeted Chinese stakeholders to consider participating in their work. These ranged from the Clean Coal Centre IA, Greenhouse Gas and R&D IA, Emission Reduction in Combustion IA, Photovoltaic Power Systems IA, Wind Energy IA, Geothermal IA, Bioenergy IA, Hydrogen IA, ETSAP IA and the Heat Pump Programme.

At the event, the IEA Deputy Executive Director, Ambassador William C. Ramsay, noted that "There are many joint issues to tackle, and much common ground for future activities" with China. An article about the China NEET workshop was published in the online version of the People's Daily on the evening of 1 November 2007.

Two joint IEA-MOST-CCRI press statements were released at the start of the workshop and at the end of the event. The proceedings will soon be on the IEA NEET website, under http://www.iea.org/neet.

For more information on the event, and other planned NEET events in the "Plus-Five" countries, please contact Dr. Alexandra Niez, NEET Project Manager at Alexandra.Niez@iea.org.

General

eurammon announces winners of its natural refrigeration award

Students from around the world, from the US to China, competed for this year's Natural Refrigeration Award. eurammon announced the winners at its annual general meeting in Frankfurt today. First place went to Jörg Nickl, who wrote his doctorate on "Development of an Expander/Compressor for the Transcritical Refrigeration Process with Carbon Dioxide as Refrigerant" at the Technical University of Dresden. The coefficient of performance (COP) of transcritical refrigeration circuits with carbon dioxide can be improved by 20 percent by replacing the throttle valve with an expander. So Nickl designed a low-frequency, three-stage expander that is directly connected to a compressor. In practical trials, the doctoral student was able to demonstrate the increased efficiency of this novel design.

Christine Junior, from the Technical University Carolo-Wilhelmina at Brunswick, won second place with her diploma thesis entitled "Energetic Evaluation of Different R744 Loop Concepts". Arash Soleimani Karimabad, who obtained his MSc from the Royal Institute of Technology in Stockholm with a thesis entitled "Experimental Investigations of an Ammonia/Carbon Dioxide Cascade System for Supermarket Refrigeration" came in third. The winners presented their work to eurammon's international members and accepted their awards, with prize money totalling €5 000, at the meeting.

"All three prize winners addressed technical issues relating to the natural refrigerant carbon dioxide", says Thomas Spänich, member of the Executive Board of eurammon, the European initiative for natural refrigerants. "Operators, designers and manufacturers are greatly interested in refrigeration technology using carbon dioxide, as it is an ideal refrigerant in today's energy and environmental situation. Carbon dioxide does not affect the ozone layer and, with a reference value of 1, has a low direct global warming potential. The winners' findings all contribute towards making carbon dioxide practical as a refrigerant for an increasing number of applications." eurammon's Natural Refrigeration Award recognises the best scientific dissertation or thesis on the topic of natural refrigerants.

Source: www.eurammon.com

Proheatpump website launched

The new website for the European IEEA project Proheatpump has now been launched, with some initial results also available.

ProHeatPump is an Intelligent Energy Europe project, with the main objective of promoting information and success stories about ground source heat pumps. The overall goal of the ProHeatPump project is to contribute to the reduction in the use of fossil fuels for heating purposes. A key objective of the project is to promote energy-efficient heat pumps for heating. The project focuses on systems for the residential sector and SMEs, i.e. small to medium size heat pumps, and in particular on refurbishment where the need for promotion is higher then for new buildings. The share of heat pumps and the testing of promotion means for heat pumps in identified target regions is intended to provide information on appropriate marketing approaches to promote an extended use of heat. Promotion of heat pumps will be done by means of improved and steady information on heat pumps to the target groups of end users and installers as well as to policy makers. Another important project topic is the investigation and evaluation of combinations of heat pumps and renewables.

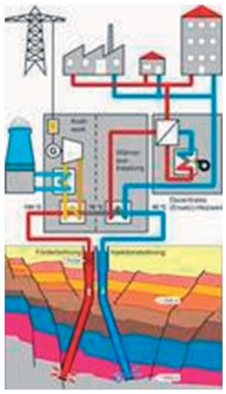
Source: www.proheatpump.eu

New version of software for energy modelling

The Florida Solar Energy Center (FSEC), a research institute of the University of Central Florida, has released EnergyGauge® Summit Premier 3.13. The software enables construction-industry professionals to reduce the time required to complete energy modelling for the commercial construction LEED® rating system of the U.S. Green Building Council. It allows engineers to enter the design building characteristics and the software calculates everything else required for point credits. It automatically creates the ASHRAE Standard 90.1-2004 baseline building; performs the ASHRAE 2004 Appendix G rating procedure, and calculates the points achieved for LEED energy optimization. It is available for free download, www.energygauge.com/

Source: The HVAC&R Industry newsletter

The first industrial year-round geothermal power plant in Germany was officially opened on the 22nd of November 2007.



The hydrothermal plant at Landau has a capacity of approximately 2.6 MWe and 5 MWth, sufficient for supplying a minimum of 5000 households with electricity. 300 households will also be supplied with heat through a small district heating network, later increasing to 1000. The project was supported by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety through an investment of over EUR 2.6 million.

The worldwide capacity of geothermal electric power currently installed is around 9000 MW, predominantly in Italy, the USA, the Philippines, Indonesia and Mexico.

Until now, the German geothermal projects have mostly been concentrated in the south of the country, but the northern German area is also highly suitable for the production of geothermal electricity.

The use of geothermal heating in Germany, supplying around 2000 GWh per year, is already a huge achievement. Approximately 150 further projects based on heating use and electricity production are already in preparation.

Bali climate talks: Global deal by 2009 still possible

UN Secretary-General Ban Ki-moon has urged world leaders to adopt a new climate change deal by 2009 to follow the Kyoto Protocol, with a key role played by business. After the first week of the UN Bali conference, results still look promising.

"We want to unleash the power of markets, capital, innovation and entrepreneurship in our fight against global warming," Ban said on Thursday before joining the climate change talks in Bali. He urged political leaders to agree on a post-Kyoto deal ratified by all nations by 2009 to seize the opportunity to jump-start growth and development, not hinder it. A recent report by the IPCC (Intergovernmental Panel on Climate Change) had stated that curbing serious global warming would cost as little as 0.1 % of GDP over the next 30 years, with already existing technologies having at least a 10 % rate of return on investment.

Meeting on the Indonesian island of Bali from 4-14 December, more than 10 000 policymakers, scientists and environmental groups are currently discussing a successor to the Kyoto Protocol, which expires in 2012. The first week revealed new climate plans and large disagreements among political leaders.
Source: www.r744.com

Working Fluids

Global deal to speed up HCFC phase-out

In a historic agreement, both industrialized and developing countries have agreed to phase out hydrochlorofluorocarbons (HCFCs) ten years ahead of the previous target date, and freeze production as from 2009 on.

Under the agreed timeline, the final phase-out of HCFC will take place in developing countries by 2030, and in developed countries by 2020. Interim targets for the maximum permissible production of HCFCs will ensure that these targets will be met in time. At present, HCFC is used in domestic appliances, refrigerators, air conditioners and other items.

Meeting in Montreal, Canada, on the occasion of the 20th anniversary of the Montreal Protocol, all 191 member parties unanimously decided on an earlier ban of HCFCs, not only to reduce ozone depletion but also as a means of fighting global warming. In the last decade, the Montreal Protocol has supported the targets of the Kyoto Protocol that seek to reduce global warming refrigerants, such as HFCs.

"Governments had a golden opportunity to deal with the twin challenges of climate change and protecting the ozone layer, and governments took it," Armin Steiner, executive director of the UN Environment Programme, welcomed the agreement.

Call for use of natural refrigerants
Didier Coulomb from the International Institute of Refrigeration in Paris told delegates at the Montreal meeting that environmentally friendly refrigerants are already available to replace ozone-depleting and global warming substances. Carbon dioxide, in particular, would make "inroads in some parts of the world".

Meanwhile, the German Federal Environment Agency (UBA) called on all countries under the Montreal Protocol to directly replace HCFC refrigeration units by natural refrigerants, such as CO_2. An early adoption of natural fluids would be "both technically and economically feasible", the UBA states in its latest press release.

A recent UN report had estimated that the atmosphere could be spared the equivalent of 1 billion tons of carbon dioxide emissions if countries used ozone-friendly refrigerants, such as CO_2, rather than continuing with HCFCs and HFCs. The natural refrigerant CO_2 (R744) is neither ozone-depleting nor contributing significantly to climate change, having a Global Warming Potential of only 1.

More than 900 participants, representing governments, UN agencies, NGOs, academia and industry, met to negotiate a new deal in line with the original Protocol signed in 1987.
Source: ScanRef Newsletter October 4th

R744, R152a and HFO-1234yf – Torino update

Experts discussed technical, environmental, safety and political issues of alternative refrigerants at the 2nd International Workshop on Mobile Air Conditioning in Torino last week.

Around 170 experts from Asia, the EU and U.S. met in Torino, Italy, on 29-30 November to shed light on the choice of refrigerant for next-generation Mobile Air Conditioning (MAC). Participants agreed that air conditioning has now become a key issue for carmakers to improve a vehicle's environmental performance, with Mr. Di Guisto from Fiat stating in his welcome address: "Mobile air conditioning is a very important and concrete tool to respond to climate change."

Read more and see the presentations at:
Source: http://www.r744.com/news/news_ida251.php

Breakthrough in air conditioning technology

The German automotive industry is going for more climate protection from air-conditioning systems.

Following investigation of numerous alternatives to the refrigerant currently being used, vehicle manufacturers in the German Association of the Automotive Industry (VDA) have now agreed to use the especially environmentally-friendly natural refrigerant R744 (carbon dioxide) in vehicle air-conditioning systems in future – and they will be the first world-wide automotive companies to do so.

According to a VDA press release, this means that the direct greenhouse effect of an air-conditioning system can be reduced by a factor of more than 1000, as compared with the technology in use today.

"With this joint step, German vehicle manufacturers will now be leading the world in climate-friendly refrigerants and are implementing their strategy of sustainable mobility in a consistent manner," declares VDA President Matthias Wissmann.

From 1 January 2011, new upper limits for refrigerants will apply in the EU. The future use of R744 will mean that German manufacturers will clearly undercut this new EU limit also.

Now the remaining technical questions have to be clarified jointly with the suppliers. Following thorough investigations, the use of the new chemical refrigerants known to date will not be pursued any further as an alternative.

None of these refrigerants – Fluid "H" from Honeywell or "D1" from DuPont – have so far applied for classification at ASHRAE 34 or ISO 817, according to James M. Calm, Distinguished Engineering Consultant ASHRAE Fellow.

The VDA-decision has put the rest of the automobile industry in Europe and Japan under pressure. So far, the Japanese industry was expected to wait for the outcome of further tests by producers of the chemical refrigerants, where toxicity and flammability in particular are still open questions.

Source: www.vda.de

RAL responds to changes in refrigerator recycling sector: New version of GZ-728 quality standard released

The RAL GZ-728 quality assurance and test specifications that contain the standards to be met when processing end-of-life refrigeration equipment containing CFCs have recently been subjected to comprehensive review and revision. The RAL Institute for Quality Assurance and Certification, which first published the GZ-728 specifications for the collection, storage, preparation and treatment of waste refrigeration equipment in 1998, has now issued the fully revised third edition of the established standard.

The need for quality standards in the fridge recycling sector has been recognized for many years. Since the introduction of the EU's WEEE directive into the European market, interest has been concentrated primarily on economic concerns. All too often, and to the detriment of the environment, contracts to supply fridge recycling services have been, and continue to be, awarded to plants offering the cheapest deal rather than to those actually capable of meeting the specified environmental targets. Eradicating this major shortcoming can only be achieved by introducing definitive quality standards that stipulate the minimum acceptable amounts of CFCs to be recovered from waste refrigerators and freezers. It goes without saying that when checking compliance with these quality standards, the interests of clients, recycling companies and technical experts must be kept separate if an independent and impartial assessment of CFC recovery rates is to be achieved. Indeed, it is only by independently monitoring the amounts of CFCs recovered that the goals of the European regulations (WEEE Directive and EU Regulation 2037/2000), i.e. the essentially complete capture and safe destruction of CFCs, can be met.

Source: http://www.ral-online.org/html_engl/detail.php?id=232

Technology & Applications

Seminar explores CO_2 refrigeration in hot climates

As climate change tops Australia's political agendas, sustainable CO_2 refrigeration has sparked great interest at a specialized NRTB seminar last week. Read here about technical and industry trends driving the application of R744 transcritical systems in hot climates worldwide.

CO_2 transcritical refrigeration is sparking great interest from the retail industry in hot climate countries. This has been shown during a one-day seminar focusing on the technical challenges associated with R744 transcritical concepts compared to cascade commercial systems and other refrigerants. Industry representatives from other warm countries, including from Woolworths South Africa, expressed surprise at the high level of sophistication of Australia's first transcritical plant installed in a supermarket.

Gathering over 60 participants from leading supermarket chains, commercial and industrial refrigeration equipment suppliers, as well as research institutes, the event more specifically identified the following trends: Transcritical CO_2 systems a viable solution in hot climates

The event, organized by the Natural Refrigerants Transition Board (NRTB) in Adelaide, started off with a visit to Angle Vale, Australia's first supermarket equipped with a transcritical CO_2 system. Sergio Girotto from the Italian engineering services company enEX, involved in the project, described the design and expected performance of the system that will start working at the end of November.
The unit is the first transcritical CO_2 system to be operated in the southern hemisphere. It has been financially supported by the Australian government to prove its reduced power consumption and better reliability. The NRTB now expects that its early operation will dispel any concerns about the viability of the system in the non-tropical regions of Australia. For this purpose, the NRTB plans to hold an open day at the facility in February, likely to be the hottest month of the year.
Source: www.r744.com

Maersk Line reefers saving energy

Danish based Maersk Line has announced the implementation of a new software solution, QUEST, which will enable a significant reduction in the energy consumption and CO_2 emissions of their refrigerated containers (reefers). QUEST (Quality and Energy efficiency in Storage and Transport) is a software solution, providing a new temperature control regime, cutting the energy consumption used for cooling by up to 50 %, without affecting the quality of refrigeration solutions. Maersk Line estimates that QUEST will lead to CO_2 emission reductions of 325 000 tonnes annually when fully implemented during 2008. "While the most energy-efficient and environmentally-friendly mode of transportation is by sea, our aim is for continual improvement in our environmental performance. We are therefore particularly pleased to be able to start the use of QUEST. It marks a new milestone in our continuous effort to develop and implement ever cleaner and more fuel-efficient solutions", says Thomas Eskesen, Senior Director and responsible for Reefer Management in Maersk Line. Traditionally, Maersk Line has maintained a constant supply air temperature in the reefer container, a process that uses high amounts of energy. QUEST, on the other hand, focuses on the temperature of the transported commodity.

"With Quest our customers and their commodities will benefit from all the usual features provided by our refrigeration solutions, and at the same time we all benefit from lower energy consumption and reduced emissions", says Thomas Eskesen. The solution is the result of a joint development project sponsored by the Dutch government, and involving Wageningen University and Research Centre in the Netherlands, Maersk Line and other parties.

"QUEST is a good example of thinking outside the box. The solution is innovative and successfully challenges conventional wisdom. We are very pleased to have been part of the project and to have the opportunity to apply scientific research into our business. We are confident that QUEST will reshape an important part of the container industry, benefiting both customers and the environment", concludes Thomas Eskesen.

Maersk Line is by far the largest container shipping line in the world, with a market share of more than 15 %.
Source: Scanref newsletter

Free research reports

As a new member benefit, members now have free online access to all ASHRAE Research Reports.
"Members who support ASHRAE research have already helped to fund these projects," said Lynn Bellenger, chair of ASHRAE Technology Council. "We are giving the members access to research that they have funded, which seems only fair. They can use the results to educate themselves without waiting for the results to appear in subsequent Handbook volumes. For members on technical committees, especially those that cover related subjects but didn't sponsor the research, it may stimulate research projects on related topics."
Source: ASHRAE Insights

New U.S. fuel economy ratings include A/C

For the first time ever, vehicle testing by the U.S. Environmental Protection Agency (EPA) includes the use of air conditioning. As a result, this year's fuel economy ratings for most car models are significantly lower than before.
Carmakers will have to re-work their advertising claims about high fuel economy after new estimates by the EPA have lowered the ratings for most car models in the U.S. This year's "Fuel Economy Guide", intended to help consumers select the most eco-

nomic car, shows that city and highway estimates have decreased by as much as 30 % for some vehicles. The use of air conditioning alone has led to a 5-25 % decrease in fuel economy, according to the EPA.
Source: www.r744.com

Carrier invests $50m R&D base in India

Carrier Corp will invest $50m in India over the next three years, to build a global R&D centre in the country.
Aimed at developing industry-leading products, the firm hopes the investment will strengthen its No.1 position in India.

Carrier expects the new facility to open in 2009, making it the company's third global R&D center in Asia.
The world's largest provider of heating, air-conditioning and refrigeration solutions will also use the $50m facility to educate and train Carrier India's customers on its products.

India has one of the fastest growing economies, and is a strategically important market for Carrier. Since 2004, the Indian air conditioning and refrigeration market has grown by 25 % a year and is expected to become one of the largest markets in the world by 2012.

Carrier's investment will bring world-class technologies and industry-leading air-conditioning and transport and stationary refrigeration products to the Indian market.
The firm says its new R&D centre in India will further Carrier's efforts to develop energy-efficient products that use non ozone-depleting refrigerants."
Source: ACR-News.com Newsletter

New brazed plate heat exchangers

Danfoss has launched a new product range of brazed plate heat exchangers especially designed for all types of commercial and industrial refrigeration, cooling and air conditioning applications. They offer a whole new level of performance and cost-effectiveness.

They have been developed and produced at the Danfoss Group company Qinbao, acquired by Danfoss in September 2006. The company was founded in 1968 and is located in Hangzhou, where about 80 employees develop, produce and market brazed plate heat exchangers (bHe), a key component designed for all types of refrigeration, process cooling, air conditioning and heating applications.

By removing heat and transferring it from one medium to another, brazed plate heat exchangers are a cost-saving alternative to conventional water-cooled condensers and evaporators. They are suitable for a wide range of refrigerants including CO_2 (subricital application) and ammonia, and they allow a reduced refrigerant volume in the system.

Benefits include less space and weight, a wide range of sizes and capacities, large heat transfer surface, great versatility and suitability for high-viscosity fluids.
Source: www.danfoss.com

CGC Releases Version 1.0 of its training course for geoexchange drillers

Expanding the knowledge base of drillers, and widening the scope of CGC's training initiative.
Montréal, September 20, 2007

The Canadian GeoExchange Coalition (CGC) is pleased to announce the release of Version 1.0 of its Canadian GeoExchange™ Coalition – Drillers' Course®. The course consists of a 222-page manual, in-class Power Point presentations and additional training material such as full documentation on provincial groundwater regulations.

The CGC and representatives from the Canadian Ground Water Association (CGWA), Fleming College (Ontario) and Red Deer College (Alberta) have worked in partnership to develop training modules that integrate geoexchange with groundwater protection techniques. The new course is designed to help drillers better understand their responsibility in the overall construction of geoexchange systems.

Drillers, installers and system designers are the three main groups of the workforce in the geoexchange industry. "Specific and comprehensive training for drillers involved in the construction of wells for geoexchange systems has never been developed before, although the ground loop is a fundamental element of a geoexchange system. It was important that the training program put in place reflects this market reality," said Denis Tanguay, CGC President & CEO. CGC has developed this course for drillers as part of a national quality initiative. This initiative is the CGC's response to over four years of stakeholder requests to "raise the bar" in available training and in the consistency of quality of work delivered by geoexchange practitioners.
Source: www.geo-exchange.ca

First industrial CO_2 heat pump by Itomic

Itomic presents the world's first Eco-Cute model for facilities in need of large volumes of hot water. Itomic's leading heat pumps offer high efficiency, reliability and safety, as well as low running costs.

Itomic's CO_2 water heater produces large volumes of 90 °C hot water, being the optimal choice for school dining, restaurants, hotels, shower rooms, swimming pools or hospitals. Even at outside temperatures of -20 °C, it operates reliably, with overall energy savings of up to 30 % compared to other combustion water heaters. While reducing the space for installation through its compact storage tank size, it achieves a coefficient of performance of 3.8. In addition, it saves large amounts of greenhouse gas emissions by not only working more efficiently but also by using the natural refrigerant CO_2 with a global warming potential of 1 compared to that of 1700 for HCFCs.

The world's first industrial CO_2 water heater features state-of-the-art safety, and easy operation through an advanced control technology. It does not require certified staff for operation, timer-controlled operation, or temperature management with six sensors. In addition, it reduces running costs significantly by using off-peak electricity at night.
Source:www.r744.com

Market

Carrier gets EPA's ozone protection award

The US Environmental Protection Agency (EPA) has honoured Carrier with the Best of the Best Stratospheric Ozone Protection award.

