Heat Pumping Technologies MAGAZINE

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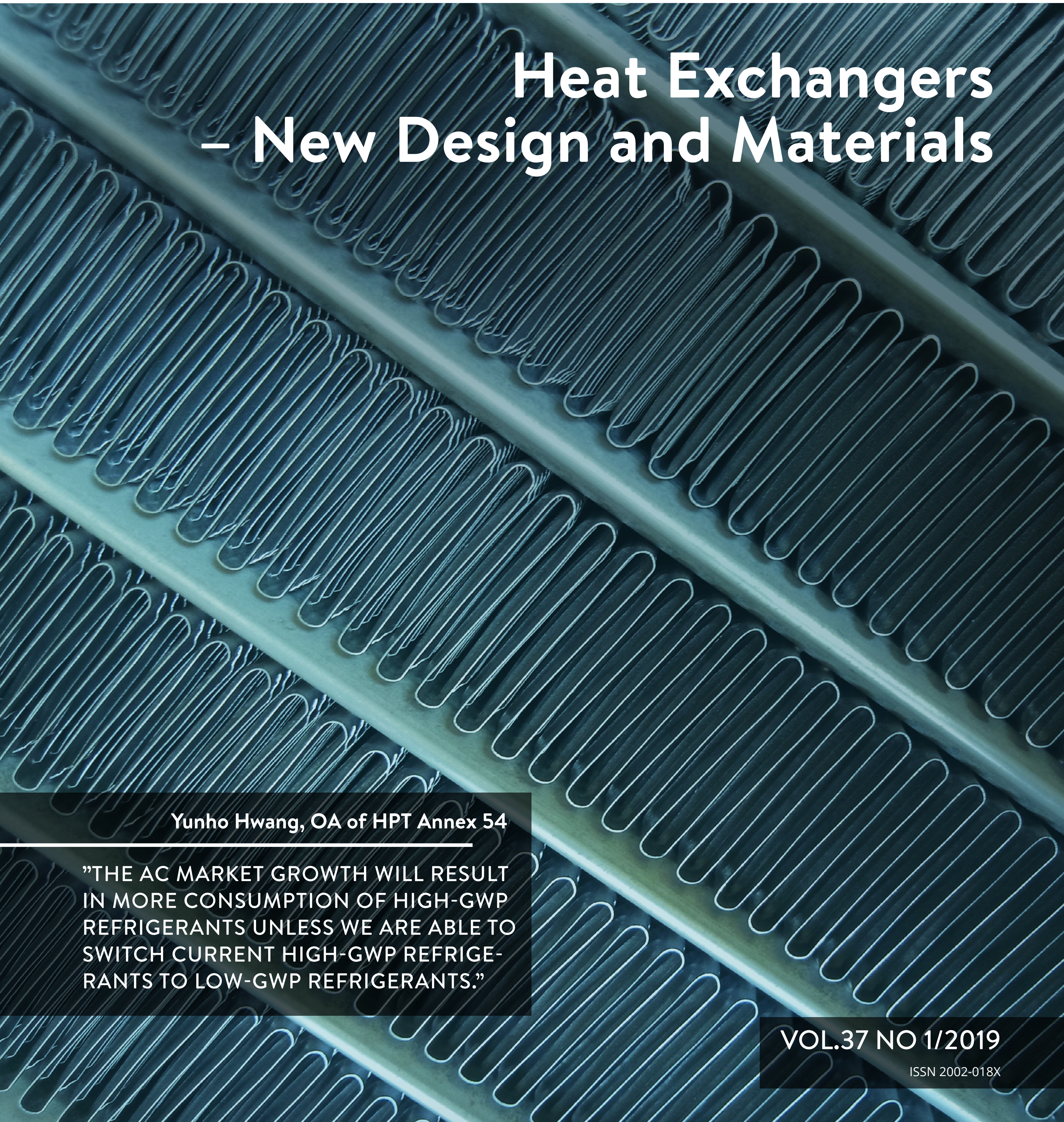

Heat Exchangers – New Design and Materials

Yunho Hwang, OA of HPT Annex 54

”THE AC MARKET GROWTH WILL RESULT IN MORE CONSUMPTION OF HIGH-GWP REFRIGERANTS UNLESS WE ARE ABLE TO SWITCH CURRENT HIGH-GWP REFRIGE-RANTS TO LOW-GWP REFRIGERANTS.”

