IN THIS ISSUE:

IEA HEAT PUMP CENTRE

NEWSLETTER
VOL. 31
NO. 4/2013

Heat pumps for cold climates

Heat Pumps - A key technology for the future

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 31 - No. 4/2013

In this issue

Heat Pump Centre Newsletter, 4/2013
The market for heat pumps is growing. However, heat pump sales in cold climate areas have been more limited, especially air-source heat pumps (ASHPs). This is partly due to competition from other types of heating, but it is also due to the ASHPs' loss of heating capacity and efficiency at low outdoor temperatures. Ground source heat pump systems, that use the warmer ground as a heat source, are popular in some regions, but costumer acceptance is limited by the relatively high cost for installation of the ground heat exchanger. If ASHP systems with better performance at low outdoor temperature would be available, this would lead to more widespread use of heat pumps in the cold areas that today, to a large extent, rely on fossil fuels for heating.

The topic of this issue of the HPC Newsletter is *Heat pumps for cold climates*. After a background in the Foreword, you will find two technical presentations, one on inhibition of growth of frost crystals on heat exchangers, and one on an improved compressor for heat pump water heaters in cold climates. Non-topical articles in this issue include the second part of the review article on refrigeration charge reduction, as well as an overview of the European Heat Pump Summit Symposium. Further, we are given a market report from South Korea.

Enjoy your reading!

Johan Berg, Editor

Heat pump news

Regulars

Topical articles

Non-topical articles

COLOPHON

Published by IEA Heat Pump Centre
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Publisher:
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PO Box 857, S-501 15 BORAS
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Tel: +46-10-516 55 12
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

Editor in chief: Monica Axell
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Language editing: Angloscan Ltd.

IEA OECD heat pump centre

Foreword

Air-Source Heat Pumps for Cold Climate Applications

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The market adoption of heat pumps has been growing, particularly in temperate climate regions. However, heat pump sales in colder climate areas, especially for air-source heat pumps (ASHPs), have been more limited for several reasons. Some have to do with local market characteristics like competition from other heating systems, such as natural gas furnaces or boilers, where gas is widely available. For ASHPs, there is also the technical issue of the loss of heating capacity and efficiency at low outdoor temperatures. The capacity loss is especially significant since most ASHP systems rely on electric resistance back up heating when their heating capacity falls below the house heating demand, resulting in low seasonal efficiency (e.g. SPF). Ground source heat pump (GSHP) systems successfully overcome the capacity loss problem by using the warmer ground as a heat source and have achieved some market success in cold climate regions, but the need for installation of a ground heat exchanger (GHX) and its relatively high cost are issues impacting their wider acceptance. Availability of ASHP systems with improved low ambient performance would help bring about a much stronger heat pump market presence in cold areas that today rely predominantly on fossil fuel heating systems.

Interest in heat pumps for cold climate applications goes back many years. In the mid-1970s in the US, following the first oil embargo, heat pumps became of great interest to northern US electric power companies where heating season peak electric demands increased sharply due to increased usage of direct electric heating. ASHPs were of primary interest as an electrical heating system alternative at that time. But the aforementioned loss in heating capacity and reliance on direct electric back up heat limited their peak electric demand reduction potential and their acceptance in areas that experience large numbers of hours at cold temperatures. Considerable R&D activity has been undertaken in the US, Japan, and other countries to improve the performance of ASHPs from the late 1970s and 1980s through the early 2000s, resulting in more efficient, reliable, and more competitive ASHPs for cold climate applications.

With increasing concern for technology options that can result in reduced CO_2 emissions and continuously changing market realities, governments and companies in Europe, the Far East, and North America are revisiting the prior R&D studies to examine newer ASHP capacity and efficiency improvement solutions that could lead to expanded usage of electric heat pumps in cold regions. Accordingly the IEA Heat Pump Programme has initiated Annex 41 (Cold Climate Heat Pumps) with participation by Austria, Japan, and the USA to share information on these R&D efforts. Primary technical objectives of the Annex are to define pathways to limit heating capacity loss at -25 °C to ≤ 25 % vs. nominal rated capacity at 8.3 °C and achieve an "in field" heating $SPF_h \geq 2.63$ (HSPF ≥ 9.0 Btu/Wh).

Articles in this issue examine some of the new cold climate heat pump R&D activities underway. These include two studies from Japan which are part of their contribution to Annex 41. R&D issues of interest in Canada are the focus of the non-topical article in coming Heat Pump Centre Newsletter.

Column

Heat Pump Technology and Next-Generation Refrigerants

Tetsuro Kishimoto
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Japan

Environmental issues such as global warming prevention have become, and are becoming, increasingly important on a global scale. The rise in CO_2 emissions from burning fossil fuels is recognised as one of the causes of climate change. As a means of solving these problems, high hopes have been placed on heat pump technology in recent years. In fact, heat pump technology is internationally accepted as one of the solutions to energy and environmental issues.

Heat pump technology transfers heat from a low temperature source to a higher temperature sink, and is employed in different applications depending on the temperature of the heat to be utilized, such as water heaters or space heating systems that utilize 'warm heat' (high-temperature heat), as well as refrigeration equipment and space cooling that utilize 'cold heat' (low-temperature heat). As it is able to deliver more output thermal energy than the input drive energy, a heat pump is superb in energy saving, and thus is highly expected to play a key role in preventing global warming and promoting an effective use of energy.

A heat pump abstracts heat from a low-temperature location and pumps it to a higher temperature location, so it is not a device such as an electric heater that transforms electricity into heat. By transferring unused low-temperature heat, such as heat in the atmosphere, waste heat from rivers, seas, households or factories, which is available anywhere around us and of which the utility value is low, to a higher temperature area, a heat pump can utilize heat efficiently, thereby being called an excellent energy-saving technology.

For use in water heaters or space heating, compared with a device in which heat is created by burning fossil fuels, a heat pump has higher energy efficiency, and with no CO_2 emitted from itself, heat pumps can substantially reduce greenhouse gas emissions.

Heat pump technology is now in the spotlight, although it is not a new technology at all. Its principle is based on a theory proposed by France's Nicolas Carnot in 1824. Although it has been known for more than 100 years, practical and highly efficient machines had not been developed until recently due to immature manufacturing techniques. But, at the beginning of the 20th century, heat pumps at last entered a new stage thanks to discovery of new materials and significant progress in component technologies.

The majority of heat pumps use fluorocarbons as refrigerant. When fluorocarbons were discovered, they were called one of the most important materials discovered in the 20th century, since they had ideal properties as a refrigerant. Then they were found first to have destroyed the ozone layer, and more recently have been identified as having a major impact on global warming. As a result, production and use of fluorocarbons are restricted or banned in many countries. For these problems to be solved, there is an urgent need to develop next-generation refrigerants with less effect on global warming.

Meanwhile, to decrease the effects of fluorocarbons on global warming, the use of refrigerants with a high GWP, and their emissions into the atmosphere, should be reduced. In the EU, for example, the F-Gas Regulations control maintenance, refilling, disposal and labelling of equipment containing more than a specified amount of refrigerant, and the MAC Directive bans, from 2017, the use of refrigerants with GWP of 150 or more for air conditioners in new vehicles placed on the EU market.

Continue on next page

In Japan, the bill for the Act for Rationalized Use and Proper Management of Fluorocarbons passed the Diet (the Japanese Parliament) in June 2013, and implementing measures are being considered which require periodic checking for leakage and facilitate the conversion to refrigerants with a low GWP.

Evaluation of next-generation refrigerants should consider not only GWP, but also include comprehensive assessment of GWP, safety, LCCP index, etc. The LCCP index is calculated taking into account both direct and indirect emissions. Direct emissions include CO_2 emissions resulting from the manufacture of refrigerant and equipment, plus refrigerant leaks during use and disposal of equipment. Indirect emissions are those released from energy that is used to operate the equipment.

The air conditioning and refrigeration industry has investigated the use of natural refrigerants, such as H_2O, air, NH_3, CO_2 and HC. These refrigerants pose many problems in terms of safety, such as flammability, and also performance when they are used for air conditioning and refrigeration equipment, and so their use is limited to specific niche applications of such equipment. HC refrigerants, in particular, are liable to cause explosions if they leak and are ignited, creating the possibility of a serious accident. Consequently, we think HCs should not generally be used.

Several kinds of next-generation refrigerants have been developed and presented so far. They all have a low GWP, but each has its drawbacks; such as, for example, being slightly flammable or requiring to be used at high pressure. Nevertheless, we shall need to use these refrigerants in some way in an effort to prevent global warming, one of the big challenges facing our industry.

IEA Heat Pump Programme News

Strong technical content confirmed for the 11th IEA Heat Pump Conference

The 11th IEA Heat Pump Conference will take place in Montréal from May 12-16, 2014. This unique forum promises to highlight the state of the international heat pump and refrigeration industry with reports on technology components, research, emerging technology, applications, markets, and much more.

As previously announced, over 300 abstracts were submitted from 32 countries. On November 12th, regional coordinators met in Tokyo to finalize the conference program. In total, 52 proposals were retained for oral presentations in addition to 8 topical keynote addresses. The original program was designed to accommodate two parallel tracks over three days.

In addition to the core conference oral presentations, over 200 posters will be sequentially presented over the three days throughout the exhibition area where all the conference social gatherings will take place. Past experiences show that poster sessions are extremely popular among participants as they engage in vibrant and passionate discussions.

Oral presentations and posters all have to be supported by a formal paper of up to 12 pages. Full papers will be published in the conference proceedings and distributed free of charge to conference participants.

Prior to the conference itself, on May 12, a number of the IEA Heat Pump Programme Annexes will also hold a half-day or full day workshop. Registrants to the conference will have full access to the Annexes workshops as part of their registration. By mid-December, a preliminary program, including description of the Annexes' workshops, will be available on the conference website at www.iea-hpc2014.org.

The registration for the conference is open and it is now possible to register at the early bird rate. The National Organizing Committee (NOC) also invites delegate to book their room at the Fairmont Queen Elizabeth as early as possible if they wish to stay at the conference location. Conference registration and hotel reservation instructions are available on the conference website.

The NOC also recommends to potential exhibitors to reserve their booths now in order to secure the best locations. The sponsorship and exhibition package is also available via the conference website.

Heat Pump Programme seeks candidates for Rittinger award

The IEA Heat Pump Programme is announcing that nominations are being sought for the Peter Ritter von Rittinger award.

This award, presented for the first time at the IEA International Heat Pump Conference in 2005, is awarded to deserving individuals or teams who have achieved distinction in the advancement of heat pumping technologies, applications, market development and management or organization of activities with lasting international impact.

The award is named for Peter Ritter von Rittinger, an Austrian engineer who is credited with design and installation of the first practical heat pump system at a salt works in Upper Austria in 1856.

The awards will be presented at the International Heat Pump Conference 2014, which will be held in Montreal, Canada in May 2014. The deadline for nominations is the **1st of March** 2014.

For full information on the award selection guidelines and nomination applications, see www.heatpumpcentre.org/en/hppactivities/rittingeraward/Sidor/default.aspx

General

ASHRAE/IES publish 90.1-2013 Energy Standard

Major changes to requirements regarding the building envelope, lighting, mechanical and the energy cost budget are contained in the newly published energy standard from ASHRAE and IES.

ANSI/ASHRAE/IES Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings, incorporates 110 addenda, reflecting changes made through the public review process.

"While many things have changed since the first version of Standard 90 was published in 1975, the need to reduce building energy use and cost has not," Steve Skalko, Chair of the committee that wrote the 2013 standard, said. "This standard represents many advances over the 2010 standard, as we worked toward our goal of making the standard 40 to 50 percent more stringent than the 2004 standard."

Significant changes include requirements for higher equipment efficiencies for heat pumps, packaged terminal air conditioners, single-package vertical heat pumps, air conditioners and evaporative condensers.

Source: www.ashrae.org

Osaka Gas passes sale of 100 000 residential gas cogeneration systems

Osaka Gas announced that, as of August 6, its cumulative sales of residential gas cogeneration systems reached 100 000 units including orders received. Osaka Gas is the first company to attain sales of 100 000 cumulative units. In March 2003, Osaka Gas began selling the Ecowill, a residential cogeneration system that generates electricity by driving a gas engine with natural gas for gas power generation, water heating, and space heating. In June 2009, the company began selling the Ene-Farm system, which is a residential fuel cell cogeneration system that generates electricity by extracting hydrogen from natural gas for reaction with oxygen in the air.

Source: www.ejarn.com

EU: Van Rompuy flags two million buildings efficiency jobs by 2020

The president of the European Council, Herman Van Rompuy, has called for a strategy to provide long-term emissions-cutting and money-saving major renovations of Europe's ageing building stock, saying that it could create two million jobs.

Van Rompuy used a video address to tell a conference that EU regulations requiring new properties to have zero net carbon emissions by the next decade are not enough. "Renovating existing buildings is also essential because 90 % of them are here to stay," he said.

The unusually forthright speech from an EU Council president known for his measured and unassuming approach, was hailed as "a strong statement by a strong player" by one former EU energy policy architect.

Source: www.euractiv.com

Efficiency lags behind in EU's triple energy target

Only four EU countries are on course to meet their energy efficiency target for 2020, while the Union is broadly on track to meet its renewable energy and greenhouse gas emissions reduction goals, the European Environment Agency says in a new report.

In the report released in October, the EEA provides an overview of progress on the EU's energy objectives for the year 2020.

These targets, also called the '20/20/20 targets', include a 20 % reduction in greenhouse gas emissions, a 20 %

rise in the amount of energy provided by renewable resources, and 20 % more efficiency in energy use across the EU.
The EEA report paints a more complex picture at the member state level. Not a single country is on track to meet all three targets at the same time, but none is lagging behind on all three targets at once either.
Source: www.euractiv.com

Policy

IEA: Treat energy efficiency as 'world's first fuel'

Global energy saving investments - and their effects on energy demand - are now equal to the net contribution of other fuel sources, the International Energy Agency (IEA) said on 16 October, as it launched its inaugural Energy Efficiency Market Report.
The IEA valued worldwide energy efficiency investments in 2011 at $300 billion, on a par with global funding of renewable energy and fossil fuel power sources.
"Energy efficiency has been called a 'hidden fuel', yet it is hiding in plain sight," said the IEA's executive director Maria van der Hoeven, at a presentation for the paper in Korea. "Indeed, the degree of global investment in energy efficiency and the resulting energy savings are so massive that they beg the following question: Is energy efficiency not just a hidden fuel but rather the world's first fuel?" she asked.
Source: www.euractiv.com

Can a big automaker negate EU's MAC Directive?

At the end of August 2013, France's highest administrative court temporarily suspended the ban on German automaker Daimler's sales of Mercedes-Benz vehicles that use Rl34a-based air conditioning systems. With this ruling, Mercedes-Benz vehicles equipped with R134a refrigerant may currently be registered and sold in France. While Rl34a refrigerant is permitted in mobile air conditioners in Japan and the United States, as of January 2013 sales of new vehicles with air conditioners that use refrigerant with a global warming potential (GWP) of more than 150 are banned in the EU.
Source: JARN, October 25, 2013

Correction
The news item "Energy Efficiency Standard for ATW heat pump to be enforced in China" in the previous issue of the HPC Newsletter (issue 3/2013, p. 6, under the "Policy" heading) did not contain the correct text.The editor regrets this mistake. The correct version of this news item is provided below.

Energy Efficiency Standard for ATW heat pump to be enforced in China

For many years, the lack of unified energy efficiency standard for air-to-water (ATW) products has led to quality issues caused by enterprises varying considerably in production capabilities. Recently, China General Administration of Quality Supervision, Inspection and Quarantine and China Standardization Administration have approved the release of GB 29541-2013 Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for ATW Heat Pump Water Heater, which was enforced on October 1, 2013.

