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IEA HEAT PUMP CENTRE

NEWSLETTER
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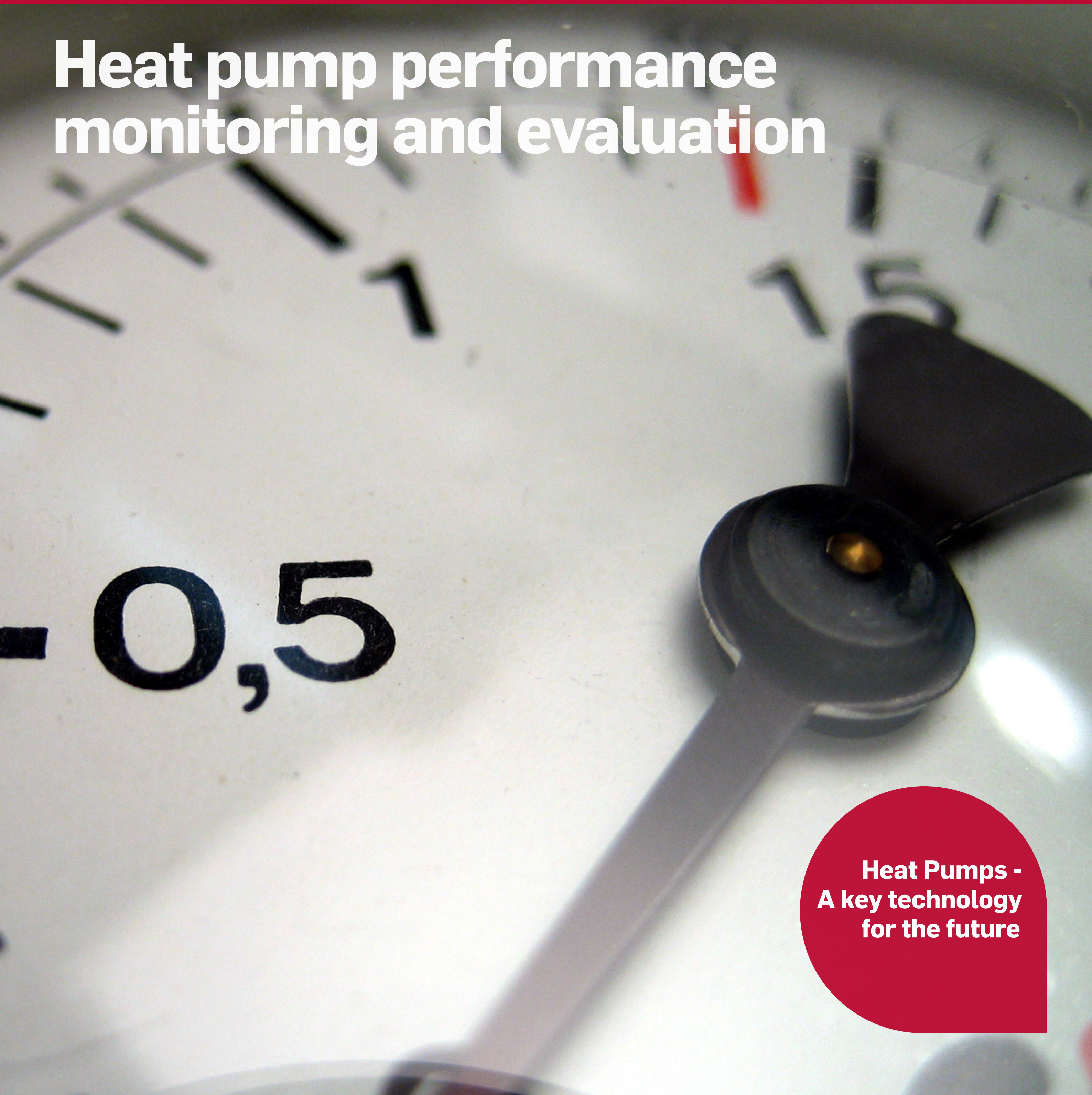
Heat pump performance monitoring and evaluation



Heat Pumps -
A key technology
for the future

IEA **Heat Pump** CENTRE
NEWSLETTER

Volume 31 - No. 2/2013

In this issue

Heat Pump Centre Newsletter, 2/2013
In technical product development in any field, it is necessary to be able to track performance of the product, in order to check if a specific modification resulted in an improvement or not. Also, the end user wants his purchased and installed product to perform as specified (at least), and needs methods to check this. Any other actor along the developing, marketing and dissemination chain needs to be aware of the end-user's reaction and needs – and preferably be able to anticipate them. All this calls for performance monitoring and evaluation.

The topic of this issue is heat pump performance monitoring and evaluation. A summary of the long-term heat pump field monitoring performed by the Fraunhofer ISE is provided, as well as evaluations of a part-load performance of a multi-split type air conditioner, and of a foundation heat exchanger. Also, a method for on-line monitoring and evaluation of heat pump performance is described. In addition, you will find a Strategic Outlook from the US.
Enjoy your reading!

Johan Berg
Editor

Heat pump news

Regulars

Topical articles

COLOPHON

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IEA OECD heat pump centre

Heat pump performance monitoring and evaluation

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Germany

The importance of accurate data on the real-life performance of heat pumps is well known. Although we speak of heat pumps as a mature technology, there are still prejudices concerning their efficiency or reliability. Heat pump performance, efficiency and reliability are therefore constantly recurring discussion points among specialists, and also among present and future users.

The IEA Heat Pump Programme is currently operating three annexes on these themes, which will contribute meaningful results to these discussions:

- **HPP-Annex 37 Demonstration of field measurements of heat pump systems in buildings - Good examples with modern technology:** We need to be able to demonstrate the potential for energy savings and CO_2 reductions of heat pump technology. There is also a need for better knowledge of the efficiency of heat pumps in real installations, especially concerning heat pump systems for combined operation including heating, cooling and domestic hot water production.
- **HPP-Annex 39 A common method for testing and rating of residential HP and AC annual/seasonal performance:** If a heat pump system is to deliver the best performance, it is important that the right type of heat pump is chosen and installed with a matching heat distribution system. For this reason, it is important to have reliable information on both the heat pump itself and on how it is influenced by the surrounding system.
- **HPP-Annex 41 Cold Climate Heat Pumps - Improving low ambient temperature performance of air-source heat pumps:** The goal of this annex is to identify technology solutions leading to successful (efficient & reliable) systems/equipment for residential and small commercial buildings in cold climate locations, with the primary focus on air-source heat pumps.

In this Newsletter you will find further projects with extensive information.

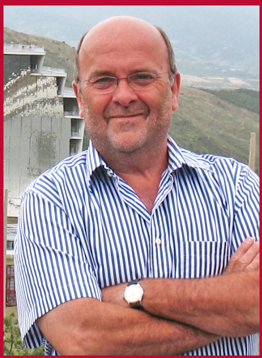
Within the framework of the ***Efficiency of heat pump systems under real operation conditions*** project, the Fraunhofer Institute for Solar Energy Systems ISE (Freiburg, Germany) carried out a large-scale monitoring project for over ten years. Concentrating on heat pumps in single-family houses, about 200 heat pumps have already been monitored. In addition to enabling efficiency to be calculated, the detailed measurements also permit analysis of operational behaviour, thus enabling important questions to be answered. One goal of the field study was the independent determination of heat pump efficiency and illustration and analysis of the behaviour of systems.

In the *Evaluation of partial load performance of multi-split type air conditioner for buildings* project, the partial load performance tests were made on a multi-split type air-conditioner for buildings, having rated cooling and heating capacities of 45 kW and 50 kW, respectively. In the cooling performance test, the outdoor air temperature was changed from 20 °C to 45 °C, and the indoor cooling load was changed from 12.5 % to 100 % of the rated cooling capacity of the air conditioner. Cooling COPs were measured under 36 operating condition sets. In the heating performance test, COPs were measured under 31 sets of operating conditions. Very detailed partial load performance of the air conditioner was provided by these tests.

The *Performance inspections to pick the low-hanging fruits in existing and new plants* article describes how optimisation of existing air-conditioning and heat pump systems delivers the "low-hanging fruit" of reducing the energy consumption and giving savings in commercial and industrial buildings. Few systems analysed were found to be operating at an optimal level or within their original design specifications. In most systems, energy savings of 10-40 % were found to be possible without significant investments.

Column

The Netherlands as a guiding country



Mr. Onno Kleefkens
Agentschap NL
Divisie NL Energie en Klimaat
Netherlands

In the nineties, a competition was announced to develop a heat pump for the Dutch market, based on the idea that if you can develop a heat pump that is competitive on the Dutch market, you will have a world product. It took some time, but a presentation from a colleague at the last Chillventa acknowledged the fact that the Netherlands is one of the most successful countries in experimenting with new heat pump applications. As soon as this is drawn to your attention, you will start viewing 'ordinary' things happening in your own country in another perspective.

So what makes the Dutch heat pump market different? To name a few: hybrid, small domestic heat pumps for heating and cooling, and high-temperature DHW heat pumps. But that is 'just' technology. For me, as a policy-maker, it is important to look at market developments. In new domestic housing projects, heat pumps installed for heating, cooling and domestic hot water production are becoming standard reference technology for renewable energy in low-energy and zero-energy buildings.

On the negative side, failures in installation and maintenance in some projects were big news. The Netherlands is probably unique in its plans to rework a housing project with individual heat pumps, going back to conventional gas boilers! The reaction has resulted in suppliers focusing more on installation guidelines, certification and quality control of the building process. New strategies have been developed to make heat pumps acceptable and financially attractive to the end user. Adequate monitoring by built-in software in heating systems is the basis for these strategies. Used for on-line servicing, it is very effective, as I personally have noticed with my own heat pump. More than 8000 individual heat pumps are already serviced in this way.

Monitoring makes it possible to keep the heat pump system within the boundaries of efficient operation. A large step forward in the market, in a large project with zero-energy buildings, is the offer to the end user of a 25-year performance guarantee for the system, consisting of a ground-source heat pump and photovoltaics.

Is the Netherlands giving guidance with these developments?

The latest statistics on renewable heating and cooling in the Netherlands show that we are lagging behind in developments in the market. The world-wide economic crisis is to blame, as the building of new houses and large-scale building renovation projects have virtually come to a halt. In Europe, recent analysis by European Renewable Energy Council (EREC) in its '2020 – Keep on Track' project shows that this does not differ much from the rest of Europe. Policy discussions in Europe are now considering a '2030 policy framework after 2020', for which business as usual is not an option. However, it is my firm belief that, particularly for renewable heating and cooling, we can't wait until after 2020, as measures taken now will have a considerable effect on energy use in existing building stock in 2030 and 2050. I'm not sure whether the Netherlands can take the role of a 'guiding country' in this respect, but regarding market developments and technologies we are more than happy to share our experiences.

IEA Heat Pump Programme News

Call for papers to 11th IEA HP Conference - Extended Deadline to June 30, 2013

Due to requests from authors wishing to amend their abstracts and many who missed the initial abstract deadline, we are pleased to announce that the International Organizing Committee has agreed to **extend the deadline for abstracts to June 30, 2013**.

Please visit the conference website at http://www.iea-hpc2014.org/ to submit an abstract.

This will be the final call.

The CGC, Canadian GeoExchange Coalition, is the host organization for the International Energy Agency Heat Pump Conference 2014 which will be held downtown Montréal (Québec, Canada) on May 13-15, 2014 at the Fairmont Hotel - The Queen Elizabeth.

Talks and know-how on heat pumps: The European Heat Pump Symposium

What role do smart grids play in the future of heat pumps and what prospects are offered by hybrid systems? The Symposium of the third European Heat Pump Summit (EHPS) on 15–16 October 2013 will provide the answers to these questions, and many others.

The Symposium, in the Exhibition Centre Nuremberg, supplies extensive information on the current state of heat pump development and research and on the European heat pump market.

At the accompanying Foyer-Expo, heat pump and component manufacturers present new products and developments that point the way to the future of heat pumps.

You are invited to give a presentation at this Symposium.

You will find the call for papers here: http://www.hp-summit.de/en/symposium/1b30f931-0055-4ba4-a65d-b31f344cb0ea/

The deadline for abstracts is extended to **July 7, 2013**.

For an overview of the EHPS, see http://www.hp-summit.de/en/

Link to the EHPS Symposium: http://www.hp-summit.de/en/symposium/

New HPP Annex Approved!

At the recent meeting of the Executive Committee of the HPP in Oslo a new annex was approved: **Annex 44**, ***Performance indicators for energy efficient supermarket buildings***.

See further information in this issue, page 20.

General

ASHRAE launches online discussion platform

Looking to exchange information with your peers about your latest project? Then visit the new online ASHRAExCHANGE discussion platform. Through ASHRAExCHANGE, the Society is providing both ASHRAE members and others in the industry with an online platform for real-time discussion and information exchange for design, construction, operation and support of the built environment.

Source: https://www.ashrae.org/news/

European Heat Pump City of the Year: Amstetten, Austria!

After having reviewed a number of applications received from several countries in Europe (Italy, Estonia, Germany, Austria, Denmark, Portugal and Belgium), the jury of heat pump experts decided to select the City of Amstetten as this year's winning case! The city of Amstetten is a city of 20000 inhabitants and has been very active in the field of sustainable development. The aim of the project was to explore and optimize the use of waste heat in the city. The first waste water plant was established in October 2012

Source: http://www.ehpa.org/about/news/

Efficient air conditioners could save over 360TWh/yr

The deployment of super-efficient air conditioners worldwide could avoid the need for more than 120 500 MW power plants by 2020, saving over 360TWh/yr, according to a new report by the USA's Lawrence Berkeley National Laboratory.

The authors maintain that their predictions that air conditioning efficiency could be cost-effectively improved by 20 to 40 % in most major economies may have a large impact on energy efficiency strategy for countries such as India and China as they attempt to cope with high energy demand and the capacity required to address peak load.

Source: http://www.acr-news.com/news/

Russia to ban disposables, to stop illegal imports

Following meetings earlier in the year the United Nations Industrial Development Organisation (UNIDO) has recommended that Russia bans the use of disposable refrigerant cylinders in line with the EU, USA, Canada and other developed countries. In a meeting with the Russian Ministry of Natural Resources it was recommended to initiate a ban on the use of disposable packaging for all types of refrigerants.

Illegal imports of refrigerants from China via the bordering countries of Ukraine and Kazakhstan have become a problem for Russia in its efforts to phase-out ozone-depleting substances. It is argued that the imports of refrigerants in small volume disposable bottles, as opposed to reusable packaging, is difficult to control because of the large number of imported containers

Source: http://www.acr-news.com/news/

Make your heat pump visible on a European online map!

EHPA is involved in the European project Repowermap, which aims at promoting renewable energy and energy efficient installations in Europe. By the means of an online map, it wants to raise awareness on what is available on the market and convince consumers to also go for renewable and energy efficiency.

EHPA has the goal to get as many heat pump installations on the map as possible. EHPA hopes that consumers can actually see that the heat pump technology isn't a niche product any longer but a widespread installed and used technology, delivering your daily heating, cooling and hot water.

Source: http://www.ehpa.org/about/news/

Wigan the centre for Japanese-led heat pump study

Leading air conditioning manufacturers Hitachi and Daikin are part of a Japanese-led consortium which is to study the feasibility of heat pumps and information and communication technologies (ICT) in a demonstration project in Wigan.

The consortium, which is being led by Hitachi and also includes Japanese bank Mizuho and the IT strategy company Mizuho Information & Research Institute, has been selected to execute the Smart Community Demonstration Project in various types of housing across Wigan. The project will be spearheaded by Japan's New Energy Development Organization (NEDO).

The project will see the delivery of Japanese cutting-edge technologies including heat pumps and ICT systems and will contribute to the UK's aim to supply over 15 % of its energy demand with renewable energy sources by 2020 and to support the penetration of heat pumps up to 30 % by 2030.