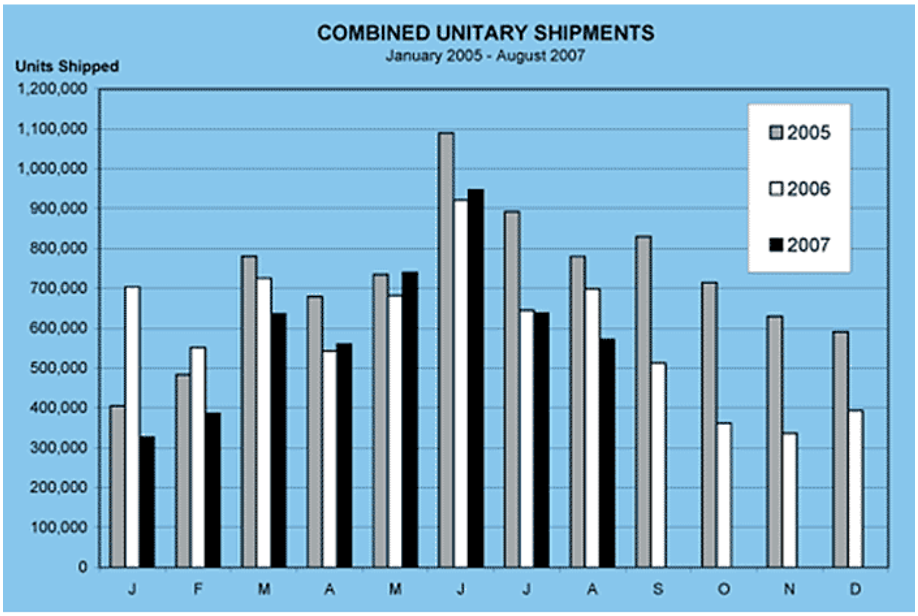
Carrier, the world's largest provider of heating, air-conditioning and refrigeration solutions, received the award in Montreal to coincide with the 20th anniversary of the Montreal Protocol.

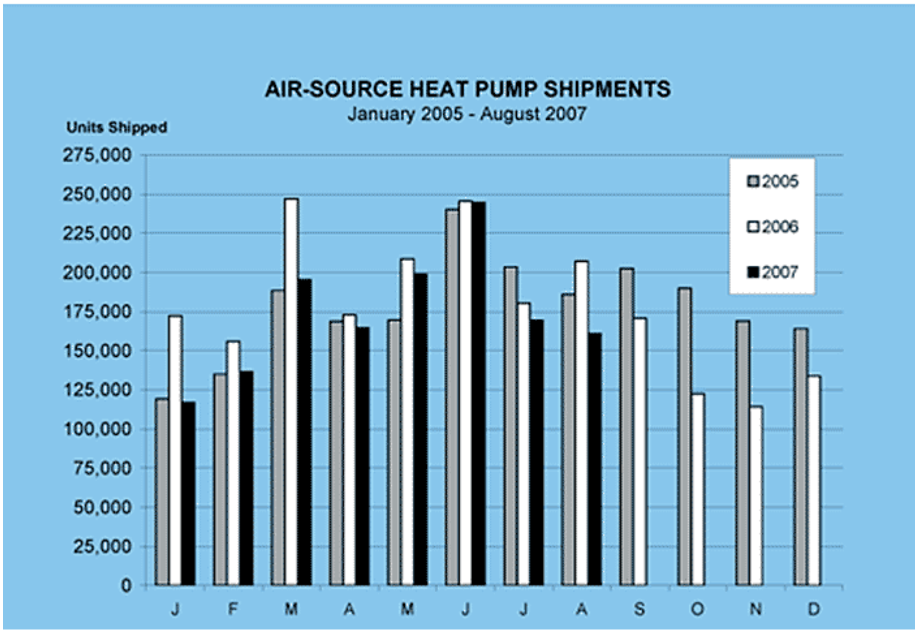
Carrier's expertise in providing innovative green products enabled it to capture 70 % of all HVAC contracts awarded.

With Carrier's success in supplying energy-efficient HVAC products for the 2008 Olympic Games, the company plans to offer similar solutions to organisers of the 2012 Games in London.

Best-of-the-Best award nominees were evaluated by the Federal Environmental Protection Agency staff and judged by an international panel representing industry, government and non-governmental organizations.

Source: www.acr-news.com/news/news.asp?id=439





August Central AC, Heat Pump Shipments Down From Last Year

Combined U.S. factory shipments of central air conditioners and air-source heat pumps for August totaled 571 420, down 19 percent from August 2006 shipments. Year-to-date combined U.S. factory shipments totaled 4.8 million, down 12 percent from the same period last year.

Heat pump shipments for August totaled 160 989, down 23 percent compared with August 2006. Year-to-date heat pump shipments totaled 1 387 643, down 12 percent from the same period last year.

Source: www.ari.org

IEA Heat Pump Programme

EU Directive on metric-only use postponed indefinitely

The European Parliament on Sept. 11 postponed indefinitely a directive requiring the exclusive use of SI (metric) units on products sold in the European Union (EU). Although originally passed in 1979, the European Commission (EC) Directive requiring the use of SI units in the EU has been postponed several times.

"I know ARI members will be pleased with this development," said Jim Walters, ARI Senior Director of International Affairs. "They worked very hard to retain the freedom to show dual units on all of their equipment and publications. This does not prevent anyone from going metric. It simply allows the consumer, regardless of background, to easily read labels about those purchases."

EC Directive 80/181/EEC, issued on December 20, 1979, provided a "transitional period" to facilitate the phasing out of non-SI units. This transitional period was originally to have terminated on Oct. 1, 1981, 90 days after each EC country was to have adopted and published laws and regulations adopting the SI units.

On Nov. 27, 1989, the EC again amended the 1979 Directive to recognize the continued use of specific "imperial" units of measurement in Ireland and the UK until Dec. 31, 1999, (e.g., the mile on road signs, the pint for draft beer and for milk in returnable containers, the troy ounce for sale of precious metals, the fathom in marine navigation, the gill for liquors, and the therm for gas supplies). For more information on this issue, please contact James Walters, ARI Senior Director, International Affairs.

Source: www.ari.org

U.S. National Team Meets in Preparation for Fall ExCo Meetings

The U.S. National team met on October 3 in Cazenovia, New York (near Syracuse) for their Fall meeting. Eleven members took part in the meeting, either in person or by conference call. The major topics of the meeting were reports on the Spring ExCo meetings and Workshop, status reports on current Annexes, and discussions concerning the Zurich Heat Pump Conference. Meeting time was devoted to identification of ideas for new annexes and for Newsletter articles. Those members attending the meeting enjoyed the very nice fall weather and resplendent colors.

Source: Jerry Groff, USNT, IEA Heat Pump Programme

Ongoing Annexes

Bold text indicates Operating Agent.

Annex 29 Ground-Source Heat Pumps - Overcoming Market and Technical Barriers	29	AT, CA, JP, NO, SE, US
Annex 30 Retrofit heat pumps for buildings	30	DE, FR, NL
Annex 31 Advanced modelling and tools for analysis of energy use in supermarkets.	31	CA, DE, SE, US
Annex 32 Economical heating and cooling systems for low-energy houses.	32	CA, CH, DE, NL, SE, US, JP, AT, NO
Annex 33 Compact Heat Exchangers In Heat Pumping Equipment	33	UK, SE, US, JP
Annex 34 Thermally Driven Heat Pumps for Heating and Cooling	34	AT, **DE**, NL,

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

IEA HPP

Two distinguished, long-time members retire from the Heat Pump Programme

Two distinguished members of the heat pump community, with a long career in the Heat Pump Programme (HPP) behind them, have retired this year - John Ryan (USA) and Takeshi Yoshii (Japan).

Mr. John Ryan is one of the longest serving members of the Heat Pump Programme, and was one of the initiators of the HPP shortly after he joined the U.S. Department of Energy in 1978. He was involved in the very first project (Annex 1) and served as Chairman of the Steering Committee for the Heat Pump Centre after it was established. John has been one of the most active in the organization of the work in the programme and served as HPP Executive Committee chairman three times.
He has been a staunch supporter of the HPP within the USA and led efforts to establish and maintain a U.S. National Team comprised of representatives from U.S. industry and research organizations. As a result the U.S. has participated in many Annexes and other activities over the duration of the programme. He was a leader in establishing Annex 10, a highly successful project. Furthermore, John assumed responsibility as chairman for the International Organising Committee (IOC) for the Beijing International Heat Pump Conference and was a guiding hand in organization of the 1987 and 2005, conferences that were held in the U.S.

Mr. Takeshi Yoshii was involved in the IEA Heat Pump Programme for more than twelve years, as National Team leader and as alternate delegate for Japan in the Executive Committee. During the same time he was director and responsible for the HPP at the Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ).
During his tenure at the HPTCJ, he acted as coordinator for the Japanese National Team in putting together experts in heat pumping technologies, securing funds for joint IEA heat pump activities, organizing national teams for the Annexes, and contributing news and articles from Japan for the IEA Heat Pump Centre Newsletters. He also supported the Heat Pump Programme as regional coordinator for Asia and Pacific for the past two IEA Heat Pump Conferences. He also was a strong proponent for the programme in Japan and an active contributor at Programme National Team Working Meetings over the years.
His own most memorable experience in the Programme was his presentation of the regional report on the rapidly glowing "Asia & Pacific" market, which he prepared and presented at the 8th IEA Heat Pump Conference in Las Vegas in 2005.

Both John and Takeshi are highly recognised and appreciated by all executive committee members as being very kind and inviting representatives of their respective countries. They have both embraced new members, and have been generous in sharing their vast knowledge and experience with others.

All members of the Heat Pump Programme would like to give Takeshi Yoshii and John Ryan thanks for their contributions in the past and the very best wishes for the future. You will always be connected with the achievements of the programme and for the great persons you are! We will miss you both!

The IEA Heat Pump Programme colleagues
Through Roger Nordman, Editor of the HPC newsletter.

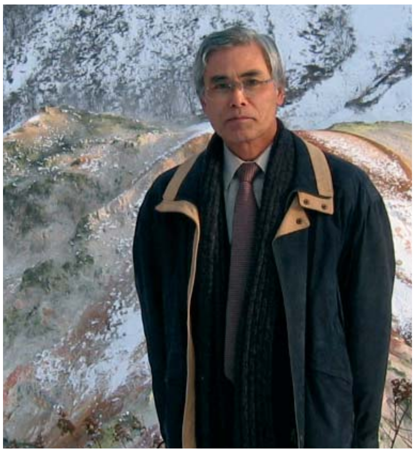


Photo 1: Mr Takeshi Yoshi at the Jigokudan Valley, Noboribetsu, during the Annex29 Workshop in Sapporo, 2007.

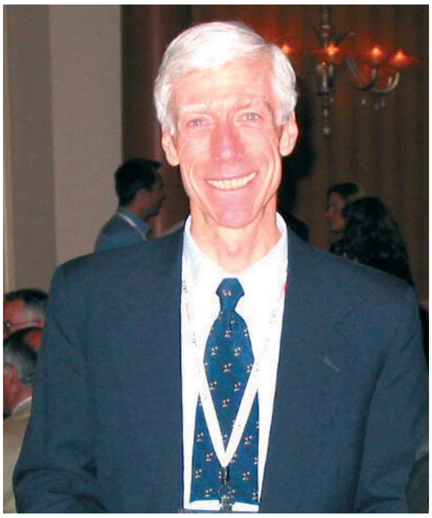


Photo 2: Mr John Ryan at the 8th IEA Heat Pump Conference in Las Vegas, USA, 2005.

Simultaneous performance factors for combined multifunctional ground-source heat pumps

Vasile Minea, Canada

Ground-source heat pumps can simultaneously or alternately supply space heating or cooling and domestic hot water with high energy efficiency. They may have different output capacities and performance factors depending on operating modes. A combined, multifunctional ground-source heat pump for simultaneous space heating (with direct condensing radiant floor or air coil) and cooling (with air coil), and domestic hot water heating (with desuperheater) has been developed at Hydro-Québec Research Institute's LTE Laboratory. For this brine-to-refrigerant/air heat pump designed for the eastern Canadian cold climate, simplified testing and simultaneous performance factors calculation methods based on the ASHRAE 137 standard are proposed.

System configuration

In Canada, space air heating in winter is still very popular, even if the radiant floor heating systems offer advantages such as homogeneous air temperature stratification and high indoor thermal comfort. In addition, in the Canadian warm and humid summer weather, air cooling and dehumidification are indispensable. On the other hand, domestic hot water (DHW) heating with heat pump desuperheaters provides energy cost savings and overall performance improvements in both heating and cooling modes. All these reasons have led to the development of a 7 kW_C (nominal cooling capacity) combined multifunctional ground-source heat pump (GSHP) using the R410A refrigerant [1, 2, 3] (Photograph 1). The system can operate in three different modes: space heating with radiant floor (*floor* HEAT&DHW), space heating with air coil (*air* HEAT&DHW) and space cooling/dehumidifying with air coil (*air* COOL&DHW). Each of these modes includes simultaneous domestic hot water heating with the heat pump desuperheater (DSH). The heat pump configuration includes a simple control module with motorized valves for switching the system in one of the three modes (Figure 1). The geothermal fluid (brine) contains 25% (by weight) antifreeze and flows in a closed loop between a 122

Photograph 1 – View of the combined multifunctional GSHP prototype (GEOPAC-LTE)

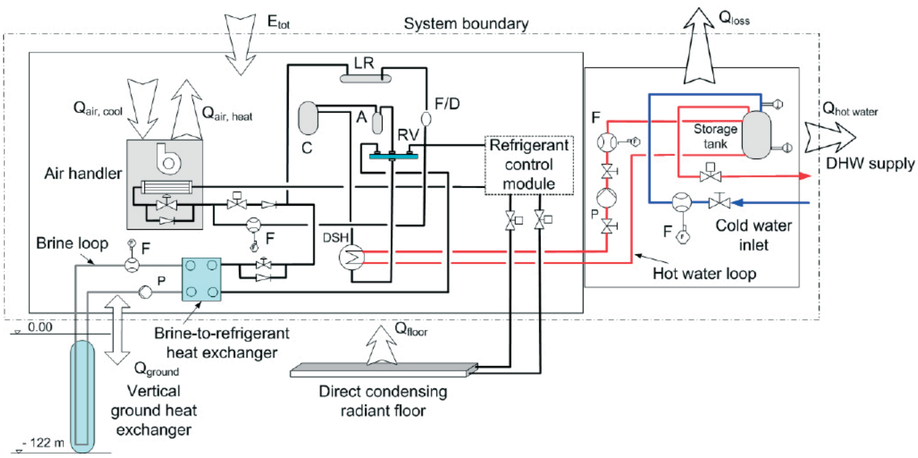


Figure 1 – Configuration of the combined multifunctional GSHP prototype
C: compressor; A: suction accumulator; LR: liquid receiver; DSH: desuperheater; RV: reversing valve; F/D: filter/dryer; P: brine or water circulating pump; F: flow-meter; DHW: domestic hot water; E: electrical energy; Q: heat

m deep vertical U-tube and a brine-to-refrigerant intermediate heat exchanger. This heat exchanger acts as an evaporator in space *floor* and *air* heating modes, and as a condenser in the space air cooling mode. The direct condensing radiant floor is a 100 mm concrete slab in which the heat pump condenser is horizontally inserted. The air handling unit with fan and refrigerating coil operates in both the air heating and air cooling modes, at the user's choices. The heat pump coaxial desuperheater is connected to a hot water loop including a circulating pump, a 151 L storage tank and standard controls. For this multifunctional heat pump system, test procedures and seasonal performance calculation methods were proposed, and then briefly validated in the laboratory [2].

Context

The efficiency of air-source heat pumps varies significantly with outdoor air temperature and humidity. For such systems, steady-state calculations can yield good results for annual energy consumption, if different temperature intervals and time periods are evaluated separately. This approach is known as the *bin* method because the consumption is calculated for several outdoor temperature values and multiplied by the number of hours in the temperature range (*bin*) centered around that temperature. For air-to-air heat pumps, the ASHRAE 137 standard requires, for each *bin*, the total building space heating and cooling capacities, total energy associated with domestic hot water delivered to the consumer, electrical energy supplied to the additional electric heater (when used), and electrical energy supplied to the heat pump [4]. Temperature data is required in the form of 2.7°C [5°F] *bins*, including the hours of occurrence of each *bin*. In this study, the *bin* methodology has been extended to simultaneous space heating/cooling and domestic hot water heating with ground-source heat pumps. The method assumes that the operating conditions are average, and set in the center of each *bin*. The seasonal performance factors are calculated for the space *floor* or *air* heating modes (SPF_H) and for the space *air* cooling mode (SPF_C), both including simultaneous domestic water heating. SPF_H represents the sum of the total space heating load and the useful portion of the total water heating load divided by total power consumption (compressor, water pumps and, if applicable, additional electric water heater). SPF_C is the sum of the total space cooling provided and the useful portion of the total water heating load divided by total power consumption (compressor, water pumps, air fan and, if applicable, electric water heater). By the way, the *bin* approach of IEA HPP Annex 28 has been implemented as a "step-by-step" calculation method in European standards [5].

Simplified testing method

For simultaneous space and domestic hot water heating GSHPs, a simplified testing method consistent with the ASHRAE 137 standard has been developed (Figure 2). A total of 18 testing points, including geothermal fluid (brine) flow rate and temperatures, refrigerant flow rate, pressures and temperatures, electrical power inputs, and radiant floor, air and hot water temperatures, is necessary. Continuous water flow between the storage tank and the desuperheater at constant inlet/outlet temperature should be provided. Before initiating data collection (pre-test operation), the heat pump and the water pump shall operate in the selected mode for one hour. Data is recorded at 2- to 10-minute intervals and will continue until four consecutive data sets are collected while test tolerances are met. The air heating and air cooling capacity measurements and calculations should be performed in accordance with the ASHRAE 116 Standard [6]. According to this standard, both refrigerant-side (enthalpy method) and air-side energy calculations for radiant floor and air condensers respectively, and the air evaporator, have to be used. The domestic hot water heating capacity is determined for each sample data from the water flow rate and temperatures entering and leaving the desuperheater. The refrigerant enthalpy method could also be used to determine the desu-

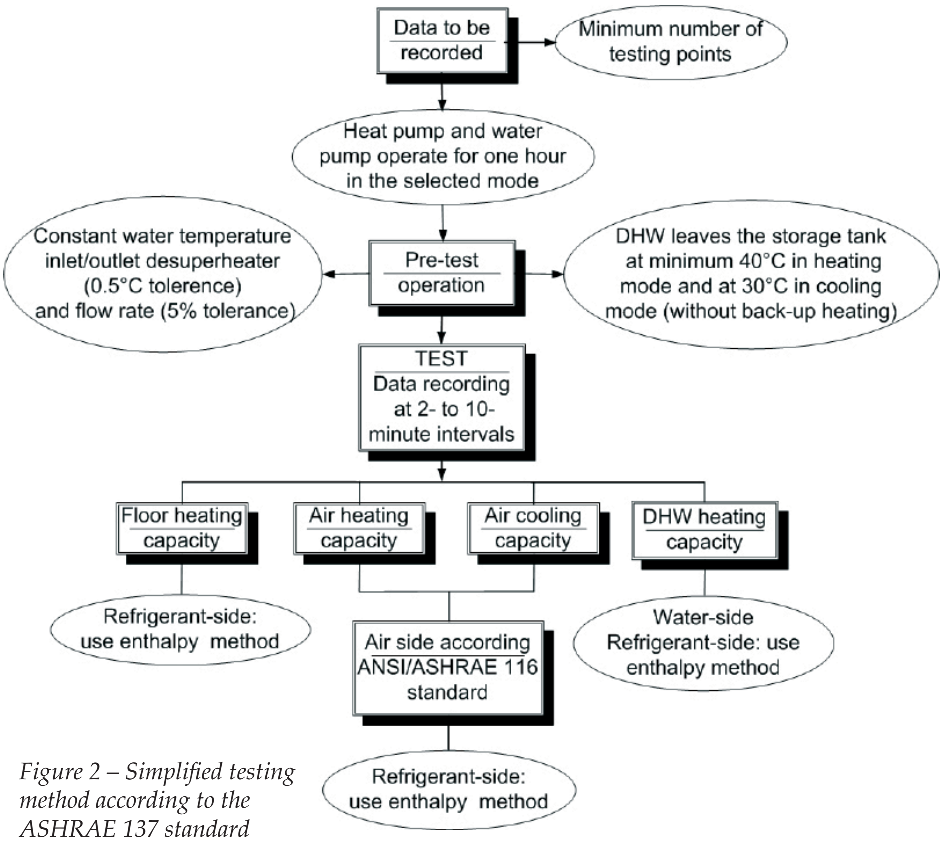


Figure 2 – Simplified testing method according to the ASHRAE 137 standard

perheater water heating capacity. To use this method, the refrigerant pressures and temperatures entering and leaving the desuperheater shall be measured.