Source: JARN, July 25, 2013

Working fluids

HFC phase-out stalls at Bangkok summit

Progress towards phasing out HFCs suffered a setback at the annual Montreal Protocol summit in Bangkok, which took place in October.
According to reports, India is opposed to the issue coming under the Montreal Protocol as proposed by the US, and wants to see it addressed under the Kyoto Protocol instead. The reasoning behind India's objection is that the Montreal Protocol was designed to phase out substances that are specifically ozone-depleting, which HFCs are not considered to be. The proposal submitted by the US is that HFCs should be monitored under the Montreal Protocol on the basis that they are a direct replacement for the previous ozone-damaging chemicals. The Kyoto Protocol would also see the responsibility rest on richer countries, with greater emissions of ozone-depleting gases.
However, other countries are of the opinion that the phase-out of HFCs in developing countries will be possible only through support from the Montreal Protocol's Multilateral Fund - which was established in 1991 to assist those countries in meeting their Montreal Protocol commitments.
Source: www.acr-news.com

Dupont and Daimler on Germany's Federal Motor Transport Authority's (KBA) final report

"KBA confirms once again that its testing has found no adequate evidence of a serious risk related to HFO-1234yf" said Thierry Vanlancker, President of DuPont Chemicals & Fluoroproducts, following publication of the final report on testing of HFO-1234yf by Germany's Federal Motor Transport Authority, the Kraftfahrt-Bundesamt (KBA).

"The KBA report proves our earlier statements that it is only under extreme testing conditions, that do not represent real-life crash scenarios, that the refrigerant could be made to ignite in a few instances. The results of the KBA testing confirm DuPont's high level of confidence that the refrigerant can be used safely in automotive air conditioning. This has been proven by years of cooperative testing conducted by automakers from around the world."

Daimler's stance since the results of the final KBA report has not changed. "Since the results of the final KBA report are the same as of the preliminary report," said a spokesman for Daimler, "it doesn't change our position at all." The KBA report states that the safety level of vehicles using R1234yf is poorer than that of vehicles using R134a, which doesn't match with the high safety requirements of Mercedes-Benz. "That's why we started the development of CO_2 air conditioning systems and we are putting a lot of effort into this."

Source: www.acr-news.com

HFC/HFO mixture: lower GWP without flammability

A recent study published in the International Journal of Refrigeration (IJR) by Inha University, South Korea, compared the performance of HCF134a, HFO1234yf and HFO1234yf/HFC134a mixtures at three concentrations of 5 %, 10 % and 15 % HFC134a with a heat pump bench tester.

When the mixture contains 10-11 % HFC134a, it is both virtually non-flammable and azeotropic and has no ODP and a GWP below 150, making it, with minor modifications, an environmentally friendlier and regulatory-compliant solution for various HFC134a applications.

Source: www.iifiir.org

Japan starts moving to R32

While the direction that the global air conditioner market will take in choosing next-generation alternative refrigerants is still uncertain, momentum in Japan to adopt R32 as the next-generation air conditioner refrigerant is visibly building. The debate over R32's mild flammability and environmental impact has been in progress for some time among air conditioner manufacturers in Japan, but they seem finally to have reached a consensus on adopting the refrigerant in their room air conditioners (RACs). Following Daikin 's product launch announcement last autumn, major manufacturers announced the launch of premium models that use R32 refrigerant for the Japanese market this autumn.

Source: JARN, October 25, 2013

COA fights counterfeit gases with new database

The Container Owners Association (COA) has created a database of refrigeration machinery repair / service companies around the world in an effort to reduce the likelihood of counterfeit refrigerants being used to service equipment.

In 2011, a number of incidents resulted in three deaths, and investigations concluded that the refrigeration machines involved had contained a gas other than the R134a refrigerant with which they were designed to operate, which had created explosive gases inside the system.

Source: www.acr-news.com

Natural refrigerant market trends at Atmosphere Europe

On October 15, 2013, the Atmosphere Europe Conference was held in Brussels. It brought together over 200 HVAC&R industry experts to discuss the latest natural refrigerant market trends, technology innovations and regulatory issues.

The shecco Head of Market Research, Nina Masson, presented exclusive figures from the latest market trends for natural refrigerants in Europe. The study showed that to date (2013) in Europe, 2881 CO_2 transcritical systems have been installed, a significant increase of 116 % compared to 2011 records of 1331 units. Based on 2013 data, the country with the most installations is Denmark (712), followed by the United Kingdom (441) and Germany (429), where the number of systems increased by almost 16 % since 2011. There were a total of 1568 CO_2 cascade systems combined with HFC systems installed in Europe, compared to only 16 CO_2 cascade systems with ammonia.

Worldwide, there are over 3050 transcritical CO_2 systems and 1950 cascade systems, European data included. The USA and Canada have respectively 5 and 43 transcritical systems, and 102 and 12 cascade systems. Japan has over 100 transcritical systems, but only four cascade systems. Australia has one transcritical system, but 160 cascade systems

Source: www.iifiir.org

Markets

World production of refrigerants

An analysis by the journal cci Zeitung (Germany) gives data on the maximum production capacity of the principal countries supplying refrigerants to the world market. China is listed as the international leader for R22 at 469 000 tons, followed by the United States at 134 000 tons. This compares with a world market total of 860 000 tons. For R134a, China leads with 120 000 tons, compared with the United States with 80 000 tons.

Source: JARN, September 25, 2013

China: major change in AC market

Over the last 20 years, China's air conditioning industry has been growing at the same high speed as China's economy. Market expansion has also caused tremendous changes in the market structure.
Recently, at the '2013 China Air Conditioning Industry Summit', jointly organised by the State Information Center and cheaa.com, air conditioner makers and component suppliers recalled the past decade of development.
According to the National Bureau of Statistics, China produced 48 million air conditioner units in 2004. By 2012, annual production volume exceeded 100 million units, with an average annual growth of 14 %, and accounted for 80 % of the global market. Data shows that China achieved a remarkable success of air conditioner exports between 2004 and 2013. In 2004, China exported 22 million units of air conditioners, with the number almost doubling by 2012 to more than 43 million units.
Source: JARN, October 25, 2013

Europe: 3rd quarter 2013 HVAC-R market trends

Eurovent Market Intelligence (EMI) has just released the latest trends for the European HVAC&R market along with the trend for 2014.
Source: www.iifiir.org

Europe: "Heat pump implementation scenarios" released

The study "Heat pump implementation scenarios until 2030" covers the eight major European heat pump markets. The aim of this study is to quantify the potential of heat pumps to reduce CO_2 emissions from the EU's building sector until 2030, and to assess related impacts on energy use, investments, energy costs and the necessary supply of refrigerants. Three scenarios are presented, all comprising the same very ambitious energy efficiency measures on the demand side, but with different implementation shares for heat pumps on the supply side. In the scenario with the highest heat pump implementation share ("HP++"), overall CO_2 emissions for heating, cooling, hot water and auxiliary energy in buildings can be reduced by 47 % from 2012 until 2030. Thomas Boermans, Ecofys, explains "The EU sectoral target of 88-91 % less emissions by 2050 in the built environment in Europe will not be met without the contribution of heat pumps".
Source: www.ehpa.org

Financing: New EIB lending criteria for geothermal projects

As noted in the EGEC Policy Paper on Financing Geothermal Energy, public institutions' support in this difficult time of financial crisis and low levels of liquidity is key to attracting private investors, particularly for a technology requiring high upfront costs.

The European Investment Bank is intended to play an active role in implementing EU policies, including the 2020 energy and climate package and the long-term decarbonisation objective. In this regard, in July 2013 the Bank officially approved the new Screening and Assessment Criteria for Energy Projects. Conventional geothermal electricity and geothermal district heating fall under the category of 'Mature technology', and are eligible for EIB funding within and outside the EU.
Source: http://egec.info

World Air Conditioning future

Looking at a possible world future scenario for air conditioning, Michael Sivak at the University of Michigan calculates that if developing countries adopted the same summer comfort standards as the United States, global energy demand could theoretically rise to 50 times as much as the United States uses at the moment. His analysis looked at eight countries including China, India and the Philippines: for example, he finds that if the city of Mumbai in India developed its full potential for air conditioning it would need a quarter of the current energy demand for the whole of the United States. The trends are already there: in India for example the growth of air conditioning is already at 20 % per year.
Source: www.ejarn.com

HVACR Manufacturers prospects for 2014

HVACR manufacturers are optimistic about business prospects for the coming year, according to an ASHRAE/AHR Expo survey sent to more than 1,000 manufacturers worldwide. Seventy-nine percent of respondents said their prospects for business in 2014 were either excellent (19 percent) or good (60 percent). The remaining 21 percent of the respondents said prospects were fair.
These results reflect a significant improvement over last year's survey that found 70 percent of respondents expecting the economy to be better in 2013 than 2012, with 3 percent predicting it would be worse. No one responding to this year's survey felt economic prospects would worsen in 2014.
In keeping with this positive outlook for next year, 90 percent of the HVACR manufacturers believe sales will increase, with 32 percent expecting sales increases of more than 10 percent. Thirty-one percent forecast sales increases between 5 percent and 10 percent, and 27 percent expect increases of less than 5 percent. Ten percent believe sales will remain the same, while no one predicts sales will decrease. This year's survey registered a 4 percent jump over last year when 86 percent of the respondents forecasted sales would increase and 3 percent expected sales to decrease.
Source: www.achrnews.com

The heat pump market and its potential in Korea

Minsung Kim, Gilbong Lee, Bong-Joo Shin
Korea

This article describes the Korean market for heat pumps. Although growing steadily, the market share is less than that of other countries. However, heat pumps have been treated as support for technology developments, and so the market potential of heat pumps in Korea is very high.

Introduction

The heat pump is a device to transfer low-temperature heat to a high-temperature heat sink, so the delivered heat is sum of the low-temperature heat and the drive energy. This means that heat pumps can deliver useful heat from waste heat with the output temperature higher than the input temperature. According to the IEA/HPP report, heat pumps can reduce CO_2 emissions from the building sector by 50 %, and by 5 % from the industrial sector. The European Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC, RES Directive) recognises energy delivered by heat pumps from air, water and the ground as renewable energy. The European Strategic Energy Technology plan (SET-2020) aims to produce 20 % of energy supply from heat pumps. The application of heat pumps is spreading into houses, offices, buildings, factories, and so on.

Market trend

Due to its high energy-saving potential, the global heat pump market has grown rapidly in recent years. Japan is one of the leading nations in the market, with a 95 % share in its domestic air conditioner market. With such a strong domestic market, Japan has led with heat pump technologies such as VRF, inverter systems, cold climate systems, domestic hot water heating and so on. Europe considers heat pumps as important solutions in reducing green house gas emissions, and recommends installation of them not only in new houses but also in existing houses.

Year	*Cooling only*	*Heat pumps*
2005	1494	42
2006	1495	45
2007	1138	52
2008	1261	65
2009	1025	89
2010	1224	157

Table 1. Shipment of residential air-to-air heat pumps and cooling-only air conditioners (thousand units). [Source: KEMCO 2011 Report]

Korea lags behind in heat pump market development. Table 1 shows the shipments of residential cooling-only air conditioners and heat pumps. As of 2010, compared to the 1.224 million cooling-only units, only 0.157 million heat pumps were sold for other applications, amounting to an 11 % market share.

Various market features have contributed to the low share of heat pumps. This report briefly reviews two unique features of the Korean market: high penetration of natural gas, and low energy prices. In 2010, the nationwide penetration rate of natural gas in the residential sector was 72.2 %. The Seoul Special City, which is the capital and largest metropolis of Korea, had a 92.3 % penetration rate. Other major cities also have penetration rates approaching 90 %. These high numbers reflect the fact that almost every resident in the city uses natural gas, either for heating or cooling – with boilers, rather than heat pumps, taking by far the largest share.

Table 2 shows the retail energy prices of natural gas and electricity from IEA 2012 Key World Energy Statistics.

Retail prices ($)	*Finland*	*Germany*	*Ireland*	*Korea*	*New Zealand*	*Poland*	*Spain*	*United Kingdom*
Nat. gas for industry (MWh), GCV	45.19	54.37	43.91	60.21	23.76	42.57	37.72	35.51
Nat. gas for consumers (MWh), GCV	62.18	92.63	80.65	64.98	102.43	72.2	89.27	64.84
Electricity for industry (MWh)	113.64	157.23	152.39	(61.94)	73.72	121.77	148.77	127.39
Electricity for domestic consumers (MWh)	213.61	351.95	259.47	88.64	212.1	198.5	295.31	204.92

Table 2. The retail prices of natural gas and electricity in OECD countries [Source: IEA 2012 Key World Energy Statistics]

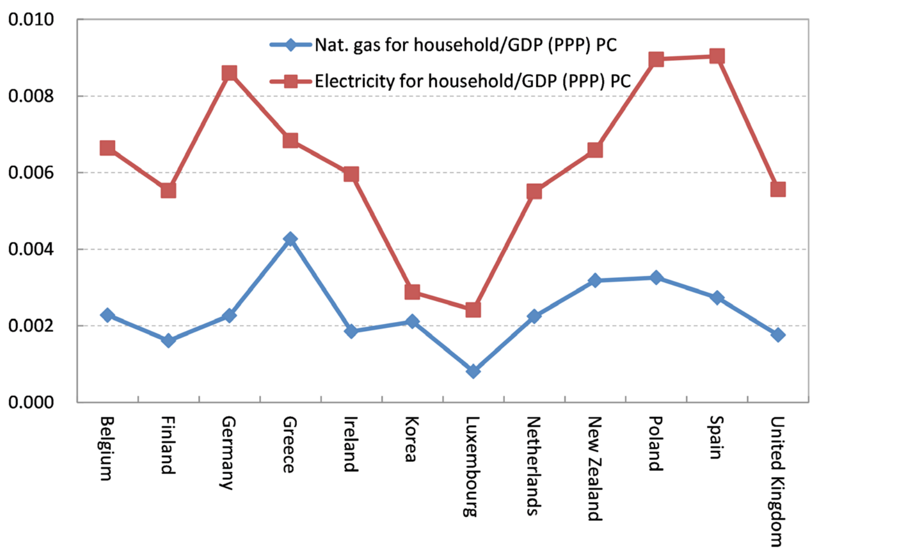

Figure 1. The retail prices of natural gas and electricity for domestic consumers divided by GDP (PPP) per capita. [Source: IEA 2012 Key World Energy Statistics]

Figure 2. High efficiency ATW(air-to-water) heat pump system for residential application

Among the selected OECD countries, Korea has the lowest energy prices, even considering the GPD (PPP) per capita (Figure 1). The price of electricity for domestic consumers is, for example, only 43 % of that paid by UK domestic consumers. Low energy prices make customers more sensitive to the initial cost than to the running cost. Due to Korea's preference for floor heating, boilers are typically installed in houses for domestic hot water production. Since boilers are far cheaper than water-heating heat pumps, the payback time of a heat pump is longer than in other countries. In addition, heat pumps are usually regarded as appliances, in the same way as are air conditioners. This makes it more difficult for the concept of payback to be considered by customers.