Source: http://www.acr-news.com/news/

Policy

China: New inverter AC standard may be implemented in September

According to industry insiders, the new national standard of inverter air conditioners has been reviewed by experts and corporate representatives and is now in the process of approval. It may be announced soon and implemented together with the extended energy-saving subsidy policy. However, since there are still uncertainties in the policy, air conditioner manufacturers are suggested to take 'both kinds of preparations'.
Source: http://www.ejarn.com/news.asp?ID=24639

China government to take lead in selecting Green Buildings in 2014

According to the 12th Five-year Green Building Development Plan released by the Ministry of Housing and Urban-Rural Development (MOHURD), green building standards will be enforced in 2014 on public and residential estate invested by the government, as well as all public facilities with construction area of more than 20 000 m^2, such as airports, railway stations, hotels, restaurants, shopping malls and office buildings.
Source: http://www.ejarn.com/news.asp?ID=24692

European Heat Pump Forum

This year's European Heat Pump Forum brought together stakeholders within the heat pump value chain – manufacturers, component manufacturers, national associations, test and research institutes etc. - as well as policy makers, with a high level panel of speakers. They addressed the three most important policy areas for heat pumps, namely:

- the RES Directive and potential targets beyond 2020
- the upcoming Ecodesign Directive for heaters (to be expected for publication in the Official Journal in July)
- the currently debated revision of the regulation on the use of fluorinated gases (which are used in heat pumps).

Source: http://www.ehpa.org/about/news/

Working fluids

Interest in CO_2 refrigeration grows in North America

Interest in CO_2 refrigeration is growing in the USA and Canada according to reports. Over 125 secondary, cascade and transcritical refrigeration installations systems are said to have been installed in North America, with many more planned.
While the report compilers - the Belgium-based market development company Shecco - recognises the region's considerable opportunities it acknowledges that it still remains a market of largely untapped potential. Europe still leads the way with this technology - Shecco estimating that around 3,000 such systems exist in Europe, with 300 in the UK alone.
Source: http://www.acr-news.com

EU environment committee votes to ban HFCs

The European Parliament's environment committee has voted to ban HFCs in new equipment from 2020. The overwhelming vote by 48 votes to 19 is the latest stage in the planned revisions to the F-gas regulations but will still have to be ratified by Parliament.
Andrea Voight of industry body EPEE expressed her dismay at the decision. "We are very disappointed that the Environment Committee has chosen the course of command and control politics with the highest price tag that Europeans will have to pay for," she said.
EPEE called upon decision makers to continue to support a phase-down to achieve Europe's climate objectives and sustaining a € 30 billion economy, over 200,000 direct jobs and millions of indirect jobs in Europe.
Understandably, the environmental group the EIA were cock-a-hoop describing the decision as a significant win for the climate and a boost for

the European economy.
The EIA's senior campaigner Clare Perry welcomed the vote as "a strong step in the fight against climate change and one which signaled that Europe is leading the way to move beyond HFCs."
"This is an important result as it comes despite a powerful HFC chemical lobby, one dominated by a handful of multinationals engaged in a relentless campaign to protect their profits at the expense of the environment and smaller European companies. "
Source: http://www.acr-news.com

EHPA is concerned about the introduction of a heat pump definition that is not in line with other legislation, namely EPBD, and on top of it fails to recognise the development status of the technology. EHPA calls upon the Council and Parliament to augment the current text in the next round of negotiations by a set of precise definitions on the scope of the regulation in general and on heat pumps in particular. The environmental, technical and economical advantages heat pumps bring should not be put at risk by unclear legislation.
Source: http://www.ehpa.org/about/news/

Daikin announces first R32 unit for Europe

Daikin has announced that Europe will see its first air conditioning heat pump using the "mildly flammable" refrigerant R32 as early as this autumn. Following the announcement of the commercialisation of R32 as a replacement refrigerant for R410A in the Far East at the end of last year, the Japanese manufacturer has announced the launch of an updated Ururu Sarara range in Europe in autumn 2013.
Source: http://www.acr-news.com

SAE investigates MAC refrigerant alternatives

With R1234yf still being shunned by some German car manufacturers as the replacement refrigerant for R134a in car air conditioning systems, the engineers group SAE has been assessing two other potential alternatives. The two low GWP blended refrigerants, both developed by Mexichem, meet the requirements of the EU MAC Directive.
Operating, technical and safety assessments carried out by SAE International's MAC Refrigerant Blend Cooperative Research Programme (MRB CRP), has found the risk profile of the two blends to be equal to or better than R1234yf. The blends are based on R-1234ze(E) with additional refrigerants that are all currently in production. AC5 is a mixture of R32, R152a and R1234ze(E) and AC6 is a mixture of CO_2, R134a and R1234ze(E).
Source: http://www.acr-news.com

Technology

Milestone in Chinese technology: Midea's centrifugal cuts refrigerant

In March, a high energy-efficiency two-stage, full falling-film centrifugal chiller developed by Midea passed accreditation by a committee composed of members of the Chinese Academy of Sciences, members of the Chinese Academy of Engineering, and experts from the Architectural Society of China (ASC), China Refrigeration and Air-conditioning Industry Association (CRAA), and China Association of Refrigeration (CAR).
Source: http://www.ejarn.com

Magnetic refrigeration technology set to break through

Magnetic refrigeration is to hit the mainstream with launches planned in domestic and commercial sectors over next two years. Cooltech set to launch integrated cold counter later this year, while Whirlpool advances field trials on domestic refrigerator for production launch.
French company Cooltech is to launch a 500 W cold counter, using the principles of magnetic refrigeration later this year. The firm, together with six partners has rapidly advanced development of a commercial product, thanks to the backing of technology investors, including 20 million euros from the French government. The news comes as UK magnetic refrigeration specialist Camfridge said that domestic fridges developed in association with manufacturing partner Whirlpool were likely to be available to buy by 2015.
Source: http://www.racplus.com/news/

BOC trials cryogenic refrigeration in trucks

BOC has initiated trials of Frostcruise, a cryogenic alternative to diesel-powered mechanical refrigeration in refrigerated transport systems. Frostcruise has been developed by BOC's parent The Linde Group, and uses the cryogenic effect of liquid nitrogen at a temperature of -196 °C. It is said to be able to maintain accurate product temperature throughout the truck compartment during multiple delivery stops, reducing the risk of food spoilage and improving food safety. As the technology does not rely on vehicle engines to perform the cooling process it is substantially quieter and can also run independently in the event of a mechanical breakdown.

Source: http://www.acr-news.com

Markets

Chinese ACR demand to hit 237 million by 2016

Chinese demand for air conditioners will reach 124,000,000 units and refrigerators will reach 113,000,000 units by 2016, according to the China Refrigerant Compressor Industry Report, 2013-2016 released by Sino Market Insight.

Chinas sales of inverter compressors in 2012 decreased by 2 % to 34.77 million units, of which total domestic sales also fell by 2 % to 32.16 million unit. Total exports were static at 2,612,000 units.

The refrigerator compressor market is fairly mature in a relative sense, and current industry players include Huayi, Donper, Qianjiang, Wanbao and Embraco.

Source: http://www.acr-news.com

Refrigerant demand to grow by 50 % by 2018

Worldwide refrigerant consumption is set to grow from an estimated $10.5 billion (equivalent to 1,207 thousand Metric Tonnes) last year to $15.7 billion by 2018, with a Compound Annual Growth Rate (CAGR) of 6.9 % from 2013 to 2018.

This latest report by marketsandmarkets.com covers all refrigerants - HCFCs, HFCs, hydrocarbons, ammonia and CO_2 - and defines and segments the global refrigerant market with analysis and forecasting of the global volume and revenue.

Asia-Pacific accounted for around half of refrigerant demand in 2012, mainly due to rising demand for cooling products in China and India.

To purchase the report: http://www.marketsandmarkets.com/Purchase

Source: http://www.acr-news.com

The air-conditioning market in India

A recent study published by Frost and Sullivan gives an overview of the air-conditioner (AC) market in India.

Concerning the residential AC market, foreign manufacturers are establishing infrastructures in India in order to capture the growing consumer durable/white goods market, propelled by growth factors such as higher disposable incomes, the propensity of the young workforce to spend on electrical and electronic goods and an increasing base of middle-class households.

According to National Council of Applied Electronic Research (NCAER) findings, the number of middle-class households is expected to reach 53.3 million by 2015, from the current level of 31.4 million. By 2025, it is likely to grow to 113.8 million.

NCAER figures indicate that currently only 52 % of these households possess air conditioners, which allows for an immense opportunity for AC manufacturers in India. The "bottom-of-the-pyramid" (BOP) income section is also a potential market as only 9 % of households in this category are equipped with AC.

Source: http://www.iifiir.org/

Strategic outlook items from the U.S., as of May 2013

Van Baxter, Gerald Groff, Antonio Bouza, US

The US Department of Energy's Buildings Technology Office is working toward a strategic goal to reduce energy consumption of residential and commercial/institutional (service sector) buildings by 50 % in 2030 vs. 2010 baseline consumption. This article lists a number of news items reflecting recent activities in the U.S. reported by various organizations that may have some impact on future buildings energy use and/or the direction of DOE/BTO's buildings RD&D activities

Introduction

The US Department of Energy's Buildings Technology Office (BTO) is working toward a strategic goal to reduce energy consumption of residential and commercial/institutional (service sector) buildings by 50 % in 2030 vs. 2010 baseline consumption [1]. In support of this overall strategy BTO is sponsoring R&D and technology deployment/implementation activities aimed at reducing energy use for water heating by 60 %, building heating and cooling by 20 %, and appliances by 20 % by 2030.

This article lists a number of news items reflecting recent activities in the U. S. reported by various organizations that may have some impact on future buildings energy use and/or the direction of DOE/BTO's buildings RD&D activities.

Incentives/Initiatives

Clean energy race to the top reintroduced [2]

Colorado U.S. Senator Michael Bennet has reintroduced a bill to incentivize states and communities to work with local energy businesses to utilize clean energy technologies that help reduce carbon pollution. The Clean Energy Race to the Top Act would establish a $5 billion competitive grant program for states and local governments that enact policies that move the clean energy economy forward. The bill would be fully paid for.

Under the bill, states, local governments, or public-private partnerships would be eligible to apply for competitive grants to develop and carry out clean energy and carbon reduction measures. Their applications would be evaluated based on a reviewing, scoring and ranking system.

Possible measures include:

- Renewable electricity standards, such as those enacted by Colorado;
- Regional or statewide climate action plans;
- Increased percentage of energy efficient public buildings;
- Participation in a regional greenhouse gas reduction program; and,
- Tax incentives for the manufacture or installation of clean energy components or energy efficiency upgrades.

AHRI participates in forum on building a stronger national standardized network [3]

AHRI (Air-Conditioning, Heating and Refrigeration Institute) staff has participated in a forum to explore new avenues to address the standardization needs for North America. Key industry stakeholders identified and discussed sources of redundant costs to cross border trade resulting from poorly aligned regulatory objectives and duplicative standards and certification requirements between Canada and the United States. Karim Amrane, AHRI Vice President, Regulatory & Research, presented on AHRI's issues and concerns affecting HVACR and water heating manufacturers. He reported on diverging Canadian and U.S. HVACR and water heater standards as an unnecessary burden for industry and consumers, noting that such de-harmonization results in added costs for producers as well as higher prices and less choice for consumers. In addition, he reported on the earlier AHRI – HRAI (Heating, Refrigeration and Air Conditioning Institute of Canada) submission on this subject to the Canada/U.S. Regulatory Cooperation Council.

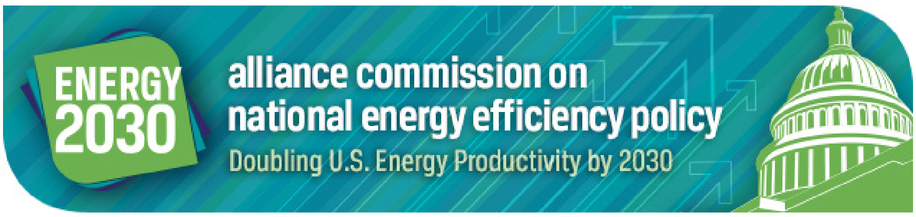
Those in attendance worked to develop a set of common principles.

Statistics/Prognoses

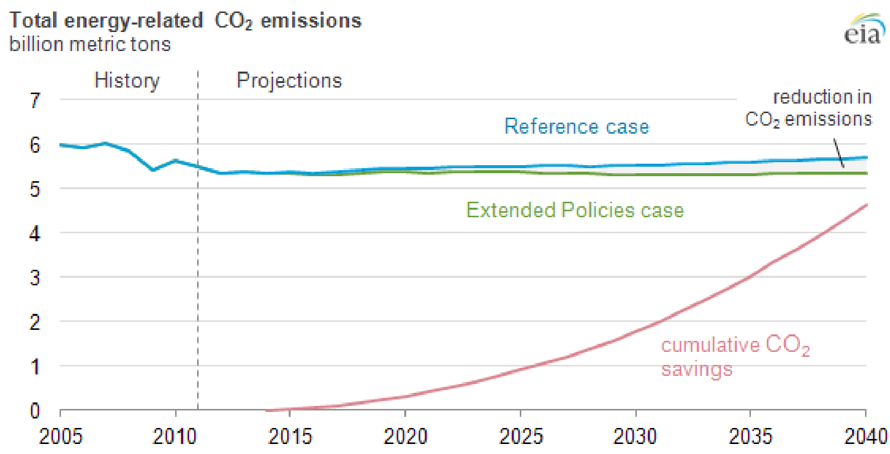
Energy efficiency: the U.S. can double its energy productivity by 2030 [4]

The National Renewable Energy Laboratory (NREL) Director Dan Arvizu and a panel of 20 energy experts concluded that the United States can double its energy productivity by 2030 — and do so in ways that will strengthen the nation's economy.

Arvizu and other members of the Alliance to Save Energy (ASE) Commission on National Energy Efficiency Policy said that doubling energy productivity could create a million new jobs, while saving the average household $1,000 a year and reducing carbon-dioxide emissions by one-third. The commission was organized and sponsored by the ASE, and the full report is available on the ASE website [5].



Energy efficiency: the U.S. can double its energy productivity by 2030. The commission was organized and sponsored by the ASE. (Source: www.ase.org)



Total energy related CO_2 emissions (Source: U.S. Energy Information Administration, Annual Energy Outlook 2013)

Extending current energy policies would reduce U.S. energy use, carbon dioxide emissions [6]

By extending certain federal energy efficiency and renewable energy laws and regulations, annual energy-related carbon dioxide emissions in the United States could be reduced by roughly 6 % in 2040, relative to a reference case projection that generally assumes current laws and policies. This is shown in The Extended Policies case, released as part of U.S. Energy Information Administration's (EIA's) Annual Energy Outlook 2013. Between 2013 and 2040, this reduction adds up to a cumulative emission savings approaching five billion metric tons.

"Sustainable Energy in America 2013 Factbook" released

The "Sustainable Energy in America 2013 Factbook" [7], researched and produced by Bloomberg New Energy Finance and commissioned by the Business Council on Sustainable Energy [8], provides independent analysis and market intelligence for clean energy sectors in the U.S.

Highlights from the Factbook include:

- Renewable energy installations hit an all-time record with at least 17 GW of new nameplate capacity added in 2012;
- In April 2012, electricity generation from natural gas equaled that from coal for the first time in US history;
- Policies and approaches for financing energy efficiency continued to make market headway; energy intensity for US commercial buildings has now dropped by more than 40 % since 1980 and investments in smart grid topped $4 billion; and,
- Carbon dioxide (CO_2) emissions from the energy sector were on pace to sink to their lowest level since 1994.