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In this issue

Heat pumps are often looked at from a systemic perspective. That is reasonable, considering the vast demand for smart systems for housing, industries or entire cities. However, in order for a system to be truly energy efficient, its components also need to be efficient. In a heat pump, one of the key components is the heat exchanger.

This issue of HPT Magazine focuses on heat exchangers and how their efficiency is affected by design and choice of material. One of the challenges with heat pumps is the refrigerant: the alternatives either deplete the ozone layer, have a high global warming potential, are flammable, or are toxic. In the Foreword it is pointed out that research is needed to develop heat pumps that use less refrigerant. One of the topical articles also cover this aspect and conclude that there is a need for improved efficiency in the heat pumps as such, and also for development of low charge evaporators for industrial heat pumps. The other topical article describes testing of an interesting novel type of evaporator: falling film.

The Column moves away from the focus on heat exchangers and looks at hybrid heat pumps. In such systems, the heat pump operates at a baseload and is complemented with a gas boiler. The potential for decarbonisation of heating is particularly high if hydrogen is used. There is also a market report for Sweden, declaring that the largest problem is the difficulty of finding and recruiting competent personnel in all segments: management, white collar and service technicians.

Finally, don't forget about the 13th IEA heat pump conference! The call for abstract closes on May 15.

Enjoy your reading!

Johan Berg, Editor

Heat Pump Centre

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FOREWORD

Minimizing refrigerant charge

Heat exchangers play a vital role in any energy-related system. This also applies to Industrial Heat Pump applications. With the stricter regulations for doing away with ozone depleting as well as greenhouse gases, the industry is tirelessly working to find solutions to this serious issue. Most halocarbon-based refrigerants are on the hit list, especially with new regulations to be imposed on HFCs after the Kigali amendment. One of the options the global chemical community is suggesting is to opt for olefin-based refrigerants, commonly called HFOs. These are new, and there are no long-term data available regarding their safety and stability. However, with the information that is available, it turns out that there are two possible barriers for their wide-spread usage. Firstly, most of these refrigerants fall under ASHRAE category A2L, mildly flammable, secondly, they are extremely expensive. On the other hand we have natural refrigerants such as ammonia, which is time-tested with excellent thermodynamic and transport properties. It has zero Global Warming Potential (GWP) and zero Ozone Depletion Potential (ODP). Its only drawback is the toxicity issue.

To cope with the issues each type presents, it is strongly recommended to devise systems that require a minimum amount of refrigerant. By doing so, the price aspect and the potential damage from an accidental leak can be minimized to a greater extent. The larger the system the greater will be the release. A larger release from a small quantity source will be smaller than a smaller release from a much larger source. In a refrigeration system, most of the refrigerant stays within the evaporator. Engineers and designers ought to concentrate on reducing the foot print of evaporators, so that even if all of the refrigerant escapes it would not create a life-threatening situation to people around the facility. One way to achieve this is to use low charge evaporators that are already available in the market. At the same time research is needed to develop new innovative heat exchangers that would require orders of magnitude less refrigerant charge. In the light of this discussion the topical papers in this issue relate to the subject of low refrigerant charge exchangers used as evaporators in heat pumps.

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Decarbonising heat with heat pumps: a role for hybrid heat pumps?

With the carbon intensity of electricity falling, replacing fossil-fuelled heating systems by heat pumps is an obvious strategy. But it is not the only possible route: other possibilities include low-carbon replacement fuels. To varying degrees, each of these options faces challenges of investment cost, resource availability or consumer inconvenience and cost. Economic studies in the UK[1] suggest that the overall costs of several possible strategies are similar. Hybrid electric/gas heat pumps could reduce the impact of some of these obstacles but would still generate greenhouse gas emissions. Recent studies suggest that the use of hybrid heat pumps with back-up heat eventually coming from low-carbon bio-methane or hydrogen may be the most practicable option[2, 3], and hybrid heat pumps is also the subject of HPT Annex 45. In the short run the back-up would be provided by natural gas.