Strategy

Despite the adverse market conditions for heat pumps, there is no doubt that they are energy-saving devices and one of the promising solutions for tackling energy problems. The Korean government supports measures to improve energy efficiency and the use of new renewable energy sources because it considers them as key players to achieve its goal of Green Growth with Low CO_2. On the government's road map to Green Energy, heat pumps were selected as one of the 15 green energy sectors to increase energy efficiency. KETEP (Korea Institute Energy Technology Evaluation and Planning) selected four heat pump systems in its Green Energy Strategy Road Map 2011, and has supported their technical development, which it hopes will create a new heat pump market in Korea. These heat pumps are "Unified heat pump system of refrigerator, air conditioner and freezer", "High efficiency mid-scale ATW (air-to-water) heat pump system" (Figure 2), "Mid-scale multi-stage heat pump system for hot water generation", and "Heat pump combined with latent heat storage".

Conclusions

This report has briefly described market trends, features and government strategies. Since there is a need to replace the current gas-fired domestic hot water boiler systems, Korea has a great market potential for heat pumps. Although some features of the Korean market make it difficult for heat pumps to obtain significant residential market shares in the near future, they could find more favourable conditions in the commercial and industrial markets instead. The major heat pump manufacturers (LG Electronics and Samsung Electronics) have achieved high export sales in spite of their weak domestic market. Many R&D projects are in progress to generate new heat pump markets and develop future technologies. These factors mean that the heat pump technology level of Korean manufacturers is up to the top tiers. If there are proper strategies, the market will grow in Korea.

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Ongoing Annexes

IEA HPP Annex 35 / IETS Annex 13 Application of Industrial Heat Pumps

The Annex 35, a joint venture of the IEA Implementing Agreements "Industrial Energy-related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP), organised its second Annex meeting 2013, again in connection with the European Heat Pump Summit 2013 on Monday, October 14 at the Exhibition Centre Nürnberg/Germany. The meeting was attended by 15 participants from 8 countries.

The following main themes were discussed:

- The status and content of the report of task 2 "Modeling calculation and economic models", in particular overview of software for the process integration of industrial heat pumps, principles for the integration of heat pumps in industry and a database of information of industrial heat pumps and their performance figures, still in an early stage of development.
- Task 5 "Communication and presentation of the Annex reports and results". There are presently no direct contributions. An Annex 35/13 webside should be used for the publication of the task reports as well as all other information, publications, reports and minutes of the meetings. As one possible solution the homepages of the IEA HPC and IEA IETS should be used.

The annex expires on April 30 2014. As the next IEA Heat Pump Conference will take place on May 12-16, 2014 in Montreal, Canada, it has been decided to organize a final Annex 35 Workshop on the May 12 in Montreal. One-page abstracts with title and author(s) were requested not later than November 30, 2013.

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IEA HPP Annex 36 Quality Installation / Quality Maintenance Sensitivity Studies

Annex 36 is evaluating how installation and/or maintenance deficiencies cause heat pumps to perform inefficiently (i.e., decreased efficiency and/or capacity). On 10 – 11 October 2013, the Annex 36 Participants (France, Sweden, United Kingdom, United States) held their third annual meeting to review progress and to finalize details for concluding all annex-related activities. The meeting took place at the Electricité de France (EdF) R&D facility Site des Renardieres near Moret sur Loing, France.

Presentations from each of the Annex Participants summarized their field survey, laboratory analysis, and/or modeling simulations to date:

- ***France*** –The EdF-led effort is in four independent areas of interest:

    a. Literature study aimed at determining the satisfaction level of heat pump end users.

    b. Field analysis of an in-situ heat pump to explore how various attributes impact COP.

    c. Sensitivity analysis of refrigerant charge, low voltage, and clogged indoor/outdoor exchangers on air-to-air heat pump performance.

    d. In-situ field trials, and subsequent modification for an European market, of an advanced thermodynamic water heater (or heat pump water heater, HPWH) using CO_2.

- ***Sweden*** – The effort being championed by Royal Institute of Technology (KTH) is aimed at:

  a. The development of a heat pump smart fault detection and diagnosis system.

  b. A summary of Swedish insurance company heat pump service cost statistics.

  The work being led by the Technical Research Institute of Sweden (SP) focuses on three projects:

  1. Operation and maintenance (O&M) of refrigeration and heat pump systems in multifamily buildings.

  2. A review of 1980's R&D results for large heat pump systems.

  3. A study on improved heat pump reliability funded by insurance companies.

- ***United Kingdom*** –The Department of Energy and Climate Change (DECC) residentially-focused effort includes:

  a. Reporting on two years of heat pump field trials (before and after upgrades/ repairs to some of the test systems).

  b. A number of laboratory test programs.

  c. Recent improvements made to their national heat pump sizing and installation standards (mainly arising from results of the field study).

- ***United States*** –The work being advanced by the National Institute of Standards & Technology (NIST) centers on a sensitivity analyses for a wide range of heat pump installation or maintenance faults (e.g., refrigerant charge, indoor coil airflow, leaky ducts, heat pump sizing, electric voltage, etc.) – both single fault analyses and multiple-fault analyses. The underlying laboratory and modeling project combines building effects, equipment effects, and climate effects to evaluate the impact of the faults on seasonal energy consumption of a residential air-to-air, centrally-ducted heat pump through seasonal simulations of the house/ heat pump system.

During the two-day meetings, four of the seven EdF laboratories were visited:

» "Smart Energy House" Test Building: Constructed to be representative of a typical French single-family home built to 1980s French building standards. It has been used to evaluate a number of different home HVAC and water heating (WH) systems. Currently it has an inverter driven air-to-water heat pump (9 kW nominal capacity) connected to individual room radiators for apace heat distribution. Geothermal systems are among the HVAC options tested in past years.

» CLIMATRON Lab: Includes several climate-controlled test chambers used for heat pump systems.

Annex 36 Attendees (from left to right): Kristin Larsson (SP), Jean-Marc Lebreton (EdF), Oliver Sutton (DECC), Hatef Madani (KTH), Glenn Hourahan (ACCA), Van Baxter (ORNL), and Jan-Erik Nowacki (KTH)

Testing can be conducted for outdoor ambient conditions of -15 °C to >45 °C and for systems of up to 300 kW capacity (cooling).

» Concept Smart Grid: It includes a small "neighborhood" of several test homes, a battery storage test facility, and a facility that emulates a 120 km distribution grid. Among the R&D activities they have undertaken are tests of the impact of heat pump start/stop on the grid, impact of variable frequency drives, impact of large scale short circuits on a real grid, etc.

» Building Envelope and Solar Technologies Laboratory: A building with six independent test cells with a removable wall on the first floor and six more cells in the attic with a removable roof. The cells and the BEST Lab are designed so that only the removable section (with the envelope system to be tested) is exposed to outdoor ambient conditions. One system currently on test is a heat pump integrated with the wall facade.

The final results from effort are to be presented at a workshop to be held in conjunction with the upcoming 11th IEA Heat Pump Conference (Montreal, Quebec, Canada; 12 – 16 May 2014).

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IEA HPP Annex 38 Solar and heat pump systems

The objective of Annex 38 of the Heat Pump Programme, which is also Task 44 of the Solar Heating and Cooling Programme of the IEA, is the assessment of the performances and the relevance of combined systems using solar thermal collectors and heat pumps.

Task 44 investigates the main parameters that influence the performances of hybrid solar and heat pump systems. This work in progress shows that the following criteria should be carefully considered when designing a solar and heat pump system:

- Simplicity of hydraulics configuration
- Parallel configuration rather than more complex systems
- Serial configuration if control is optimally implemented
- Connection to the tank in proper locations
- Temperature sensors in the tank at the correct height
- Return temperatures to the tank (always as low as possible)

Other parameters can also have a large influence, especially if they are not adequately designed from the beginning (for example, flow rates or capacity of heat exchangers).

Task 44 will provide more insights into these parameters in all final reports that will be available at the beginning of 2014.

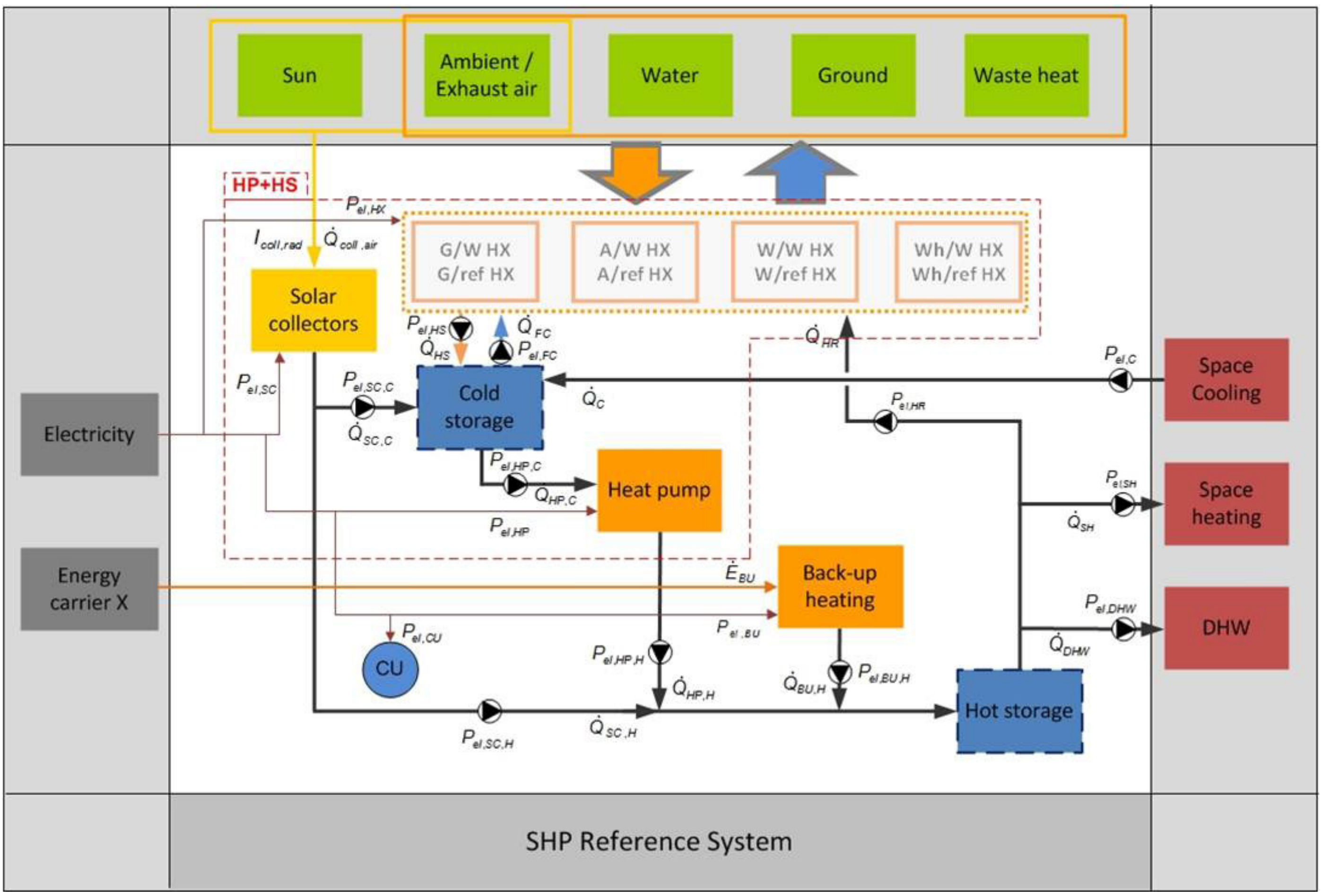
Meeting #8 was held in October 23-25 in Switzerland just prior to Exco meetings. This meeting was mainly devoted to the review of the Task final handbook and the final reports.

Annex 38 has progressed as follows:

1. All chapters of the handbook have been revised. The handbook is planned to be publically available through the editor Wiley-VCH by September 2014.

2. Simulation results with the common framework developed in 2010-2011 have been delivered for ten projects. First comparisons were made during the meeting and showed large influences on Seasonal Performance Factors of key parameters, but also usually neglected devices such as circulating pump and controllers always on.

Annex 38 Attendees at the recent meeting in Switzerland



Annex 38 - In calculating a SPF (seasonal performance factor) the auxiliary pumps are to be considered

3. All reports have been prepared and are in the process of validation, and they will be available from December 2013 to March 2014 on the web site.

Reports A1 (survey of solar heat pump systems on the market), C1 (simulation framework and boundary conditions), C2 (component models for simulation of solar and heat pump systems) are available at the end of 2013 on the Annex web site; further, three industry newsletters are available from Subtask D. All reports can be found on: http://task44.iea-shc.org/

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IEA HPP Annex 39 A common method for testing and rating of residential HP and AC annual / seasonal performance

In the Annex 39 project, the fifth work meeting was held in conjunction with the ExCo meeting in Tokyo, Japan, November 12.

The meeting gathered 12 experts from seven countries. Among the topics most discussed during the meeting was the fact that more and more regional interpretations and calculation models are showing up to account for climatic conditions in the specific regions. The task of this annex is therefore not to find one true, global methodology for the calculation of seasonal/annual performance, but rather to align and make the different models comparable in a transparent way. The second aim of the project is also to propose changes in existing test standards, so that the same test points could be used for numerous different calculations in the future. This would substantially cut manufacturers' costs for independent lab testing.

Finally, different alternative measures to analyse heat pump performance was discussed in the meeting. It was concluded that depending on the target group for communication, different measures/ key numbers should be used. For example, foe end users, energy savings and cost savings are the most important aspects when choosing between heat pumps and other heating alternatives, while for policy makers, abated CO_2 emissions or primary energy use could be much more important. The Annex participants will spend the remaining time of the project on developing these measures in a way that is acceptable for all participating countries.

At the upcoming IEA HPP conference in Montreal next year, Annex 39 will hold a half-day workshop to disseminate results acquired during this project.

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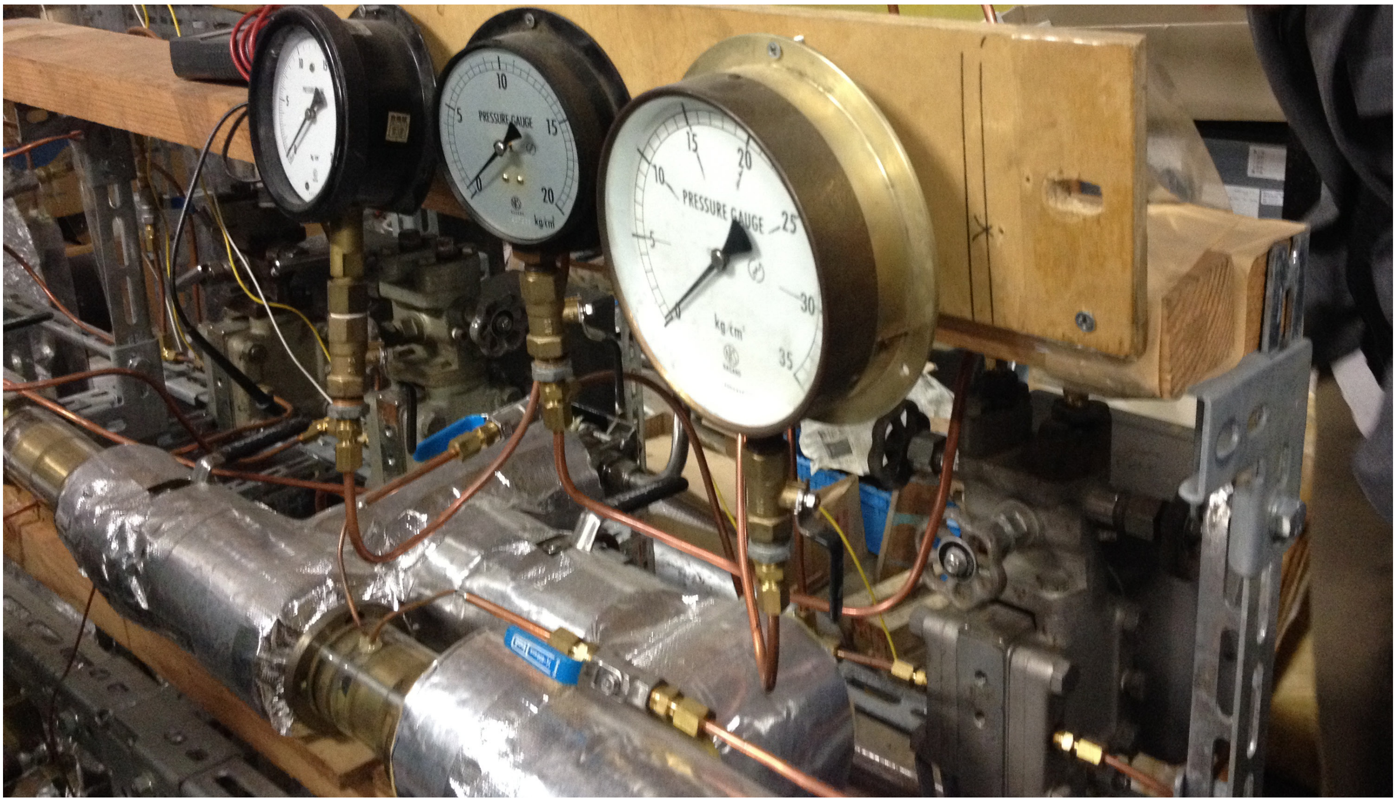

Figure 1. Monitoring equipment at one lab research station at the Waseda University lab, where the project team was invited by the host, Prof Saito.