Global research funding forecast released [9]

According to an annual report released by Battelle [10] and R&D Magazine [11], global research and development (R&D) spending is forecast to grow by 3.7 % — or $53.7 billion — in 2013 to $1.5 trillion. Much of this funding is expected to come from China, predicted to account for $23 billion in project growth. At the same time, due to the uncertainty facing the U.S. federal budget, predictions range from growth just over 1 % to 2 % contraction in spending.

Despite the growth, global economic conditions will continue to affect R&D investment in 2013.

"In a year of economic upheaval and turmoil, it's important to remember that R&D is not an instrument that can be quickly turned on and off to trigger economic growth," said co-author Martin Grueber, a Battelle Research Leader.

Under optimal budget circumstances, the U.S. R&D enterprise, which accounts for 8.3 million jobs, would see expenditures grow by 1.2 % to $424 billion. Since sequestration took effect on March 1st, the chance of contraction in federal spending is greatly increased.

"The watchword heading into 2013 is uncertainty, and the effect on U.S. R&D is more unclear than ever," Grueber said. "The current economic condition and uneasy prospects for the future combined with a federal government funding projection that could range anywhere from flat to significant declines have limited the prospects for 2013."

Federal budget authority for R&D declined in fiscal years 2011-12 [12]

Federal budget authority for research and development (R&D) and R&D Plant (R&D facilities and fixed equipment) declined in fiscal years 2011 and 2012, mostly due to a drop in defense-related R&D, according to a recent report from the National Science Foundation.

Under the fiscal year 2013 budget authority for R&D activities proposed by the president last year, total investment in this area would rise somewhat, although a further decrease would be seen in defense-related R&D. Investment in non-defense mission areas, such as space, energy, health and commerce, would increase slightly in fiscal year 2013.

The drop in the federal budget authority for fiscal years 2011 and 2012 follows increases each year over fiscal years 2006-10. When adjusted for inflation, the yearly rate of growth over this period averaged 0.4 %, somewhat ahead of the U.S. economy's general pace of price increases.

Opportunities

Smart grid R&D opportunities outlined in two new NIST reports [13]

The nation's aging power grid is rapidly evolving into a modern, "smart" energy distribution network, and with these changes comes a host of challenges for the research and development community, as outlined in two new reports issued by

National Institute of Standards and Technology (NIST). The documents should provide valuable perspective to high-level planners involved with the smart grid.

Both reports, Technology, Measurement, and Standards Challenges for the Smart Grid and its companion, Strategic R&D Opportunities for the Smart Grid, focus on the most important technical issues that confront smart grid development.

The reports are the product of a workshop held during 2012 for more than 90 leading technical and industry experts in the smart grid community. The workshop was a collaborative effort of NIST and the Renewable and Sustainable Energy Institute (RASEI), which is a joint institute of the University of Colorado, Boulder, and the National Renewable Energy Laboratory (NREL). The documents reflect the consensus opinions of the attendees, and are intended to be of value to industry.

Tools

National Laboratory launches interactive tool for developing a cleaner energy future [14]

The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) has created an energy analysis tool to help individuals and educators experiment with future energy use scenarios. The interactive Buildings, Industry, Transportation, Electricity, and Transportation Scenarios (BITES) allows users to explore how changes in energy demand and supply can impact carbon dioxide emissions and the current U.S. energy trajectory.

"BITES can help people understand the complex issues surrounding the energy and carbon implications of altering America's energy profile," according to NREL Senior Analyst Austin Brown. "By imagining 'what-if' scenarios, users are able to adjust inputs from things like electricity generation to transportation fuel use in order to compare their outcomes to baseline cases."

BITES was adapted for the web, so anyone can investigate possible pathways for the U.S. energy economy. Users can adjust assumptions to each sector of the U.S. economy in order to evaluate outcomes, or combine these sector-specific strategies into a more complete picture of potential future energy use.

Scenarios created in BITES can be private, or they can be shared with the analysis community for discussion. Educators and students interested in energy and sustainability can use BITES to help teach the combined impacts of research, policy, or other forms of national action in energy. The BITES team has developed and piloted a college level workshop and is seeking interested educators to help further refine the curriculum

Montreal Protocol/ Clean Air Act

AHRI submits Letter on Montreal Protocol Amendment [15]

AHRI recently submitted a letter [16] to the Department of State and Environmental Protection Agency (EPA) regarding the recent North American HFC phase down amendment to the Montreal Protocol. The letter noted that when the amendment was originally proposed in 2009, the phasedown schedule for developed countries included a 2013 start date and 2033 end date. However, as this amendment has been reintroduced annually since 2009, the phase down end date has not been adjusted beyond 2033, resulting in a “compression” of the proposed phase down schedule. In light of this, AHRI asked that any proposal introduced or supported by the United States Government ensure that it include a minimum 20-year phase down period.

North America Proposes Amendments to Control HFCs in Montreal Protocol [17]

The United States, Canada, and Mexico have submitted a proposed amendment to the Montreal Protocol seeking a global freeze and phasedown of HFC production and consumption. The amendment has been submitted five years in a row, but has failed to gain the necessary traction for adoption. This year, the proposal contains several changes, including more recent data for establishment of the baseline, removal of HFOs from the proposal, and reducing the necessary steps to reach the ultimate phasedown for developed countries. The amendment will be considered at the meeting of the Open-Ended Working Group of the Montreal Protocol that began on June 24 in Bangkok, and at the Meeting of the Parties in October.

EPA proposes to exempt venting of certain hydrocarbons under the Clean Air Act [18]

The Environmental Protection Agency (EPA) has issued a notice in the Federal Register [19] proposing to exempt three hydrocarbons from the venting, release, and disposal prohibitions contained in Section 608 of the Clean Air Act. The three hydrocarbons are isobutane (R–600a), R–441A, and propane (R–290), which have been listed as acceptable substitutes subject to use conditions under EPA’s Significant New Alternative Policy (SNAP) Program. The proposed exemption to the venting prohibition would not apply to hydrocarbon blends containing any amount of CFCs, HCFCs, HFCs, or PFCs. The EPA is proposing this exemption on the basis of current evidence that the venting, release, and disposal of these three substitutes does not pose a significant threat to the environment.

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Annexes, ongoing

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

The Annex 35 is a joint venture of the IEA Implementing Agreements "Industrial Energy-related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP).
At the annex meeting on the March 17, 2013 in Gothenburg, Sweden, with 13 participants from 8 countries, it has been officially decided to extend the annex for one year until April 30, 2014 and to finance the additional year either in cash, or with more contributions in kind.

The work of the extended year will be mainly concentrated on the **task 2** programme "Modeling calculation and economic models", in particular on updating and modernizing a database for industrial heat pumps.
The task 2 leader proposed the following activities for the remaining time of the annex:

- Database/collection of information on manufacturers of large/industrial heat; pumps and their performance figures including a selection of compressor manufacturers
- Overview of software for process integration (PI) of industrial heat pumps
- SWOT-analysis
- Principles for the integration of heat pumps in industry

Task 1 Report "Heat Pump Energy situation, energy use, market overview, barriers for application" has been finished, however new results may require a permanent update.

Task 3 (R&D) and 4 (case studies) contributions to the final reports should be completed based on a standardized factsheet proposed.

Task 5 will be related to communication and awareness on heat pumping technologies for industry for policymakers, industrial planers and designers, stake holders as well as heat pump manufacturers in such a way that it will lead to a better understanding of the opportunities and using these in the right way for the reduction of primary energy consumption, CO_2 emissions, as well as energy costs of industrial processes.

The second Annex meeting during 2013 will be organized again in connection with the next European Heat Pump Summit at the Exhibition Centre (Messezentrum) Nürnberg/Germany, 15 – 16 October 2013.

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R&D: VHT heat Pump, up to 140 °C, with water as working fluid (Source: EDF R&D)

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). Also under investigation are the extent that operational deviations are significant, whether the deviations (when combined) have an additive effect on heat pump performance, and whether some deviations (among various country-specific equipment types and locations) have greater impact than others. The focus and work to be undertaken by each participating country is given in the table below.

The participants held an electronic conference on 19 March 2013. That meeting was devoted to presentations of work progress from each participant and to discussion of the final report preparation schedule. It was reaffirmed that each participant would provide draft country reports (with executive summary) to the Annex Operating Agent (OA) by early September 2013. The OA will then assemble the country reports into a rough draft final Annex report and re-share with the participants by end-September 2013.

A working meeting is planned for 10 – 11 October 2013 at EdF's facilities just outside of Paris, France. The main purpose of the meeting will be to finalize the Annex report and secondarily to update planning for the final results workshop to be held at the upcoming 11th IEA Heat Pump Conference (Montreal, Quebec, Canada; 12 – 16 May 2014).

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Annex 36 Participants	Focus Area	Work to be Undertaken
France	Space heating and water heating applications.	Field: Customer feedback survey on heat pump system installations, maintenance, and after-sales service. Lab: Water heating performance tests on sensitivity parameters and analysis.
Sweden	Large heat pumps for multi-family and commercial buildings Geothermal heat pumps	Field: Literature review of operation and maintenance for larger heat pumps. Investigations and statistical analysis of 22000 heat pump failures. Modeling/Lab: Determination of failure modes and analysis of found failures and failure statistics.
United Kingdom	Home heating with ground-to-water, water-to-water, air-to-water, and air-to-air systems.	Field: Replace and monitor five geothermal heating systems Lab: Investigate the impact of thermostatic radiator valves on heat pump system performance.
United States (Operating Agent)	Air-to-air residential heat pumps installed in residential applications (cooling and heating).	Modeling: Examine previous work and laboratory tests to assess the impact of ranges of selected faults covered augmented by seasonal analyses modeling to include effects of different building types (slab vs. basement foundations, etc.) and climates in the assessment of various faults on heat pump performance. Lab: Cooling and heating tests with imposed faults to correlate performance to the modeling results.

Participating countries in Annex 36

IEA HPP Annex 37 Demonstration of field measurements on heat pump systems in buildings – Good examples with modern technology

The aim of the project is to demonstrate and disseminate the economic, environmental and energy saving potential of heat pumping technology. The project is in its final stages; all deliverables have been sent out for approval to the Executive Committee. The active participants are Sweden, Switzerland, and the United Kingdom. Norway and Austria participate as observers.

During the project, we set SPF limits that we consider to be acceptable for good heat pump systems: 3.0 or above for air-source heat pumps and 3.8 or above for ground-source heat pumps. The resulting SPF values for the included heat pump systems range from 2.6 to 4.7, see Figure 1. Four ground-source heat pumps and five air-source heat pumps were found to have SPFs above the limits.

Important factors for achieving high energy efficiency of heat pump systems are:

- Low-temperature emitters in the building, for example floor heating.
- Heat pumps may be combined with solar heating or exhaust air heat exchanging, but the system must be correctly sized.
- The heat pump should be correctly sized for the building it is intended to heat in order to use minimal electrical backup.
- The circulation pumps should be energy efficient, they should not run unnecessarily and they should be correctly sized.
- For ground-source heat pumps, the borehole needs to be accurately dimensioned

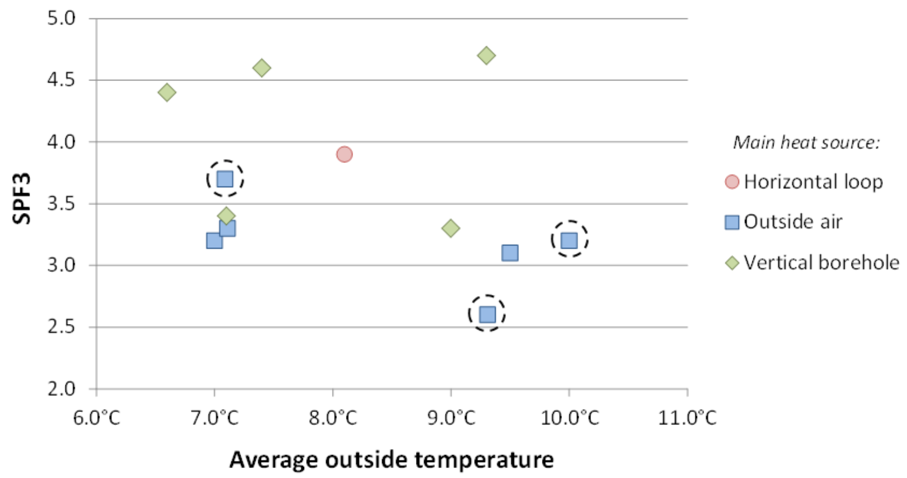

Figure 1. SPF3 values for the heat pumps versus the average outside air temperature. The symbols are coloured based on the main heat source, and the heat pumps that only supply heat for space heating are encircled.

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contribute to successful market penetration of these new systems.

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 and heat pumps.

Participants come from research institutions, engineering firms, and HVAC and solar industry. Participating countries are Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Portugal, Spain, Sweden, Switzerland, and USA.

The objective of this Annex is the assessment of performances and relevance of combined systems using solar thermal and heat pumps, to provide common definition of performances of such systems, and to contribute to successful market penetration of these new systems.

Annex 38 has progressed on several fronts:

1. A newsletter number 3 was issued in February 2013 showing for the first time results of three installations of solar and heat pump.
2. A report on a market survey of solar and heat pump systems in 80 European companies is available.
3. Interesting field test results have been reported during meeting 7 in April 2013
4. A Report (code B1) which defines all performance figures for solar and heat pump systems is available.
5. System simulations have been done by several teams. The use of the Annex 38 framework is however not generalized yet, so that comparisons between systems cannot be performed.
6. The publisher Wiley VCH will publish the final handbook of the Annex in early 2014. It will be a comprehensive 250 pages handbook on solar and heat pump systems.

All reports can be found on:
http://task44.iea-shc.org/

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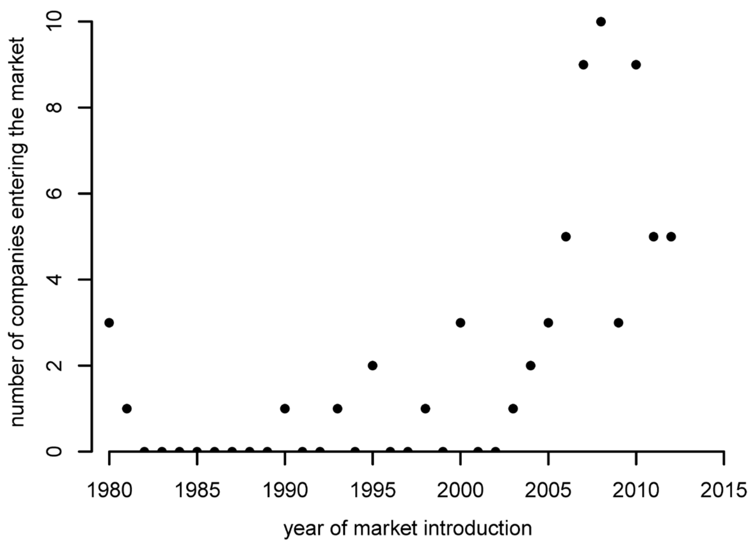

Number of companies providing a solar and heat pump solution on the market by year of market introduction (from report code A1)

IEA HPP Annex 39 A Common Method for Testing and Rating of Residential HP and AC Annual / Seasonal Performance

The outcome from Annex 39 will be proposals for a common transparent SPF calculation method for domestic heat pumps, including heating, cooling and domestic hot water production, as well as proposals for global harmonization of test points, to minimize testing efforts. The idea is to conduct pre-normative research, which later can be incorporated in standardization (ISO, CEN etc.) in the same way as HPP Annex 28, on the results of which Annex 39 will partly build.

The following task-sharing activities have been planned and initiated:

- **Task 1**: Review and evaluation of existing test and calculation methods for SPF - In task 1, a template for reporting has been developed, and the national methods are currently summarized.
- **Task 2:** Development of a matrix defining needs for testing and calculation methods
- **Task 3:** New calculation methods for SPF/commonly accepted definitions on how SPF is calculated
- **Task 4:** Identification of improvements to existing test procedures
- **Task 5:** Validation of SPF method
- **Task 6:** Development of an alternative method to evaluate heat pump performance
- **Task 7:** Communication to stakeholders.