Proposed test conditions

The main factors affecting the energy performance of combined GSHPs are the geothermal fluid temperatures and flow rates, the refrigerant condensing temperatures and the domestic hot water daily tapping profile and temperature. For such systems, four tests are proposed: A, B, C and D (Table 1). These tests correspond to four evenly spread operating points, three for heating and one for cooling, covering the outdoor temperature range between -30.5°C [-23°F] and 38.8°C [102°F], as defined in the ASHRAE 137 standard. Since the brine temperature variations are relatively small compared to outdoor temperatures, a fixed temperature entering the heat pump is assigned to the middle point of each selected interval. These temperatures represent, similarly, four new *bins* (called here *geo-bins*) for ground-source heat pumps (Figure 3). In space *floor* or *air* HEAT&DHW modes, the heat pump may operate under three conditions according to the proposed *geo-bins.* The "low temperature" condition occurs in winter with outdoor temperatures varying between -30.5°C [-23°F] and -16.6°C [2°F], while the brine enters the heat pump at -5°C [23°F] (*geo-bin* #1). The winter "standard condition" corresponds to outdoor air bin temperature intervals varying from -13.8°C [7°F] to 0°C [32°F] (*geo-bin* #2). The "high temperature" condition occurs during the transition seasons at outdoor temperatures between 2.7°C [37°F] and 16.6°C [62°F], while the brine enters the heat pump at +5°C [41°F] (*geo-bin* #3). In the air COOL&DHW mode, the brine enters the heat pump at +10°C [50°F] (*geo-bin* #4), while the outdoor temperatures may reach 38.8°C [102°F]. In both *floor* and *air* heating modes, the minimum temperature of the domestic hot water produced by desuperheating is 40°C [104°F], with condensing temperatures of 45°C [113°F]. In the air *cooling* mode, the minimum temperature of the domestic hot water is 30°C [86°F], and the condensing temperature, 25°C [77°F].

Table 1 – Proposed test conditions for combined multifunction GSHPs

Test	Proposed outdoor air bin temperature intervals	Proposed heat pump brine inlet temperature (geo-bin #)	Simultaneous operating mode condition (season)	Condensing temperature	Domestic hot water – minimum heating/supply temperature
-	°C (°F)	°C (°F)	-	°C (°F)	°C (°F)
A	-30.5 to -16.6 (-23 to 2)	-5 (23) (geo-bin #1)	Floor or air HEAT&DHW Low temperature (winter)	45 (113)	40 (104)
B	-13.8 to 0 (7 to 32)	0 (32) (geo-bin #2)	Floor or air HEAT&DHW Standard (winter)	45 (113)	40 (104)
C	2.7 to 16.6 (37 to 62)	+5 (41) (geo-bin #3)	Floor or air HEAT&DHW High temperature (transition)	45 (113)	40 (104)
-	19.4 to 22.2 (67 to 72)	-	Thermal equilibrium	-	-
D	25 to 38.8 (77 to 102)	+10 (50) (geo-bin #4)	Air COOL&DHW (summer)	25 (77)	30 (86)

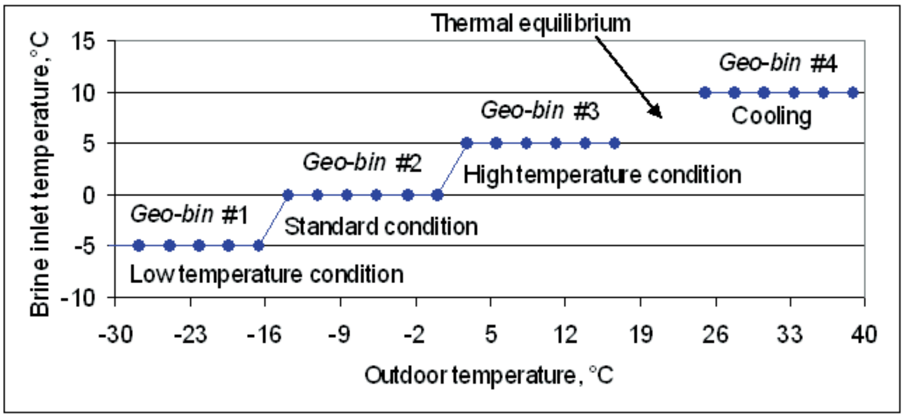


Figure 3 – Correlation between the outdoor air-bin temperature intervals and the proposed heat pump brine inlet temperatures (geo-bins) [2]

Calculation of simultaneous performance factors

The calculation approach is an extension of the ASHRAE 137 standard where the simultaneous performance factors are calculated for each of the four *geo-bins* representing the brine temperatures entering the ground-source heat pump. Laboratory tests in the space floor and air HEAT&DHW and space air COOL&DHW modes were carried out with entering brine temperatures close to the four proposed *geo-bins*. Data was recorded at fifteen-second intervals and averaged every two minutes when the compressor was running with relatively stable thermodynamic parameters.

Simultaneous floor and DHW heating

In the simultaneous floor HEAT&DHW mode, the #6 43-hour test (Table 2) allowed the heat pump to operate with average entering brine temperatures close to 0°C [32°F] representing geo-bin #2 for winter "standard" conditions. The radiant floor temperatures ranged from 28°C [82.4°F] to 32°C [89.6°F] providing indoor temperatures from 20°C [68°F] to 25°C [77°F], while the outdoor temperatures varied between 0°C [32°F] and -10 °C [14°F] (Figure 4). The domestic hot water tapping strictly followed the Canadian residential hourly hot water use pattern with a 95% confidence level [7].

Table 2 – Floor HEAT&DHW mode – average parameters

Test	Domestic hot water		Compressor (heat pump)	DHW pump	Geothermal fluid (brine)		
-	Consumption	Supply temperature (without electrical back-up)	Input power	Flow rate	Pump electrical input power	Temperature entering heat pump	Flow rate
-	Litres	°C (°F)	kW	L/min.	W	°C (°F)	L/sec.
#4	23	35.8 (96.4)	1.06	3	220	3.5 (38.2)	0.65
#6	656	41.2 (106)	1.15	1	220	-0.4 (31.3)	0.65

The temperature differences of the refrigerant superheated vapor across the desuperheater varied from 15°C [59°F] to 20°C [68°F], while the condensing temperatures inside the radiant floor averaged 45°C [113°F] (Figure 5). With these parameters, the domestic hot water supplied from the storage tank was about 41°C [105.8°F], without back-up electrical heating. During test #6, the compressor used 78.1%, the brine pump 15.2% and the hot water circulating pump 6.7% of the total power consumption (61 kWh) (Figure 6). At the same time, the heat pump supplied 82.1% of the total thermal energy generated to the radiant floor and 17.1% to the desuperheater (Figure 7).

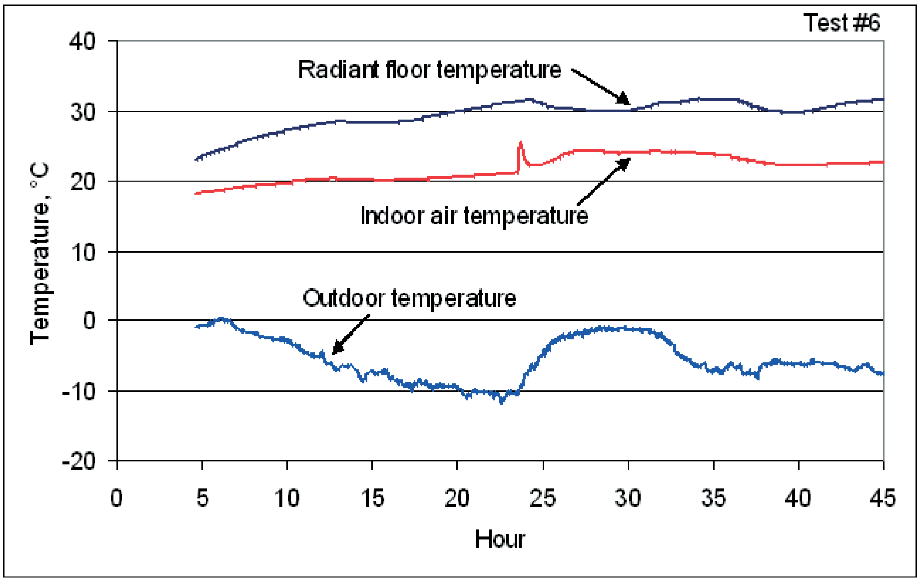


Figure 4 – Outdoor and indoor air and (surface) radiant floor average temperatures (floor HEAT&DHW mode - test #6)

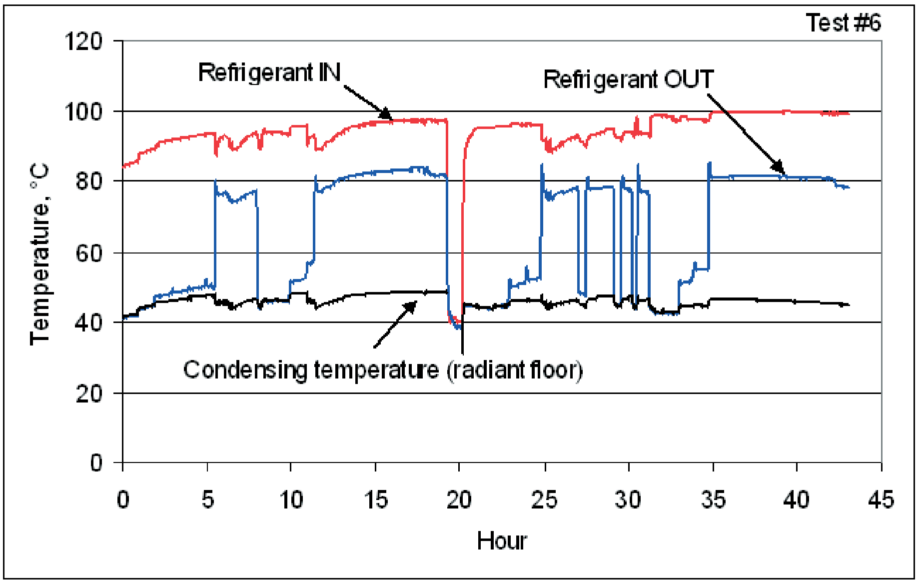


Figure 5 – Refrigerant temperatures entering (IN) and leaving (OUT) the desuperheater, and condensing temperatures (floor HEAT&DHW mode - test #6) [3]

With brine entering the heat pump at 0°C [32°F] (test A, geo-bin #2), the performance factors for the simultaneous space and domestic hot water heating mode were calculated using equation (1) [4]:

$$SPF_H = \frac{\text{Energy supplied (space/floor + DWH heat - storage heat losses)}}{\text{Power consumed (compressor + fluid pumps)}} \quad (1)$$

For the 151 L water storage tank, the standby losses were estimated, using the temperature difference between the stored hot water and the room air average temperatures, at 69 Watts. All previous data allowed calculating the simultaneous space (floor) and DHW heating performance factors (4.3 in test #4 and 4.4 in test #6) with energy balance errors averaging 6.2% (Table 3).

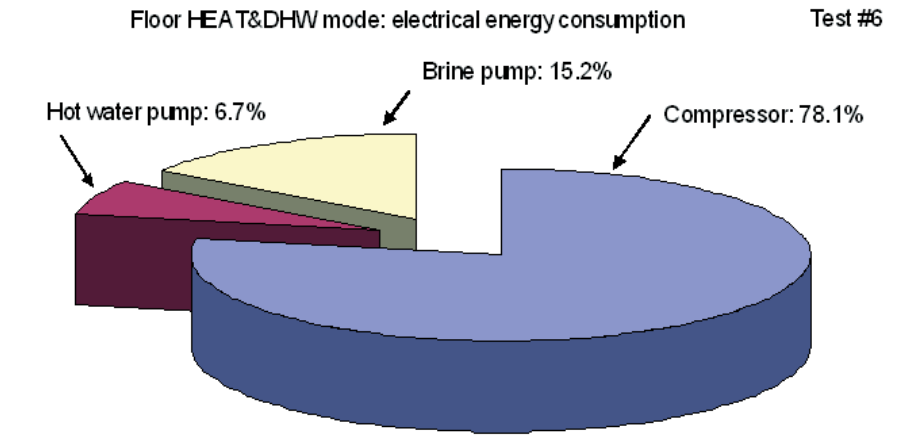


Figure 6 – Distribution of power consumption (floor HEAT&DHW mode - test #6)

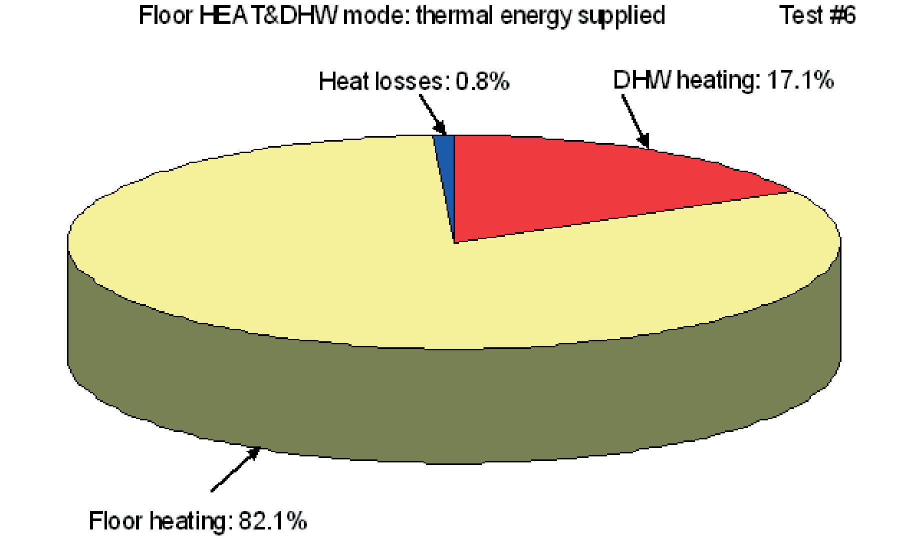


Figure 7 –Distribution of total heating energy supplied (floor HEAT&DHW mode - test #6)

Table 3 – Energy balance and simultaneous performance factors in the floor HEAT&DHW mode

Test	Heat extraction (from the ground)	Heat supplied			SPF_H	Error
-	-	Condenser (to the radiant floor)	Desuperheater (to the hot water)		-	-
-	kWh	kWh	kWh	%*	-	%
#4	6.6	7.0	1.76	20	4.3	6.8
#6	233	220	45.7	17	4.4	5.7

*Versus the total heat supplied

Simultaneous air cooling and DHW heating

The performance factors for simultaneous space air-cooling and DHW heating were calculated for several 24-hour tests with domestic hot water tapping following the Canadian residential hourly hot water use pattern with a 95% confidence level (Table 4). In test #13, the brine entered the heat pump at 10°C [50°F], as in the proposed "high temperature" condition for summer (Table 1).

During test #13, the indoor air temperature varied around 25°C [77°F] inside the test chamber. Compared to the heating mode, the average temperature of the refrigerant entering the desuperheater was much lower (46.3°C [115.3°F] versus 80°C [176°F]) in simultaneous air COOL&DHW mode (Figure 8) than in the floor HEAT&DHW mode as shown in Figure 5. Moreover, during the first about seven hours of operation, the discharged refrigerant has condensed inside the desuperheater at around 20°C [68°F]. As a result, the maximum temperature of the domestic preheated hot water was lower (about 33°C [91.4°F]). In this case, the total energy consumption was shared between the heat pump compressor (42.4%), the fan coil (26.1%), and the brine (23.5%) and desuperheater hot water circulating pumps (8%) (Figure 9).

Table 4 – Air COOL&DHW mode - average parameters

Test	Domestic hot water		Compressor (heat pump)	Geothermal fluid (brine)		
-	Consumption	Supply temperature (without electrical back-up)	Input power	Pump input power	Temperature entering heat pump	Flow rate
-	Litres	°C (°F)	kW	W	°C (°F)	L/min.
#10	407	33.7 (92.6)	0.56	230	11.6 (52.9)	0.68
#13	387	33.0 (91.4)	0.42	220	10.0 (50)	0.66

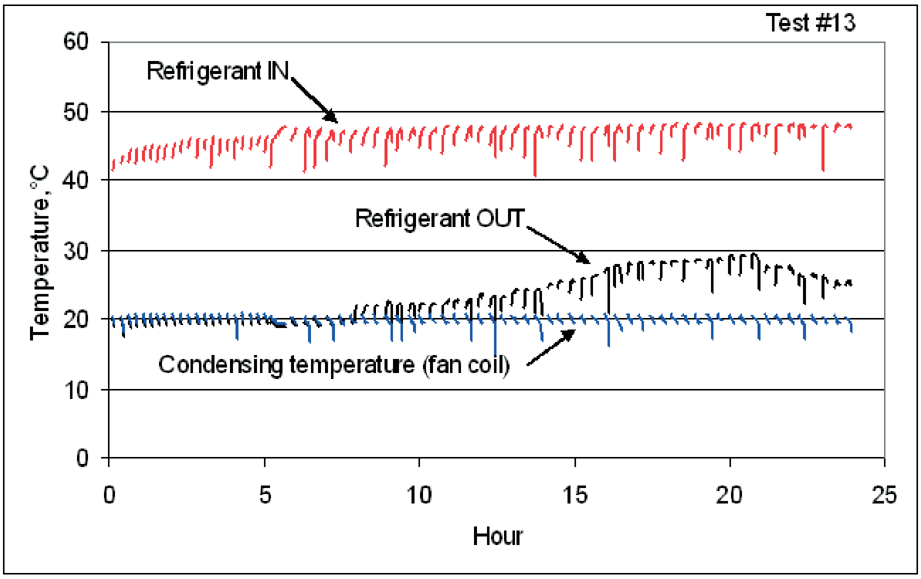


Figure 8 – Refrigerant temperatures entering (IN) and leaving (OUT) the desuperheater, and condensing temperatures (air COOL&DHW mode - test #13)

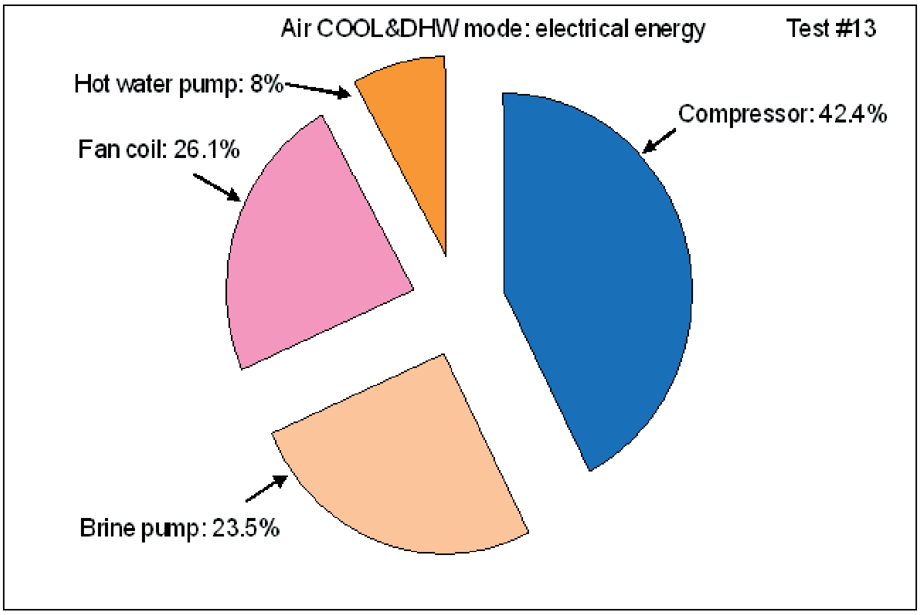


Figure 9 – Distribution of power consumption (air COOL&DHW mode - test #13)

For brine temperatures entering the heat pump at 10°C [50°F] (test D, *geo-bin* #4), the simultaneous performance factors in the space cooling and domestic hot water heating mode, calculated using equation (2) ranged from 5.62 (test #13) to 6.81 (test #10) with energy balance errors of 4.5 to 5% (Table 5).

$$SPF_C = \frac{\text{Space cooling effect + DWH heat - storage heat losses}}{\text{Power consumed (compressor + pumps + fan)}} \quad (2)$$

Table 5 – Energy balance and simultaneous performance factors in the air COOL&DHW mode

Test	Heat extraction (from indoor air)	Heat rejection (to the ground)	Heat supplied (to desuperheater)		Heat losses (storage tank)	SPF_C	Error
-	kWh	kWh	kWh	%**	kWh	-	%
#10	107	109	11.9	10.9	0.64	6.81	5
#13	75	66	12	18.2	0.61	5.62	4.5

***Versus the heat rejected to the ground*

Conclusions

The ASHRAE 137 standard, applied to air-to-air heat pumps, has been extended to ground-source heat pumps operating in cold weather conditions with simultaneous space heating/cooling and domestic hot water heating. A simplified test procedure and a simultaneous performance factors calculation method were developed in accordance with this standard. The proposed correlation between the outdoor air temperatures and ground temperatures reduces the number of outdoor air bins to four for ground-source heat pumps. The four operating points (geo-bins) represent the brine temperatures entering the ground-source heat pump at -5°C [23°F], 0°C [32°F] and +5°C [41°F] in the space floor or air HEAT&DHW modes, and at 10°C [50°F] in air COOL&DHW mode, respectively. These proposed operating points correspond to four extended outdoor temperature intervals the upper and lower temperature limits of which are specified. Experimental validations showed that in the space floor or air HEAT&DHW modes, the simultaneous performance factors ranged around 4.2, while in the space air COOL&DHW mode they were higher (5.6 to 6.9), especially due to lower condensing temperatures and to simultaneous domestic hot water heating. Calculations of the domestic hot water heating capacity versus the heat pump's total heat supplied in the space floor or air HEAT&DHW modes showed that the desuperheater recovered 17% to 20% of the total heating capacity. In the simultaneous space air COOL&DHW mode, this percentage ranged between 11% and 18% of the heat pump's total heat rejection.