Figure 2. Meeting participants preparing for the meeting, which was held in Waseda University, Tokyo.

Figure 3. Waseda university campus main building.

Attendees of the 3rd IEA HPP Annex 40 working meeting at TNO in Delft in October 2013

IEA HPP Annex 40 Heat pump concepts for Nearly Zero Energy Buildings

IEA HPP Annex 40 is to investigate and improve heat pump concepts applied in Nearly or Net Zero Energy Buildings (nZEB). The countries CH, JP, NL, NO, SE and US attended the 3rd Annex 40 working meeting at TNO in Delft. The countries CA and DE intend to join the Annex 40 soon and also joined the working meeting.

The Annex 40 has been structured in 4 Tasks:
Task 1 on the state-of-the-art in the participating countries has been finished by the end of August 2013. Many nZEB are currently built in the central European countries Germany, Austria and Switzerland as well as in North-America. Norway has several nZEB in the planning phase. In Canada, a field test of so-called EQuilibrium houses has been performed.

In Task 2 and Task 3 the analysis of nZEB heat pump concepts and technology developments are carried out. CA is investigating different options to integrate the heat pump with other heat generators like CHP and solar thermal collectors. Moreover, components of the heat pump like ejectors are examined. CH project is studying the integration of heat pumps and solar components for the functions space and water heating and space cooling for residential and commercial buildings by simulation and hardware-in-the-loop testing. DE has a focus on the evaluation of load match and grid interaction by simulations as well as monitoring projects for residential and commercial buildings. JP is comparing system configurations by simulations under both European and Asian boundary conditions. NL has a large monitoring programme called Energy leap. Currently, a business model for retrofitting dwellings to net zero on the meter by solar PV is developed. NO project contributions are dedicated to monitoring of systems installed in nZEB for Nordic climate conditions. Also, a calculation tool for the heat pump design is under development. SE has development projects for heat pumps for single and multi-family houses, which are tested in houses by the beginning of next year. Also, further monitoring projects are started. The USA is further developing a highly integrated heat pump IHP, which covers the building functions space heating and cooling, ventilation, dehumidification and water heating. Moreover, the ThermCom software for the evaluation of thermal comfort for radiant heating and cooling systems is developed, and a test facility for Net Zero Energy residential buildings has been set up, where heat pump technologies are tested.

On the IEA Heat Pump Conference 2014 in Montréal interim results of IEA HPP Annex 40 will be presented in a half-day workshop.

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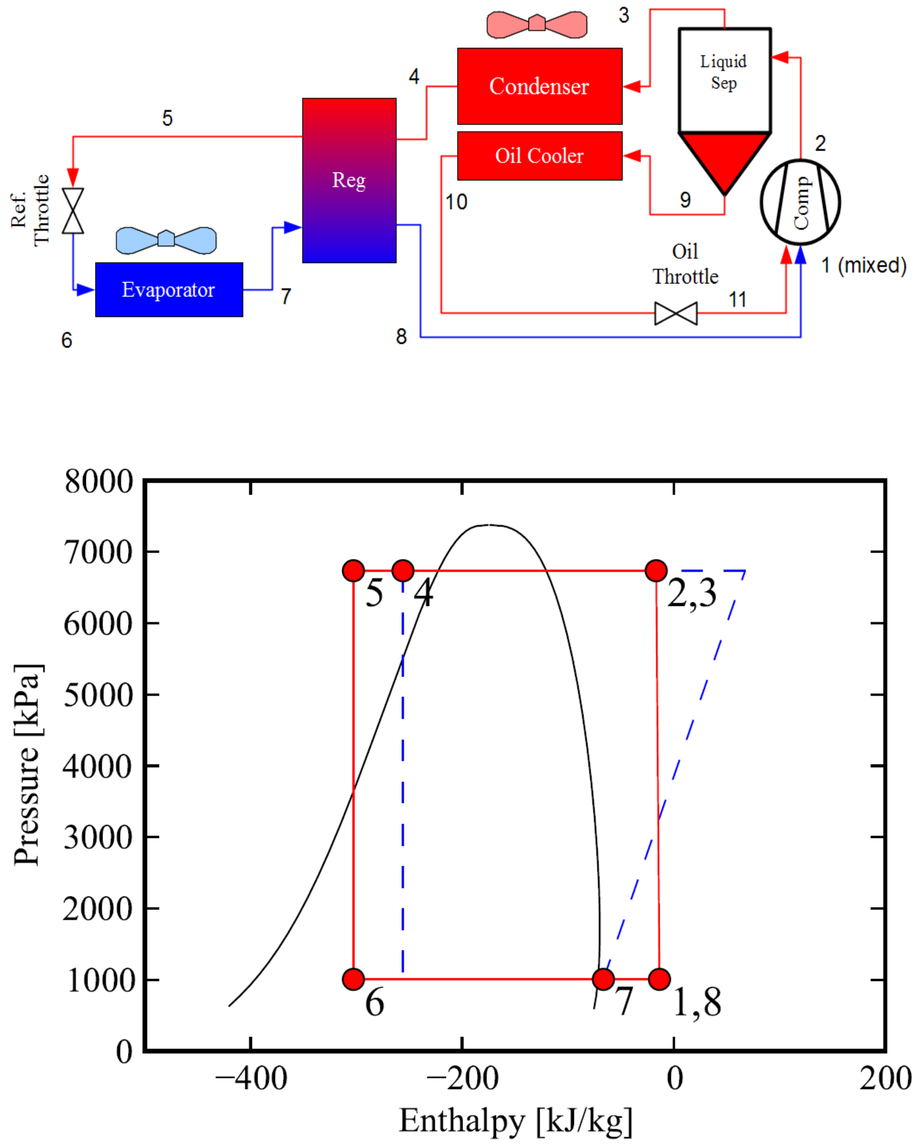
IEA HPP Annex 41 Cold Climate Heat Pumps

Heat pump technology provides a significant potential for CO_2 emissions reduction. Annex 41 will revisit research and development work in different countries to examine technology improvements leading to successful heat pump experience in cold regions. The primary focus is on electrically driven air-source heat pumps (ASHP) with air (air-to-air HP) or hydronic (air-to-water HP) heating systems, since these products suffer severe loss of heating capacity and efficiency at lower outdoor temperatures. Thermally activated (engine-driven, absorption, etc.), ASHPs and ground-source heat pumps (GSHP) may also be included in individual country contributions, if desired. The main technical objective is to identify solutions leading to ASHPs with heating SPF ≥ 2.63 W/W, recognized as a renewable technology. The main outcome of this Annex is expected to be information-sharing on viable means to improve ASHP performance under cold (≤ -7 °C) ambient temperatures.

During the past quarter a summary presentation on the Annex was made by Van Baxter at the 2013 European Heat Pump Summit and the U.S. Task 1 report draft was submitted to the other Participants in October.



Annex 41: Oil-flooded compressor heat pump cycle concept to approach isothermal compression – schematic (top) and P-H diagram (bottom); test system under construction at Purdue

Austria has officially joined the Annex bringing the number of Participants to three along with Japan and the U.S. Dr. Thomas Fleckl, Austrian team leader, summarized Austrian plans for the Annex at a national workshop in October. The Annex web site is: http://web.ornl.gov/sci/ees/etsd/btric/usnt/QiQmAnnex/indexAnnex41.shtml.

The next planned meetings of the Annex are a web meeting (February/March 2014) and the 2nd working meeting and workshop to be held at the Heat Pump Conference in Montreal. The Annex officially began in July 2012 and is expected to run through September 2015. We still welcome additional Participants until December 31, 2013.

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IEA HPP Annex 42 Heat Pumps in Smart Grids

Overall, the annex can be described by an overview figure, together with an outline in bullet points, see below and next page.

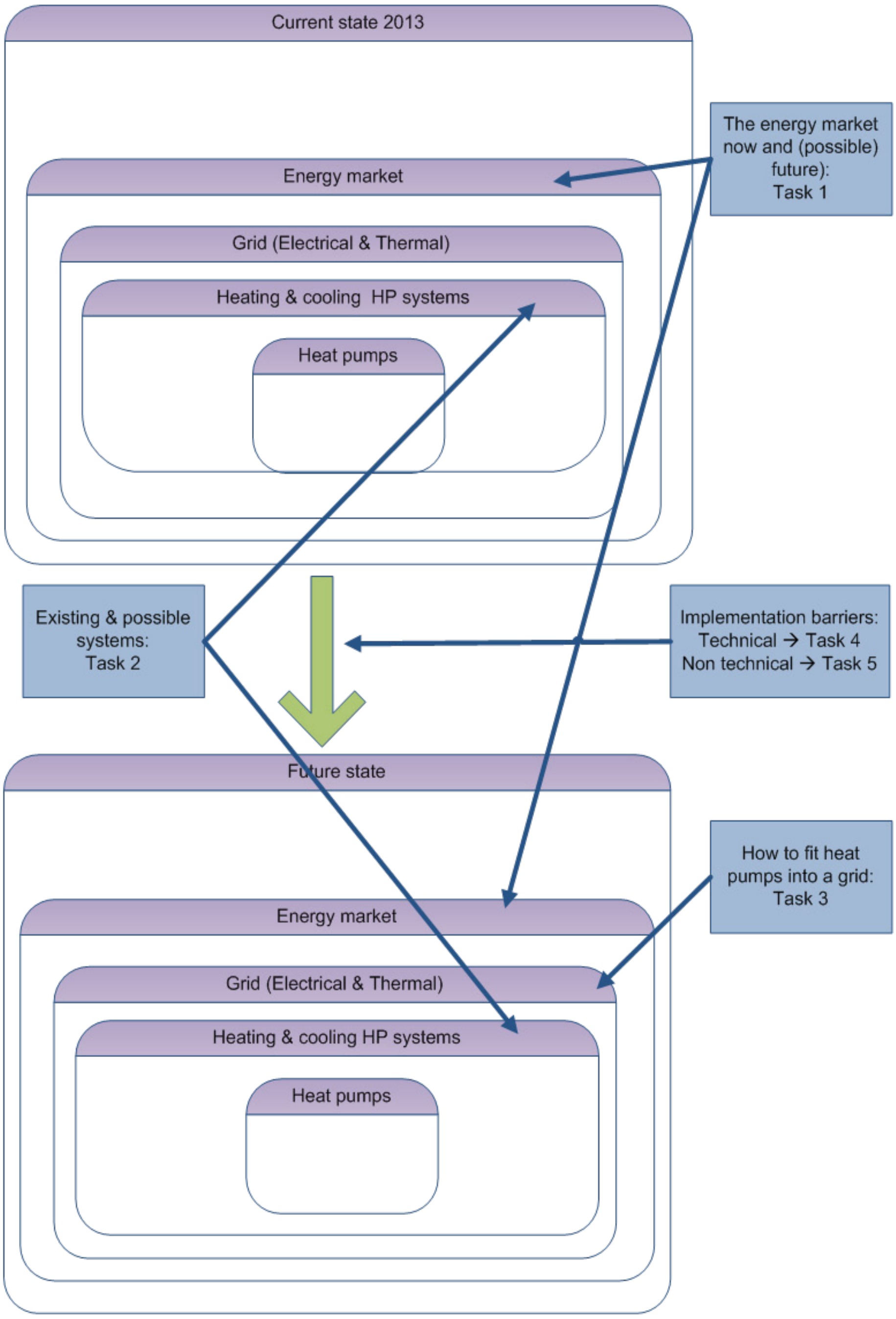

Figure 1: Annex 42 described by an overview figure

Who will read / use the annex?

- Policy makers (both macro and micro)
- Housing companies
- Grid companies
- Energy suppliers
- Installation consultants
- HP manufacturers / control designers
- Researchers in the HP / SG field

Approach

- Observe and study running projects →
- Combine the information →
- Order and structure the questions and answers that are imposed in the projects →
- Produce new knowledge out of the combinations AND/OR test models that have not been tested in the running projects.

The main problems regarding the electricity grids in the future

1. Electrical load management issues
2. Energy load from supply of sustainable energy sources

What is our main goal of the annex?
-which cannot already be obtained in running projects?

A region or country specific implementation model so readers can decide what the best options are in a given situation to implement heat pump systems and the best way to implement them into an electrical or thermal grid

Sub questions

1. What is the potential 'peak shave' capacity of both electrical and thermal loads for the different flexibility options?
2. What is the potential for using thermal grids as a storage option and reduce E-load?
3. What are the costs of different technology options for flexibility (thermal storage, hybrids)?
4. What is the time scale to balance peak considering the different storage options and how does it affect control strategies?
5. What is of will be the acceptability to households? (comfort, technology, pricing, feeling of control)
6. What are the best control strategies? How to balance between the peak / highest COP / Comfort / economy (since they can be conflicting) And how

much flexibility and potential for E-load reduction will it give?

What not

1. No gas grid, just the description that there is potential for hybrid HP's (hybrids ARE included in the annex)
2. Power to gas (this is storing electricity by using this power to produce hydrogen and reform this into gas) is not included as an option to balance the E-grid
3. Not E-storage

Brief status update

Based on the information available so far, we assume that we will run the Annex 42 with at least eight countries. The actual startup of the Annex 42 and the application process are run as two processes in parallel. The general process of engaging the various countries is pursued until all administrative issues are solved. In the meantime we proceed with the actual work in the Annex.

On October 16, 2013, an Annex 42 project meeting took place during the Heat Pump Summit in Nurnberg – Germany. Attendants during the meeting present were from USA, Sweden, United Kingdom, South Korea, Denmark, Germany, The Netherlands and France.