Two meetings were held in 2012, one in Chicago during the ASHRAE winter meeting, and one in Nurnberg during the Chillventa. Information on national and international standards has been collected, analyzed and a SWOT analysis of current standards has been made. In addition, Japan has compiled information on test laboratory accuracy which can serve as a benchmark for minimum requirements in testing. What is extra interesting is the detailed schematics of the set-up of the test equipment.

The Netherlands and Japan have joined the Annex in 2012. The project website (link to website) has been set up and contains material from the first meetings and the open workshop that was organised in conjunction with the Heat Pump Summit in Nurnberg 2011.

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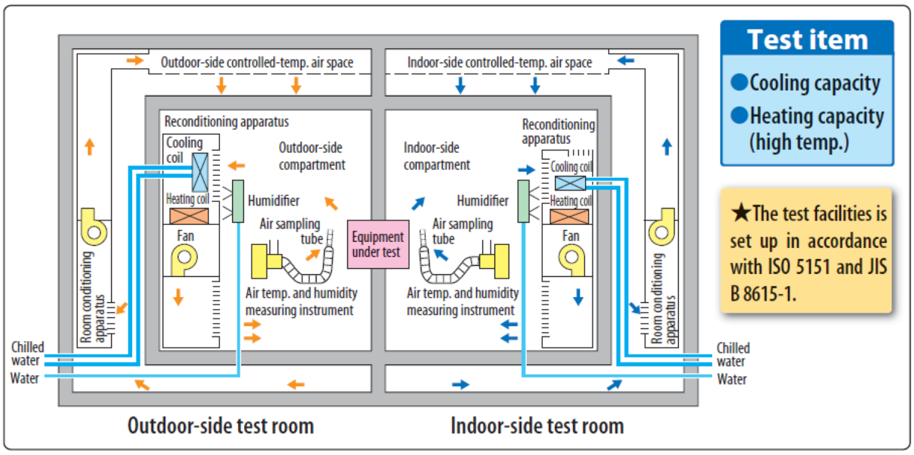


Balanced ambient room-type calorimeter

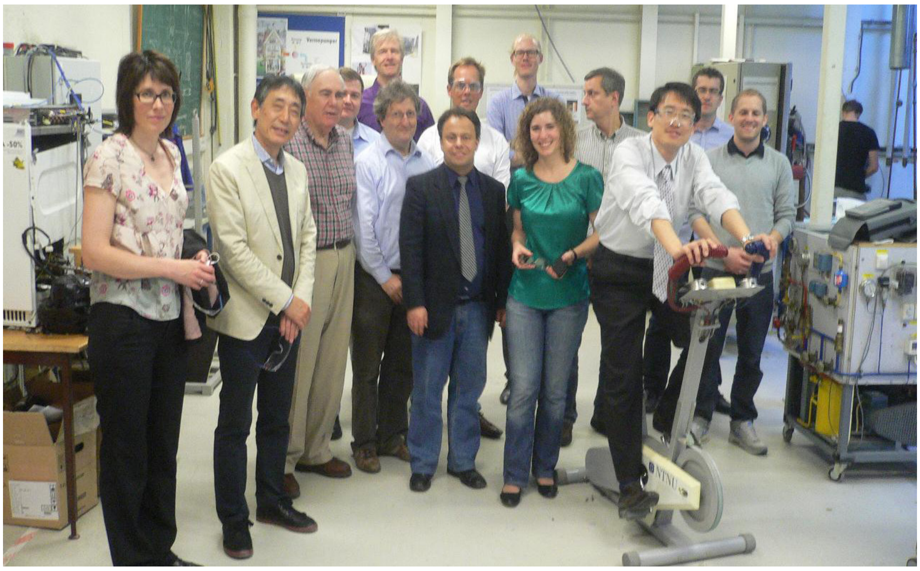
IEA HPP Annex 40 Heat pump concepts for Nearly Zero Energy Buildings

IEA HPP Annex 40 is to investigate and improve heat pump concepts applied in Nearly or Net Zero Energy buildings (NZEB). The Annex 40 was started with a Kick-off meeting in Rapperswil, Switzerland, in July 2012. The working time of the Annex 40 is scheduled for three years, 2013 - 2015.

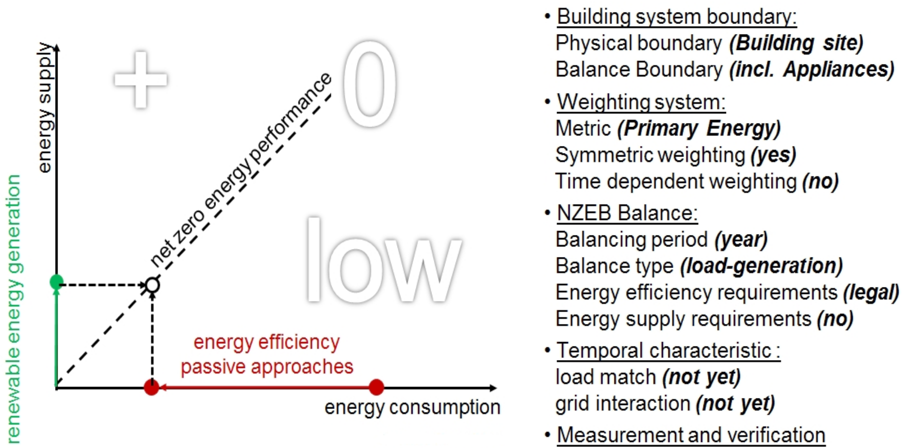
The second working meeting of IEA HPP Annex 40 has been held at SINTEF Energy Research, Trondheim, Norway. The main topic of the meeting has been the presentation of interim results on the state-of-the-art of NZEB and respective building systems installed in NZEB, as well as the definition of NZEB in the individual participating countries for the following work in Annex 40. As a frame programme, the SINTEF labs have been visited.

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.

Even though referred to in political strategies, no common definition of NZEB exists, yet. The common understanding of the NZEB is a grid-connected building which produces as much energy as it consumes from renewable sources on-site, on an annual basis. For Annex 40, the boundary has been fixed to the building and to the energy consumption of the HVAC technology and appliances. The metric was set to primary energy and with a symmetric weighting of imported and exported energy. No additional requirements have been set on energy efficiency and energy generation. No requirements on the load match or grid interaction characteristics have been set, either. A verification of the NZEB balance is currently mainly accomplished in the planning phase of the building, thus design values are used.



Visit of SINTEF energy research labs



Definition of NZEB in IEA HPP Annex 40 based on the framework of Sartori et al. (2012)

Moreover, a common depiction of NZEB concepts and the collaboration in the follow-up Task 2 on detailed system analysis by simulation, Task 3 on technology development and field-monitoring as well as Task 4 on the integration of NZEB into the energy system has been discussed.

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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-to-air or air-to-water air-source heat pumps (ASHP), with air or hydronic 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.

The Annex work is divided into four tasks:

Task 1 is dedicated to a thorough review of prior RD&D activities related to heat pump applications in cold climates to identify potential equipment and system options for detailed evaluation.

In **Task 2**, detailed analyses of promising component/system concepts are performed, considering the system performance and cost implications as well as design and control issues. Laboratory prototype and field prototype testing may be included in this task as well.

Task 3 will involve seasonal/annual performance simulations based on the prototypes developed in Task 2 to estimate energy and emissions savings potential.

Laboratory prototype test system at Purdue University – Photo courtesy of Prof Eckhard Groll, Purdue University

Task 4 is dedicated to development of a final report comparing CCHP design options on a common format.

The Annex officially began in July 2012 and is expected to run through September 2015. A 1st working meeting is planned to be held in the US in mid-2013 at Purdue University with a 2nd meeting and open workshop planned for May 2014 at the 11th IEA Heat Pump conference in Montreal. The final Annex meeting is planned to be held in Japan in August 2015 in conjunction with the next IIR International Congress of Refrigeration. Currently Japan and the US (OA) are the only official participants in this Annex, but Austria, Canada, and Italy have all expressed interest in joining. The Annex remains open to new members at least through mid-2013 so other HPP member countries are strongly encouraged to join.

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IEA HPP Annex 42 Heat Pumps in Smart Grids

After discussing this item as a potential subject for an Annex in fall 2011, the Legal Text was further developed in close cooperation between the IEA Heat Pump Centre in Sweden and the undersigned during summer 2012. Initial presentations at the HPP Symposium in Nurnberg in October 2012 about, at that time, the 'Proposed Annex' were received very well by delegates of the member states within the HPP.

During the National Teams' meeting, the member states gave their input for further detailing and elaboration of the Legal Text. The conclusion at the end of this meeting was that more or less 'a full house' of member states intended to join and support the Annex. At the ExCo meeting in November in London, a final presentation and brief discussion of the proposed Annex led to a clear positive vote by the ExCo delegates. Commitment to the Annex 42 was expressed by, amongst others, Sweden, USA, Korea, Finland, Germany, The Netherlands, and Austria. Several other member states consider participating in this Annex 42 in due course as well. Due to the upcoming new year, with the new budgets, this might take somewhat more time.

Status of activities:

- Template notification letters have been sent to the member states in which they can officially confirm their participation to the IEA office in Paris, HPP and the Operating Agent.
- The first version of a planning scheme is being drafted.
- An online project management tool in ActiveCollab is equipped to enable all participants from all over the world to cooperate within one single online project management environment.
- The first meeting of the Annex 42 project group is foreseen in May 2013 (Parallel to EHPA General Assembly in Brussels).

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IEA HPP Annex 43 Fuel-driven sorption heat pumps - Proposal for a new annex

In parallel with the work on Annex 34, "Thermally Driven Heat Pumps for Heating and Cooling", it became apparent that there was increasing interest in the field of fuel-driven sorption heat pumps, with a growing number of products approaching market release. The work of Annex 34 showed that the fields of solar thermal cooling and fuel-driven heat pumping need to be treated separately for wider market penetration, with the result that a common understanding to continue this work in two different annexes or tasks emerged. The work of Annex 34 concerning solar thermal cooling will therefore be continued as part of the IEA-SHC Task 48 "Quality Assurance and Support Measures for Solar Cooling", while a new annex, "Fuel-driven Sorption Heat Pumps", was proposed to the ExCo in March 2012 for continuation of the work on fuel-driven heat pumps. After an annex definition meeting, a legal text was compiled and accepted by the ExCo in draft form, so a start in May 2013 is planned.

The scope of the work of this Annex will cover the use of fuel-driven sorption heat pumps in domestic and small commercial or industrial buildings applications. If appropriate, the additional possibility of supplying cooling will also be considered.

The planned structure is as follows:

Task A Generic Systems and System Classification

- Available sources and heating systems
- Existing market and regulatory boundary conditions
- Control strategies
- Evaluate different fuels (oil, gas, wood -> no hot water)

Task B Technology Transfer

- Link research to industrial development for faster market penetration of new technologies
- Novel materials (e.g. MOFs for adsorption heat pumps)
- Novel components (integrated evaporators/condensers, compact heat exchangers)
- System designs (e.g. façade collector as a heat source)

Task C Field test and performance evaluation

- Measurement/monitoring procedures standardisation (e.g. how to cope with different fuel qualities, system boundaries, auxiliary energy etc.)
- Continue work from Annex 34 and Task 44, and extend standards to seasonal performance factors at system level
- Develop quality insurance procedures in cooperation with IEA-SHC Task 48

Task D Market potential study and technology roadmap

- Simulation study to evaluate different technologies in different climate zones, different building types and different building standards
- Combine with market data and actual building stock for technology roadmap

Task E Policy measures and recommendations, information

- Dissemination
- Workshops for planners, installers and decision makers
- Technology road show
- Develop recommendations for policies, e.g. building codes and funding schemes

So far, several countries have expressed interest in joining, but of course more participants are welcomed.
A kick-off meeting is planned in May 2013, and a duration of four years is expected.

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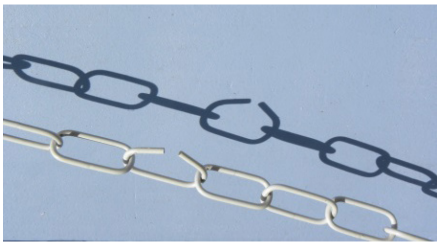
IEA HPP Annex 44 Performance indicators for energy efficient supermarket buildings

If you have the responsibility for the energy consumption of a chain of supermarket stores, then how should you invest in energy efficiency with the best value for money? The best bet is to start with the store having the lowest energy efficiency, the weakest link in the chain. Therefore you would need to identify which store is – energy-wise - the weakest link in the chain.



A good projection can help to identify the weakest link in the chain.

This may not be obvious at first sight; a good projection helps to identify the weakest link – just as the figure shows. This is the objective of the IEA Annex 44 "Performance indicators for energy efficient supermarket buildings".

It has been estimated that 3-5 % of total global electricity use stems from supermarkets in industrialized countries. Typically, 40 to 60 % of this electricity use is related to the refrigeration equipment, with a potential for economically viable energy savings amounting to more than 50 %.

Global energy consumption data for individual stores of supermarket chains are often available, through own measurements or from the utility bills. But these data only become meaningful when put in the right context of sales area, outdoor temperatures, etc. - only then can the actual energy performance of individual shops be assessed. A method to do this will be developed in this Annex, with an emphasis on practical use instead of academic perfection. The kick off meeting for this Annex will be held in June 2013 in Stockholm – with participants from Sweden and The Netherlands. Other participants are encouraged and welcome to join this new Annex.

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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, **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**, FR, JP, NL, NO, US
Annex 41 Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps)	41	JP, **US**
Annex 42 Heat Pump in Smart Grids	42	DE, FI, KR, **NL**, US
Annex 43 Fuel Driven Sorption Heat Pumps	43	**DE**, 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.

Efficiency of heat pump systems under real operating conditions

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The importance of accurate data for real-life performance of heat pumps is well known. Although we talk of a mature technology, there is still discussion concerning the efficiency or the burden of heat pumps. This, and other reasons, has led the Fraunhofer Institute for Solar Energy Systems ISE (Freiburg, Germany) to carry out large-scale monitoring projects for over ten years. With particular emphasis on heat pumps in single-family homes, about 200 heat pumps have already been monitored. The detailed measurements enable us not only to evaluate the efficiency, but also to analyse the operational behaviour, and so provide answers to important questions.

Introduction

The results described in this article are based on three monitoring projects, all carried out over different time periods since 2005. The current project, HP Monitor, has just ended and will be followed by "HP Monitor PLUS" to evaluate best practice heat pumps. The common main goals of all projects are assessment of the efficiency of heat pumps in residential buildings, and finding ways to optimise heat pump systems, their installation and their control systems. For this reason, minute-by-minute values of volume flows, temperatures, heat quantity and electricity consumption have been collected and sent daily to the Fraunhofer ISE headquarter, where they underwent an automatic plausibility check. The following results concern ground-source heat pumps (GSHPs) and air-source heat pumps (ASHPs).

	building type	number of heat pumps	duration
HP in Existing Buildings	building stock	approx. 80	10.2006 to 12.2009
HP Efficiency	new buildings	approx. 100	10.2005 to 09.2010
HP Monitor	new buildings	approx. 90	12.2009 to 05.2013

Figure 1. Characteristics of heat pump monitoring projects

Monitoring projects

The main features of the three projects in terms of building type, measured heat pumps and project duration are shown in Figure 1.