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Use of solar heat in systems with ground-source heat pumps

Elisabeth Kjellsson, Sweden

Solar collectors may be used in combination with ground-source heat pumps in order to minimize the use of electricity, and/or also if there is a need to increase the temperature in the brine or recharge the ground. The latter might be the case if the borehole has become too short e.g. due to system changes or if it affected by other boreholes in the vicinity. TRNSYS simulations have been conducted in order to analyse the advantages in different systems for dwellings.

Introduction

In Sweden, interest in the combination of ground-source heat pumps and solar collectors has steadily increased in the residential sector in recent years. Several systems from different contractors are available on the Swedish market.

Solar heat can be utilized either for heating of domestic hot water, heating the building, increasing the temperature in the heat pump evaporator, recharging the borehole or combinations of any of these. The system can be designed in many ways, and the performance of the components results in different operational conditions. Together with the climate at the specific site, and the actual need of energy, such systems are complicated to evaluate as there are many variables.

A project at Lund University has investigated the combination of solar collectors and ground-source heat pumps by means of TRNSYS simulations (1). The aim of the simulations has been to find the advantages with solar heat in these combined systems, and to find the best strategies in system design and operation. A collector model (2) including condensation has been developed to cover more collector designs.

Figure 1. Drilling a borehole for a single family dwelling

Background

Ground-source heat pumps, in combination with solar heat, have been tested with different system design during the last 25 years in several countries. Experiences from 1984/85 with operation of 14 heat pump plants in Sweden, including equipment like simple solar collectors or air collectors to recharge heat into the ground, was reported. The system performance was considered to be satisfactory regarding operating time, energy performance, coefficient of performance (COP) etc. However, it was concluded to be more cost-effective to achieve a higher source temperature and thus an improvement in performance by drilling a deeper borehole. The source temperature increase, due to recharging, only reached about 2°C.

Components and systems

The heat source for a conventional ground-source heat pump is provided by boreholes. One borehole is normally enough for single-family dwellings, but several boreholes can be linked together to meet higher heat loads. The depth of boreholes varies from 60 to 180 m.

Each borehole normally contains a collector in the form of a U-pipe heat exchanger with a circulating heat carrier fluid. In ground-source heat pump systems without solar collectors, the heat carrier fluid is normally an antifreeze solution of ethanol/water. If the system is connected to high-temperature solar collectors, this antifreeze liquid cannot be used due to explosion risks, and a glycol-based rape oil is normally used instead.

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

When the solar heat is used directly for domestic hot water production, the advantages are a reduction of the use of electricity during the summer, coupled at the same time with natural recharging (temperature recovery) of the borehole from the surroundings.

The advantages of recharging the borehole may be:

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

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

The solar recharge may also be used to:

- increase the evaporator temperature when the active borehole depth is undersized, e.g. because of
  - o higher heat demand than assumed
  - o the ground thermal conductivity was lower than assumed
  - o the groundwater level was lower than assumed
  - o replacement of an old heat pump with a larger one, or additional loads such as a pool or an annex.
- counteract freezing of boreholes

Fig. 2. Typical size of solar collectors on a single-family dwelling in Sweden in a combisystem for domestic hot water and space heating of the building.

System with flexibility

With glazed solar collectors, the solar heat can be used also for more than heating domestic hot water, either when there is no demand for hot water, or when the irradiation is not high enough to reach the needed temperature. With a system as in Figure 3, solar heat can also be used to heat the building, the evaporator or the borehole.

The disadvantage with the combination of solar collectors and ground-source heat pump is primarily that of investment cost. The cost of operating the circulation pumps also increases, as the operating time is extended. Although the conventional circulation pumps in both the solar collector circuit and the borehole circuit have a low investment cost, their efficiency is also low. This means that the regulation of the pumps and pressure drop, must be optimised for the overall system performance. Modern high-efficiency pumps may be cost-effective too.

Simulations

Simulations for the combination of solar collectors and ground-source heat pumps have been performed for a single-family dwelling situated in the Stockholm climate. The first part of the simulations was performed in TRNSYS 15 in 2004, and has been reported in (1). From these results, new simulations have been performed in TRNSYS 16, and a new report with the results will be available in 2008.

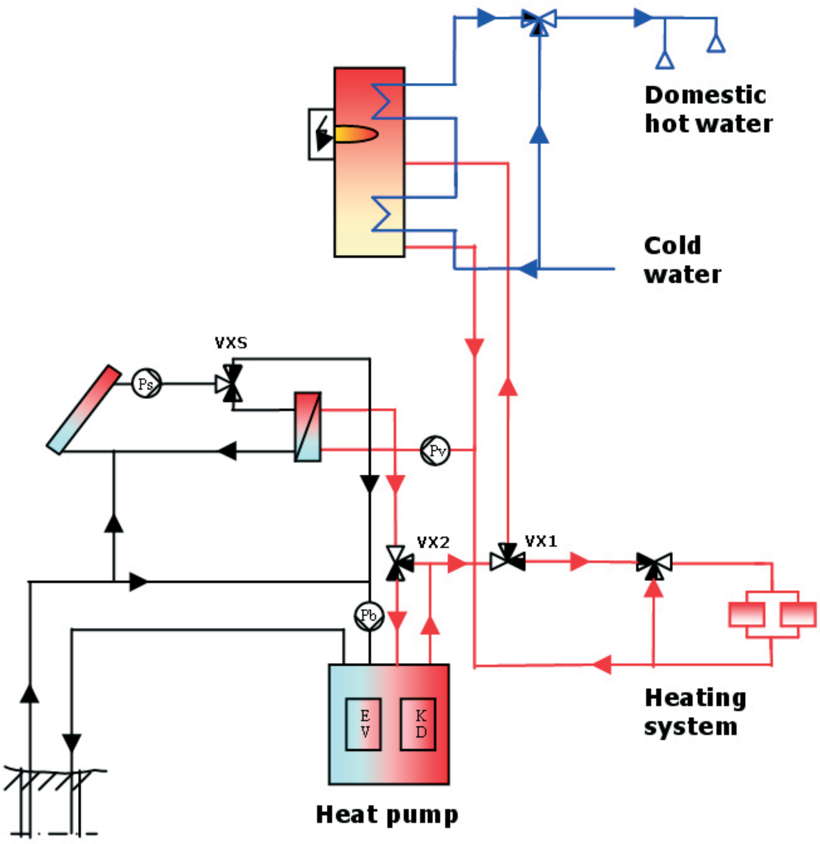

Figure 3. System with a heat pump and glazed solar collectors. Solar heat can be used for heating domestic hot water, heating the building, increasing the temperature to the evaporator in the heat pump or recharging the borehole.

The overall aim has been to find the advantages of solar heat in combination with ground source heat pump systems. The TRNSYS simulations make it possible to analyse the energy flows on different time scales, and the calculations are made for 20 years.

One objective was to find out the benefits for heat pump operation of solar recharge of the borehole. The maximum increase of the inlet evaporator temperature is achieved by delivering all the collected solar heat to the borehole circuit,. The result from the simulation in 2004, with a system as in Figure 3, shows that the energy-weighted temperature to the evaporator, for the whole year during the time when the heat pump is in operation, will increase by about 2,5 – 3,5 °C with 14 m2 of solar collectors, as compared to a system without solar collectors. The greatest increase is for the shallowest boreholes, which have a lower temperature, compared to deeper boreholes, for the same load. This option can be used for undersized boreholes to compensate for increased load. Studies of the energy-weighted temperature to the evaporator for the coldest month shows an increase of about 1-2 °C in systems with recharging from solar heat.

The simulations from 2007 have also investigated the effects of varying sizes of heat pumps. The highest temperature to the evaporator during the coldest month occurs in systems with the smallest heat pumps, and when all solar heat is recharged in the bore hole. When the solar heat is used for domestic hot water production, the temperature to the evaporator during the coldest month is almost the same as in systems without solar heat contribution, but if the solar heat is recharged to the borehole during the winter (November to February) the temperature is increased, particularly for the shallower boreholes.

The seasonal performance factor (SPF) is calculated as the ratio between the heat produced over the year and the electricity used in the compressor. This means that electricity for circulation pumps and auxiliary heat is not included. For the simulated systems, the increase in SPF is about 0,1 – 0,2, depending on different depths of the boreholes.

Calculations also including the use of electricity for the pumps show that the total use of electricity may exceed the advantage with recharging, and give a lower total system seasonal performance (SPF) compared to systems without solar collectors. The control strategy and model of the circulation pumps must be optimised in order not to use electricity inefficiently.

The problem with using the seasonal performance factor is that it does not express the benefit of solar heat in the system. In operation strategies with recharging the solar heat, the SPF is high for different sizes of heat pumps and length of bore holes, but the savings of electricity in the system may be high only for shallow boreholes and large heat pumps, while they can even be negative for deep boreholes. This will be described in more detail in the coming report.

In systems where the solar heat is used for domestic hot water, the SPF may be almost the same as in systems without solar heat, but there may be a relatively high reduction in the use of electricity by using solar heat.

A positive effect of recharging boreholes may be utilized when neighbouring boreholes thermally interfere. It is possible to compensate the extracted heat and the boreholes can be placed more closely together.

Conclusions

Recharging with solar heat is one way of improving the temperature to the evaporator in a system with a ground-source heat pump, especially when the system is undersized with too shallow active boreholes. Recharging may also be necessary in areas where the ground-source heat pumps are so close that they affect each other. Solar heat can also be used directly for heating domestic hot water. The best savings of electricity can be obtained by using a combination with recharging during winter,. The energy balance of these kinds of systems are very complicated, and also size-dependent, and futher studies are recommended.

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A new report will be available in 2008.

Hoshinoya Karuizawa, Japanese Style Onsen Hotel - The Largest Geothermal Heat Pump System in Japan

Mr. Takashi Matsuzawa, Mr. Yoshiro Shiba, Japan

Introduction

"Hoshinoya Karuizawa" is a hot spring ("onsen" in Japanese) hotel in Karuizawa, a town on the border of Nagano prefecture where the winter Olympics were held in 1998. The Hoshino Onsen Hotel, which boasts a 100-year history, was fully refurbished prior to its reopening in 2005. The town of Karuizawa lies amidst highlands at an altitude of about 1,000 meters near the foot of Mt. Asama – an active volcano. Surrounded by a rich natural environment, it is one of the best-known resort areas in Japan.

In essence, resort facilities situated in such rich natural environments should strive to impose the minimum environmental impact. On the other hand, the operation of resort facilities depends to a large extent on fossil fuels due to their high thermal demand. Deep down, we have been feeling a growing sense of crisis about our continued use of fossil fuels from the perspective of global environmental issues, fuel costs and stability.
Furthermore, safeguarding the fresh water, air, natural sound of the water and wind, and abundant flora and fauna is of crucial importance to guests who visit resort facilities. We believe that providing these environmental factors is both valuable and meaningful.

Under the above concept, the "Hoshinoya Karuizawa" project was launched in the 1990s, and we originally considered the use of natural energy. We have been operating an in-house hydropower plant since 1904, but we planned to establish a facility that does not depend on fossil fuel by adopting a geothermal heat pump heating system.
As a result, about 75% of the power used for the facility is self-supplied.

Figure 1 Exterior of Hoshinoya Karuizawa

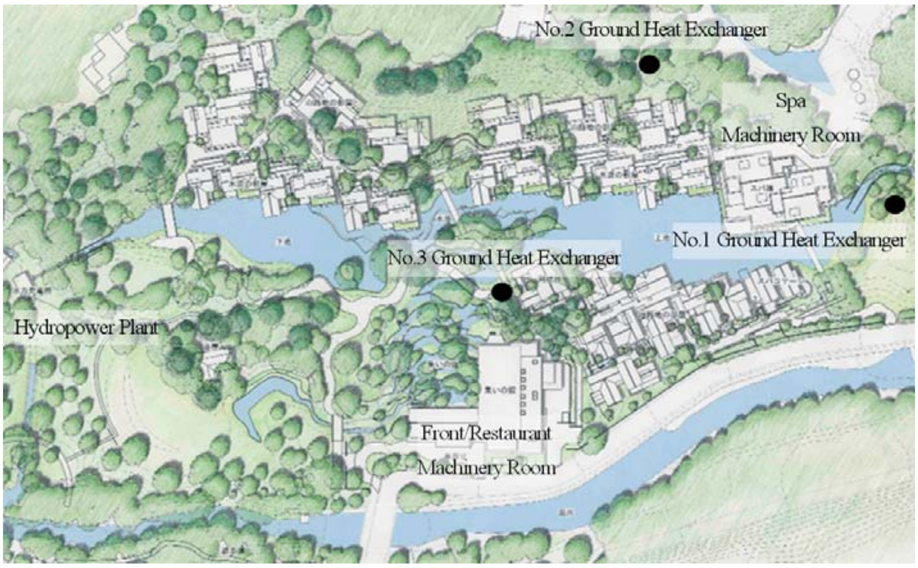

Figure 2 Architecture Of Hoshinoya Karuizawa

Fossil fuels are not used at all except for the liquefied petroleum gas (LPG) used in the kitchens and the fuel used for our vehicles. There are neither chimneys nor flue gas emissions anywhere in our facility.

Overview of the architecture and facilities

1) Architecture

Building name: Hoshinoya Karuizawa
Address: Hoshino, Karuizawa, Kitasaku-gun, Nagano Prefecture
Site area: 42,055.10 m2
Building area: 6,303.16 m2
Total floor space: 8,507.92 m2
Structure: Reinforced concrete (partially, steel-reinforced concrete), steel-framed, wooden construction
Storeys: 1 basement, 2 storeys above ground (77 guest rooms)

2) Heat source facilities

Ground heat exchangers: 400 m x 3 / 600 kW
Hot-spring exhaust heat recovery facility: 418 kW
Water-to-water heat pumps: 25 HP x 16 modules
Hot water storage tanks: 42 t x 1; 28 t x 1
Hot spring tank: 26 t x 1
Ice thermal storage tank: 20 t x 1 (static)
Central monitoring facility

Geothermal utilization

Heat drawn from the ground heat exchanger and through heat exchange from the hot spring runoff is pooled, and termed geothermal utilization in the wide sense. The main advantage is that a high temperature heat source is readily available throughout the year. This represents the heat source for the heat pump.

Ground heat exchangers

Steel pipes of 200-mm (almost 8-inch) diameter and a fiberglass pipe are stored concentrically for the ground heat exchanger. Water circulates within the ground heat exchanger, with the heat absorbed from the ground, and then extracted above ground. The ground heat exchangers, which feature the coaxial double-pipe method, are sunk to a depth of 400 m, and there are three such wells within the site.

Terrestrial heat exchange is dependent on the passage of a fluid, such as groundwater, which is mainly heated through advective flow. Using this method, about ten times more thermal output (500 W/m) is possible per unit length compared to the heat collection method through thermal conduction that is generally popular in Europe and America.

The average ambient temperature near to the heat exchanger is about 30 °C. Fluid circulates around a closed loop between the ground surface and deep underground. Flowing at a rate of about 300 liters per minute, it is inverter-controlled in accordance with the load demanded by the terrestrial facilities. An extraction temperature of 25 °C can be achieved when the input temperature is 15 °C, allowing about 200 kW of heat energy to be collected.

Use of hot spring run-off heat

300 liters per minute of hot spring water flows continuously through the hot spring facility attached to the accommodation. Since the temperature of the run-off water is about 35 °C, a plate-type heat exchanger is used to extract the heat, which is then used as a heat source for the heat pump, before the water is allowed to drain away after being cooled to ambient temperature.

Water-to-water heat pumps

Water-to-water heat pumps made by Zeneral Heat Pump Industry are used by our facility. Geothermal energy and heat from the hot spring run-off are used as its heat sources. 25 HPs constitute one module. Multiple modules are linked together to form one unit, with operation performed by controlling the number of modules used.

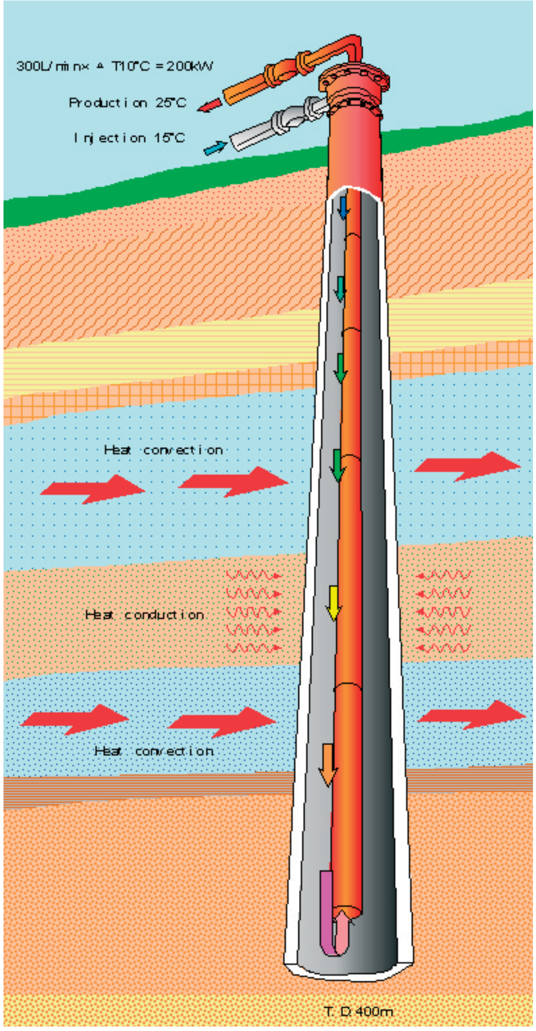

Figure 3 Structure of Ground Heat Exchanger


Figure 4 Water-to-Water Heat Pumps

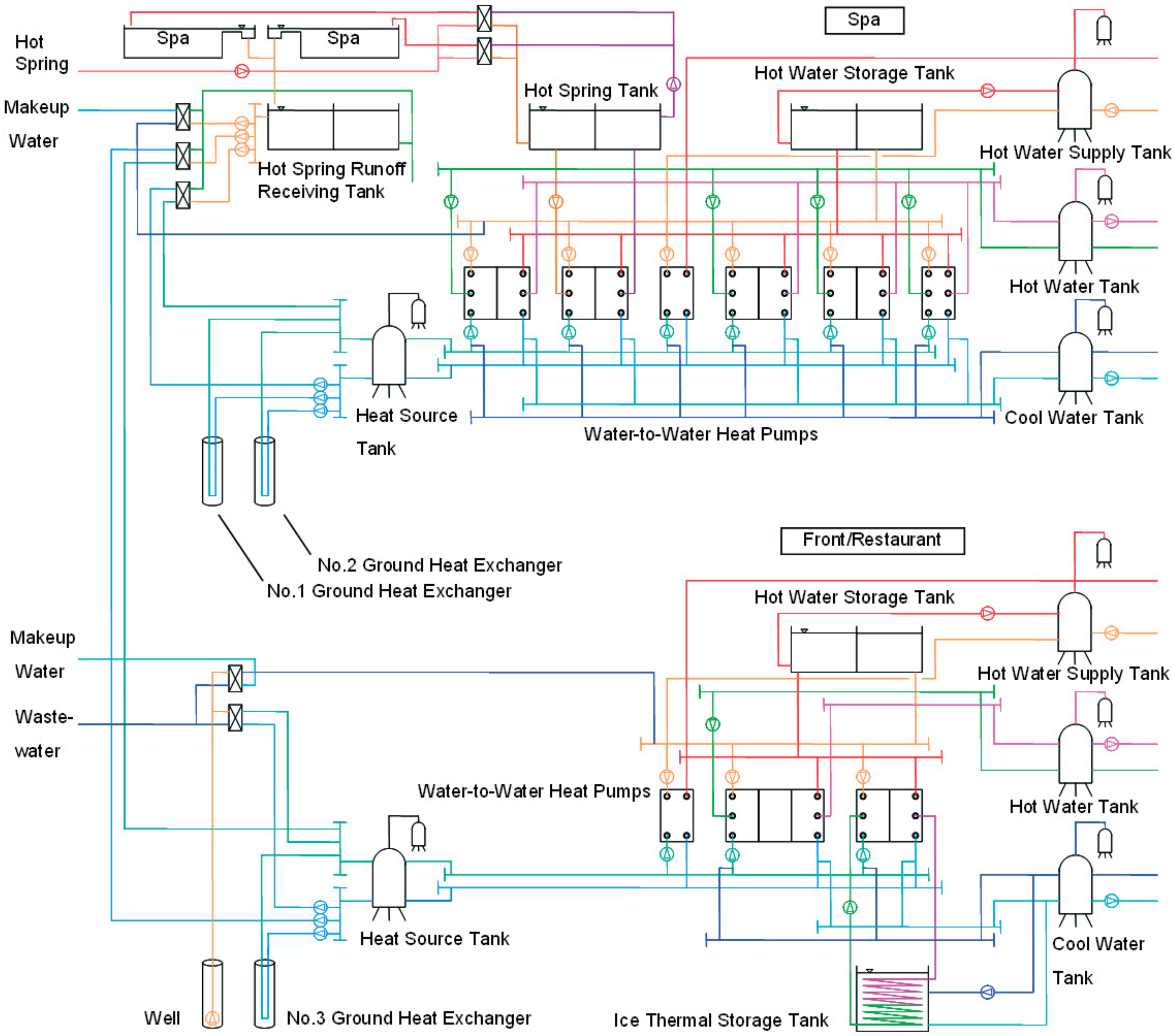

Figure 5 Diagram of Geothermal Heat Pump System

By using plate-type heat exchangers which significantly improve their surface areas, and using liquid-gas heat exchangers, etc, the heat pumps are more efficient than conventional types. This heat pump unit is multi-functional and supports high temperature usage. Simultaneous cooling and heating is possible through heat recovery in addition to the hot water supply circuit, heating circuit, and cooling circuit.