The main topics of the meeting were:

1. Application procedure for Annex 42
2. Discussion of scope of Tasks
3. Assignment of Task leaders

The following meetings are planned:

» February 2014, EDF office Fontainebleu – France
» May 2014, Montreal conference – Canada
» October 2014, Nurnberg – Germany (during Chillventa exhibition / HP summit 2014)

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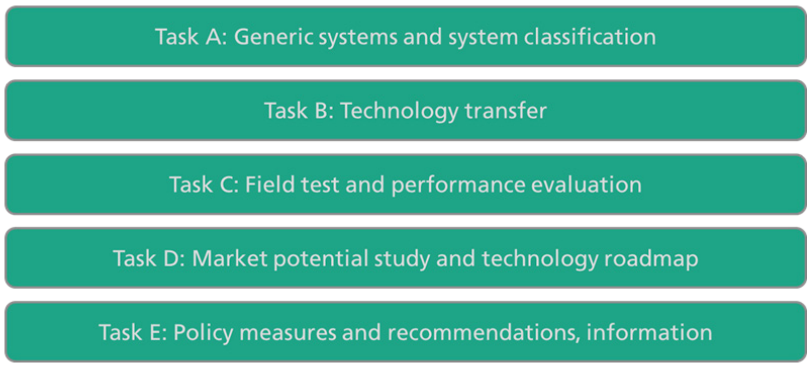
IEA HPP Annex 43 Fuel-driven sorption heat pumps

In recent years a rising market interest in the area of fuel driven sorption heat pumps can be observed, more and more products have entered the market or the demonstration phase. Since one lesson from annex 34 "thermally driven heat pumps" was that thermally driven heat pumps need other measures for a wider market penetration than solar cooling, a new annex "Fuel driven sorption heat pumps" was proposed to the HPP ExCo in March 2012. After several definition meetings, a legal text was compiled and, as a draft, accepted by the ExCo, so the annex 43 started officially in July 2013, with a duration of 4 years.

The scope of the work under this Annex will be on the use of fuel driven sorption heat pumps in domestic and small commercial or industrial buildings, or applications. If applicable, the additional possibility of supplying cold will also be considered. The main goal is to widen the use of fuel driven heat pumps by accelerating technical development and the way to market as well as to identify market barriers and supporting measures. Conducting a field test, as well as proposing performance evaluation figures and optimal system layouts, are among the means of this annex.

At a kick-off meeting held on October 9-10 in Freiburg, Germany, 25 participants (including 8 companies) from 5 countries agreed on a final



Annex 43: Task overview.

Annex 43: Group picture of the Kick-off meeting held in Freiburg, Germany, October 2013.

version of the legal textand on the annex task structure and discussed contributions from the participants.

The tasks are further specified as follows (see figure "Annex 43: Task overview" and below):

Within Task A, country reports will be compiled for the participating countries as well as some other market relevant countries, summarising the state of the art, the markets, legal barriers and incentives.

A template was sent out to all participants in October 2013. Task B is in charge of connecting the newest research from scientists to companies, mostly by expert meetings and workshops. Within task C, data from field tests should be collected and compared to lab test results; further within this task performance figures will be proposed to normative bodies based on these data. Additionally, these field test data will be used to validate simulation models which will then be used in Task D for a parameter study: which systems are best suited for a certain climate and application. From these data, recommendations to decision makers will be derived and disseminated in Task E.

So far, four countries confirmed joining the annex (DE, UK, FR, IT), several more have expressed their interest (Austria, USA), but of course more participants are welcome.

The next meeting will be held in May 2014 in Milano in conjunction with the Mostra Convegno trade fair and exhibition.

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IEA HPP Annex 44 Performance indicators for energy efficient supermarket buildings

Ten countries responded on the Electronic approval of the legal text of Annex 44 (Electronic approval 2013:05). The ten countries approved the legal text for the Annex, which has now been forwarded to the International Energy Agency.

The annex 44 activities must result in a methodology to analyse the energy efficiency of individual stores from a chain of supermarket stores. Based on simple data concerning energy consumption – e.g., from the energy distributor – and some key figures concerning the stores, the methodology must make it possible to quickly target the stores with a high efficiency and the stores with a low efficiency within the chain. From there on, the supermarket chain can focus on improving efficiency in those stores where the expected results are the highest. At this moment, the Annex activities are focused on setting up liaisons with supermarket chains for further involvement in the Annex. In the Netherlands, we have associated the project with 5 supermarket chains, varying from small chains (40 and 60 stores) to larger chains (200, 260 and 350 stores).

A kick off meeting for Annex 44 was held on June 27th, 2013 in Stockholm with participants from Sweden and The Netherlands. A second meeting is planned for November 25th in The Netherlands.

The Annex now involves Sweden and The Netherlands. Serious contacts for participation have been set up with Finland, and interest in participation has been shown from Germany and Austria. Also, contacts with Norway and USA will be followed up for possible participation.

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Ongoing Annexes

Bold text indicates Operating Agent. ** Participant of IEA IETS or IEA SHC

Annex 35 Application of Industrial Heat Pumps (together with Task XIII of "Industrial Energy-Related Technologies and Systems" (IEA IETS))	35	AT, CA, **DE**, DK, FR, JP, KR, NL, SE
Annex 36 Quality Installation/Quality Maintenance Sensitivity Studies	36	FR, SE, UK, **US**
Annex 37 Demonstration of Field measurements of Heat Pump Systems in Buildings – Good examples with modern technology	37	CH, NO, **SE**, UK
Annex 38 Solar and Heat Pump Systems	38	AT**, BE**, CA**, **CH**, DE, DK**, ES**, FI, FR**, IT**, UK
Annex 39 A common method for testing and rating of residential HP and AC annual/ seasonal performance	39	AT, CH, DE, FI, FR, JP, KR, NL,**SE**, US
Annex 40 Heat Pump Concepts for Nearly Zero-Energy Buildings	40	**CH**, DE, JP, NL, NO, SE, US
Annex 41 Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps)	41	AT, JP, **US**
Annex 42 Heat Pump in Smart Grids	42	DE, FI, KR, **NL**, US
Annex 43 Fuel Driven Sorption Heat Pumps	43	**DE**, FR, IT, UK
Annex 44 Performance Indicators for Energy Efficient Supermarket Buildings	44	**NL**, SE

IEA Heat Pump Programme participating countries: Austria (AT), Canada (CA), Denmark (DK), Finland (FI), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US).
All countries are members of the IEA Heat Pump Centre (HPC). Sweden is the host country for the Heat Pump Centre.

Control and inhibition of frost crystal formation and growth

Hidetoshi Ohkubo, Japan

A mechanical frost removal method is proposed here with the aim of further improving energy saving techniques. The method is able to remove frost on a cooling surface while maintaining its temperature below 0 °C. To be able to implement this method, it is important to be able to quantify the cohesive force of a frost layer, and to reduce it. We machined micro-grooves on a metallic cooling surface to modify the surface characteristics, succeeding in reducing the frost formation on the cooling surface under natural convection.

Introduction

Heat exchangers operating at low temperatures are prone to frost formation on their cooling surfaces, due to condensation and freezing of moisture in the air. If the air humidity is high and the cooling surface temperature is above –40 °C, the condensate formed on the cooling surface is a super-cooled liquid, which will produce crystals if the super-cooled state conditions in some way no longer apply. This frosting phenomenon involves simultaneous processes of both heat and mass transfer. In addition, it is an unsteady process where frost crystals grow with time. Frost formed on heat exchangers of low-temperature devices acts as a thermal barrier to heat transfer, causing the devices' thermal efficiencies to deteriorate. Thus, in most cases, heating needs to be used for the removal of frost.

Lately, techniques are being sought for the reduction of frost formation, with the aim of developing various energy-saving methods. To reduce frost formation requires both the frost layer thickness and the amount of ice deposit to be reduced. However, at present there is no innovative method to do so without heating the cooling surface and maintaining the cooling surface temperature below 0 °C. With the objectives of prevention and control of frost crystal formation and growth, we subjected the cooling surface to micro-machining in this work, and investigated its structure/shape effects on the frost formation phenomenon.

Crystal formation & growth mechanism

Our finding that the surface characteristics of a metal surface can be modified by forming grooves on it was successfully used for the prevention and control of frost crystal formation and growth. The method is different from the processing techniques that modify the cooling surface wettability, and it is effective in that the micro-machined structure does not change even if the heat exchanger is operated for a long period of time. The grooves machined on the cooling surface were either in the form of stripes or blocks (a lattice). The grooves were machined by an electric-arc discharge method. The dimensions of the surfaces of grooves and projections were determined from observation results of super-cooled liquid droplet experiments. Fig. 1 shows an example of the observations made. The

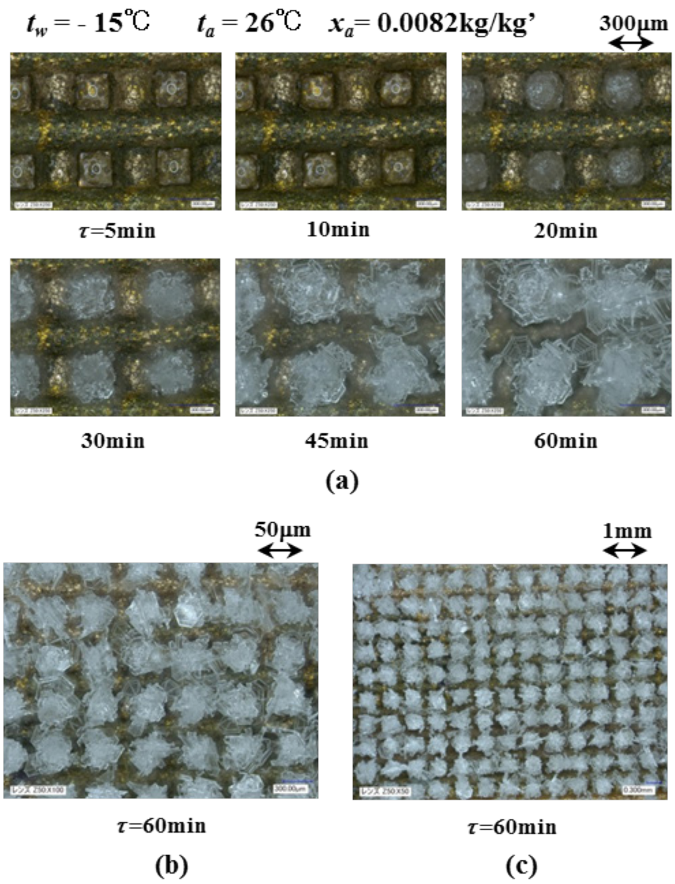

Figure 1. Snapshots showing formation and growth of frost crystals

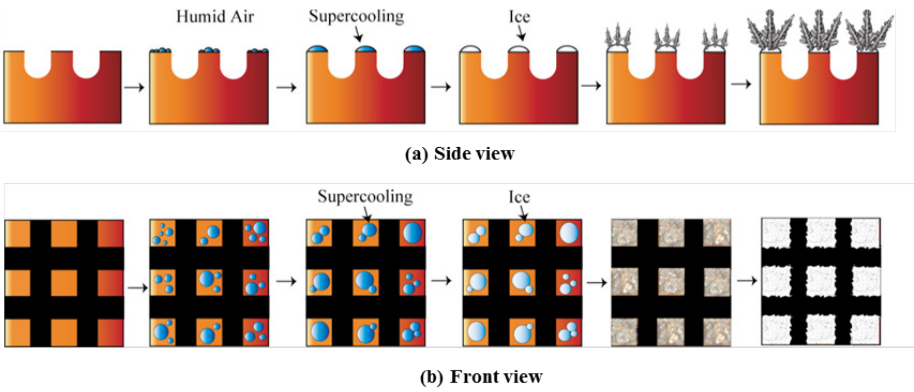

Figure 2. Mechanisms of formation and growth of frost crystals

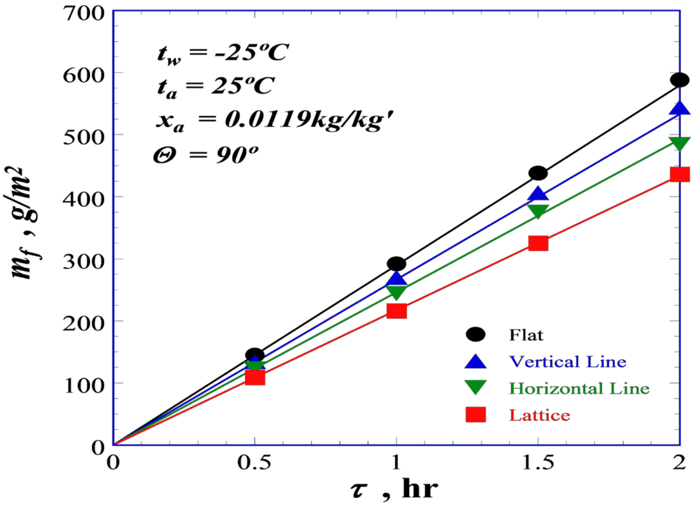

Figure 3. Frost deposition as a function of time

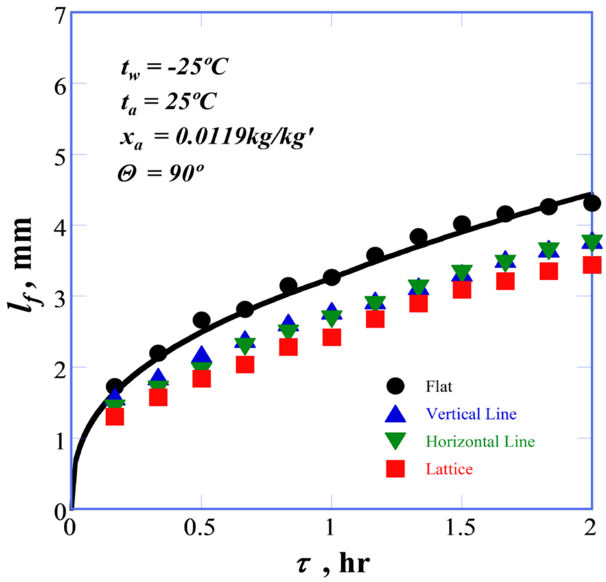

Figure 4. Frost layer thickness as a function of time

heat transfer surface shown here is micro-machined so as to produce a regular grid on it. Based on the observations, a model was developed to describe the mechanisms of formation and growth of frost crystals, as shown in Fig. 2. The figure shows the formation of super-cooled liquid droplets on the protrusions of the heat transfer surface, which merge to become larger. Subsequently, the super-cooled state of droplets disappears, and they become ice, and frost crystals are formed out of several

Reduction of frost formation

The micro-machined shapes or structures on the cooling surface are also effective for reducing frost formation (as seen above). It was found that such machining can reduce the frost layer thickness by 20~25 %, the amount of frost deposition by about 25 %, and the frost scrape-off force by 80~85 % in comparison with the case of a flat surface. On the other hand, the machining did not drastically affect the heat transferred. It was therefore possible to achieve a reduction in the mass transfer while maintaining the heat transfer. Numerical simulations show that there exist small vortexes on the cooling surface, which possibly affect the mass transfer. The implication of the above results is that an air jet stream can possibly be used to remove the frost mechanically, while maintaining the cooling surface at a low temperature. If such a system can be realized, it will not only improve the heat exchanger efficiency, but also will save energy.

Fig. 3 shows frost deposition as a function of time. It shows that the effect of the differences in the machined shapes becomes significant as the frosting time increases. Therefore, it is safe to conclude that micro-machined shapes /structures have a significant effect on the frost deposition in comparison with a polished flat surface. The amount of frost deposition decreased in the order of flat to vertically-grooved, to horizontally-grooved, to the lattice type surface. Thus, it demonstrates that frost deposition can be reduced by micro-machining a cooling surface.