The 'Heat Pumps in Existing Buildings' project dealt with heat pumps in non-retrofitted buildings, and was funded by E.ON Energy AG. Approximately 80 heat pumps were examined. The heat pumps were installed in buildings occupied by E.ON customers, where oil-fired boilers had previously been used. The aim of the project was to investigate the performance of heat supply to buildings by heat pump systems with high-temperature heat distribution systems, typical in older buildings. Furthermore an environmental and economic comparison in relation to the use of an oil heating system has been made. [1]

In the HP-Efficiency field test, the performance of approximately 100 heat pumps in new single family houses was monitored. In co-operation with seven heat pump manufacturers and two power suppliers (EnBW and E.ON Energy), the Institute examined how efficiently electrical heat pumps can meet the heat requirements of new detached houses. The project received a funding of 50 % from the Federal Ministry for Economics and Technology (funding characteristic 0327401A). In addition to financially, the power suppliers and the manufacturers support the project by supplying the content. [2]

The HP Monitor project has just finished, and the final results are being processed. Eleven German and Austrian heat pump manufacturers, together with the power supplier EnBW, have taken part in the project. Slightly more than half of the 90 measured heat pumps are also being monitored in the HP Efficiency project. This expansion of measurement extends the observation of heat pumps for a time period of up to six years. As in the HP Efficiency project, the extension is targeting the evaluation of heat pumps in new energy-efficient buildings.

Characteristics of the examined heat pump systems and buildings

All of these projects aimed to consider a representative number of different types of heat sources. This objective has been successfully achieved as far as the ground source and outside air heat source systems are concerned: groundwater systems (water/water heat pumps) played only a smaller part. The heat distribution and heat delivery systems correspond to the specific requirements of newly built or old (non-retrofitted) buildings.

The dominance of heat pumps with a low-temperature heat distribution system is plain to see in the HP Efficiency project: over 90 % of the houses are equipped with floor heating. In older buildings, the tendency is reversed – more than 95 % of the systems use radiators as the heat distribution system. This inevitably requires higher inlet temperatures than for systems with floor heating. For both projects, the average heated floor area of the investigated installations is marginally over 190 m².

The evaluated installations from the HP Efficiency project have an average specific heating energy consumption of approximately 70 kWh/m² and year, with lowest and highest consumptions of 30 and 150 kWh/m² and year respectively. Based on their oil consumption figures for the last five years, the calculated space heating and domestic hot water heating demand of the old buildings amounted to an average value of 177 kWh/m² and year, with respective lowest and highest values of 80 and 340 kWh/(m², year).

The system performances measured in the HP Monitor project show similar characteristic properties to those in the HP Efficiency project.

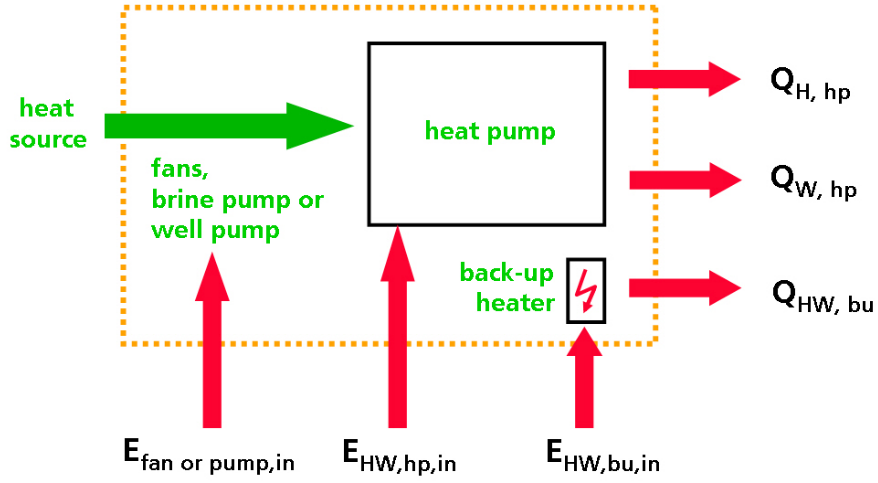

Figure 2. System boundaries and characteristic quantities

System boundaries for SPF calculation

The SPF calculation follows the methodology in the SEPEMO-Build project (IEE/08/776/SI2.529222).

Figure 2 shows the system boundaries and characteristic quantities used for assessment of the heat pump systems. The following equation was used for the computation of the seasonal performance factor, SPF:

$$SPF = \frac{Q_{H,hp} + Q_{W,hp} + Q_{HW,bu}}{E_{fan or\ pump,in} + E_{HW,hp,in} + E_{HW,bu,in}}$$

The SPF is the ratio of the heat energy produced by the heat pump and the back-up heater to the corresponding input energy requirement of the heat pump, back-up heater and source fans (for the ASHP case) and brine pump (for the GSHP case).

Nomenclature:
SPF: Seasonal Performance Factor of the heat pump system (including electrical back-up heater) [-]
SH: Space Heating
DHW: Domestic Hot Water
$Q_{H,hp}$: Heat energy delivered by the heat pump for space heating [kWh]
$Q_{W,hp}$: Heat energy delivered by the heat pump for domestic hot water heating [kWh]
$Q_{HW,bu}$: Heat energy delivered by the electrical back-up heater for SH and DHW [kWh]
$E_{fan\ or\ pump,in}$: Electrical energy use by the HP source: fan (ASHP) or brine pump (GSHP) for SH and DHW [kWh]
$E_{HW,hp,in}$: Electrical energy use by the heat pump for SH and DHW [kWh]
$E_{HW,bu,in}$: Electrical energy use by the electrical back-up heater for SH and DHW [kWh]

Efficiency of ASHPs

The database varies from project to project. It is necessary to select individual systems in order to arrive at a group of comparable heat pumps. Among other things, combinations of heat pump and solar thermal heating have not been considered. Finally, with 20 heat pumps in HP in Existing Buildings, 18 in the HP Efficiency, and 19 heat pumps in the HP Monitor projects, three groups with nearly the same number of heat pumps were assembled and could be evaluated. The evaluation period also differs in each project. An operation period of three years (July 2007 to June 2010) could be realised in the HP Efficiency project, followed by two years (January 2008 to December 2009) in the HP in Existing Buildings project and one year (April 2012 to March 2013) in the HP Monitor project.

The main results for the ASHPs are shown in Figure 3. The average SPF of each project is shown as a blue point. The grey lines illustrate the spread of the SPF values. Extreme values are illustrated separately as a grey rhombus

At first glance, the results of the SPF values differ considerably: on the one hand from project to project, and on the other hand within each project. The average lowest SPF value of 2.6 occurs in the HP in Existing Buildings project. This is easily ex-

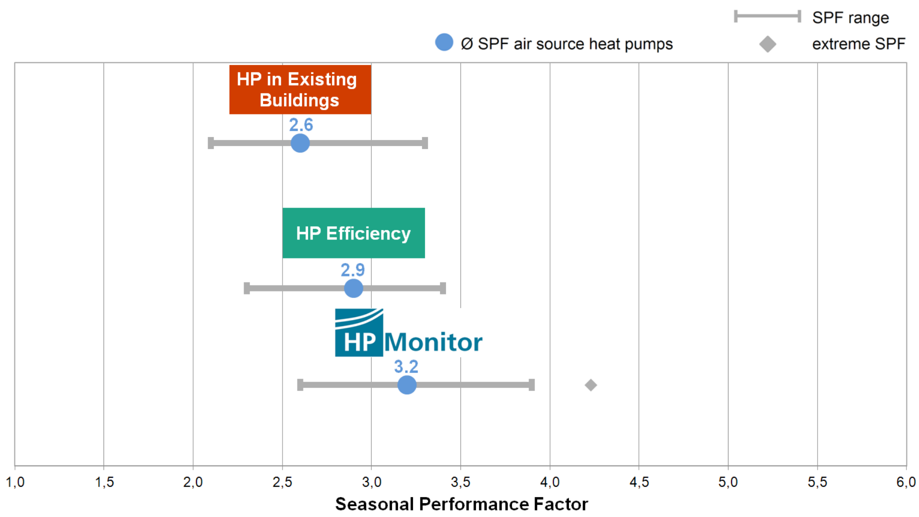

Figure 3. Seasonal performance factors of ASHPs based on different monitoring projects

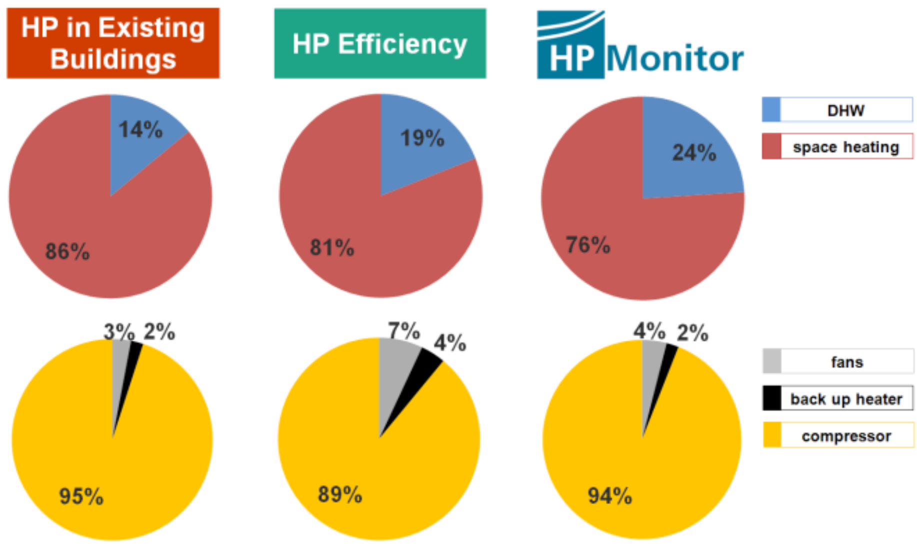

Figure 4. Proportions of the delivered thermal energy and the consumed electrical energy of ASHPs

plained by the higher heating circuit temperatures required compared to the temperatures in both of the other projects. The flow temperature in the old buildings was about 45 °C because these buildings mainly used radiators for their heat distribution systems. Since the space heating in the other projects was provided mainly by floor heating, average flow temperatures were lower, at about 36 °C. The flow temperatures for domestic hot water heating differ only between 49 and 51 °C. In this context, the share of produced energy for DHW and space heating, shown in Figure 4, should be taken into account. Due to the increasing share of delivered energy used for DHW (from 14 % in the old buildings up to 24 % in the latest project), the SPF is adversely affected by the poorer efficiency of DHW production mode. This confirms the general trend that is occurring with new energy-efficient buildings. Another aspect concerning lower efficiency in the old buildings is the fact that no significant specific adaptions were made when the heat pumps were installed to replace the oil boilers.

The average SPF values in the new building projects amounted to 2.9 and 3.2. The main differences can be attributed to the installed heat pumps. Measurements in the latest project started at least three years later, by which time new and innovative serial production models were available. Thus, heat pumps with power-controlled compressors and fans were being installed. The influence of these improved systems on the average SPF is clear, but not as high as possible, as the majority of the measured heat pumps are still conventional ones. The influence of the new heat pumps is also obvious in the electrical energy share shown in Figure 4. The share of the input energy for powering the fans, as well as that for the back-up heaters, is smaller than in the HP Efficiency project.

Efficiency of GSHPs

The framework conditions are as described above for the ASHPs. The factors affecting the results in each project are similar, and so this chapter is not as detailed as above.

When compared, the database of ASHPs and the database of GSHPs differ considerably. The majority of the monitored heat pumps (56) were part of the HP Efficiency project. 20 heat pumps were monitored in the old buildings project, and nine systems in the latest project, the HP Monitor project. The SPFs are shown in Figure 5 and the energy shares of delivered thermal energy and electrical energy input are illustrated in Figure 6.

With the poorest framework conditions, the lowest average SPF of 3.3 was found in old buildings, although the delivery temperature of 42 °C was better than with the ASHPs in old buildings. The temperature of the new buildings project amounted to 36 °C (HP Efficiency) and 33 °C (HP Monitor). The temperatures for DHW range between 48 and 51 °C.

The lower average SPF of 3.9 in the HP Efficiency project, as against 4.3 in the HP Monitor project, is mainly the result of the above-mentioned different framework conditions and use of innovative heat pumps in the latest project. With GSHP systems too, an increased number of systems had power-controlled compressors or brine pumps as well as direct evaporation or CO_2 probes

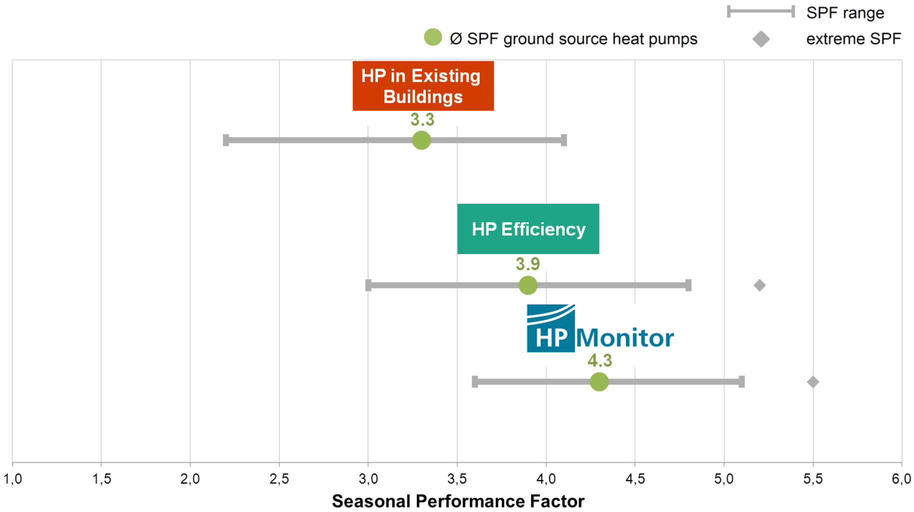

Figure 5. Seasonal performance factors of GSHPs based on different monitoring projects

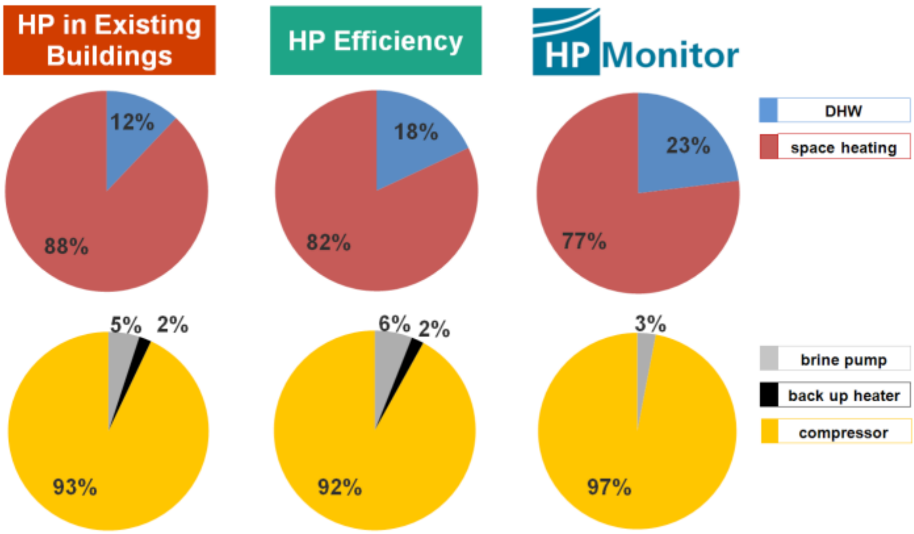

Figure 6. Proportions of the delivered thermal energy and the consumed electrical energy of GSHPs

The effects of the newer systems are also visible in the proportion of input energy in the form of electricity. Whereas, in the HP Efficiency project, the primary pump used 6 % of the whole electrical energy, the latest project required only 3 %. In particular, heat pumps using direct evaporation are able to strongly influence this share. Also remarkable is the non-use of the electrical back-up heater. Since back-up heater operation in the HP Efficiency project mainly occurred as a malfunction, this problem could obviously be solved.