This is used separately, depending on the time and season, in an effort to optimize the facilities' capacity. They are automatically operated using an

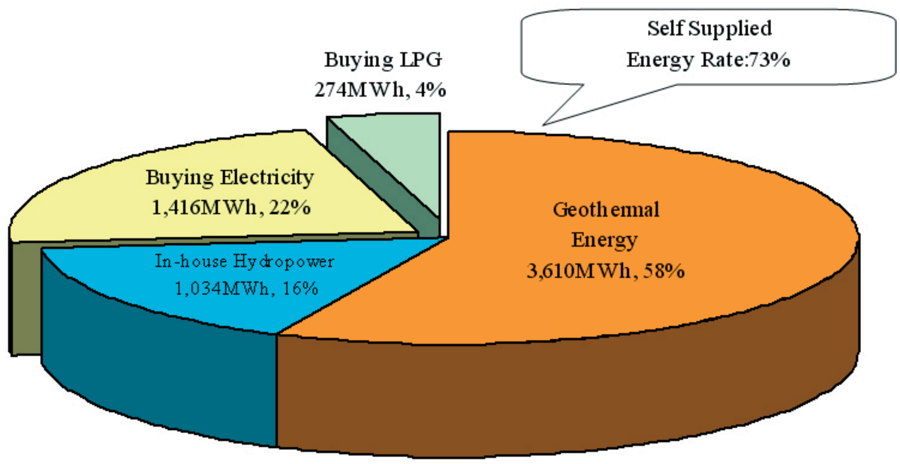

Figure 6 Self Supplied Energy Rate of Hoshinoya Karuizawa

optimization control system via a central monitoring panel integrated into the heat source system, together with remote monitoring and operation via a telephone line.

Load leveling through thermal storage

Heat pumps that use geothermal energy as their heat source produce hot and cold water for hot water supplies and air conditioning. These are supplied centrally to facilities, with the underground machine room defined as the energy center.

Energy-saving measures, such as the adoption of triple glazing and low-E glass are thoroughly implemented for secondary equipment. Floor heating has been fully adopted. The temperature of the hot water supply to the floor heating system is set low in accordance with its load. Highly efficient operation of the heat pumps is sought, as well as improving users' comfort and safety.

An ice thermal storage tank and hot water tank are combined for the heat source facility. The load factor reaches 56 % in the evenings or later due to load leveling operation using late night service. In summer, heat discharged from the cooler can be recovered for the hot water supply using these thermal storage tanks, thus boosting operational efficiency. Automated operation and optimization control are also conducted using the central monitoring facility, achieving an average system COP of 3.7.

Assessment of economic efficiency and environmental performance

73 % of our energy needs can be self-supplied by combining our entire existing hydropower generation (rated 225 kW) and geothermal utilization. The total reduction in carbon dioxide emissions is estimated to be 1,581 t CO_2/year.

The unit price for energy is ¥1.4 per kWh. This is about 20 % of existing systems, which is equivalent to an 80 % cost reduction. Installation of geothermal facilities is more expensive than existing systems, but the difference in equipment investment costs could be recovered in two years due to its low running costs.

Conclusion

Bear in mind that the need to match facilities and secondary equipment is very important when adopting natural energy. One of the reasons is the reduced consistency in energy quality in comparison with fossil fuels, etc. Different methods and timing may be needed from existing designs.

Economic viability must not be ignored with environmental investment: rather, cost-effectiveness should be the motive for equipment investment. We focused on customer satisfaction as the most important factor. We selected and introduced natural energy usage as a means to this end. As a result, significant environmental benefits and cost performance have been achieved, and we are certain that our customers approve.

Acknowledgement: We would like to extend our grateful thanks in writing to Zeneral Heat Pump Industry for their cooperation from the design through to operational stages of this project.

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Biomass- driven small-capacity ammonia / water absorption heat pump for heating and cooling

Harald Moser, René Rieberer, Austria

This paper describes the development, system layout and test results of a biomass driven small-capacity ammonia/water absorption heat pumping unit (heating capacity 15 kW), which is designed for both heating and cooling purpose in order to reduce the energy demand for heating and to increase the share of renewables in the cooling/refrigeration sector. Standard plate-type heat exchangers have been used in the absorption heat pump for all heat exchangers, including the absorber and generator, in order to reduce first costs. A standard biomass boiler has been modified to operate at higher supply temperatures, using oil as the heat carrier to the absorption heat pump. The system has been tested at different operating conditions.

The experiment results, and a mathematical model, show an approximately linear correlation between the temperature lift and the COP of the absorption heat pump. The calculated COPH for heating varies from about 1.75 to 1.4, depending on the temperature lift. The experimental results show a similar correlation, but slightly below the results of the mathematical model.

The efficiency of the biomass boiler decreases approximately linearly with increasing supply temperature: for steady-state operation at full load the efficiency was about 92% at 100 °C, falling to about 80% at 180 °C supply temperature.

Introduction

Absorption heat pumps make it possible to raise heat from a low temperature level to a medium temperature level, with the driving energy for the process being mainly heat at a high temperature level. Depending on whether the low temperature heat source or the medium temperature heat sink (or both) of the heat pumping unit is used, the system acts as a cooling or a heating system, e.g. for air conditioning or residential heating systems. The high temperature heat source can be supplied by any technology, e.g. solar, biomass, process heat or other source, as long as the temperature level is sufficiently high. As opposed to large units (>100 kW), only a few installations of small-capacity units can be found. The main reasons are relatively low efficiencies, control issues and high first cost, but a large number of research projects have been concerned with small systems over the last few years. With respect to the working fluids investigated, it can be clearly seen that the focus is set on the environmentally friendly working pair ammonia/water for applications with evaporation temperatures below 0 °C, and water/lithium bromide for air-conditioning applications. In the case of absorption heat pumps for residential heating and cooling purposes, the evaporation temperature can drop below 0 °C during the winter, and so ammonia/water has to be used.

While the temperature lift (ΔT_{Lift}) - which is the temperature difference between the low temperature heat source and the medium temperature heat sink - is small for a typical residential cooling application (e.g. 20 K), it can increase up to 50 K or more for heating and/or refrigeration purpose.

The “BioAWP” [1] project has developed a biomass-powered, small-capacity ammonia/water absorption heat pumping unit suitable for heating and cooling purposes, and has investigated the feasibility of CO_2 as a working fluid in ground probes to be used as a heat source (heating mode) and as a heat sink (cooling mode).

System Design

Depending on the temperature level of both the heat source (evaporator) and the heat sink (condenser and absorber), the generator temperature required to drive the absorption heat pump lies between 80 and 150 °C. As different heat sources shall be possible, the generator of the absorption heat pump investigated is indirectly driven, which means that the driving heat is supplied to the heat pump via a heat transfer medium.

To utilise biomass as the driving heat source, a standard KWB - Kraft und Wärme aus Biomasse GmbH pellets boiler has been modified, and oil has been used as the heat transfer medium to the heat pump, because the vapour pressure of water would exceed the maximum allowable operating pressure of the boiler.

The basis of the absorption heat pump development was a direct gas-fired absorption heat pump developed by DLR - Deutsches Zentrum für Luft und Raumfahrt e.V. [2], which has been further developed by the company Heliotherm Wärmepumpentechnik GmbH. The absorption heat pump consists of a capacity-modulated single-stage process including solution and refrigerant heat exchanger. Standard plate heat exchangers have been used for all heat exchangers – including absorber and generator. These plate heat exchangers offer very large heat transfer areas in compact dimensions, and so small temperature differences can be achieved. In addition, plate heat exchangers are off-the-shelf products which offer a high prefabrication standard and - compared to specially designed heat exchangers - a considerable cost reduction. A rectification column with a dephlegmator has been developed for purification of the refrigerant. The liquid phase in the column is produced in a plate heat exchanger cooled by the rich solution (dephlegmator).

Figure 1 shows a schematic diagram of the single-stage process. Starting at the absorber (ABS) the rich solution flows via the solution accumulator (SAC) to the solution pump (PUMP), where the pressure is increased to the high-pressure level. The rich solution flows to the dephlegmator (DEP) where it is heated by the refrigerant at the top of the rectification column (REC), and then on to the solution heat exchanger (SHX) where it is preheated and possibly partly evaporated by the heat from the poor solution, before it enters the generator (GEN). In the generator, the rich solution is partly evaporated by the high-temperature heat source (Q_{GEN}). The two-phase flow leaves the generator and enters the rectification column, where it separates into liquid (poor solution) and vapour phase (refrigerant). The poor solution flows through the solution heat exchanger (SHX) via the solution throttle (STH) to the absorber, expanding to the low pressure level in the throttle. In the rectification column, the refrigerant flows upwards through a random packing in counter-flow to the liquid fraction (condensed refrigerant). In the random packing, the vapour and liquid are in contact with each other in order to enable heat and mass transfer. The vapour leaving the random packing at the top of the column flows to the dephlegmator (DEP) where it is partly condensed. The condensate flows back to the random packing, and the purified vapour flows to the condenser (CON) where it is completely condensed by rejecting heat to the cooling water (Q_{CON}). After the condenser, the refrigerant flows via the refrigerant accumulator (RAC) to the condensate pre-cooler (PRC), where it is cooled by the refrigerant leaving the evaporator. After the pre-cooler, the refrigerant expands through the refrigerant throttle (RTH) to the low-

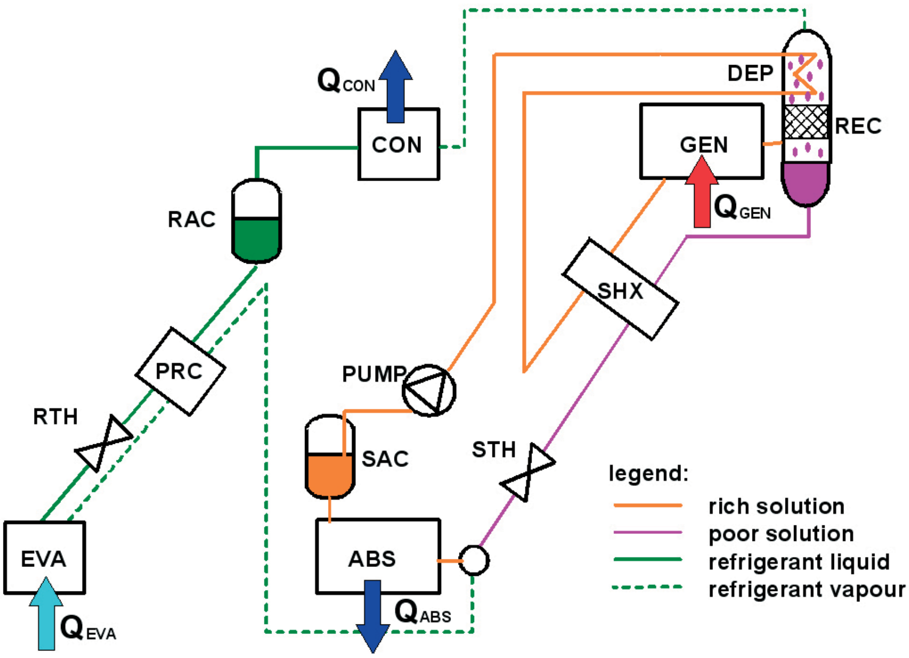


Figure 1 Realized single-stage process

pressure level and enters the two-phase region and flows further to the evaporator. Receiving the heat from the low-temperature heat source (Q_{EVA}), the refrigerant evaporates either partly or completely and flows to the condensate precooler, where the refrigerant is further evaporated or superheated. From the condensate precooler, the refrigerant flows to the absorber inlet where it is mixed with the poor solution and the mixture flows through the absorber where the refrigerant is absorbed and heat is rejected to the cooling water (Q_{ABS}).

Calculation And Experimental Results

A mathematical model of the absorption heat pump has been constructed, using the EES [3] software program in order to study the effects of component behaviour, to perform sensitivity calculations and to compare the calculations with the experimental results. The model solves the energy-, mass-, and ammonia mass-balances for all components. The effects of internal heat exchangers efficiencies were considered, and the influence of the rectification process on the dephlegmation capacity was calculated using the theoretical plate mode. Pressure drops in components and pipes were neglected.

A prototype unit of the absorption heat pump has been constructed, equipped with measurement instrumentation and tested under various operating conditions.

The biomass boiler has been tested at various supply temperature levels in order to investigate the maximum temperature of the heating surface, the capacity and the efficiency. The results show that the efficiency of the pellets boiler decreases approximately linearly with increasing supply temperature: during steady-state operation at full load, the efficiency was about 92 % at 100 °C, but fell to about 80 % at 180 °C supply temperature.
After successful standalone tests of both the biomass boiler and the absorption heat pump, the sub-systems have been coupled and operated together. During the tests, no trouble or limitation due to the coupling of the components or control issues was observed.

Figure 2 shows the calculation results for the “Coefficient of Performance” for heating (COP_H) and cooling (COP_C) for the absorption heat pump as a function of the temperature lift (ΔT_{Lift}), in comparison with some results of the experiments for a generator capacity of about 10 kW (full load) and about 5 kW (part load). The COP_C and COP_H are calculated using Correlations 1 and 2. The expected measurement uncertainties are shown as vertical bars in Figure 2.

$$COP_C = \frac{\dot{Q}_{EVA}}{\dot{Q}_{GEN}} \quad (1)$$

$$COP_H = \frac{\dot{Q}_{ABS} + \dot{Q}_{CON}}{\dot{Q}_{GEN}} \quad (2)$$

The COP_H according to the mathematical model varies approximately linearly from about 1.75 to 1.4 for a temperature lift of 10 to 50 K. The experimental results show a similar correlation, but approximately 7 to 10% below the results of the mathematical model for COP_H.

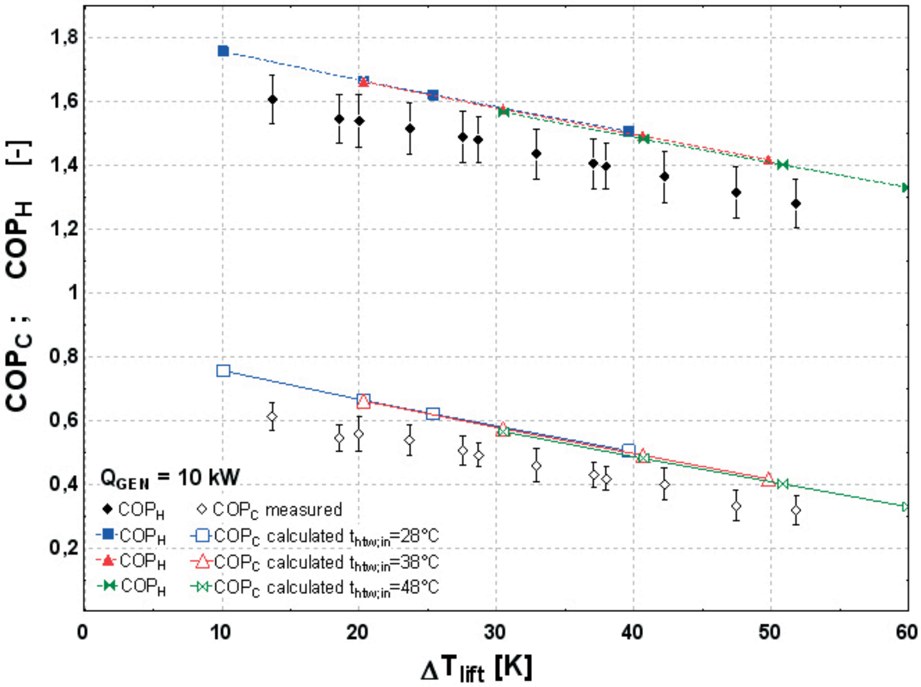
The main reason for the difference between the model and the experiments seems to be the temperature difference between the rich solution at the absorber outlet and the cooling water, which is higher than expected and is possibly caused by a non-uniform flow distribution in the plate heat exchanger. Further optimisation will be done in order to bring the experimental results toward the calculated values.

Conclusions

With absorption heat pumps, it is possible to reduce the energy demand for heating by using free energy at low temperature from the environment, and to achieve cooling or refrigeration by the use of heat, e.g. from renewable energy sources. A small-capacity (15 kW heating capacity) biomass-fuelled single-stage ammonia/water absorption heat pump for heating and cooling purpose using standard plate heat exchangers for all heat exchangers has been developed, coupled to a modified biomass boiler and tested together. In addition to the experimental results a mathematical model of the absorption heat pump has been constructed for comparison and sensitivity calculations.
According to the mathematical model, the COP_H of the absorption heat pump decreases approximately linearly from about 1.75 to 1.4 when the temperature lift is raised from 10 to 50 K. The experimental results show a similar correlation, but some % below the results of the mathematical model.

The efficiency of the pellets boiler decreases approximately linearly with increasing supply temperature: for steady-state operation and full load, the efficiency was about 92 % at 100 °C, but fell to about 80 % at 180 °C supply temperature.

After successful standalone tests of both the biomass boiler and the absorption heat pump, the sub-systems were coupled and operated together without any trouble. Further optimisation will be done to improve the system efficiency.
However, the results collected so far are promising for the use of the renewable energy source biomass for heating and cooling purpose.



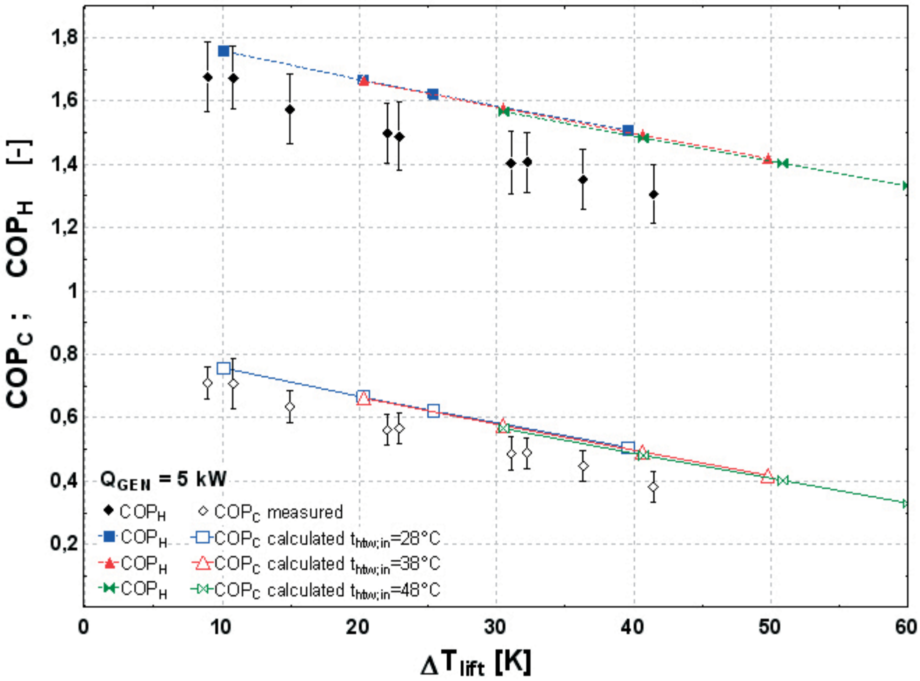


Figure 2 COP – calculated results vs. experiments at full load (top) and part load (bottom)

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A Sewage Source Heat Pump System

Kazutoshi Ito, Japan

Urban areas have a vast potential of unused energy in sewage. An existing sewer pipe was used in experiments to try to extract and deliver heat from and to the sewage. Pipes were laid along the sewer pipe to form a water jacket heat exchanger which was used to extract and dissipate heat from and to the sewage. This heat was then used as a heat source for the heat pump. Three types of water jackets were constructed and laid along the sewer pipe. Experiments were carried out using sewage heat as the heat source to measure heat which could be extracted for heating during winter or for melting snow on the roads. Experiments were also performed to measure heat that could be used for cooling during the summer.