Fig. 4 shows the frost layer thickness as a function of time. It shows that micro-machining has a signifi-

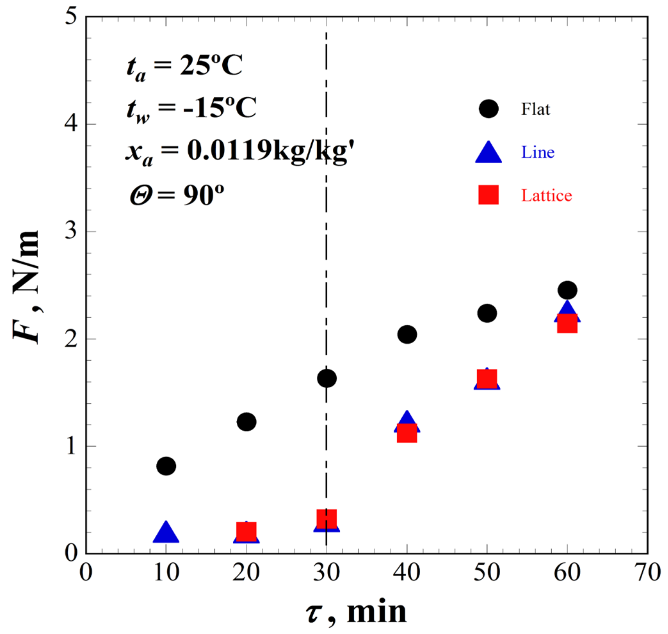

Figure 5. Force required to scrape off the frost layer as a function of time

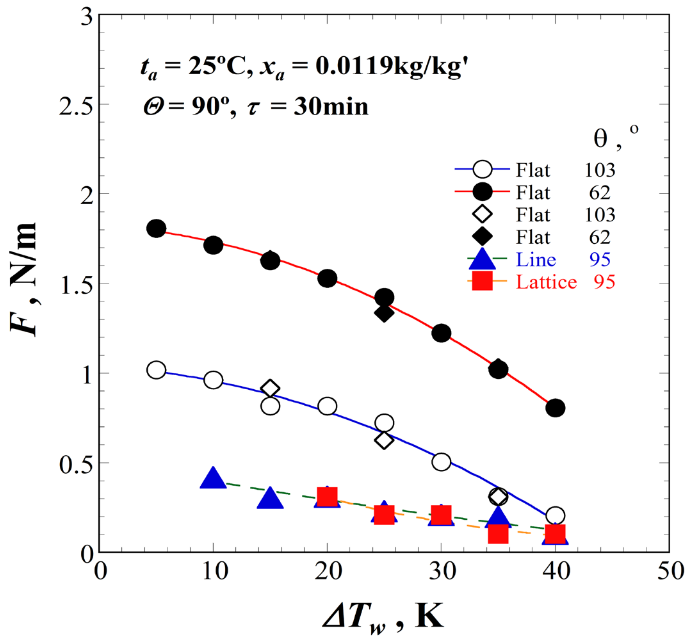

Figure 6. Relationship between the scrape-off force and degree of supercooling of the cooling surface

cant effect on the frost layer thickness in the same way as on the frost deposition. The frost layer thickness also decreased in the order of flat to vertically-grooved, to horizontally-grooved, to the lattice type surface.

Frost scrape-off force

Frosting is a phenomenon involving simultaneous heat and mass transfer processes. From the relationship between the heat and mass transferred, it can be stated that the mass transferred will increase if the thermal performance of a heat exchanger is raised. There are at least two methods that have successfully removed frost crystals without having to melt the frost layers away: namely, the method that uses air-solids two-phase flows, and one that uses an electric field. The former needs a closed environment so as not to let solid particles scatter around. On the other hand, the latter method is effective only during the initial period of frosting, and becomes less effective with the growth of the frost layer. The author's group has reported a mechanical frost removal method where an external force such as an air jet is used to remove frost. For this method to be effective, it is important to reduce the cohesiveness of frost crystals.

Fig. 5 shows the force required to scrape off the frost layer, as a function of time. Note that there is no direct method at present to measure the cohesive force of a frost layer, and so we measured the force required to remove the frost layer by scraping, which we used here as the cohesive force.
It was found that the scrape-off force was reduced considerably by the micro-machining compared to a flat surface. However, no significant differences were observed between the striped or lattice-type heat transfer surfaces. The figure shows that the grooves are effective for about 30 minutes, and also that the scrape-off forces can be reduced significantly. Further, it shows that the scrape-off force increased sharply at $\tau > 30$ minutes, where τ is the frosting time. Thus, the mechanical frost removal method will be effective if the removal is carried out at $\tau < 30$ min.

Finally, Fig. 6 shows the relationship between the scrape-off force and the degree of supercooling of the cooling surface. It shows that the scrape-off force falls sharply with an increase in the surface supercooling. It can also be seen from the figure that the micro-machining is effective in reducing the scrape-off force even if the cooling surface is at different temperatures.

In the case of heat-pumps used in cold countries, defrosting is done at present by raising the cooling surface temperature above 0 °C, which is the melting point of ice. However, if we use the proposed frost removal method for the heat exchangers, it will not only be possible to improve the efficiency of the heat exchanger, but also to use the mechanically-removed ice crystals as a regenerative material. If heat pumps designed with cold-country specifications are to become popular, there is no doubt that their coefficient of performance needs to be improved. To demonstrate the effectiveness of the described frost removal method, experiments were performed on micro-machined surfaces even under forced-convection conditions at low temperature and humidity. It was found that even under those conditions, frost crystal formation and growth could be prevented as well as under the conditions of natural convection.

Conclusions

This work is aimed at using micromachining to modify the apparent properties of a cooling surface. Experiments were carried out to investigate the effect of such micromachined cooling surfaces on frost formation and the growth of frost crystals under natural convection.

The following conclusions can be drawn.

- It was found that micro-machined cooling surfaces can successfully prevent or control frost crystal formation and growth. The modified cooling surface did not allow the growth of frost crystals over a sizable surface area, which covered 75 % of the cooling surface at the most.
- Using such surfaces, it was possible to reduce mass transfer while maintaining the heat transfer. The most effective cooling surface for the frost reduction showed reductions of 20~25 % in the frost layer thickness, 25 % in frost deposition, and 80~85 % in the frost scrape-off force, all compared with the flat surface.
- Micro-machined shapes on the cooling surface had a drastic effect on frost deposition under natural convective conditions. By using such micro-machining, it was possible to reduce mass transferred without a reduction in the heat transferred.

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Acknowledgment
This work was supported by JSPS KAKENHI Grant Number 22560207.

R744 two-stage compressor for commercial heat pump water heater

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The use of heat pump water heaters is becoming more widespread in response to energy conservation requirements. However, one of the weaknesses of heat pump systems is the drop of heating capacity under low ambient temperature conditions. This is why heat pump systems are not catching on in cold regions.
This paper describes the development of a high-efficiency compressor for commercial CO_2 heat pump water heaters. The new compressor is the world's first to employ a two-stage compressor design, a combination of rotary and scroll compressors that can overcome specific issues of CO_2 refrigerant, such as a large pressure difference and high operating pressure. It is the most suitable compression mechanism for the operating conditions of a heat pump water heater.
By using this compressor, heating capacity and efficiency can be significantly improved in comparison with conventional water heaters. These improvements have made it possible to introduce heat pump water heaters in cold regions.

Introduction

In order further to improve the performance of heat pump systems in cold regions, the authors have developed a novel compressor for commercial CO_2 heat pump water heaters. The new compressor is based on a two-stage compressor design, using a combination of scroll and rotary mechanism to reduce leakage and mechanical losses. In addition, by employing intermediate gas injection, the new compressor has high heating capacity and high efficiency over a wide range of conditions.
We also developed a commercial heat pump water heater using the new compressor. One of the issues of heat pump systems is the drop of heating capacity under low ambient temperature conditions. However, this system provides sufficient heating capacity even in cold areas, and a high COP over the entire operating condition range by using an economiser cycle and the high-efficiency two-stage compressor.

Structure of the new two-stage compressor

CO_2 as a working fluid has the advantages of low GWP, no toxicity and no flammability, and is expected to become one of the alternative refrigerants to current HFC refrigerants in refrigeration and air-conditioning fields. On the other hand, CO_2 requires a high operating pressure and high pressure difference compared with conventional refrigerants, decreasing the efficiency and reliability of the compressor. Therefore, it is especially important for the development of a CO_2 compressor to ensure that its design fundamentals are right.

In order to establish the basic structure of the new compressor, the number of compression stages, the shell pressure and the type of compression mechanism have all been investigated.
Table 1 compares compressor performances for different types and combinations of compressors. Based on this study, the main features of the new design are as follows.

(1) Two-stage compression

The pressure difference between the discharge and suction pressures

Number of stage	Shell pressure *1	Type of compression		Shell thickness	Gas injection	Reliability		Efficiency	
		1st stage	2nd stage			1st stage	2nd stage	1st stage	2nd stage
Single stage	HP			-	-	-		-	
	LP			+	-	-		-	
Two stage	HP			-	+ *2				
	MP	Scroll	Scroll	+	++	+ *3	+ *3	+	++
		Scroll	Rotary	+	++	++	-	+	+
		Rotary	Scroll	+	++	++	++	++	++
		Rotary	Rotary	+	++	++	-	++	+
	LP	Scroll	Scroll	+	+ *2	+ *3	+ *3	+	++
		Scroll	Rotary	+	+ *2	++	-	+	+
		Rotary	Scroll	+	+ *2	-	++	++	++
		Rotary	Rotary	+	+ *2	-	-	++	+

*1 LP: Suction pressure, MP: Intermediate pressure, HP: Discharge pressure
*2 Connection pipe between 1st and 2nd stage is required.
*3 Oil pump needs to be placed in the middle of crankshaft

Table 1. Performance comparison of compressor types

for CO_2 refrigerant is several times larger than that of conventional HFC refrigerants. This leads to an increase of gas leakage and mechanical losses. However, efficiency and reliability can be improved by using two-stage compression, which decreases the pressure rise across each stage. In addition, the new compressor has an intermediate gas injection mechanism to boost COP and heating capacity. By employing two-stage compression, gas injection can be introduced between the first and second stages, and thus mixture loss can be reduced in comparison with that of single-stage compression with direct injection to the compression chamber.

(2) Intermediate-pressure shell

Since the operating pressure of CO_2 is much higher than that of conventional HFC, shell pressure has a great effect on the shell thickness and hence on the compressor weight. This effect increases as the size of the compressor becomes larger, such as in commercial and industrial applications. Because of this, it is desirable to keep the design shell pressure low in order to keep down the weight of the compressor shell. The new compressor has an intermediate pressure shell so that the discharge pressure does not directly affect the shell, allowing downsizing and a reduction in weight.

(3) Combination of scroll and rotary mechanisms

The compression mechanism is one of the most important factors in determining the efficiency and reliability of a compressor. Particularly in a two-stage compressor, it is necessary to select appropriate compression mechanisms for the respective operating characteristics of the first and second stages. The main mechanisms of positive-displacement compressors include reciprocating, screw, scroll, and rotary designs. The new compressor employs rotary and scroll mechanisms for the first and second stages respectively, as the most suitable compression mechanisms for a heat pump water heater. This innovative combination of scroll and rotary mechanisms gives high reliability and high efficiency over a wide range of operating conditions.

Figure 1 shows the structure of the compressor. It is driven by a brushless DC motor between the two rotors, with a compression chamber on each side of the motor. The rotary-type first-stage compression chamber is below the motor, and is connected to a suction pipe via a suction accumulator. The scroll-type second-stage chamber is located above the motor and is connected to a discharge pipe via a discharge chamber. Refrigerant gas is introduced into the first-stage compression chamber through the accumulator and is compressed to an intermediate pressure. The compressed gas is then discharged into the shell. Injection gas is introduced into the shell through the gas injection port and is mixed with compressed gas from the first stage. The mixed gas is then introduced into the second-stage compression chamber and compressed to discharge pressure. The compressed gas is discharged to the outside of the compressor through a discharge pipe on top of the shell.

Efficiency of the developed two-stage compressor

To verify improved efficiency, performance tests of the new two-stage compressor and a conventional single-stage scroll compressor were carried out. Figure 2 shows a comparison of the efficiency as a function of operating pressure ratio between the new compressor and the conventional compressor. The vertical scale represents the values obtained by dividing the efficiency of the new compressor by the efficiency of the

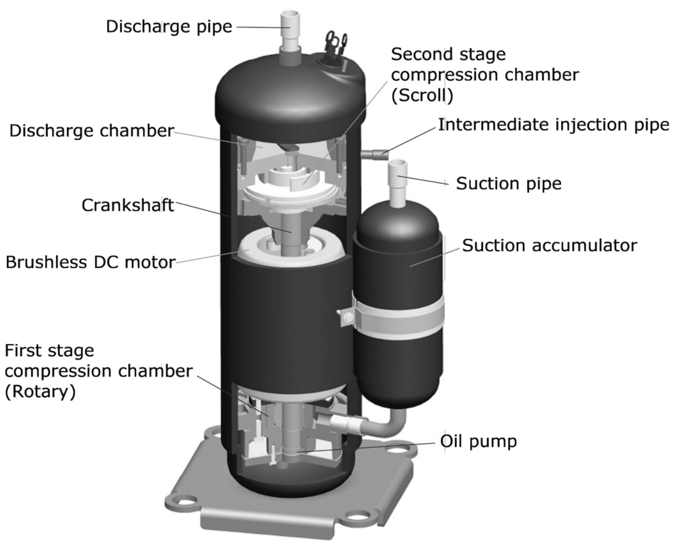


Figure 1. Structure of the new compressor

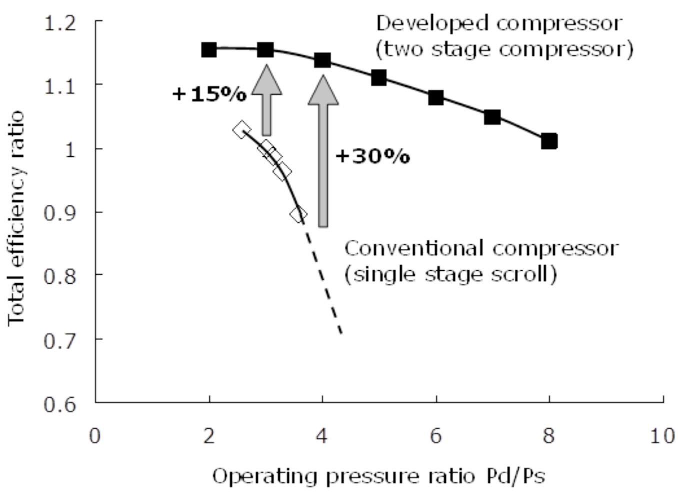
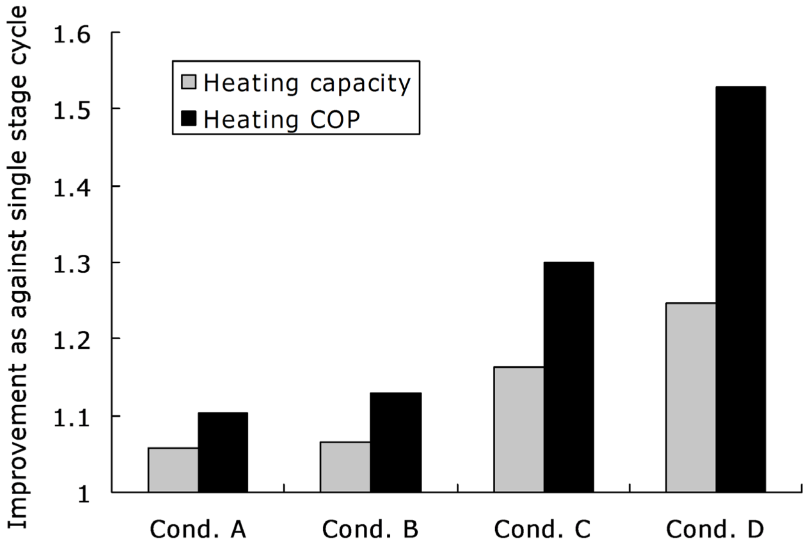


Figure 2. Efficiency variation against operating pressure ratio



	Ambient air temp. [degC]	Inlet/Outlet water temp. [degC]
Cond. A	16	27 / 65
Cond. B	7	9 / 65
Cond. C	-7	6 / 65
Cond. D	-20	5 / 65

Figure 3. Improvement of heating capacity and COP

conventional compressor at a compression ratio of 3. For the conventional compressor, the efficiency decreased significantly with increasing operating pressure ratio, due to increased leakage and mechanical losses. On the other hand, the new two-stage compressor showed little loss of efficiency, even with an increased operating pressure ratio, as a result of the two-stage compression arrangement. The new compressor showed a 15 % improvement in efficiency for a compression ratio of 3, and more than 30 % improvement at a compression ratio of 4 or higher, compared with the conventional compressor. The developed two-stage compressor therefore achieved significant efficiency improvement over a wide range of operating conditions.