General results

First of all, the reliability of the investigated systems could be confirmed: malfunctions occurred only marginally. Nevertheless, there is considerable potential for improving heat pump efficiency. As shown in Figure 3 and Figure 5, the span of the individual SPF values is remarkably wide. Comparing the correlation between the measured SPF and the temperature difference between heat source and heat sink with the theoretical correlation showed a large difference, indicating that the wide span was the result of additional reasons.

The following energy consumption influencing aspects could be noted:

- simple designs (e.g. no buffer storage) are more robust in terms of control strategy, and cause less problems
- wrong positioning of temperature sensors (especially with combined storage systems) adversely influences the load strategy
- primary pumps with oversized capacity (especially concerning water-source HPs)
- application of conventional primary pumps and fans instead of power-controlled ones
- incomplete closure of three-way valves causes unnecessary heat losses
- charge pumps often running unnecessarily (24 hours instead of intermittently)
- back-up heater operation in GSHP systems (not necessary if HP is operating correctly)
- failure to balance systems hydraulically
- poor insulation.

The improvement in efficiency observed in the HP Monitor project is also partly due to learning effects based on results of the previous monitoring projects.

Web visualization

The work of the HP Monitor project included creation of a publicly accessible web site showing online visualisation of measurement data [3]. Currently, the results of 26 heat pumps, covering a wide range of different systems, are accessible. Each heat pump is displayed with its basic data regarding the building and the heating system, with an explanation of the results. The measured data include monthly electrical energy demand for identified purposes. Monthly thermal energy production for space heating and domestic hot water are, of course, shown, as are the SPF values. Daily values of all measurement data shown for the particular hydraulic scheme show more detail. The anonymous online visualisation targets end users as

Figure 7. Illustration of the public online visualisation of measurement data on the HP Monitor project homepage

well as professionals with an interest in the versatile applications and real performance of heat pumps.

Conclusion

Although heat pump systems are capable of working with an efficiency which ensures ecological and economic advantages over systems based on fossil fuels, high efficiency cannot be guaranteed automatically. The work described in this report has found installations with poor performance as well as installations with a high performance.

There are aspects which clearly play an important part for the future efficiency of a system that are already determined by the selection of the kind of heat pump system chosen. For example, the heat source and the heat distribution system determine to some extent the efficiency which can be expected. However, such aspects are not exclusively crucial. Whether the occupants are satisfied with their heat pump systems depends not only on the heat pump manufacturer, but also (and particularly) on the planning, the installer and, finally, on the behaviour of the occupants themselves. The formula for high seasonal performance seems to be quite simple - the best results can be expected from simple and robust systems which are correctly planned, installed and well suited to the building and to the heat source. In addition, the latest monitoring project indicates increasing of efficiency values resulting from innovative heat pump technologies.

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Evaluation of part-load performance of a multi-split type air conditioner for buildings

Masafumi Hirota, Japan

Partial-load performance tests were made on a multi-split type air conditioner for buildings with rated cooling and heating capacities of 45 kW (cooling) and 50 kW (heating). For the cooling performance test, the outdoor air temperature was raised from 20 °C to 45 °C, and the indoor cooling load was changed from 12.5 % to 100 % of the rated cooling capacity of the air conditioner. Cooling COPs were measured at 36 test points. For the heating performance test, COPs were measured at 31 test points. Very detailed partial load performance of the unit was delivered by these tests.

Introduction

In a business-related building, the energy used for air conditioning amounts to 30 % - 40 % of its total energy consumption. Development of air conditioners with lower energy consumption is therefore crucial for energy saving in buildings. Over the year, air conditioners are mostly operated with indoor thermal loads lower than their rated capacities; this situation is called partial load operation. Japanese Standard JIS B 8616:2006 specifies the method of calculation of annual energy consumption of EHP-type packaged air conditioners with rated cooling capacities less than 28 kW. For an accurate prediction of the annual energy consumption of an air conditioner, we need to know its detailed part-load performance. In general, however, the COP of an air conditioner operating under part load changes, depending on the indoor thermal load and the outdoor air temperature, in quite a complex manner. In particular, the part-load performances of multi-split type air conditioners for buildings have not been clarified yet.

With these points as background, we have been carrying out part-load performance tests of multi-split type air conditioners for buildings with rated conditioner cooling capacities of 45 - 56 kW. In addition, based on the results of these tests, we have been evaluating the applicability of JIS B 8616: 2006 to prediction of the annual energy consumption of air conditioners with larger capacities [1]. This report presents some examples of COPs measured in the part-load performance tests.

Cooling performance test		Heating performance test	
Outdoor air temp. DBT / WBT [°C]	Thermal load ratio [%]	Outdoor air temp. DBT / WBT [°C]	Thermal load ratio [%]
20 / -	12.5, 25, 50, 65, 75, 85, 100	-7 / -8	12.5, 65, 75, 85, 100
25 / -	12.5, 25, 50, 65, 75, 85, 100	-3 / -4	25, 50, 65, 75, 85, 100
30 / -	25, 50, 65, 75, 85, 100	2 / 1	25, 50, 65, 75, 85, 100
35 / -	25, 50, 65, 75, 85, 100	7 / 6	12.5, 25, 50, 65, 75, 85, 100
40 / -	12.5, 25, 50, 65, 75, 85, 100		
45 / -	50, 75, 100		

Table 1. Conditions of the partial load performance tests

Test method and conditions

The part-load performance tests were conducted in the heat pump test facility of Chubu Electric Power Inc. In this facility, the performance of an air conditioner with a rated cooling capacity up to 168 kW and a rated heating capacity up to 200 kW can be measured by the air enthalpy method. The temperature and relative humidity of air in test chambers can be changed from -20 °C to 50 °C and 40 % - 90 % respectively, independently of the thermal load in the indoor test chamber. Details of this facility are described in the reference [2].

The tested machine shown here is a multi-split type electrically driven building air conditioner, manufactured in 2011, with rated cooling and heating capacities of 45 kW and 50 kW respectively. It consists of one outdoor unit and four indoor units, with inverter-controlled variable-speed compressors. The refrigerant is R-410A.

Table 1 shows the test conditions of the part-load performance tests. In the cooling performance test, the dry-bulb temperature of outdoor air t_j was raised from 20 °C to 45 °C, and the indoor thermal load BL_c was raised from 12.5 % to 100 % of the rated cooling capacity Φ_{cr}. The sensible heat factor was set at 0.85. The temperature in the indoor test chamber was maintained at 27 °C by the tested air conditioner itself, to simulate its actual working condition in a building. Cooling COPs were measured at 36 test points. For the heating performance test, COPs of the air conditioner were measured at 31 test points while maintaining the indoor test chamber air temperature at 20 °C. In addition to the performance of air conditioner, the pressure and temperature of the refrigerant, compressor speeds etc. were also measured in these tests.

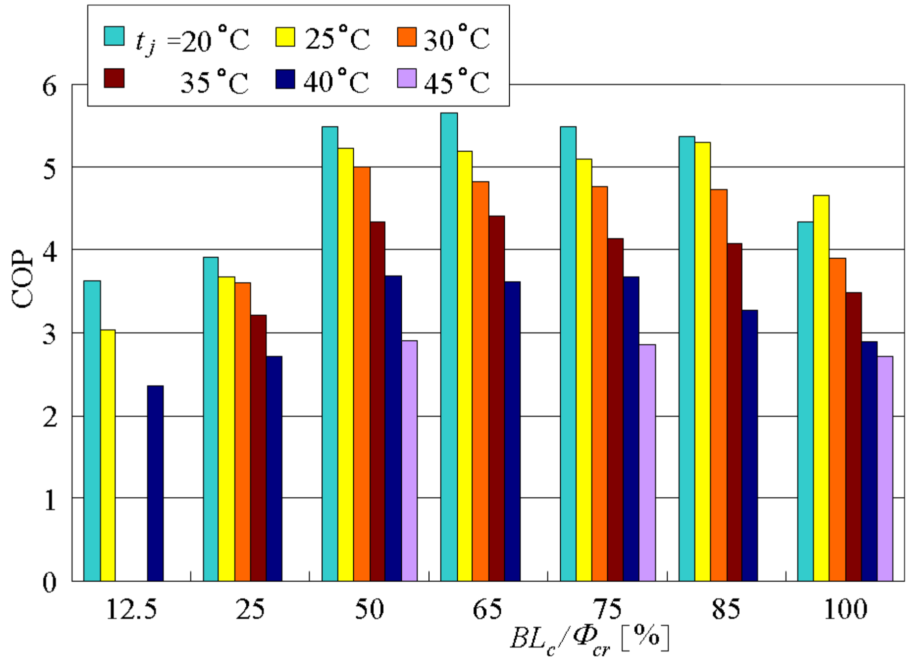

Figure 1. COPs measured in the partial cooling load performance test

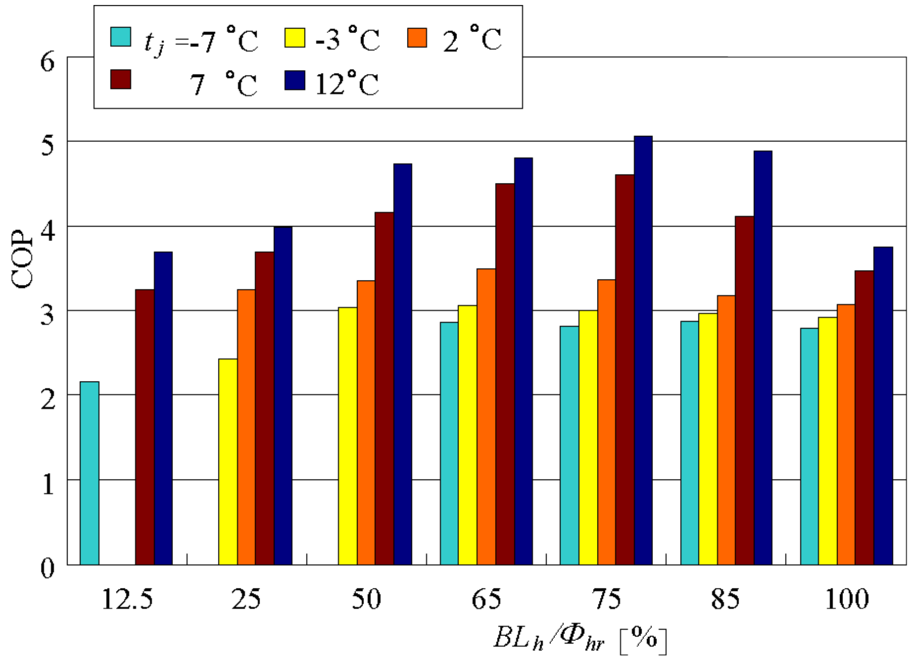

Figure 3. COPs measured in the partial heating load performance test

Results of performance tests

Figure 1 shows the results of COPs measured in the part-load cooling performance test. The abscissa is the cooling load ratio BL_c/Φ_{cr}, and the parameter is the dry-bulb temperature of the outdoor air t_j. For all values of BL_c/Φ_{cr}, COP decreases as t_j rises. At constant t_j, COP shows relatively high values in BL_c/Φ_{cr} = 50 – 75 %, and decreases as BL_c/Φ_{cr} is further decreased. This deterioration of COP at low values of BL_c/Φ_{cr} is caused by the intermittent on-off operation of the compressors. Based on these detailed COP data, we can plot the cooling COP surface of this air conditioner as shown in Fig 2 by expressing COPs as a function of t_j and BL_c/Φ_{cr}.

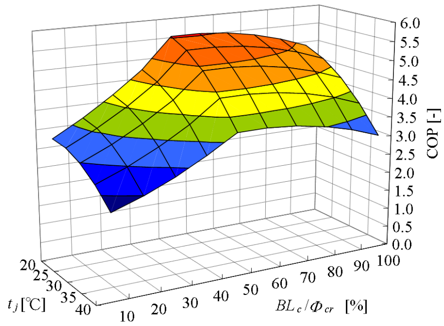

Figure 2. COP surface of air conditioner in cooling mode

This surface is quite helpful for intuitively grasping the dependence of COP on the outdoor air temperature and the indoor thermal load. We can see that this new air conditioner can maintain a high COP over quite a wider range of BL_c/Φ_{cr} in comparison with conventional machines [1].

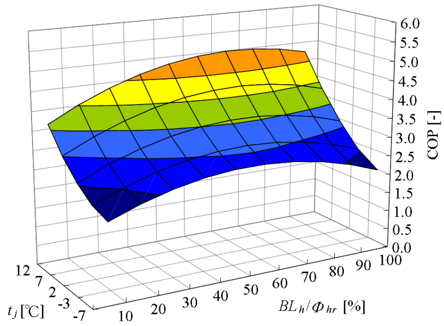

Figure 4. COP surface of air conditioner in heating mode

Figures 3 and 4 show the results of the partial heating load performance test. In the same way as for the cooling COP, the heating COP shows high values in the intermediate heating load range of BL_h/Φ_{hr} = 50 – 75 % and decreases at lower values of BL_h/Φ_{hr}. From a comparison of COP surfaces shown in Figs. 2 and 4, we can see that the heating COP is more sensitive to the outdoor air temperature than is the cooling COP. The deterioration of the heating COP at low heat load conditions is less than in comparison with that of the cooling COP. By combining these COP surfaces and the thermal load models of buildings, we can calculate the annual energy consumption of an air conditioner with high accuracy.

Concluding remarks

This work has investigated the part-load performance of a multi-split type building air conditioner with a rated cooling capacity of 45 kW and a rated heating capacity of 50 kW. The outdoor air temperature and the indoor thermal load were varied over a wide range. The cooling performance was measured at 36 test points, and the heating performance at 31 test points. Very detailed COP values and conditions of refrigerant and compressor data in part-load operation were given by these tests. These data would be useful in the development of air conditioners with higher energy-saving performance in actual operations in buildings. In addition, based on COPs obtained by the performance tests, the authors are trying to develop the method to predict accurately the annual energy consumption of multi-split type high-capacity air conditioners. Detailed COP characteristics under the part-load conditions described here can be used to develop and evaluate such a prediction method as well.

The results of the performance tests shown here were obtained by collaboration with Chubu Electric Power Inc. Their assistance is greatly appreciated.

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Performance inspections to pick the low-hanging fruits in existing and new plants

Klas Berglöf, Sweden

"To measure is to know" is very true when it comes to energy efficiency in air conditioning and heat pump systems. Optimisation of existing systems is the 'low-hanging fruit' to reduce energy consumption in commercial and industrial buildings. Two-thirds of today existing buildings will still be in use in 2050, and the potential energy savings are enormous. It has been found that few systems operate at an optimal level, or within their original design specifications. The real challenge is to change the 'Don't wake the sleeping dog' attitude; equipment owners need to become aware of their equipment's actual performance through cost-effective performance inspections that are non-invasive, unbiased, and do not require inputs from unit or component manufacturers. When owners request consultants, commissioning agents, or contractors to measure, analyse and optimise their systems, there will be justification to invest in tools and training to service the demand.

Introduction

To measure is to know is a valid statement for air-conditioning and heat pump systems. The savings potential from optimising existing systems is the 'low hanging fruit' to reduce energy consumption in existing buildings. It is estimated that 15-20 % of global electricity is used by vapour compression systems (IIR, 2002). According to the International Energy Agency (IEA, 2012), two-thirds of existing buildings will still be in use in 2050, indicating the importance of optimising energy use in existing buildings and systems. This is resulting in requirements such as those in the EU Energy Performance of Buildings Directive (EPBD, 2010) for performance inspections of air conditioning systems above 12 kW, and incentive programs to re-commission plants in North America. When measured in the field, few systems show the performance that they are designed for. Savings of 10-40 % are often possible at minimal cost (Prakash, 2006). In most cases, the cost of the inspection and optimisation is repaid in a few months. The challenge is to change the 'Don't wake the sleeping dog' attitude when return of investment in measurements cannot be presented in advance. Air conditioning and heat pump systems are looked on as a 'black box' in a ventilation or plumbing system, assuming good performance if the temperature is correct. The Internal Method, based on a thermodynamic analysis of the refrigeration system opens the black box. Performance and all parameters to evaluate the process are measured in 20-40 minutes. There is no requirement for pre-installed meters or inputs from unit or component manufacturers. Capacity can be established with an accuracy of ±7 %, and COP with an accuracy of ±5 %, (Fahlén, 1989) for most compressor-driven heat pump, air-conditioning and refrigeration systems.