Results showed that heat could be extracted from sewage without any effects on the sewage treatment plant. Compared to underground heat extraction, heat extraction from sewage using water-jacket heat exchangers provides far better heat extraction performance per unit length, and is much more economical.

Introduction

Sewage and sewage effluent temperatures are not greatly affected by the weather and, unlike ambient air, can provide a stable heat source throughout the year. They are therefore a suitable heat source for heat pumps. Sewage heat is not only economical, but it conserves natural resources and energy, and contributes to preservation of the environment.

Heat extraction by heat exchanger method

There are various methods of extracting or dissipating heat from or to sewage water. In this experiment, the heat exchanger method was chosen because of the following reasons.

1) Easy to maintain
2) Can easily be applied to existing sewer pipes
3) Does not affect the treatment plant

In this experiment, pipes were laid along a sewer pipe and brine was supplied to the pipes laid to extract heat from sewage. Since the water jacket heat exchanger is laid along the sewer pipe, it does not affect the treatment plant, and the heat exchanger is not affected by problems associated with sewage such as corrosion, leakage or blockage. It is almost maintenance-free.

Water jacket heat exchanger

Three types of exchangers were constructed. A plastic type which is cheap, and two copper types with high heat transfer efficiency. One of the copper-type heat exchangers was wrapped with insulation material as shown in Figure 1. Table 1 shows the specifications of the heat exchangers, while Figure 1 shows the cross-section and pictures. The sewer pipe is ductile cast iron, with an outside diameter of 450 mm. Three heat exchangers, each 6 m long, were laid on the sewer pipe.

Experimental method

Figure 2 shows the experimental apparatus, which is mainly composed of a brine chilling unit, brine tank, pump and heat exchangers. In experiments to represent heat extraction during the winter, brine is cooled to a designated temperature using the chilling unit and then supplied to the heat exchangers using a pump. The brine flow rate, inlet and outlet temperatures are measured and used to calculate the extracted heat from sewage. Brine inlet temperatures to the heat exchangers were set at -5 °C, 0 °C and +5 °C, while the flow rates were set at 5, 7 and 10 l/min respectively.

Table 1 Specifications of the heat exchangers

Item	Heat exchanger 1	Heat exchanger 2	Heat exchanger 3
Material of heat transfer tube	High density polythene	Copper	Copper
Thermal conductivity	0.38W/m/K	403W/m/K	403W/m/K
Diameter	27.0 (t3.0) mm	19.05 (t1.0) mm	19.05 (t1.0) mm
Distribution method	Header type (4 tubes)	One-way	One-way
Length	5.5m	5.5m	5.5m
Total length	44.8m	198m	198m
Heat transfer area	3.378m2	11.228m2	11.228m2
Lining	Gravel	Cement mixed with silica sand	Cement mixed with silica sand
Insulation	None	None	Polythene (t8)

To minimize weather effects, every experiment was run for a week.

For heat dissipation during the summer, brine was heated to 30 °C, 35 °C and 40 °C and then supplied to the heat exchanger at 10 l/min, while heat dissipated to sewage water was measured.

Heat extraction results

The results show the same trend for all the experiments. Figure 3 shows experimental results of a day with brine inlet temperature of -5 °C and flow rate in each of the heat exchanger set at 10 l/min.

As shown in Figure 3, sewage water temperatures start to rise in the evening and reach a peak at midnight, after which the temperatures fall and are constant during daytime. The sewage surface temperature varies from 3 to 4 °C over an interval of 30 minutes. From 18:00 to 24:00, the temperature variation interval is less than 30 minutes, and the surface temperatures rise with sewage temperature. The surface temperature gradually decreases, with a wide variation interval of 60 to 90 minutes between 2:00 and 6:00. This is due to the intermittent running of sewage water. Sewage pumps are intermittently run to control sewage levels. The sewage pump at the experimental station ran for about 44 % of the time.

Sewage surface temperature variations are affected by both sewage water temperature and sewage water flow rate, due to the operation rate of the pump. The temperature difference between sewage water and sewer pipe surface is 1 °C when the pump is in operation.

Heat extracted from sewage depends on sewer pipe surface temperatures and increases between 18:00 to 24:00, when sewage temperatures and flow rate increase. When sewage flow rate decreases and temperatures fall, after midnight, the quantity of extracted heat falls drastically. Therefore the pump operation rate affects the amount of heat extracted.

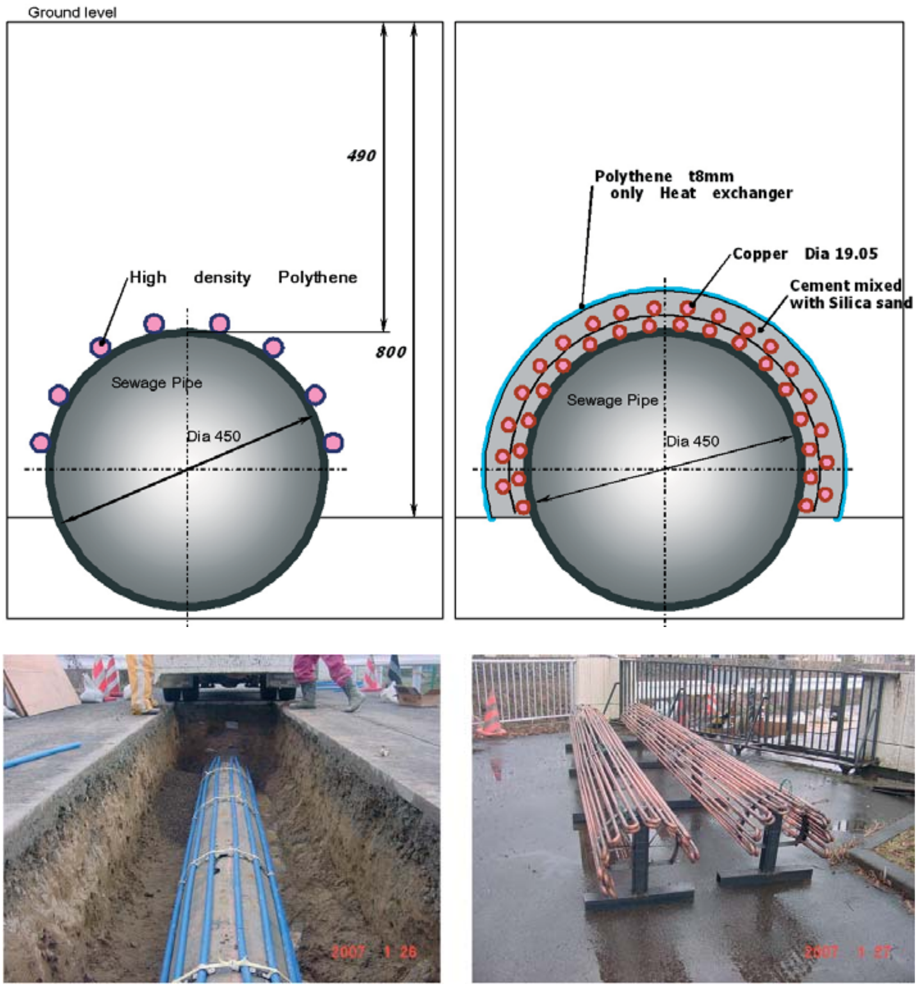


Fig 1 Heat exchangers. Heat exchanger 1 (left) Heat exchangers 2 and 3 (right)

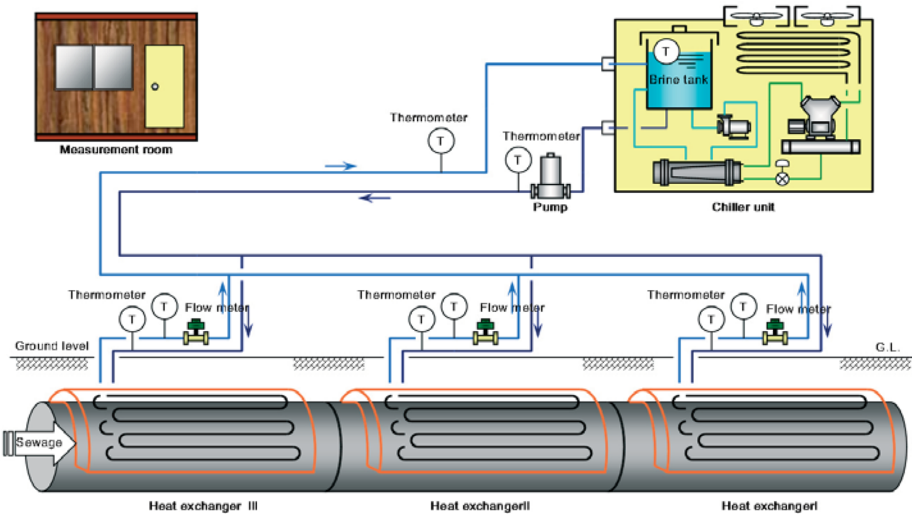


Fig.2 Experimental apparatus

The relationship between heat extracted and sewer pipe surface temperatures for a day and at the same conditions is shown in Figure 4. As the surface temperature increases, the extracted heat also increases and at high surface temperatures the performance of the water jacket heat exchangers is remarkable. This is because the temperature difference between the surface and brine increases.

As shown in Figure 5, Heat Exchanger 3 gives the best performance and the heat extracted by the heat exchanger is twice that of Heat Exchanger 1 for all the conditions. Heat Exchanger 3 gives a slightly better performance than Heat Exchanger 2, indicating the slight benefit of insulation. The average sewage temperature was 14.3 °C, and the average extracted heat was 3400 W. However, at high sewage water temperatures (16.9 °C), the surface temperature rises and the extracted heat also increases (4600 W).

Figure 5 also shows that heat extracted increases with increase in the flow rate. Doubling the flow rate increases the extracted heat by 15 %.

The heat extracted also increases as the inlet temperature is lowered, or as the temperature difference between sewage water and brine increases.

Heat dissipation results

In summer, the average sewage water temperature is 24.4 °C (maximum 25.5 °C, minimum 23.3 °C), ten degrees higher than the average winter temperature (14.3 °C). As in winter, the temperature difference between sewage water and sewer pipe surface was 1 °C when the pump was in operation.

Figure 6 shows the average heat dissipation under various conditions. Since sewage water temperature rises towards midnight, the dissipated heat decreases. This is because the temperature difference between the brine and the sewage water decreases. Dissipated heat increases during the time when the temperature difference is maximum.

As in heat extraction, Heat Exchanger 3 gives the best performance and twice as much heat as Heat Exchanger 1. Again, the effect of insulation is confirmed by the slightly better performance of Heat Exchanger 3 when compared with Heat Exchanger 2. Temperature distributions between the pipe and road surface were measured. Road surface temperatures reached 55 °C and underground temperatures decreased towards the

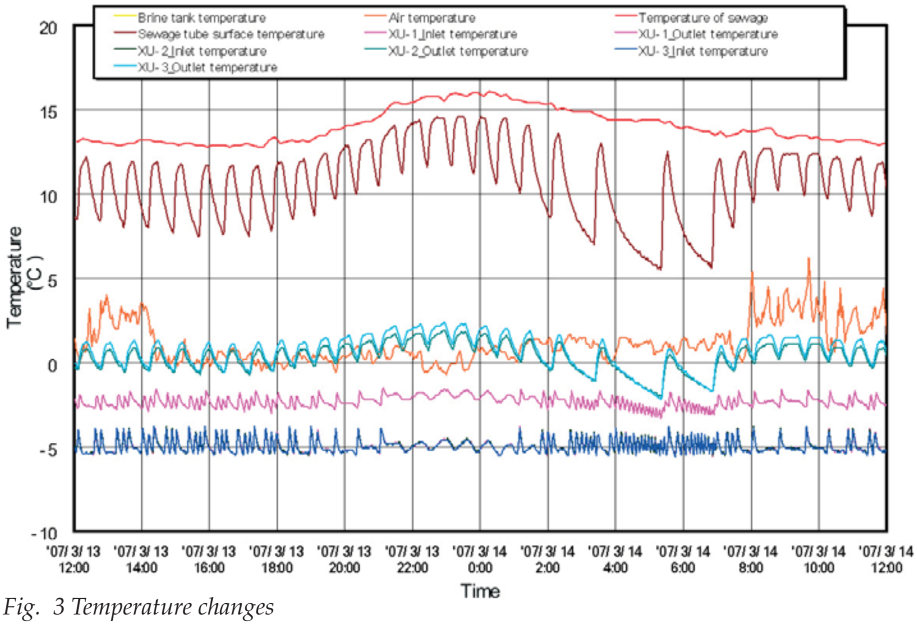


Fig. 3 Temperature changes

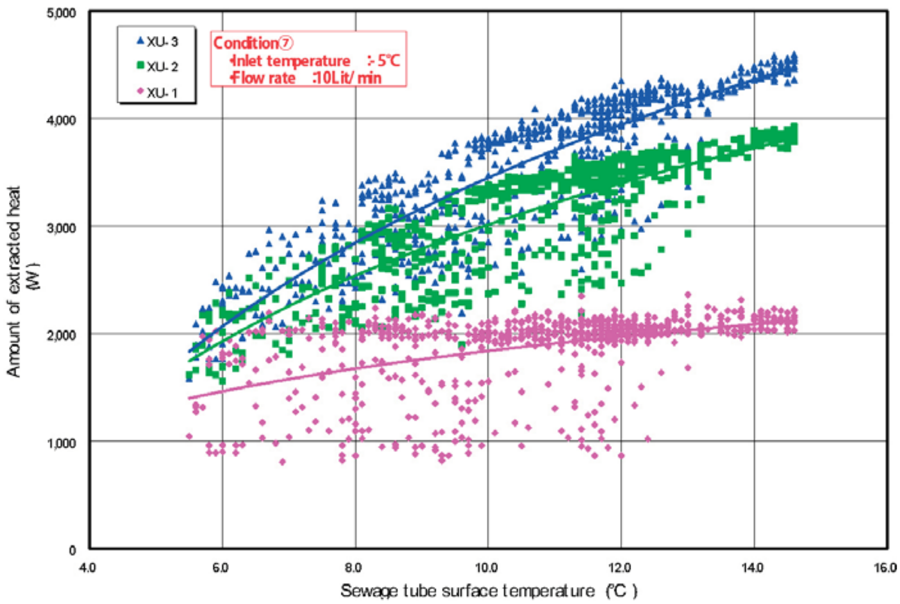
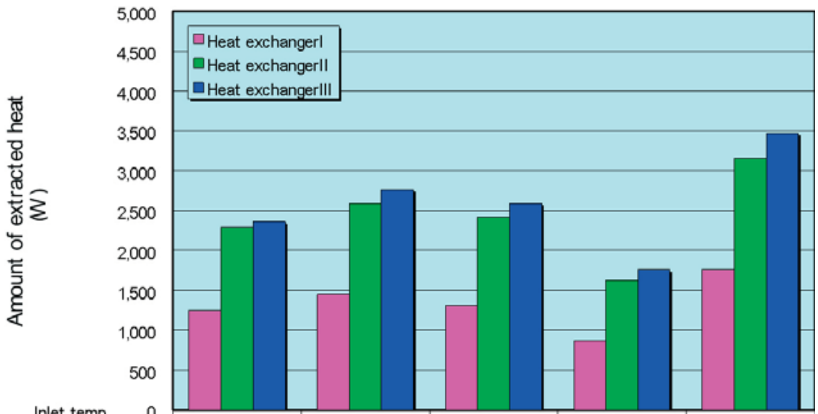


Figure 4. Relationship between surface temperature and extracted heat



Inlet temp / Flow rate	0°C 5Lit/min	0°C 10Lit/min	0°C 7.5Lit/min	5°C 7.5Lit/min	-5°C 10Lit/min
Heat exchangerI	1,252	1,451	1,309	871	1,762
Heat exchangerII	2,290	2,585	2,418	1,625	3,156
Heat exchangerIII	2,360	2,763	2,591	1,757	3,472

Figure 5 Average extracted heat

sewer pipe. By insulating the water jacket heat exchanger no. 3, the effects of changes in atmospheric temperatures were minimized. For different brine inlet temperatures, dissipation heat increased with increase in temperature difference between brine and sewage water. By changing the brine inlet temperature from 30 °C to 40 °C, heat dissipation increased by 2.5 times.

Conclusions

In order to investigate the effective use of sewage heat, water-jacket heat exchangers were laid along a sewer pipe. Heat extraction and dissipation experiments were then carried out. The experiments showed that;

(1) Water jacket heat exchangers do not affect the sewage treatment facility, since they are laid along sewer pipes.

(2) Compared to underground heat extraction, heat extraction from sewage using water-jacket heat exchangers provides far better heat extraction performance per unit length, and is much cheaper.

(3) A comparison of the heat exchangers shows that Heat Exchanger 1 is cheaper than Heat Exchangers 2 and 3. However, Heat Exchangers 2 and 3 offer better performances with twice as much heat.

(4) Heat extracted increases with the brine flow rate, and a high temperature difference between sewage water and brine temperature.

(5) Insulating the heat exchanger slightly improves performance.

(6) The extracted heat is affected by the operation rate of the sewer pump.

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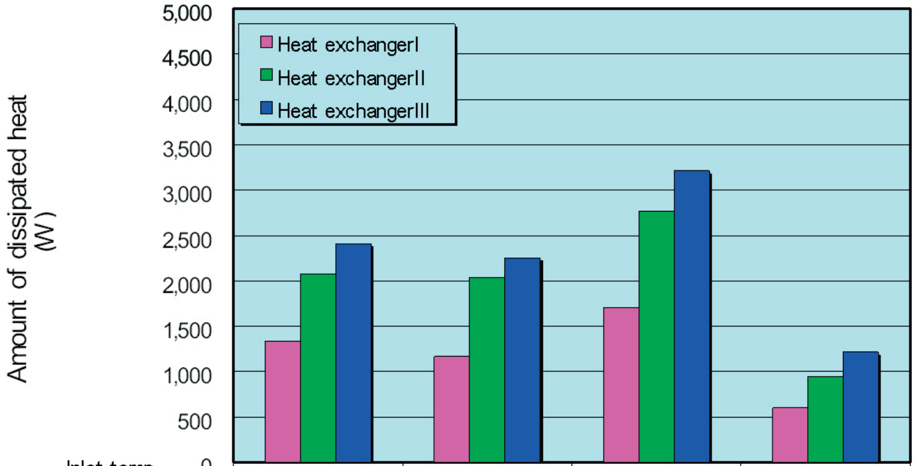

Inlet temp Flow rate	35°C 10 L/ min	35°C 10 L/ min	40°C 10 L/ min	30°C 10 L/ min
Heat exchangerI	1,336	1,166	1,705	602
Heat exchangerII	2,079	2,039	2,772	942
Heat exchangerIII	2,407	2,251	3,214	1,216

Figure 6 Average dissipated heat

Near-Zero-Energy Homes help electric utilities meet record system peaks

Jeffrey E. Christian, USA

Five near zero energy houses (ZEH) are under test at an energy research park near Oak Ridge, TN. Data from 2006-2007 show that these homes have ~7 kW lower summer peak electric demand than typical conventional homes in the same region. Combining 17,000 such homes in a "zero energy neighbourhood" could provide a utility with peak demand management capability equivalent to a 120 MW power plant.

Introduction

The US DOE Building America Project collaborated with Oak Ridge National Laboratory (ORNL), the Tennessee Valley Authority (TVA), Habitat for Humanity's Loudon County Affiliate, and local building and energy service equipment companies to build an energy research park comprising five low-energy homes near Oak Ridge, Tennessee. The five homes provide a living laboratory for research on integrated energy-saving technologies that will lead to the development of marketable near-zero-energy homes (ZEHs). Four of the homes (ZEH1 through ZEH4) range in size from 93 to 115 m2 (1,000 to 1,240 ft2). At the suggestion of TVA, a larger 242 m2 (2,600 ft2) house (designated ZEH5) was included in the research park so that it could be determined whether the unique integrated technology package is scalable to larger homes. The current research is focused on the mixed humid climate typical of the TVA service area – an area in the south eastern US comprising Tennessee and parts of surrounding states Kentucky, Georgia, Alabama, and Mississippi. However, the findings are relevant to all U.S. regions.