In order to evaluate the performance improvement of a heat pump system using the developed two-stage compressor, a performance comparison between a two-stage cycle with intermediate gas injection and single-stage cycle was conducted for four different ambient air temperature and inlet water temperature combinations. Figure 3 shows the improvement in heating capacity and COP of a two-stage intermediate gas injection cycle with the developed two-stage compressor, compared with a single-stage cycle using a conventional compressor. An improvement over the conventional cycle was noted for each of the air temperature / water temperature combinations. The improvement ratio increased as the ambient air temperature decreased because the refrigerant flow rate of the gas cooler was increased by the gas injection, and the efficiency of the compressor was improved through use of the new two-stage compressor. The new compressor showed a 25 % improvement in heating capacity, and more than 50 % improvement in COP under deep-freeze conditions (cond. D). These results indicate that the developed two-stage compressor offers particular advantages for applications operating under large temperature differences, such as refrigeration or chilling units, as well as heat pump water heaters in cold region.

Commercial heat-pump water heater

The new two-stage compressor is used in our commercial CO_2 heat pump water heater, with the following main design features:

1. Two-stage compression and an intermediate gas-injection cycle.
2. The rated heating capacity is 30 kW, and is sustainable at ambient air temperatures as low as -7 °C.
3. The COP at rated conditions reaches 4.3, which is the highest level in the industry.
4. A 90 °C hot water supply is available even at ambient air temperatures as low as -25 °C.

Figure 4 (see next page) shows the variation in heating capacity and COP as functions of ambient air temperature. Because the performance of conventional heat pump water heaters declines at low ambient temperatures, their applicability in cold regions has been limited. However, the developed system achieves both high heating capacity and high COP under conditions of low ambient temperatures by using the new two-stage compressor and an intermediate gas injection cycle. Consequently, new CO_2 heat pump water heaters make it possible to employ heat pump water heaters in cold regions, which has always been a difficult problem.

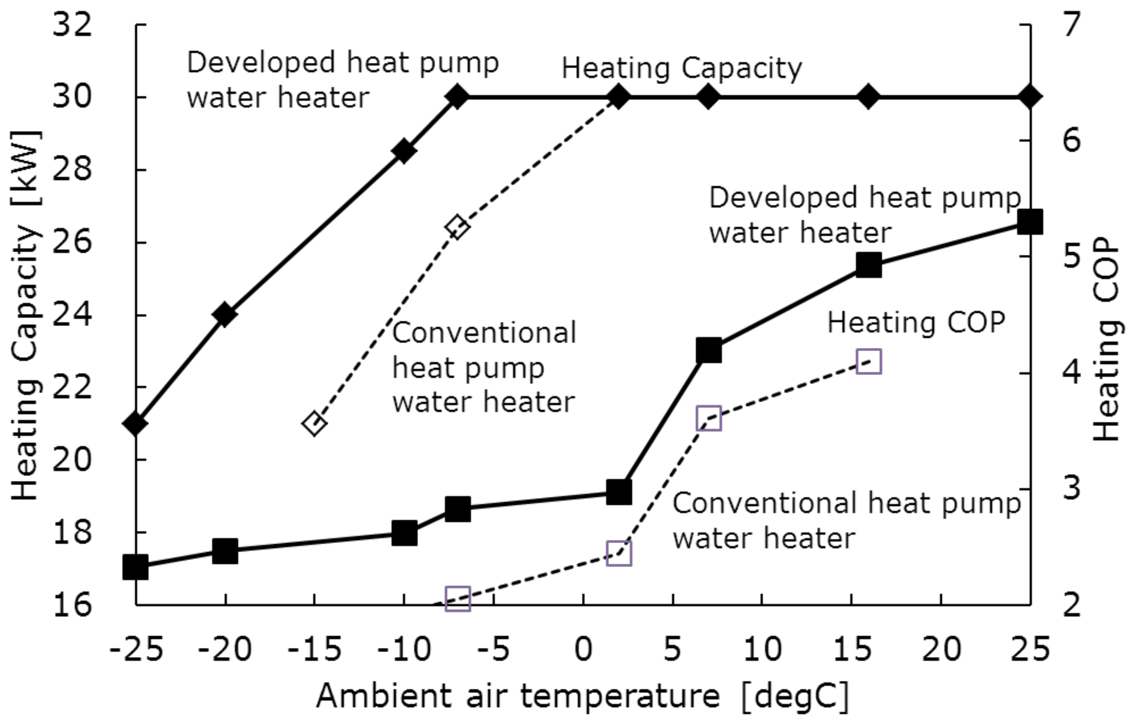


Figure 4. Heating capacity and COP as functions of ambient air temperature for the new heat pump water heater (Inlet/outlet water temperature = 5/65 °C)

Conclusions

The authors developed a two-stage compressor for commercial CO_2 heat pump water heaters. Using the world's first combination of rotary and scroll mechanisms and intermediate gas injection, the new compressor combines high reliability and high efficiency operation over a wide range of conditions. The authors also developed a commercial CO_2 heat pump water heater using the developed compressor, achieving significantly improved heating capacity and COP in comparison with previous water heater designs, making it possible to introduce heat pump water heaters in cold regions, which has always posed difficulties.

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Refrigerant Charge Reduction in Heat Pumps: Part II – Charge Reduced Heat Pump Design

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This second part of the article series about refrigerant charge reduction in heat pumps is intended to provide an overview of ways of designing a charge-reduced heat pump. A close look at each of the main components of the heat pump reveals its potentials for charge reduction.

Charge-reduced system and component design

In order to design charge-reduced heat pump or refrigeration systems, there are several aspects which can be optimised. In general, the greatest charge reduction can be achieved by reducing the internal volume of the components containing liquid refrigerant.

Volume reduction in the cycle as a whole can be done by reducing the hydraulic diameter of tubes, but this leads to higher flow velocities and consequently to higher pressure drop. The resulting penalty in COP reduction must therefore be considered when reducing hydraulic diameters.

Most design indications are inspired by the Keynote Lectures of the 3rd IIR Workshop on Refrigerant Charge Reduction [1-3] and by Vaitkus' study on a low-charge transport refrigerator [4].

Selection of refrigerant

The choice of refrigerant has several implications concerning charge. One general criterion is that refrigerants with high latent heat require less mass flow for the same heating capacity, resulting in lower refrigerant charge.

In addition to these general rules, the thermodynamic and transport properties of the refrigerant determine by how much the hydraulic diameter of the components can be reduced while keeping the performance penalty to an acceptable level [2, 5].

Selection and sizing of components and systems

The following sections describe the refrigerant charge reduction strategies and potentials for the various components of a heat pump.

Compressor

The refrigerant charge quantity that is affected by the compressor is mainly that of the refrigerant dissolved in the compressor oil. There are therefore two approaches to charge reduction:

1. use of oils with low miscibility
2. reduction of internal volume and oil charge.

Oils with good miscibility are usually used in heat pumps in order to ensure oil return. Accumulation of oil in the circuit can lead to reduced heat transfer in the heat exchangers and to a lack of oil in the compressor. So use of less miscible oil requires measures to avoid the oil being drawn into the circuit e.g. by using an oil separator and return connection at the outlet of the compressor. This measure is costly and some oil will still drain into the circuit. It is therefore helpful to ensure oil return from the circuit by suitable pipe design [6-8].

In many cases, the initial oil charge of a compressor is more than a compact heat pump circuit would require, so the oil charge can be adjusted to the inner volume. A volume-reduced system with its oil charge matched more specifically to the refrigerant circuit can be designed only in close cooperation between the compressor manufacturer and the heat pump manufacturer.

Another possibility for an oil-free cycle is the use of lubricant-free compressors. There are recent advances in developing coatings for piston compressors to be used without lubricant [9], and in developing small turbo-compressors with gas-dynamic sealing principles [10].

Evaporator

In general, the internal volume of an evaporator can be decreased by reducing the hydraulic diameter of the refrigerant path through the evaporator. But this must be done without reducing the COP due to higher pressure loss [5]. A general way to avoid higher pressure drops is to employ parallel, instead of serial, paths.

In heat pumps, the usual heat sources are water (with or without antifreeze) or air. As these two heat sources require different types of evaporator, they are treated separately.

For heat exchange from air to refrigerant, the most common design is the fin and tube heat exchanger. In order to improve heat transfer on the air side (which has a considerably lower heat transfer coefficient than the refrigerant side), aluminium fins are bonded on to the copper tubes.

The usual tube diameters are around 10 mm. A straightforward way of reducing the internal volume is to use smaller tubes. Today, heat exchangers with tube diameters down to 5 mm are available [11]. But in order to maintain a low pressure drop, a greater number of parallel paths is required. The usual distributors for air-source heat pumps are available for up to about 60 parallel paths, but they are more expensive.

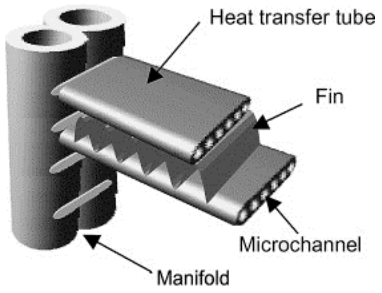

Figure 1.Schematic of a microchannel heat exchanger [12]

An alternative heat exchanger technology is the brazed microchannel heat exchanger. Instead of round tubes, these heat exchangers use multi-port extruded (MPE) tubes with several channels in each tube. Aluminium fins are brazed on the tubes, so the heat transfer from fin to tube is better than that of traditional fin and tube heat exchangers.

However, some problems need to be solved if these heat exchangers are to be used as evaporators. Frosting is a greater problem than in traditional tube and fin heat exchangers due to smaller distance between the fins and a more difficult drainage through the flat tubes. Approaches to solve this are the use of coatings [13] and modification of fin geometry.

Another problem is refrigerant distribution to the high amount of tubes, which goes hand-in-hand with charge reduction. Several approaches have been investigated [14-16], that can be applied to small-diameter fin-and-tube or to microchannel heat exchangers. The internal volume of the distributor itself should be small in order to not cancel out the advantage of the charge-reduced evaporator.

For a water to refrigerant heat exchanger, the most common design is the brazed-plate heat exchanger (BPHE). Low charge designs are straightforward by applying plates with different hydraulic diameters to cope with the widely differing heat transfer and fluid characteristics. Recently, this design has been used by manufacturers to produce "asymmetric" heat exchangers; see Figure 2. If high superheat is not required, and the evaporator is connected in counterflow, pressure drop on the refrigerant side does not adversely affect the COP if the reduction in evaporation temperature due to lower evaporation pressure does not exceed the reduction of water temperature in the evaporator. In this case, a lower pressure drop in the evaporator would only lead to a higher pressure drop in the expansion valve.

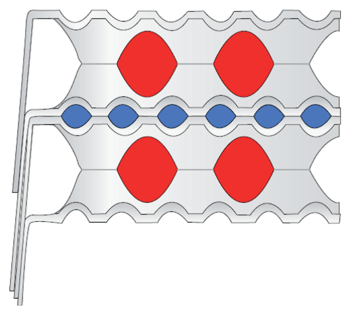

Figure 2. Principle of the asymmetrical micro plate heat exchanger [17]

Another design for charge-reduced refrigerant-to-water heat exchangers that has been investigated has the refrigerant flowing inside microchannel tubes while the water flows around them [18]. But these designs are costly: similar designs with flat copper tubes were used in heat pumps as condensers in the past but were replaced by plate heat exchangers [19].

Condenser

As far as charge reduction is concerned, condensers are subject in principle to the same possibilities and constraints as for evaporators.

If the heat sink is water, asymmetric plate heat exchangers can also provide a means of charge reduction. A pressure drop that leads to a decrease in condensing temperature which is less than the temperature rise on the water side is acceptable if no high subcooling is required and the heat exchanger is connected in counterflow.

In heat pumps with air as heat sink, the heat exchanger types presented in the evaporator section can also be used as condensers. There is no need for special actions to avoid the problems discussed for evaporators (icing, two-phase fluid distribution) since these problems do not apply to condensors.

Other heat exchangers

A suction-line heat exchanger (SLHX) between the liquid line and the suction line allows the evaporator and the condenser to be smaller, as no superheat or subcooling have to be considered.

Concerning the design of the SLHX itself, the hydraulic diameter on the liquid side should be small (accepting a high pressure drop). A high pressure drop is not acceptable on the vapour side, but volume reduction is not necessary because of the low density of the refrigerant.

If a compressor with vapour injection is used, an economiser is preferable to a flash gas tank because of its considerably lower inner volume.

Expansion devices

As far as expansion devices are concerned, capillary tubes are generally the option leading to the lowest refrigerant charge because they can directly connect the condenser and evaporator and therefore replace the liquid line. But this is only an option for heat pumps built for one clearly defined operating condition: usually, heat pumps must be able to work with variable evaporation and condensation temperatures, which requires the use of an adaptable expansion device.

When choosing between electronic expansion valves and thermostatic expansion valves, bear in mind that the former allow the superheat to be adjusted more accurately, allowing the evaporator size to be reduced and the amount of system charge to be reduced.

Receivers and accumulators

The required amount of refrigerant for a given heat pump depends on the operating conditions. In general, higher evaporation and condensation temperatures require less refrigerant than low temperatures. In order to ensure the right amount of refrigerant under all operating conditions, receivers (after the condenser) or accumulators (after the evaporator) are used to store excess refrigerant.

For charge reduction, it is preferable to fit an accumulator after the evaporator, for two reasons:

1. A receiver after the condenser impedes substantial subcooling in the liquid line. But this is necessary for designing the liquid line with small diameter and high pressure drop.
2. An accumulator after the evaporator allows operation with no or very low superheat after the evaporator.

Nevertheless, Vaitkus [4] reports that he tested currently commercially available accumulators, and the result was not convincing in terms of COP or system capacity.

Sizing of the piping system

The internal volume of the piping system can be reduced by either using shorter pipes or by using smaller diameters. The total pipe length can be optimised by adept positioning of the components and pipe routing, but often other restrictions have to be taken into account.

When sizing the piping system, it is essential to distinguish between pipes containing liquid refrigerant and pipes containing only vapour.

Reducing the pipe diameter leads to higher pressure losses in the pipe. This can have different effects on the performance, depending on the location in the circuit. The liquid line connecting the condenser to the expansion valve, and the feeder line connecting the expansion valve to the evaporator, can be designed with high pressure drops, because this does not affect the performance. The restriction for the liquid line is that the refrigerant must not start boiling before the expansion valve. An SLHX provides additional subcooling, so a higher pressure drop in the liquid line can be accepted. Expansion devices require a certain pressure drop for proper operation; which means that the required pressure drop in the expansion device plus the pressure drop in liquid and feeder lines must never exceed the total pressure difference between condenser and evaporator.