This Column outlines some of the issues and summarises information from recent UK reports, also relevant for other countries. The reports' objectives are to help to clarify strategic options; they do not represent adopted policies.

Hybrid systems, in which an electric heat pump satisfies a constrained base level of demand for which reduced hot water circulation temperatures are sufficient, could reduce the seasonality of the electricity demand for heating, substantially reducing the investment required to expand the electricity supply system. Instantaneous hot water and cold weather heating would be provided from the existing gas supply system, initially using natural gas and eventually low-carbon gas using the gas boiler. If necessary, this could also provide "peak-shaving services" at other times of high demand on the electricity supply system. For the user, a hybrid system presents less inconvenience than a boiler-to-heat-pump conversion. The hybrid unit will inevitably have a higher cost than a replacement gas boiler, and incentives or regulations would presumably be needed. A hybrid system needs an outdoor unit but should not require modifications to radiators, does not require a hot water storage cylinder and is based on familiar gas boiler technology.

Bio-methane or hydrogen only provides a proportion of the heating demand and the overall requirements appear to be within achievable levels. They could be phased in over time and at different locations if necessary. The use of hydrogen is probably more likely in areas where there are industrial markets and probably close to natural gas feedstock supplies, with access to depleted gas fields for carbon capture and storage. The boiler would need to be converted to operate on hydrogen.

The electricity demand of the heat pump element is limited by its installed power so there is no need for direct control by the system operator. More sophisticated control could be provided, by comparing the relative unit prices of gas and electricity within the hybrid unit. In principle, a hybrid heat pump could provide electricity demand side management services without compromising user comfort, for longer periods than with a heat-pump-only system.

Consumers would need to be convinced that a hybrid system will provide them with secure and economical heating. At current energy prices it will be difficult to deliver competitive running costs while natural gas remains the backup fuel. Either a significant carbon cost needs to be added to the gas price, or the pricing structure of renewable electricity needs to reflect its low marginal generation cost.

Hybrid systems have been demonstrated in a project managed by energy utilities[4] and the other elements that would be needed in a hybrid/low-carbon gas energy infrastructure are also being evaluated. The hybrid approach potentially offers a manageable, phased trajectory towards decarbonised heat with relatively few barriers to market acceptance, and provides a degree of policy flexibility in the face of the inevitable uncertainties of applying relatively untried technologies at scale.

1 Delta Energy & Environment, 2050 Pathways for Domestic Heat Final Report, Report for the Energy Networks Association 2012.
2 Element Energy Limited, Cost analysis of future heat infrastructure options: Report for National Infrastructure Commission. March 2018. https://www.nic.org.uk/wp-content/uploads/Element-Energy-and-E4techCost-analysis-of-future-heat-infrastructure-Final.pdf
3 Imperial College, London, Analysis of Alternative UK Heat Decarbonisation Pathway, Report for the Committee on Climate Change, August 2018. https://www.theccc.org.uk/wp-content/uploads/2018/06/Imperial-College-2018-Analysis-of-Alternative-UK-Heat-Decarbonisation-Pathways.pdf
4 Freedom Project Final Report October 2018. https://www.wwutilities.co.uk/media/2829/freedom-project-final-report-october-2018.pdf

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Welcome to the IEA Heat Pump Conference in 2020

1st call for Abstracts – IEA Heat Pump Conference 2020

The 13th IEA Heat Pump Conference will be held in Jeju Island Korea from Monday, May 11th through Thursday, May 14th in 2020. The abstract submission for the Conference is now open. The abstracts will be screened by a Regional Coordinator and authors will be advised of acceptance.