Recent evaluation results

ZEH5, which is temporarily being used as an office and meeting space, is undergoing 2 years of detailed thermal performance monitoring (2006–2008). The other four homes are all occupied residences and have at least one year of detailed performance measurements. Data collected were used to validate a whole-house simulation model, which in turn is used to predict performance compared to a benchmark house with identical occupancy patterns. During the 2006 calendar year, ZEH4 experienced average energy costs (for all uses, not just space conditioning) of less than $0.50/day. The average daily electricity costs for the ZEHs includes a solar-generated electricity buyback of $0.15/kwh from the solar photovoltaic (PV) arrays tied to the TVA power system with a residential rate of ~$0.07. Average total energy cost for non-ZEH homes in the same area is $5 to $6/day.

Figure 1 shows a picture of ZEH4. This home uses a two-speed, air-source heat pump to provide indoor space conditioning and uses a heat pump water heater for domestic hot water. The heat pump has a rated cooling seasonal performance factor of 4.98 W/W (a Seasonal Energy Efficiency Ratio, SEER, of 17.0 Btu/Wh). Its rated space cooling capacity at high speed is 7.0 kW (2 tons). ZEH5 uses a ground source heat pump (GHP) system with 7.0 kW rated cooling capacity. The ground loop heat exchanger (HX) for the ZEH5 GHP is completely contained within the excavation required for the house foundation and sewer and water utility trenches – see schematic illustration in Figure 2. This means that minimal additional trenching costs were incurred to install the ground HX. Several different approaches for domestic hot water supply for ZEH5 are being tested in-

Figure 1. ZEH4, a 111 m2 Habitat for Humanity house in the research park at Harmony Heights, subdivision in Lenoir City, near Oak Ridge, Tennessee.

cluding supply by the GHP desuperheater, and a solar thermal system.

During part of the test period (the summer of 2007), Tennessee experienced record high temperatures and drought, the most extreme conditions documented in 113 years of record keeping. On August 16, 2007 TVA met an all-time record power system peak demand of 33,482 MW. Both ZEH4 and ZEH5 were able to be maintained at comfortable indoor temperature and humidity conditions during this critical peak time. With the help of a remote controlled energy management system these homes were found to demand no energy from the grid during these critical utility system peaks. In most days during TVA critical system peak times in August electricity produced by the PV systems on the home roofs was flowing back onto the grid.

Several peak load control strategies have been tested at the energy park. One example evaluated for both ZEH4 and ZEH5 features an approach using a "smart" house load management system to provide remote control of electric peak load. The load control device incorporates a battery bank for power storage along with an inverter and controls to manage battery power and accept remote control signals to schedule load control operations. An example of its operation results is shown for ZEH4 in Figure 3. During the utility peak period the unit is instructed to begin discharging the battery bank, in this case to the utility grid which together with the PV generation results in more than 3kW to the grid. At 20:00 , the unit controls begin recharging the battery bank from the utility grid with full recharge achieved within 5-6 hours (well before the next day's peak period begins).

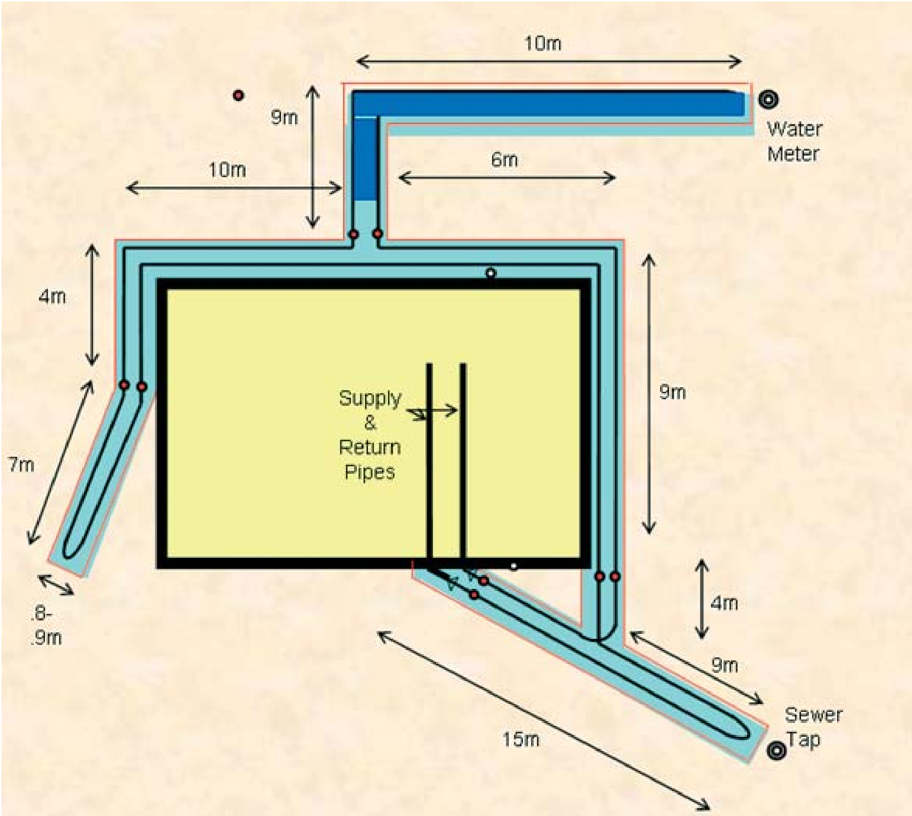

Figure 2. Ground loop heat exchanger layout for ZEH5 geothermal heat pump system.

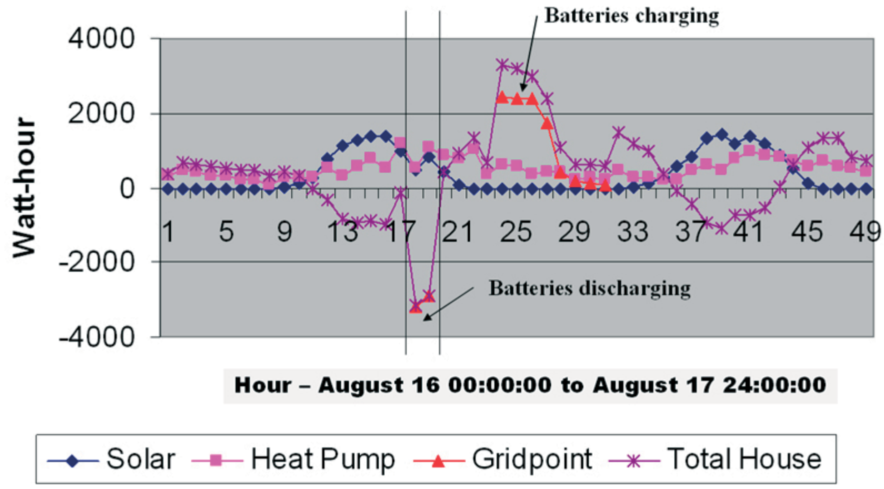

Figure 3. ZEH4 whole house and heat pump power demand for August 16-17, 2007 – impact of "smart" whole house electric load controller (Gridpoint system).

Another example features a thermostat control approach in conjunction with the house PV generation and load management systems to minimize heat pump system demand – results for ZEH5 illustrated in Figure 4. It was found that by "pre-cooling" ZEH5 (lowering the thermostat a little for a few hours before the peak demand period then raising the thermostat during the critical peak) total house demand can be reduced significantly. The critical peak demand was reduced from ~3-4 kW (what it would have been without pre-cooling, on site PV generation, and the load management system battery bank discharge) to -3 kW. Excess PV electricity generation and battery discharge power was being fed back to the utility power grid. This peak reduction was accomplished without sacrificing indoor space comfort conditions as shown in Figure 5. The house temperature floated up during the peak period, from ~21.7 °C (71 °F) to ~23.9 °C (75 °F) – just below the critical peak period thermostat setting of 24.4 °C (76 °F) and about 0.9 °C (2 °F) higher than the normal setting. The house continued to provide mechanical ventilation yet the indoor RH ranged from an acceptable 55% to 57% during the pre-cool and peak time periods.

Conclusions

This work shows that at summer utility peak load periods ZEH-type homes in the south eastern US can save on average 7 kW/home compared to typical conventional homes of similar size in the same region. This suggests that by linking about 17,000 of these homes together a green demand control capability equivalent to a 120 MW peaking power generation facility can be achieved. The demand saving can be accomplished without sacrifice of indoor thermal comfort levels.

A future direction in the research will be to take the information obtained from the individual homes in this study and to apply it to a "Zero Energy Neighbourhood," where homes are treated in aggregate to maximize their performance and to minimize the demand for electricity.

Acknowledgements

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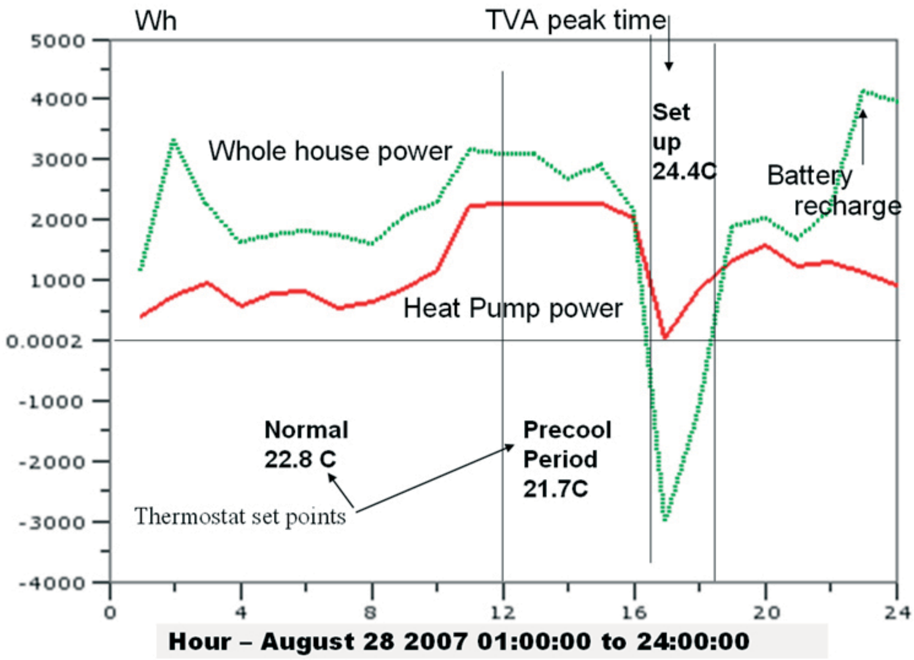

Figure 4. ZEH5 whole house and heat pump power demand - impact of thermostat control to pre-cool space before utility peak period.

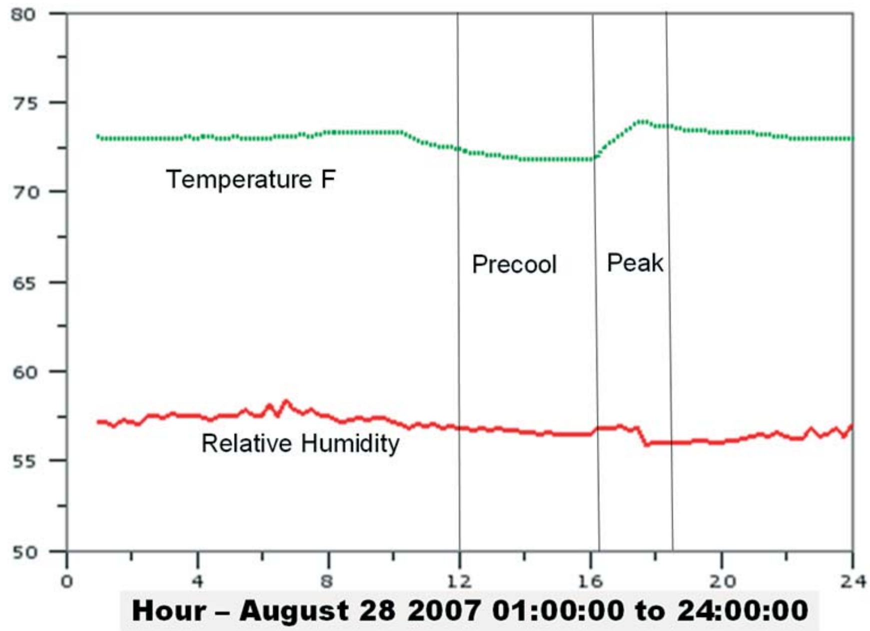

Figure 5. ZEH5 indoor temperature and relative humidity conditions during space pre-cool test period.

Is R744/CO_2 really an alternative for MACs – Consequences if put in mass production

Hans E.H. Fernqvist, Sweden

This paper has previously been presented at the "International symposium on new refrigerants and environmental technology 2006" symposium. It is reprinted with kind permissions from the Japan refrigeration and air conditioning industry association.

History

The use of R744/CO_2 as refrigerant is not new. Beginning of the last century and up to the introduction of the CFCs and HCFCs in the early 1930s CO_2, together with ammonia and methyl chloride, were the most common refrigerants. Specifically in ships transporting food like meat, fruit and other provisions that needed to be frozen or chilled in order to not be destroyed during transportation, CO_2 was virtually the only possible choice. A leek of either ammonia or methyl chloride into the cargo space would have destroyed the meat, fruit or whatever type of food that was transported. With the introduction of CFC-12 (R12) in 1933 and followed by HCFC-22 (R22), R502, R500 etc., the use of CO_2 as refrigerant was quickly reduced and had in a few years virtually disappeared completely.

Background

June 1992 Volvo Cars were visited by representatives from the Norwegian technical foundation SINTEF in Trondheim, Norway and from Hydro Aluminium. What they presented was what they called R-2000, a transcritical CO_2 system. At that meeting, message was that the only remaining engineering work to perform, before an introduction, was to design all components to cope with the significantly higher pressure levels compared to an R134a or R12 system. Also a new compressor design was needed with much smaller displacement compared to present R134a compressors. Even if it from a pure technical and engineering standpoint would have been interesting to do some advanced engineering work on this R-2000 concept, it was judged to be a futile effort to try to get any resources allocated for that. At that point in time, Volvo Cars had been in regular mass production with R134a/PAG oil systems, as replacement for the ozone depleting R12 (CFC-12), for more than one year (April 15th 1991) without experiencing any problems related to the new refrigerant and oil.

It took until 1994 and the start of the RACE project before the transcritical CO_2 concept came up on the Volvo Cars agenda again. Purpose and general guidelines for this project was to investigate the suitability of transcritical CO_2 for MACs, Mobile Air conditioning systems. The project was financed by EU money and only European companies could therefore participate. It run for three years with participation from virtually all the major European car OEMs as well as system and component suppliers. Some companies traditionally not in the automotive sector were also engaged. The outcome of this project was actually quite enlightening. Most of the problems related to the physical, chemical and thermodynamic properties of CO_2 was discovered, or actually rediscovered.

The very high permeation rate through virtually all polymeric materials (elastomers/rubbers and plastics) that prevents the use of traditional type of flexible lines (=hoses) and that causes what is called 'decompression internal delamination' in seals like o-rings, are still some of the unresolved or very problematic issues. For flexible lines, corrugated metal lines with steel braiding are still the most common type used. For seals in mechanical screw together connections, metal seals are still the only possible variant for the high pressure/temperature side of a CO_2 system. Mass flow control, connected to the wide span of speed for the engine driven compressor, compressor shaft seal durability and need of good gas cooler cooling were other examples of issues of concern (re)discovered in this project.
If all this rediscovered knowledge had been put together into design prerequisites for a transcritical CO_2 system, it would have stipulated the following design features:

- should have a hermetic or semi hermetic compressor (no shaft seal) running at constant speed or very limited speed range
- all lines should be all metallic with all connections brazed or welded together
- evaporator heat load range should be limited
- cooling of gas cooler should be significantly better than compared to typical condenser cooling in a car (no recirculation/backflow of hot air allowed)

Not many, if any, of the above prerequisites can, within reasonable cost, be achieved in a traditional passenger car or light truck.

When the RACE project was finished and the final report was to be written, Volvo Cars opinion was that transcritical CO_2 actually was inherently unsuitable for MACs. Unfortunately, other participating and more dominant OEM companies thought differently and that dictated the recommendation to continue work on this type of air conditioning system for vehicles. The RACE final report came out 1998.

Today's situation

As a result of this position, some of the German car OEMs continued to work on transcritical CO_2 systems and also made several system and component suppliers in Europe as well as in Japan to spend substantial resources on designing and testing of CO_2 system components. As a result, impressive improvements have been achieved in some areas. Hose manufacturers have developed some new hose concepts that look very promising regarding permeation but it remains to be shown if these hose types can be successfully coupled and maintain good sealing properties also after being exposed to discharge gas temperatures up into the 160-170°C range. Well working *mass flow/ discharge pressure vs. discharge gas temperature* devices has been designed. Lately it has been found that the *'quality'* of the suction gas (=compressor inlet) is crucial for the durability and sealing properties of the compressor piston rings. So called 'wet suction gas' = some liquid, not evaporated CO_2 into the compressor can be detrimental. This indicates that the internal design of the accumulator is substantially more important and critical compared to the equivalent component in an R134a orifice type system.

As a result of almost endless discussions over the comparison of performance and efficiency (COP) between transcritical CO_2 system and R134a and other alternative refrigerants, an extensive research program was organized and executed by the SAE (Society of Automotive Engineers) organisation. This was the SAE-ARCRP (Alternate Refrigerant Cooperative Research Program) that run between 2001 and 2005. In phase 1 of this program four different systems were compared regarding efficiency and cooling performance. The four systems were:

- Baseline R134a
- Enhanced (improved) R134a
- Transcritical CO_2
- Propane / R290 in a 'Secondary Loop' (= indirect) system

In short, the result confirmed previous findings that at lower ambient temperatures the CO_2 system show slightly better COP than the 'Baseline R134a' system and at higher ambient temperatures it was the other way around. When applying the measured COPs for the different systems on a standardized drive cycle and using official climatic data to calculate annualized energy consumption for running these four different AC systems, the result was quite interesting. If the Baseline R134a was used as reference with 100 units, the CO_2 system came out with 74 units (= 26% down), the enhanced R134a with 75 units and the R290/Secondary Loop system with 86 units. Considering the fact that the propane/R290 'Secondary Loop' system was a totally non optimized system and that it had an additional heat exchanger/evaporator between the primary/propane loop and the secondary water/glycol loop, it was a real surprise that it actually had a lower annual energy consumption, for the same cooling performance, than the baseline R134a system. In phase 2 of this program the same type of comparison were done between an enhanced R134a system, an R152a system and an updated CO_2 system.

Does all these improvements mean that the possibility to successfully introduce CO_2 as alternative refrigerant in MACs have significantly increased? Yes, to some extent as long as we are looking at the functionality only but from another viewpoint not very much have changed and this has to do with refrigerant containment. Even for today's R134a system and yesterdays R12 system refrigerant containment is crucial. Not only from a performance standpoint but also from a reliability and durability standpoint. If the refrigerant can be kept in the system it will virtually last for the whole lifetime of the vehicle. Through extensive field and laboratory testing, in Europe, USA and Japan, it has over the last three years been demonstrated that the so called controlled losses of R134a over a full year is typically in the range 8-15 gram/year. With a system overcharge, or leak margin of 100-150g R134a it gives a potential lifetime of at least 10 years and most probably substantially longer.

Today, very strict requirements regarding leak tightness are put on each component in a MAC system. Most system and component suppliers have today invested in what is called '*vacuum chamber – helium masspectrometer*' technology to make the leak check process as sensitive as it needs to be and to make it more independent of the operator. So today, quality of incoming components regarding leak tightness is generally very good. The remaining trick or art is to assemble these parts to a complete system in a vehicle and to do that with the regular workers on the final assembly line in a car factory with a line speed of typically 40-70 cars per hour. To be successful in doing that, experience have shown that what is needed is connections that have one or preferably two sealing elements. The type of sealing element that has been totally predominant since the early -70s is the rubber o-ring. Today the o-ring rubber material is very often HNBR or in some cases EPDM. The connections are also designed so that the sealing function and the screw together/torque down are totally separated. There are also some more design features that has been implemented to increase the probability that a connection becomes non leaking, independent of if the assembly line operator follows the given installation instructions or not.

Tomorrow

If we now take a look at connections for use in transcritical CO_2 system, you will find that rubber o-rings are not used, at least not on the high pressure/temperature side of the system. Instead metal seal rings or different type of 'seal washers' are used and the sealing capability is directly connected to how much they are being torque together. Reason why rubber o-rings can not be used is explained in the *Background* chapter above. The designs are generally also such that the line operator has to strictly follow the installation instructions and if not, you most probably have a leaking connection.