Measurement, analysis and optimisation of performance is cost-effective

"If you can't measure it, you can't control it" is another valid statement when it comes to air conditioning, heat pump and refrigeration plants. These systems are often operating with efficiency and lifetime far from their design specifications. A major reason is a lack of established cost-effective methods for measuring performance. As the inefficiencies are not understood, equipment owners, consultants and installers/service companies do not see measurements as necessary, even if cost is low compared to the investment, maintenance and failure costs. The prevailing purchasing process does not deliver the expected efficiency, in spite of investments in advanced controls (CABA, 2013). It is not uncommon for prestigious buildings, marketed as sustainable, to consume 50-200 % more energy than designed for (Roaf, 2013). A major cause is poor coordination between involved contractors/experts, and unclear responsibilities for the building as a whole. Without validation of actual performance under different loads and climate conditions, efficiency cannot be expected

Sub-metering and flow based COP/SPF measurements does not give all answers

It has been rare for electrical consumption of HVAC systems to be measured separately. With an increasing use of sub-metering and installation of flow-based energy meters, the challenges to analyse these data are becoming more pressing.

The first challenge is to measure flows and small temperature differences in real-life systems in operation with sufficient accuracy in the field. Due to the complexity of the systems, variations in loads and climatic conditions mean that any deviations in performance must be significant before a warning is generated. Flow-based Coefficient of Performance (COP) and/or Seasonal Performance Factor (SPF) measurements that do not show the expected performance levels do not give much help to identify the problem in a system with a wide range of operating conditions. Deviations require costly investigations as the data does not contain information for evaluation of the cause.

Building Managements Systems (BMS) are not automatically effective

It is often expected that investment in BMS, EMS and advanced controls replaces the need for validation of performance. In most cases, HVAC systems are treated as a “black box” communicating some measured parameters to the central system. This information normally requires a high level of competence and many hours of analysis to convert into useful information in a dynamic process.

Figure 1. Fixed installed stand-alone Performance analyser with Energy Management capability.

The internal method can be used as stand-alone, Figure 1, to upgrade existing plants, or be integrated in BMS to indicate the system performance at different loads and climate conditions, which is almost a prerequisite for optimising performance. Due to the complexity of BMS and control systems, they can even be counter-productive if they are assumed to ensure efficiency without proper set-up. Based on past experience, it has become apparent to the author that BMS systems that have not been carefully commissioned to provide correct and relevant information can result in repeated failures without alarms, or multiple alarms without faults. Careful commissioning, that includes all sub-systems, is important, as is ensuring that the results are presented in a suitable form for those using the results.

Internal method for performance analysis

Cost-effective establishment of the baseline performance of an HVAC System is a prerequisite for optimisation of energy consumption and minimisation of the risk of failures.

Figure 2. Performance Inspections give full information after 20 minutes.

The ‘Internal Method’ offers this option with portable equipment in 20-30 minutes, providing information ranging from high-level findings for overall system performance down to detailed information at component level. See Figure 2. Continuous analysis using a fixed installation is also possible, delivering continuous real-time data via an on-line portal. The method is well-proven, with 25 years of experience. Hundreds of thousands of analyses have been performed in manufacturers’ test rigs as well as in the field. The method is described in more detail in several published papers; e.g. (Berglöf, 2011), and does not require pre-installed sensors or inputs from unit or component suppliers. Performance analyses can often be done without even stopping the compressors. When systems are permanently monitored, early-warning alarms at component level can be generated, reducing the risk of failure. There is a close relationship between efficient and reliable operation. Optimisation of existing equipment is the low-hanging fruit to reduce energy costs. In order to pick these fruits, equipment owners must first realise the benefits of performance analysis, and industry as a whole must increase its skills in measuring, analysing and optimising dynamic systems.

Measurements required for an unbiased performance inspection

The Internal Method is based on the well-defined thermodynamic properties of the refrigerants, and offers an accuracy that can hardly be achieved by conventional methods in the field. All relevant data for validation of performance, optimisation and trouble-shooting can be presented dynamically in real time, i.e.:

- Coefficient of performance (± 5 %)
- Cooling and heating capacity (± 7 %)
- Power input (± 2 %)
- Compressor isentropic efficiency at full and part load
- Evaporator heat transfer
- Condenser heat transfer
- Indicators for refrigerant charge for early detection of leaks
- Superheat

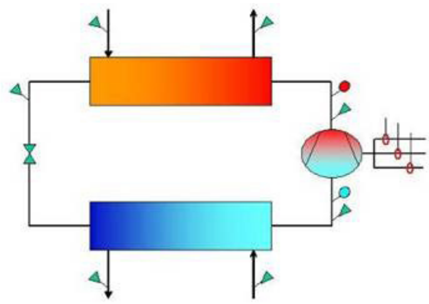

Figure 3. Sensors required and their location to establish performance of a standard refrigeration System.

A basic system requires ten easy-to-apply sensors that are attached at strategic points around the system, as shown in Figure 3:

- Temperature and pressure at entrance of compressor.
- Temperature and pressure at compressor exit.
- Liquid refrigerant before expansion device.
- Active electrical power.

The temperature of air/liquid entering and exiting the condenser and heat exchanger are measured for reference information on ambient conditions.

Well proven method

The method and technology was first developed in Sweden in 1986, and validated by SP in 1989 (Fahlén, 1989).

Figure 4. Field kit for Performance Analyser that does not require installation of flow meters to establish the performance and capacity.

Today, performance analysers, Figure 4, are used by many manufacturers and by 600 contractors/consultants in more than 20 countries. They are used in development and production tests rigs, for validation of prototypes in the field, and to improve the efficiency of existing systems. Many systems are monitored 24/7 over the internet, facilitating monitoring of system performance. Warnings are generated in response to faults or problems long before the symptoms are noticed by the users. Equipment owners have access to energy reports with energy profiles which, in combination with underlying information on the efficiency of various components, enable systems to be optimised. World-leading companies in the industry have validated and use the performance analysers to document the efficiency of products in test rigs as well as in the field. Over 20 universities and training centres around the world use performance analysers in education and research work to document and display performance.

Example – Heat pump working within manufacturing specification

Figure 5 shows a measurement of a heat pump validated to perform within manufacturer's specification, both regarding COP, capacity and all internal parameters such as, e.g. charge, superheat, heat transfer, flows and compressor performance.

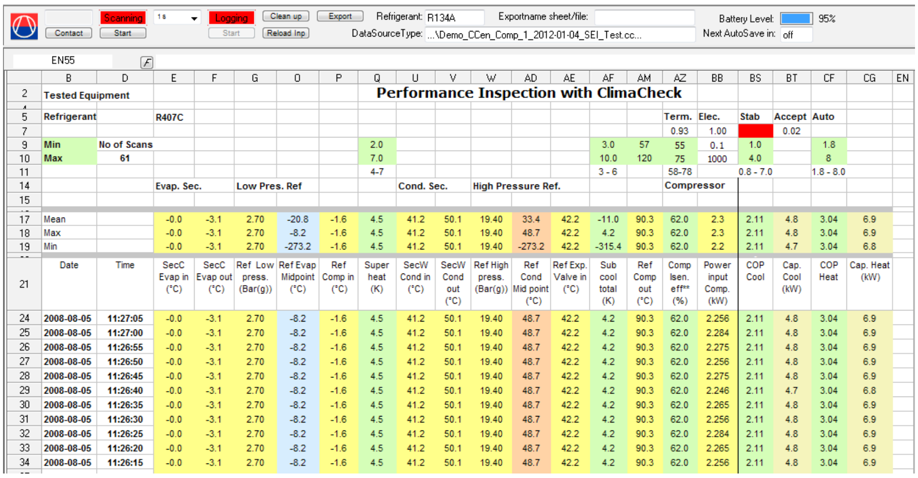

Figure 5. Validation of performance of a heat pump operating within specification.

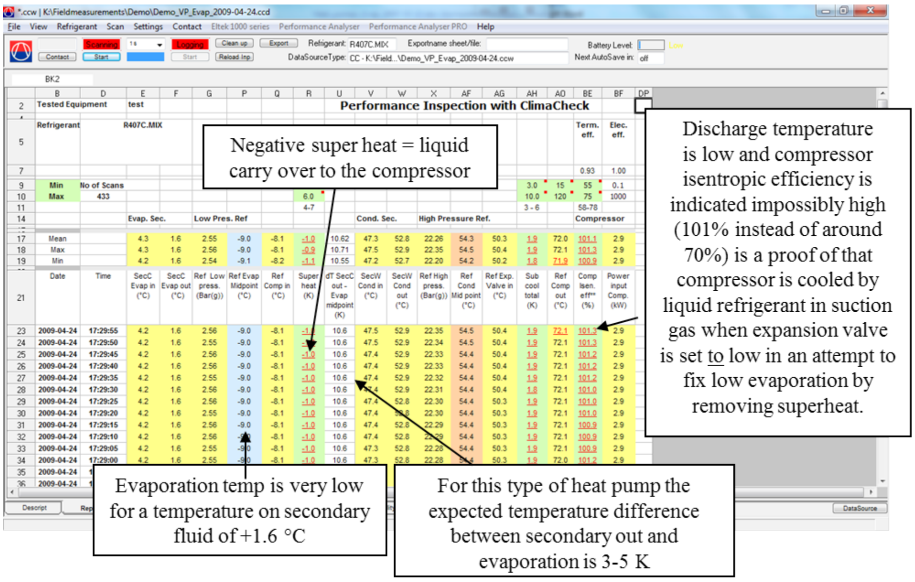

Figure 6. Validation of performance of a heat pump with problems.

These data allow any expert to fully evaluate the systems performance versus manufacturer's specificationss, as well as benchmarking the systems performance

Example – Heat pumps with problems

The internal method was developed in the booming Swedish ground-source heat pump market 25 years ago to solve the much too frequent problems. Portable and fixed equipment is now used widely to optimise systems in all applications of heat pumps, air conditioning and refrigeration. The information contains all the information that a competent person needs to evaluate the plant without having to go there. Figure 6 shows documentation that was used to resolve a two-year-long dispute. A heat pump owner was not satisfied with the performance and repeated stops due to low pressure. The contractor had spent many hours on trouble-shooting and modifying the system with a larger circulation pump for the ground collector, resetting safety limits, and adjusting the expansion valve, all without achieving reliable operation. Just before the case was due to go to court, the house owner's insurance company requested an unbiased inspection.

A performance inspection documented all the parameters of the heat pump in less than two hours. The complete information pin-pointed the problem to poor heat transfer caused by the secondary fluid

in the ground source loop. Poorly handled secondary fluid resulted in fouling of the evaporator, resulting in turn in poor evaporation and in frequent tripping on low pressure when changing from domestic hot water to radiator mode. The contractor had tried to fix the poor evaporation by increasing the flow with a larger pump and, when that did not help, had decreased superheat to increase the evaporation, causing refrigerant liquid to enter the compressor, decreasing its life expectancy. After two years of frustrating battle and many hours of work for the contractor, the performance inspection resulted in a quick decision to change the secondary fluid and clean the evaporator. Court action was avoided, and the investigation and changes cost significantly less than the original claim, to replace the heat pump, which would not have solved the problem. With hindsight it is easy to say that the contractor's and manufacturer's representatives who had visited the plant several times should have solved the problem, but without proper tools and documentation it often turns out to be difficult to identify the problem.
To measure is to know.

Conclusions

The heat pump, air conditioning and refrigeration industry is facing a new market situation, with increased focus on actual operating efficiency. Experience shows that improvements of 10-40 % can be achieved for low investment costs if plants are operating as intended. Increased quality and documentation of commissioning, maintenance and trouble-shooting with state-of-the-art performance analysers decreases energy cost and carbon footprint. Decreased repair costs, reduced down-time and minimised loss of goodwill from failures are key driving forces for new analysis methods. The biggest challenge to introducing performance inspections is the need to change the business-as-usual attitude in a conservative industry where equipment owners concentrate on initial price. The result is that failed components have to be replaced, and many contractors' survival is at stake when price levels on contracts are pushed too low.

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Foundation heat exchangers for residential ground source heat pump systems

Jeffrey D. Spitler, Piljae Im, USA

Foundation heat exchangers utilize the excavation made for a house basement to significantly reduce the cost of the ground heat exchanger used with a ground source heat pump system. This paper reports on results from two test houses and several simulation-based design and energy analysis tools. The test houses, in eastern Tennessee, had seasonal system coefficients of performance of 3.6 for heating and 4.2 for cooling utilizing water-to-air heat pumps. Domestic water heating was also provided using dedicated water-to-water heat pumps. Experimentally-validated design and energy calculation tools are now available.

Introduction

Ground source heat pump (GSHP) systems are one of the most efficient technologies available for heating and cooling of buildings. This efficiency comes at a high capital cost, due to the installation cost of the ground heat exchanger. Therefore, methods for reducing the first cost of ground heat exchangers are of significant interest.

Figure 1. High density polyethylene tubing is placed against the outer walls of the excavation.

In 2009, we gave an overview [1] of a research project aimed at reducing the first cost of GSHP systems by utilizing the excavation made for the foundation of a basement. High density polyethylene tubing is placed against the outer walls of the excavation (Figure 1) before it is backfilled. We refer to these ground heat exchangers as "Foundation Heat Exchangers" (FHX). In most cases, we expect that the FHX by itself would not be sufficient, and might be augmented by additional horizontal ground heat exchanger (HGHX), utilizing utility trenches where possible. This article focuses on two aspects of the research: measured performance of a full-scale system at an experimental house, and the performance of several simulation approaches applied to both design calculations and energy calculations.

Measurements

Figure 2a. Research house

Figure 2b. Research houses

Figure 2c. Research houses

Two side-by-side, three-level, unoccupied research houses (Figure 2a , 2b, and 2c) with walkout basements, identical 344 m² floor plans, and hybrid FHX/HGHX systems [2] were constructed to provide validation data sets for the energy performance model and design tool. The envelopes of both houses are very energy-efficient and airtight, and the homes are rated by a national energy agency to use about 45 % of the energy that would be used by typical new-build construction.

Both houses are mechanically ventilated with energy recovery ventilators, and have space conditioning provided by water-to-air heat pumps with nominal 7 kW (2 ton) capacities. Separate water-to-water heat pumps with nominal 5 kW (1.5 ton) capacities were used for water heating. In these unoccupied research houses, human impact on energy use (hot water draw, etc.) is controlled to match the national average.

For both houses, a sloping site led to a walkout basement installation with the FHX installed on only two sides of the house. At House 1 the hybrid FHX/HGHX system was installed in 91 linear meters of excavation, with the FHX installed in 31 m of trench on two sides of the house, utility trenches providing a further 24 m, and 37 m of trench dug solely for HGHX installation. At House 2, the hybrid FHX/HGHX system was installed in 110 m of excavation, similar to that of House 1, except 55 m of trench was excavated solely for HGHX installation. There are six pipes in all excavations (three parallel circuits – out and back), and the multiple instances of FHX and/or HGHX are all connected in series.