For the suction line and the discharge line, the hydraulic diameter should not be reduced below that of a conventional system, because a higher pressure drop here leads to lower COP. The charge reduction potential is also very low, because these lines are filled only with vapour. In addition, if the system uses less miscible lubricant, oil return must also be considered in pipe design [8].

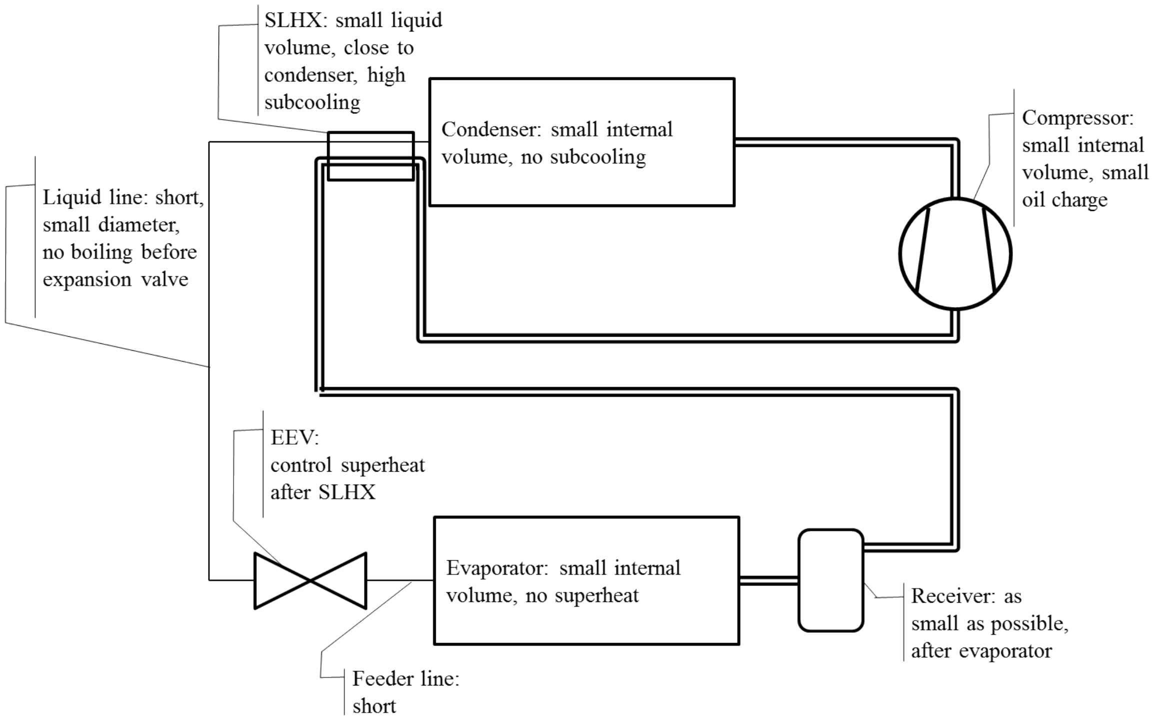

Figure 3. Scheme of a heat pump cycle with its main components and the important design aspects for charge reduction.

Charge-reduced system design

Concerning systems in their entirety, indirect systems are preferable to direct systems for charge reduction purposes, as the latter usually require large heat exchangers and piping. But this is an area where economic and exergoeconomic analysis comes into play.

Resumé

The main design indications presented in this article are summarised in Figure 3 in the form of a drawing of a simple heat pump cycle with its main components and the important aspects for each of the components.

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European Heat Pump Summit Symposium 2013

Johan Berg, Sweden

The European Heat Pump Summit Symposium 2013 took place in Nürnberg on 15–16 October 2013. More than 250 international congress participants from 26 countries gained information on current questions concerning the current status and the future of heat pumps from presentations given by German and international speakers.

The key themes of the summit were innovative approaches to technical solutions, possible applications, market analyses and the challenges and opportunities resulting from the political framework such as the F-Gas Regulation and the EU Ecodesign Directive. The summit also focused on heat pump components, which played a special role this year. The highlights also included the Annex presentations of the IEA Heat Pump Programme, which examined trends and possible future uses of heat pumps in applications such as smart grids. The current figures and information on market development in many European countries, India and Russia rounded off the spectrum of presentation topics. Some of the presentations are summarised below.

Heat pump market and statistics report 2013

Thomas Nowak, Secretary General of the European Heat Pump Association (EHPA), gave the first presentation. Regarding Greenhouse Gas (GHG) emissions, given as TEWI, advantages of heat pumps compared to gas boilers were pointed out (see Figure 1), and the large dependence on efficiency (sCOP) was emphasized. It was also underlined that GHG emissions for electrically driven heat pumps mostly are due to indirect emissions during electricity generation, not from F gases; compare the two columns in the figure for GSHPs with sCOP 4, one of which has low emissions from electricity generation.

It was also emphasized that if we want to increase chances of attaining the European 20-20-20 energy goals, the heat pump market needs to improve. The dominating heat source is air, and reversible air/air heat pumps make up half the market, although they are not considered heat pumps at all in most of Europe. Sales of Sanitary Hot Water heat pumps are increasing; they provide a good market entry for heat pump acceptance. Concerning sales by country, it is clear that the countries with large

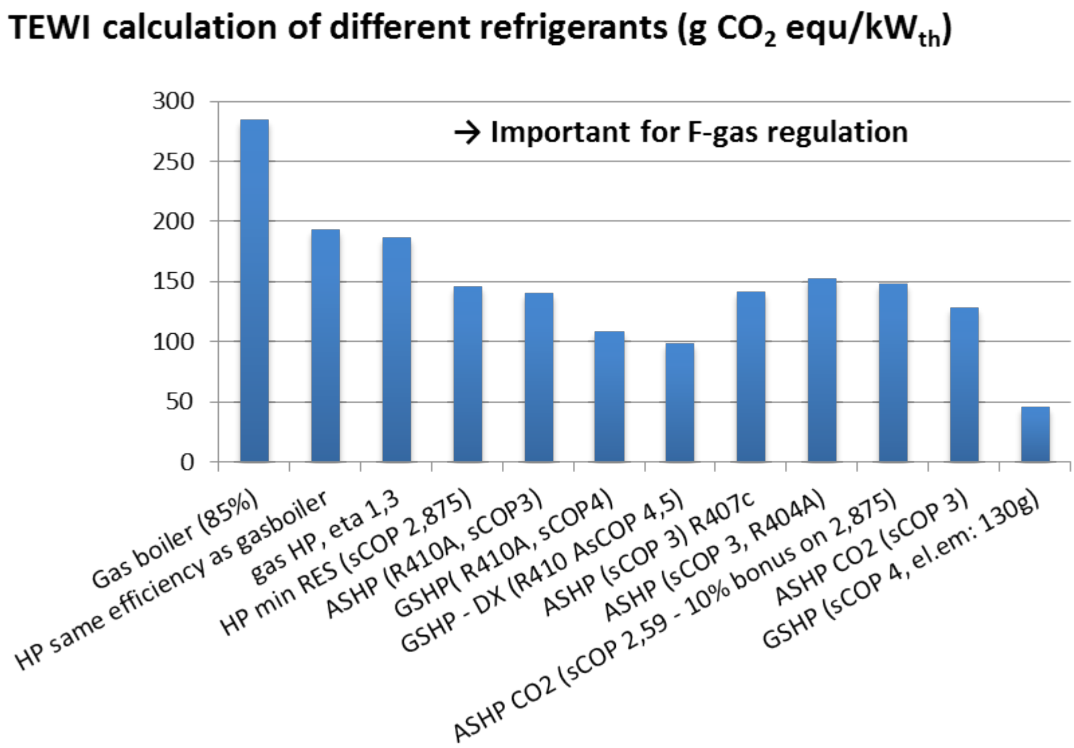

Figure 1. STEWI calculation of different refrigerants (g CO_2 equ/kW$_{th}$). [Source: EHPA, European Heat Pump Market and Statistics Report 2013]

sales are among the countries with the largest market losses during the last few years.

F-Gas Regulation & Ecodesign: A great challenge for Heat pumps

Andrea Voigt, the Director General of the European Partnership for Energy and the Environment (EPEE) presented EPEE's view on the F-gas regulation and on the Ecodesign directive.

The key actors in the revision of the F-gas directive are the European Commission, aspiring to be a global leader, the member states (Council), struggling with a north/south divide and difficult economic situation of many of the countries, and the European Parliament, very ambitious and looking forward to the elections in 2014. Two main points in which they differ is the views on the phase down of HFCs, which is steeper in the proposal from the Parliament than from the Commission or Council, and HFC bans in certain equipment, which is also the most ambitious in the proposal by the Parliament. EPEE's view is that HFC bans are counterproductive for Europe, regarding energy efficiency and refrigerant safety; it will also increase costs, and lower the competitiveness for Europe. An HFC phase-down, as the Commission suggests, is supported by EPEE.

The Ecodesign directive for Lot 1 (hydronic heat pumps) and Lot 10 (air/air heat pumps) will result in a single quality label for space heating, which will make it possible to compare the available alternatives, and thus make it possible for consumers to see the advantages with heat pumps. For Lot 6/Lot 21, which is very diverse and includes air cooled and water cooled chillers, among others, the Commission's proposal would ban 90 % of the existing equipment from the market, since they would not comply with the energy efficiency requirements. In order to achieve the necessary emission savings and maintain the competitiveness of EU industry, EPEE calls for ambitious yet realistic minimum energy efficiency requirements, as well as a clear distinction between Ecodesign requirements and the F-Gas Regulation (no bonus should be given for lower GWP refrigerants), among other items.

Finally, it was pointed out that 2014 will be a crucial year for heat pumps, with potential finalisation of the F-gas directive review, review of the Ecodesign and Energy Labelling Regulations, and potential decision on new 2030 targets and beyond.

Adsorption heat pumps for domestic heating

Johannes Üpping of Stiebel Eltron presented the concept of Adsorption heat pumps for domestic heating (radiator heating system, 55/45 °C). One motivation is that gas condensing boilers may be retrofitted with an adsorption heat pump module, to provide improved energy efficiency at a reasonable cost.

In the adsorption process in this case, water is bound to the surface of zeolites. Zeolites are porous minerals, which can be coated onto aluminum heat exchangers, providing good thermal contact and large surface area, due to the porous structure. The adsorption process is reversible, with energy released during adsorption, and heat required during desorption. Thus, a thermodynamic cycle is formed with the combination of adsorption and desorption. The ideal heat source is a solar thermal collector, with the advantage of direct usage of solar energy for hot water and enhancing the heating system. The lack of simultaneity of the heat demand and usage of source can be partly compensated by using a storage tank. The SEER of the adsorption heat pump system is lower than that of an air/water heat pump system (about 1.3 vs. 3.0), but considering the current coefficient of primary electric energy, it may be an alternative. Further, with an adsorption heat pump, the usable range of a solar thermal collector field can be extended; the minimum usable collector temperature is about 5°C.

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- *EHPS 2013 Press Release*

World Energy Outlook 2013

A new global energy landscape is emerging, resetting long-held expectations for our energy future. Incorporating these recent developments and world-class analysis, World Energy Outlook 2013 presents a full update of energy projections through to 2035 and insights into what they mean for energy security, climate change, economic development and universal access to modern energy services. Oil, coal, natural gas, renewables and nuclear power are all covered, along with an update on developments in subsidies to fossil fuels and renewable energy.

This year World Energy Outlook also gives a special focus to topical energy sector issues:

» Redrawing the energy-climate map
» Energy in Brazil
» Oil supply, demand and trade
» The implications for economic competitiveness of the changing energy map
» The global spread of unconventional gas supply
» Energy trends in Southeast Asia

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Events

2013

4-6 December
44th International HVAC&R Conference
Belgrade, Serbia
http://www.kgh-kongres.org/44kongres/eng/index.html

2014

16 January
AHRI Low-GWP AREP Conference
New York, USA
https://netforum.ahrinet.org/eweb/DynamicPage.aspx?Site=ahri&WebKey=a126175c-f185-4cd9-b376-3e442e365c59&RegPath=&REg_evt_key=f8e11179-ddcb-40ba-a9a3-075dfba874ba

18-22 January
ASHRAE Winter Conference
New York, USA
http://ashraem.confex.com/ashraem/w14/cfp.cgi

28-31 January
HVAC&R Japan
Tokyo, Japan
http://www.hvacr.jp/eng/index.html

4-6 February
Chillventa Rossija 2014
Moscow, Russia
http://www.chillventa-rossija.com/

24-26 February
First International Conference on Energy and Indoor Environment for Hot Climates
Doha, Qatar
http://ashraem.confex.com/ashraem/ihc14/cfp.cgi

26-28 February
49th AiCARR International Conference
Rome, Italy
http://www.aicarr.org/Pages/Convegni/Roma_2014/Home_English.aspx

27 February – 1 March
Acrex India 2014
New Delhi, India
http://www.acrex.in/index.html

31 March – 3 April
2014 International Sorption Heat Pump Conference
College Park, Maryland, USA
http://www.ceee.umd.edu/events/ISHPC2014

3-4 April
4th Annual CIBSE ASHRAE Technical Symposium
Dublin, Ireland
https://www.ashrae.org/membership--conferences/conferences/ashrae-endorsed-events/2014/cibse-ashrae-technical-symposium

7-8 April
High Performance Buildings Conference
San Francisco, USA
http://www.hpbmagazine.org/hpb2014

24-25 April
Efficient, High Performance Buildings for Developing Economies
Manila, Philippines
https://www.ashrae.org/membership--conferences/conferences/ashrae-conferences/efficient-high-performance-buildings-for-developing-economies

12-16 May
11th International Energy Agency Heat Pump Conference
Montreal, Canada
http://www.iea-hpc2014.org/

18-21 May
7th Asian Conference on Refrigeration and Air Conditioning
Jeju Island, Korea
http://www.acra2014.org/

20-21 May
2014 Energy Efficiency Global Forum
Washington, D.C., USA
http://eeglobalforum.org/

23-25 June
3rd IIR Conference on Sustainability and the Cold Chain
London, UK
http://www.ior.org.uk/iccc2014

28 June – 2 July
ASHRAE Annual Conference
Seattle, USA
http://ashraem.confex.com/ashraem/s14/cfp.cgi

14-17 July
Purdue Conference: 22nd International Compressor Engineering Conference
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/Events/2014Conf

14-17 July
Purdue Conference: 15th International Refrigeration and Air Conditioning Conference
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/Events/2014Conf

14-17 July
Purdue Conference: 3rd International High Performance Buildings Conference
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/Events/2014Conf

31 August - 2 September
11th IIR-Gustav Lorentzen Conference on Natural Refrigerants - GL2014
Hangzhou, China
http://www.gl2014.org/en/index.asp

10-12 September
Building Simulation Conference
Atlanta, USA
https://www.ashrae.org/news/2013/ashrae-ibpsa-usa-building-simulation-conference-announced

14-16 October
Chillventa
Nuremberg, Germany
http://www.chillventa.de/en/

2015

16-18 April
6th IIR Ammonia and CO_2 Refrigeration Conference
Ohrid, Republic of Macedonia

16-22 August
ICR 2015 – The 24th IIR International Congress of Refrigeration
Yokohama, Japan
http://www.icr2015.org/index.htm

Meet the Heat Pump Programme at Chillventa Rossija

In the next Issue
Policy and standards
Volume 32 - No. 1/2014

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 efficiency 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 benefits 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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