If you now also consider the fact that for a given leak, leak flow becomes four times higher if the pressure differential over this leak is doubled and combine it with the fact that CO_2 systems operate at pressure levels 5-10 times higher than a R134a system, it is obvious that what will happen is that the number of cars that will come off the assembly line with to high leak rate will be 20-30 times higher compared to today. Well, than you have to improve the leak check on the assembly line! That is easy to say but unfortunately it is not feasible. Why? Even if you are to use a very good sniffer, like a He-masspectrometer sniffer, and raise the He charge from today's typical 5-10bar to 50-60 bar, or even higher, the short time available (1-2min) on the fast moving assembly line and the poor access in today's very crowded engine rooms, you will not find the leaks you need to find. So, conclusion is that the design must be such that the connections become non leaking from the beginning and do not need any leak check. The problem, as described above, is that the chemical, physical and thermodynamic properties of CO_2 do not allow that.

So, what will then happen when these cars are being delivered to customers? Depending on the size of the leak(s) it will take anywhere between one week to a year before the customer will experience reduced or totally lost cooling performance. In the worst case this '*Low Charge*' situation could have caused compressor failure (seized). An experienced and skilled workshop mechanic will conclude that "there must be one or more leak on this system" and will start a leak search.

If we then combine the fact that the biggest problem, without any competition, that today's mechanics are struggling with, is to find the small and intermediate size leaks on today's R134a system, with the influence of the pressure level, as described above, that in practice means that the size of leak you need to be able to detect on a CO_2 system is some 1/20 – 1/10 of the size you need to detect on a R134a system, the conclusion is very simple: they will not find the leaks they need to find. The CO_2 itself can not be used as a tracer gas. The size of leaks we are talking about here will give an increase of approximately 10-50ppm vs. a background starting at 380ppm and varying up to 1000-1500ppm depending on number of persons and activities in the workshop. The mechanics will be forced to just recharge the system and return the car with a leaking system to the customer.

So, after approximately the same time frame, customer will experience same problem as the first time and will again go to the workshop. In the automotive business this is called '*repeat repair*'. If this happens three times within the warranty period (3-4years), which is highly likely in this case, the customer can, on many markets, demand a 'buy-back' of the whole vehicle. Increase of the bay-back rate is the worst scenario for any car OEM. It is very bad publicity and can be an economical disaster.

Conclusion

Any attempt to introduce a transcritical CO_2 system in a traditional high volume mass produced car will result in the biggest debacle and mess in mobile air-conditioning history. It is fully possible that CO_2 can be a viable refrigerant in a hybrid or fully electric vehicle where a hermetic or semi-hermetic compressor can be used and where no 'screw-together' connections are needed.

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Mechanical vapour recompression heat pump in a Swedish pulp and paper mill

Torbjörn Harrysson, Sweden

In September 1999, a mechanical vapour recompression heat pump was commissioned at Stora Enso Nymölla Mill, a sulphite mill producing fine paper. The heat pump upgrades low-pressure steam from one of the evaporation plants to replace live steam in some parts of the mill.
The main objective for the installation was to reduce the fuel cost (mainly oil, but to some extent also biomass), and to increase the capacity of steam production. A reduction in fuel costs of about 10 MSEK/year (~1.1M€/year) was accomplished.

Introduction

In September 1999, a mechanical vapour recompression heat pump was commissioned at Stora Enso Nymölla sulphite mill. The heat pump upgrades low-pressure steam from one of the evaporation plants to replace live steam in some parts of the mill.
The main objective for the installation was to reduce the fuel cost (mainly oil, but to some extent also biomass), and to increase steam production capacity in order to reduce the need for a new boiler to accommodate future capacity increase of paper production.
It was concluded that a number of applications in the mill could be operated by steam at 0.7 bar(a) and 115 °C:

- Pre-evaporation plant, unit no 1
- Cooking acid preheating (85-90 °C)
- Feed water preheating
- Hot water for the bleach plant (90 °C)
- Internal and external district heating
- A number of smaller loads are also attached to this system.

The total normal consumption in these plants is about 18-25 t/h. By introducing an MVR heat pump, about 21 t/h could be supplied by upgrading secondary vapour from the sulphite evaporation. By establishing a new steam system, excess steam can be released to the atmosphere, and deficits can be covered by low pressure (LP) live steam.

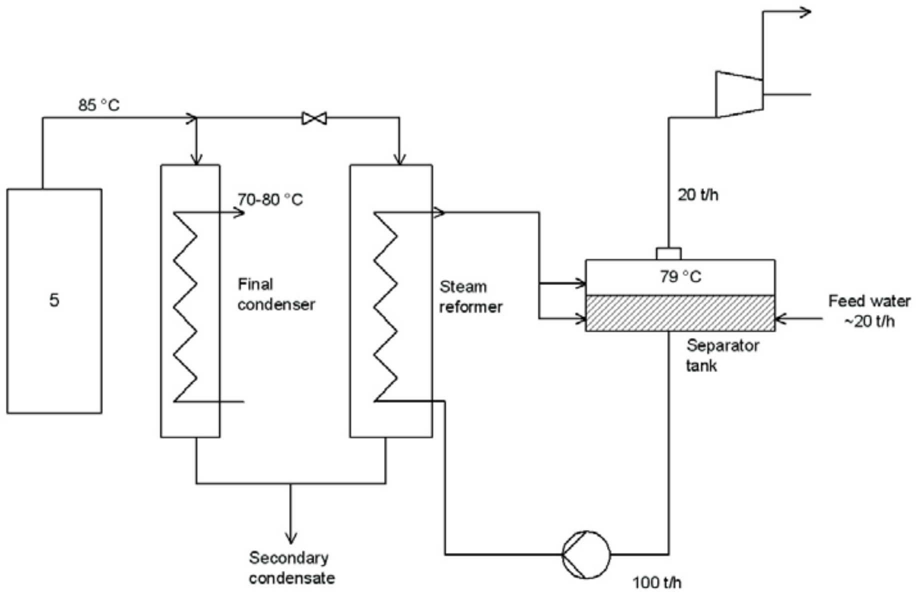

Figure 1. Flowsheet of the clean steam generation.

System design

System description (see also Figure 1):
Secondary steam (about 20 t/h, 85 °C) from the last unit (unit no 5) of the pre-evaporator, which is not clean enough to be used directly in the MVR unit, is led to a steam reformer, where it is condensed. Clean steam at 79 °C is raised and led to a two-stage mechanical steam compressor where the pressure is increased by 1.2 bar to approximately 0.7 bar(a) and 115 °C saturation temperature. The compressed steam is distributed in a separate steam system to replace live LP steam in applications where the temperature is not particularly critical, listed above. The LP steam at Nymölla is normally at 4 bar(e).

The compressor (Figure 2) differs from many other installations in not being operated by an electric motor, but by a 2 MW steam turbine that reduces high pressure steam of 60 bar to medium pressure steam of 12 bar(e). The reason this option was chosen was that the existing back-pressure turbines do not have enough capacity for extraction steam (MP stean) at the actual LP steam demand. Some HP steam was consequently reduced to MP steam by a pressure reducing valve.

The enthalpy loss in the steam corresponds to the enthalpy content of 3 t/h of LP steam. The MVR delivers about 21 t/h, so the net addition from the reformed steam corresponds to 18 t/h of LP steam.

In order to compensate for the lost production of hot water (70 °C) in the final condenser of the pre-evaporation plant (Figure 1), since the steam is led to the steam reformer; a heat recovery project was made with the objective of increasing the heat recovery in the bleach plant.

If the secondary steam is considered as waste heat, the COP of this heat pump solution is about 7.5 (13 MW waste heat plus 2 MW results in 15 MW useful heat). By this arrangement, about 20 t/h steam is generated from waste heat, which has the following benefits:

- decreased oil consumption, and consequently reduced CO_2 emissions
- Added capacity in the steam production (instead of retrofit of boilers in case of increased production)
- Decreased need of direct reduction of HP steam to MP steam

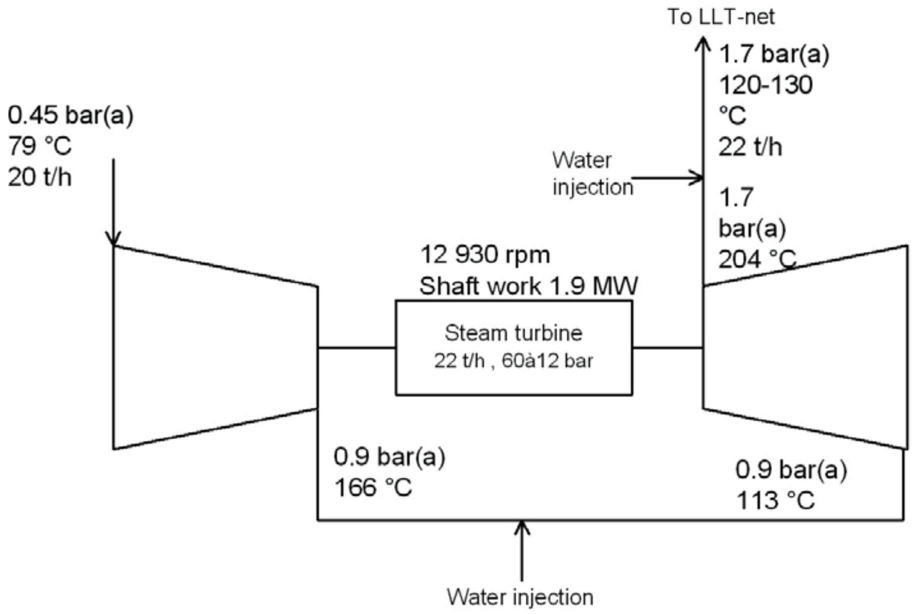

Figure 2. Steam turbine for the MVR unit.

Operation and economy

The heat pump is quite complicated to start up, but is stable when in operation. It can handle the normal variations that occur in the pre-evaporation plant. All components in the solution are known technology "off the shelf", but the applications is new. One problem is that there is a larger temperature difference in the steam reformer than expected. As a consequence, the capacity in the pre-evaporation plant is reduced by 15 % when the compressor is in operation. The heat exchanger was dimensioned for a 4 K ΔT, but in reality, the ΔT was close to 9K. Heat transfer area has been added, with a slight increase in heat transfer, but there is probably also a high concentration of inert gases present, resulting in the high temperature difference. This decreased evaporation capacity in the pre-evaporation plant results in poorer heat economy in the subsequent final evaporation plant, which has been compensated by adding more heat surface in that plant.

The investment in the equipment was 45 MSEK, whereof 10 MSEK was funded by the Swedish Agency for Economic and Regional Growth, NUTEK, under the Agency's "new technology funding" scheme.
The target of the investment was to reduce fuel cost by 13 MSEK/year. This target has not been completely reached, but a 10 MSEK/year cost reduction has been reached.

Electricity prices in Sweden have increased over the last few years, and are generally on a higher level than when the heat pump was designed. This has affected the profitability of running the heat pump when the price on the Nordic electricity market is high. High pressure steam that is used to run the steam turbine in the MVR could be used instead to increase electricity production in the back-pressure turbines, and this increased electricity production could then lead to larger profits than the savings on fuel.

Conclusions

A novel MVR heat pump solution was built in the Nymölla mill. There have been some problems, but the savings are almost as budgeted. Due to the relation between fuel price and electricity price, operation fo the heat pump depends on economic conditions, i.e. whether the high pressure steam should be used to produce electricity instead.

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Mind the Gap - Quantifying principal-agent problems in energy efficiency

Energy efficiency presents a unique opportunity to address three energy-related challenges in IEA member countries: energy security, climate change and economic development.

Yet an energy-efficiency gap exists between actual and optimal energy use. That is, significant cost-effective energy efficiency potential is wasted because market barriers prevent countries from achieving optimal levels. Market barriers take many forms, from inadequate access to capital, isolation from price signals, information asymmetry, and split incentives. Though many studies have reported the existence of such market barriers, none so far has attempted to quantify the magnitude of their effect on energy use and efficiency.

Mind the Gap is an unprecedented attempt to quantify the size of one of the most pervasive barriers to energy efficiency – principal-agent problems or, in common parlance, variations on the 'landlord-tenant' problem. In doing so, the book provides energy analysts and economists with unique insights into the amount of energy affected by principal-agent problems. Using an innovative methodology applied to eight case studies (covering commercial and residential sectors, and end-use appliances) from five different IEA countries, the analysis identifies over 3800 PJ/year of affected energy use – that is, around 85 % of the annual energy use of a country the size of Spain.
Source: www.iea.org

CO_2 emissions from fuel combustion - 2007 Edition

In recognition of fundamental changes in the way governments approach energy-related environmental issues, the IEA has prepared this publication on CO_2 emissions from fuel combustion. This annual publication was first published in 1997, and has become an essential tool for analysts and policy makers in many international fora such as the Conference of the Parties to the Climate Change Convention.
The thirteenth session of the Conference of the Parties to the Climate Change Convention (COP 13), in conjunction with the third meeting of the Parties to the Kyoto Protocol (COP/MOP 3), will be meeting in Bali from 3 to 14 December 2007.
The data in this book are designed to assist in understanding the evolution of the emissions of CO_2 from 1971 to 2005 for more than 140 countries and regions, by sector and by fuel. Emissions were calculated using IEA energy databases, and the default methods and emission factors from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.
Source: www.iea.org

World's first CO_2 refrigeration course online

A new e-learning course aims to educate students and users of CO_2 refrigeration systems on design, installation and maintenance issues. Launched by the British supplier, Star Refrigeration, it is the first certified online course on R744 technology.

The two-module course introduces the basics of working on carbon dioxide systems and helps prepare students for advanced studies of CO_2 (R744) refrigeration systems. Divided into "CO_2 Refrigeration Fundamentals" and "CO_2 Refrigeration System Basics", the course covers design, installation and maintenance issues. Explaining the advantages and challenges of using R744, it educates on leak and pressure testing, as well as charging and venting. In addition, the course describes the basic components and functionality of CO_2 systems, including volatile secondary (with direct expansion and cascade), trans-critical and direct expansion.
The course fee is £250.
Source: www.elearning-training.com

ASHRAE launches High Performing Buildings magazine

High Performing Buildings is a new quarterly magazine published by ASHRAE and distributed to building owners, facility managers, architects, contractors and engineers. The magazine helps decision makers in the building community learn about the benefits of innovative technologies and energy-efficient design and operation. Case studies of exemplary buildings, developed through the support of leading practitioners in the sustainability movement, present measured performance and lessons learned to promote better buildings.
Source: The HVAC&R Industry newsletter, November 2007

Japanese study urges world to adopt heat pumps

Widespread use of heat pumps could slash 10 % of Japan's total CO_2 emissions, according to Japanese experts. Focusing on technical developments and applications of heat pumps, they urge suppliers and consumers worldwide to switch to the energy-saving technology.

The study "Heat Pumps – Long-Awaited Way out of Global Warming", released by the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ) in October, explains in detail the current technical conditions of heat pump technology, its application fields, and energy savings. Based on latest market studies and performance data, the document urges business, policy makers and end-users to adopt heat pumps as a global solution.

Drawing attention to technical and policy developments regarding heat pumps in Japan, the study focuses more specifically on "Eco Cute" hot water heaters using the natural refrigerant CO_2 (R744). The "epoch-making product" is currently a key pillar of industry and government efforts to reduce greenhouse gas (GHG) emissions under the Kyoto Protocol Target Achievement Plan and the New National Energy Strategy.

Download the full study at:
http://www.hptcj.or.jp/about_e/contribution/pdf/hpe-all.pdf

New publications by Frperc

* Swain, M.J., Evans, J.A. & Brown, T. 2007. Improving the energy efficiency of food refrigeration operations. In Proceedings; 2007 CIGR International Symposium on Food and Agricultural Products: Processing and Innovations.
Naples, Italy. 24-26 September. [FRPERC ID: 920]

* James, S.J. 2007. Specification, design, development and optimization of food refrigeration systems. Ferial 2007 Medellin, Columbia 24th August 2007.
[FRPERC ID: 924]

* Brown, T., Foster, A., Gigiel, A. & Evans J. 2007. Combined cooking and cooling of foods using air cycle. In Proceedings; 2007 CIGR International Symposium on Food and Agricultural Products: Processing and Innovations.
Naples, Italy. 24-26 September. [FRPERC ID: 922]

Publications can be ordered via http://www.frperc.bris.ac.uk/home/pub/biblist.htm

New air conditioning reports in Europe and Asia

Products covered:
• Minisplits
• Windows and Moveables
• Large Packaged and Close Control
• Chillers
• Air Handling Units and Fan Coils
• Stock levels (minisplits) - selected countries only

Products covered:
• Residential/Light Commercial
• Unitary
• Chillers
• Air Handling Units and Fan Coils

Source: www.bsria.co.uk

New world studies for renewables

Products:
• Solar Thermal
• Heat Pumps
• Heat Recovery
• Domestic Biomass Boilers
• Solar Photovoltaic (PV) (2006 only)
• Micro-CHP (2006 only)

Countries published in 2007:

Heat Pumps: Australia, Austria*, Belgium, Canada, China, France*, Finland, Germany*, Ireland, Italy, Japan, Netherlands, New Zealand, Slovakia, Spain, Sweden, Switzerland*, UK*, USA

Solar Thermal: Austria, Belgium, China*, France*, Germany*, India, Italy*, Malaysia, Netherlands, Poland, Portugal*, Romania, Slovakia, South Africa, Spain*, Switzerland*, UK*, USA

Biomass: Austria*, Belgium, France*, Germany*, Italy, Poland, Slovakia, Switzerland*

Heat recovery: Germany, Switzerland, Austria, Denmark, Sweden, Finland, UK, France, Netherlands

Source: www.bsria.co.uk

Global study of AC/R compressors

The world market for AC&R (excluding transport) compressors compressors was estimated at around 286 million units and some US$ 21 billion in 2006, expected to increase to 343 million units by 2010. China and East Asia account for around 60 % of the world's overall production of AC&R compressors.

PRODUCTS AND COUNTRIES COVERED:
Products:
• Compressors

Countries/regions published in 2007:
Japan, China, East Asia, Europe, Americas

Source: www.bsria.co.uk

2008

ASHRAE Winter Meeting
19 - 23 January
New York, USA
http://www.ashrae.org

AHR Expo
22 - 24 January
New York, USA
http://www.ahrexpo.com

Sustainable Energy Week
28 January - 8 February
European Union
www.eusew.eu

Interclima
5 - 8 February
Paris, France

HVAC& R Japan
12 - 15 February
Tokyo, Japan

ACREX 2009
15 - 17 February
Bangalore, India
http://www.acrex.org.in/default.asp

Climate World – 2008
11 - 14 March
Moscow, Russia
International specialized HVAC exhibition
www.climatexpo.ru/eng

Mostra Convegno
11 - 15 March
Milan, Italy
http://www.mcexpocomfort.it/aspx/ShowFolder.aspx?idFolder=100

IIAR 2008 Ammonia Refrigeration Conference & Exhibition
16 - 19 March
International Institute of Ammonia Refrigeration
Colorado Springs, USA
www.iiar.org/cfp/cfp06.cfm?CFID=721129&CFTOKEN=12878787

4th International Conference on Cryogenics – ICCR'2008
1 – 2 April
Zhang Peng, China
E-mail: zhangp @ sjtu.edu.cn

Nordbygg 2008
1 – 4 April
Stockholm, Sweden
Northern Europe's most important meeting place for the construction industry
www.nordbygg.se

China Refrigeration Expo
9 – 11 April
Shanghai, China
Quality trade fair serving the HVAC&R industry
www.cr-expo.com/Crexpo/en2008

ARBS Exhibition 2008
21 – 23 April
Melbourne, Australia
AIR CONDITIONING – REFRIGERATION – BUILDING SERVICES
http://www.arbs.com.au

ISK SODEX 2008
8 - 11 May
Istanbul, Turkey
The exhibition displays the latest developments and state of the art technologies in heating, cooling and air-conditioning.
http://www.biztradeshows.com/trade-events/isk-sodex.html

IEA HPP 9th Conference
20 - 22 May
Switzerland
www.hpc2008.org

ASHRAE Annual Meeting
21 - 25 June
Salt Lake City, UT, USA
http://www.ashrae.org

HVAC Asia 2008
2 - 4 July
Singapore
www.hqlink.com

For more events, check out the heat pump centre website, www.heatpumpcentre.org

In the next Issue

Air Source Heat Pumps

Volume 26 - No. 1/2008

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 worldwide source of independent information and expertise on environmental and energy conservation benefits of heat pumping technologies (including refrigeration and air conditioning).

The Programme conducts high value international collaborative activities to improve energy effi ciency and minimise adverse environmental impact.

Mission

The Programme strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefi ts from these technologies. It serves policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers.

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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