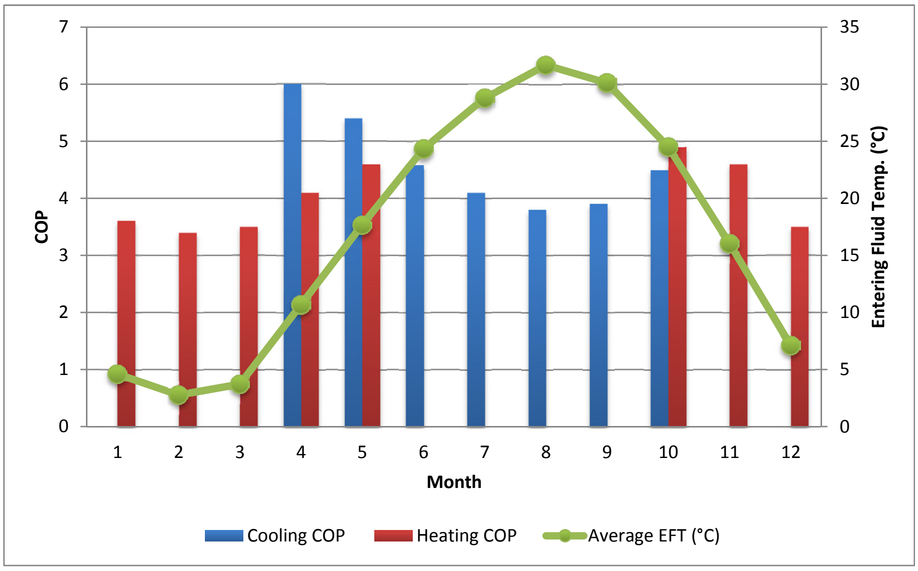

Figure 3. Measured performance for the space conditioning systems.

Measurements taken to establish FHX/HGHX performance and enable model validation included the thermal loads (heat rejection and extraction) to the FHX/HGHX imposed by the heat pumps, undisturbed far field temperature of the soil at various depths, numerous temperatures on the outside surface of the pipes, basement wall heat flux, drainage board and near-wall soil temperatures in a few locations, soil thermal conductivity, and weather data at the demonstration site. There are approximately 70 thermistors installed per house for temperature measurements at various points, and the data have been measured at 15-minute intervals during 2010, the year reported here.

In both houses, the heating and cooling thermostat set points in all four zones were maintained throughout the year at 21.7 and 24.4 °C. The systems in both houses have very similar performance. Measured performance for the space conditioning systems in House 1 is summarized in Figure 3. Annual maximum heat pump entering fluid temperatures (EFTs) measured at Houses 1 and 2 were 34.0 °C and 32.4 °C, and minimums were 0.8 °C and 0.9 °C respectively, which compare well with the design values for maximum and minimum EFT of 35 °C and -1.1 °C used to size the FHX/HGHX. For both houses, the measured water-to-air heat pump (WAHP) heating and cooling seasonal COPs (including pumping power) are about 3.6 and 4.2 respectively. These values are about what would be expected with a more traditional vertical borehole ground heat exchanger. The water-to-water heat pumps (WWHP) used for domestic water heating had seasonal COPS, including pumping, of 3.1 and 2.6. The unexpectedly low COP for the second house was caused by an undersized circulating pump that provided inadequate flow to the heat pump.

Simulations

The results from the two test houses were used to validate several different simulations that were developed for use in design tools and energy calculation programs. The project team took a multi-pronged approach – developing models for two purposes. Two of the models were developed as tools for research (e.g. which heat and mass transfer phenomena are important and need to be included?), and to serve as reference models. The remaining three models were all developed as candidates for use in design tools or energy calculation tools. For the research/reference models, the computational time is not particularly important. However, for the design and energy calculation tools, it is very important to keep the computation time reasonable. It is also highly desirable to keep the user interface simple; e.g. any computational grid must be automatically generated.

The **two research/reference models** are:

- A 2-d non-uniform rectangular grid finite volume method (2D RG FVM) model, previously developed for another application, was adapted to model the FHX. In the process of validating the model against measurements of undisturbed ground temperatures at a range of U.S. locations and against measurements at the experimental site, we concluded that it was necessary to make a full heat balance at the ground surface, including evapo-transpiration, convection, solar irradiation, and thermal radiation interchange. It was also necessary to include freezing/thawing of the soil, in addition to conduction heat transfer.

Model	*Number of cells*	*Annual Simulation CPU Time*
Analytical	N/A	seconds
2-d Rectangular Grid FVM	13 000	3-4 hours
2-d Boundary Fitted Coordinates FVM	20 000	3-4 hours
3-d Boundary Fitted Coordinates FVM	800 000	1-2 days
3-d Dual-coordinates FVM	4000 rectangular/ 360 radial cells	~2 minutes
Dynamic Thermal Networks	N/A	seconds

Table 1. Simulation models

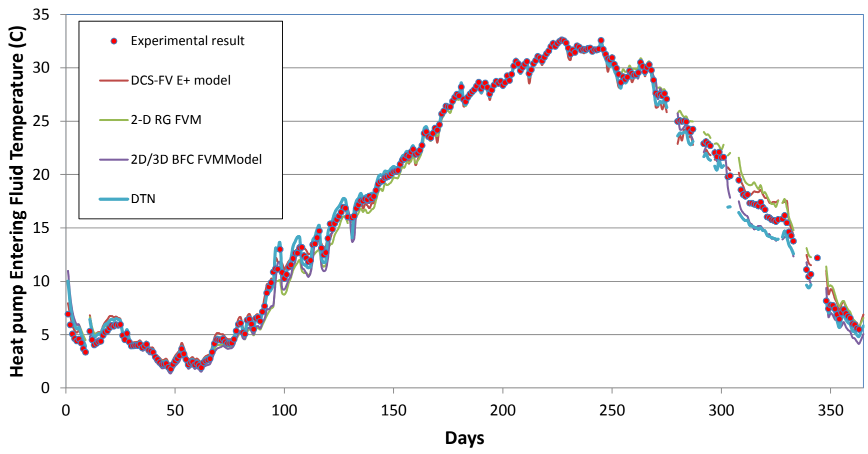

Figure 4. Daily average heat pump entering fluid temperature predicted by each of the numerical models are compared to the experimental measurement

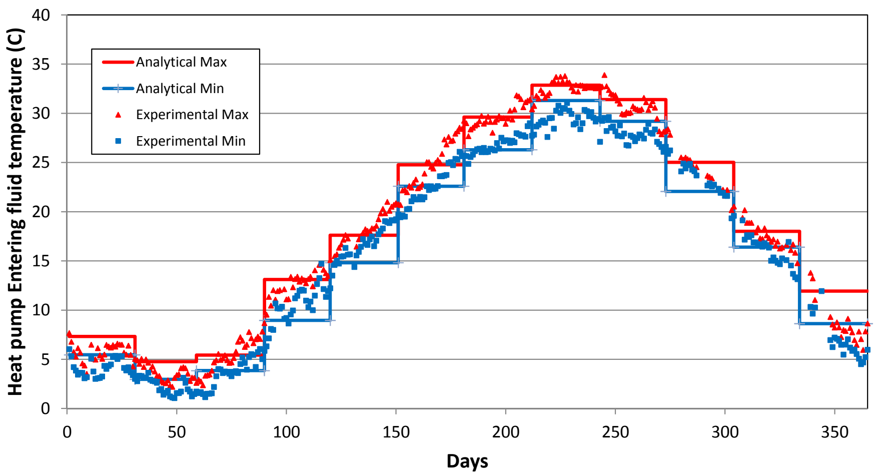

Figure 5. Measured performance for the space conditioning systems.

- 2-d and 3-d FVM models using boundary-fitted coordinates (2D/3D BFC FVM) were also developed. The block-structured grid with boundary-fitted coordinates allows close approximation of pipe surface geometry. [3] One purpose of the 3-d model was to allow proper modelling of corner effects. However, we found that, for the test house geometry, where the FHX wrapped around only two sides of the house, and hence there was only one corner, the corner effect was relatively small.

Three approaches were tested for design and energy calculation tools:

- An analytical model [4] used line source super-position to represent the FHX. This required the approximation that the basement wall was an adiabatic surface of infinite depth. This model is intended for design use and runs on a monthly time step, on which peak hourly loads are superimposed to predict monthly minimum and maximum heat pump EFT.
- The dual-coordinates FVM (DC FVM) model [5] combines a non-uniform coarse grid with a radial grid that surrounds each tube; the original idea for this approach came from Piechowski [6]. This model has the advantage of being finely gridded where the temperature gradients are the highest (near the tube) while also running quickly.
- Dynamic Thermal Networks (DTN) are an approach proposed by Claesson [7] where time-dependent heat transfers are represented in a network form. It appears similar to steady-state networks, but uses response factors that are applicable to multiple driving surfaces – here, the basement wall/floor, the FHX pipes, and the ground surface were treated as three separate surfaces for which response factors were derived. The DTN model is implemented with a full surface heat balance, including evapo-transpiration, but it cannot model freezing and thawing of the soil.

Evaluating the performance of the different models, the first question is – how do the model predictions of the fluid temperatures exiting the ground heat exchanger and entering the heat pump compare to the experimental measurements? Daily average heat pump entering fluid temperature predicted by each of the numerical models are compared to the experimental measurement in Figure 4. All of the models have similar performance, with the DCS-FVM model having the lowest RMSE of about 0.7 °C, and the 2-D RG FVM model having the highest at 1 °C.

The much simpler analytical model is used only to predict maximum and minimum temperatures at the end of each month. Figure 5 shows a comparison of these monthly predicted minimum and maximum temperatures against actual daily minimum and maximum peaks. The analytical model predicts the minimum and maximum heat pump EFT within 2 °C. This should be acceptable for a simplified design tool.

With all of the numerical models having similar performance for this application, we ultimately had to choose one for implementation into EnergyPlus. The DCS-FVM model takes more computational time, but accounts for freezing and thawing of the ground, which are important in colder climates. The DTN approach runs much faster once the response factors are computed, and has very acceptable accuracy for the southern US climate where there is little freezing of the soil. However, computation of the response factors for the DTN method requires considerable computer time, and we believe that the creation of a library of response factors would be needed in order to make this practical. This has yet to be done.

Conclusions

The FHX installed at the two large test houses in Tennessee both gave good energy performance, similar to that of a vertical borehole system. In both cases, the site layout restricted installation of the FHX to only two sides of the house, and both were supplemented by additional horizontal heat exchangers.

A range of models were developed for research, design, and energy calculation purposes. Comparison of one of the research models with experimental results led to the conclusion that a full surface heat balance, including evapo-transpiration, solar irradiation, and convection and thermal radiation to/from the environment was needed to accurately model the performance of the FHX. Comparisons with undisturbed ground temperatures at other sites strongly suggest that modelling of freezing and thawing of the soil may be necessary in colder climates.

An analytical model, implemented in a spreadsheet, gives reasonable performance for design purposes, despite several significant simplifications.

A dual-coordinates FVM model was selected for implementation in EnergyPlus, and this feature has been publicly available in the release version of EnergyPlus since 2012. The DTN approach is promising, though it cannot include freezing and thawing, but it needs development of a response factor library before it can be practically utilized in energy calculation programs.

Finally, a couple of practical but important matters need further research. The FHX were tested only in a southern US climate on a pair of fairly large, but well-insulated, houses. Simulations suggest that the FHX concept can be applied in colder climates, but we recommend that some carefully monitored FHX systems are installed and operated to confirm the application of the design and simulation tools in colder climates. Also, the driving motivation for this research was reduction of cost for the ground heat exchanger. While it is clear that the installation cost should be significantly lower, additional installations will be needed to accurately estimate the expected-to-be-small labor costs of a typical installation.

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Full Version of EnergyIQ Released

Lawrence Berkeley National Laboratory (Berkeley Lab) has issued the first full public release of EnergyIQ, its web-based action-oriented benchmarking tool for non-residential buildings. EnergyIQ is free and can be accessed at http://energyiq.lbl.gov/

EnergyIQ improves upon typical "whole-building" energy benchmarking tools by providing benchmarking at the end-use level, and enabling users to use the benchmarking data to quickly conduct a high-level assessment of energy-reduction opportunities. It also provides users with decision support information to develop and refine their action plans.

"Past users of benchmarking tools such as Berkeley Lab's CalArch and ENERGY STAR's Portfolio Manager will immediately see the benefits of EnergyIQ," says Evan Mills, staff scientist in Berkeley Lab's Building Technology and Urban Systems Department. "Being able to move immediately from gathering benchmarking data to evaluating promising energy-savings activities based on those data helps eliminate the 'what now?' frustration that sometimes accompanies benchmarking."

Source: http://eetd.lbl.gov/news/article/56315/full-version-of-energyiq-released

Energy Outlook Special Report 2013: Redrawing the Energy Climate Map

Governments have decided collectively that the world needs to limit the average global temperature increase to no more than 2 °C and international negotiations are engaged to that end. Yet any resulting agreement will not emerge before 2015 and new legal obligations will not begin before 2020. Meanwhile, despite many countries taking new actions, the world is drifting further and further from the track it needs to follow.

The energy sector is the single largest source of climate-changing greenhouse-gas emissions and limiting these is an essential focus of action. The World Energy Outlook has published detailed analysis of the energy contribution to climate change for many years. But, amid major international economic preoccupations, there are worrying signs that the issue of climate change has slipped down the policy agenda. This Special Report seeks to bring it right back on top by showing that the dilemma can be tackled at no net economic cost.

The 4-for-2 °C Scenario is presented, in which we propose the implementation of four policy measures that can help keep the door open to the 2 °C target through to 2020 at no net economic cost. The policies in the 4-for-2 °C Scenario have been selected because they meet key criteria: they can deliver significant reductions in energy-sector emissions by 2020 (as a bridge to further action); they rely only on existing technologies; they have already been adopted and proven in several countries; and, taken together, their widespread adoption would not harm economic growth in any country or region. The four policies are:

- Adopting specific energy efficiency measures (49 % of the emissions savings).
- Limiting the construction and use of the least-efficient coal-fired power plants (21 %).
- Minimising methane (CH_4) emissions from upstream oil and gas production (18 %).
- Accelerating the (partial) phase-out of subsidies to fossil-fuel consumption (12 %).

Targeted energy efficiency measures would reduce global energy-related emissions by 1.5 Gt in 2020. These policies include energy performance standards in buildings for lighting, new appliances, and for new heating and cooling equipment; in industry for motor systems; and, in transport for road vehicles. Around 60 % of the global savings in emissions are from the buildings sector.

Free download at: http://www.iea.org/publications/freepublications/publication/name,38764,en.html

Events

This section lists exhibitions, workshops, conferences etc. related to heat pumping technologies.

2013

2-4 September
Compressors 2013 - 8th International Conference on Compressors and Coolants
Castá Papiernicka, Slovakia
http://www.szchkt.org/a/conf/event_dates/6?locale=en_GB

9-10 September
International Conference on Compressors and their Systems
London, UK
http://www.city.ac.uk/compressorsconference

16-18 September
Big 5 Kuwait
Kuwait City, Kuwait
http://www.big5kuwait.com/page.cfm/link=105

25-27 September
ISH Shanghai & CIHE 2013
Shanghai, China
http://www.eco-business.com/events/ish-shanghai-cihe-2013/

25-27 September
5th International Conference Solar Air-Conditioning
Kurhaus Bad Krotzingen, Germany
http://www.otti.eu/event/id/5th-international-conference-solar-air-conditioning.html

3-4 October
7th CLIMAMED Mediterranean Congress of Climatization
Istanbul, Turkey
http://www.climamed.org/

15-16 October
Heat Pump Summit 2013
Nürnberg, Germany
http://www.hp-summit.de/en/symposium/

15-18 October
IAQ 2013 - Environmental Health in Low Energy Buildings
Vancouver, British Columbia, Canada
https://www.ashrae.org/membership--conferences/conferences/ashrae-conferences/iaq-2013

19-21 October
ISHVAC (International Symposium on Heating, Ventilation and Air Conditioning)
Xi'an, China
http://www.ishvac2013.org/v2/index.php

4-8 November
Interclima + elec
Paris, France
http://www.interclimaelec.com/site/GB/Conferences__Events/Presentation,I5151.htm

2014

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

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

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

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/

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

In the next Issue

Environmental evaluation of heat pumps as products

Volume 31 - No. 3/2013

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.

The IEA Heat Pump Centre is operated by

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