Deadline call for Abstracts: May 15, 2019

Abstract submission:
http://www.hpc2020.org/pages/call_for_papers.vm

Important dates:

January 1, 2019	Abstract submission open
May 15, 2019	Abstract submission due
November 1, 2019	Full paper submission due
February 15, 2020	Final paper submission due
May 11-14, 2020	13th IEA Heat Pump Conference 2020

The 13th IEA Heat Pump Conference will be held in Jeju Island from Monday, May 11th through Thursday, May 14th in 2020. With the theme 'Heat Pumps – Mission for the Green World', we aim to address global climate change and discuss necessary actions.

Previous Conferences
The upcoming conference will be the 13th of the series of conferences held by the International Energy Agency (IEA) Heat Pumping Technologies TCP (HPT TCP). Preceding conferences were held in Austria (1984), USA (1987, 2005), Japan (1990, 2011), The Netherlands (1993, 2017), Canada (1996, 2014), Germany (1999), China (2002), and Switzerland (2008). After successful histories in Japan and China, it is the fourth Heat Pump Conference to be held in Asia, and the first to be held in the Republic of Korea.

Conference Venue
The conference venue is Ramada Plaza Hotel Jeju, located in Jeju city, easily accessible from Jeju airport. Jeju Island is a famous holiday destination in Southeast Asia, with beautiful beaches, volcanic mountains, and extraordinary cuisine. Home to the natural World Heritage Site, Jeju Volcanic Island and Lava Tubes, participants and those accompanying will certainly enjoy visiting the beautiful island. In addition to sightseeing opportunities, a variety of technical tours are planned.

Conference Goal
Heat pumps, as a reliable and confirmed technology, is the key equipment for energy savings and greenhouse gas reductions with its wide range of application to various energy sources. The upcoming conference will serve as a forum to discuss the latest technologies in heat pumps, and exchange valuable knowledge in market, policy, and standards information on related technologies. Exhibitions will be held at the conference, to share products and technologies from domestic and foreign companies.

Conference Topics
Within the conference program, participants will encounter numerous cutting-edge presentations on the following issues:

- Recent Advances on Heat Pumping Technologies
- Environment-friendly Technology
- Systems and Components
- Field Demonstration and Multi-disciplined Applications
- Research and Development
- Policy, Standards, and Market
- International Activities

Conference Structure

Within the conference program, participants will encounter numerous cutting-edge presentations on the following issues:

- Keynote and Plenary lectures by renowned researchers
- Oral and poster presentations on innovative heat pump technology, applications and markets
- Exhibitions of heat pump equipment
- Workshops on collaborative projects, connected to annexes in the HPT TCP
- Technical tours
- Sight-seeing programs
- Social gatherings

Call for Paper

The abstract submission system is now open. The abstracts will be screened by a Regional Coordinator and authors will be advised of acceptance.

Organization

The conference is organized by the International Organizing Committee (IOC) and the National Organizing Committee (NOC) on behalf of the Executive Committee of the IEA HPT TCP.

Per Jonasson	Chairperson IOC, Swedish Refrigeration & Heat Pump Association, Sweden
Sophie Hosatte	Vice-Chairperson IOC, CanmetENERGY, Canada
Hideaki Maeyama	Vice-Chairperson IOC, HPTCJ (Heat Pump and Thermal Storage Technology Centre of Japan)
Min Soo Kim	Chairperson NOC, Seoul National University, South Korea
Minsung Kim	Conference Secretariat, Chung-Ang University, South Korea

For further information, please refer to the Conference website with the 1st announcement of the 13th IEA Heat Pump Conference. http://www.hpc2020.org/

13th IEA HEAT PUMP CONFERENCE
2020 | JEJU KOREA

Images of Jeju and Night view of Ramada Plaza Hotel Jeju

Ongoing Annexes in HPT TCP

The projects within the HPT TCP are known as Annexes. Participation in an Annex is an efficient way of increasing national knowledge, both regarding the specific project objective, but also by international information exchange. Annexes operate for a limited period of time, and the objectives may vary from research to implementation of new technology.

FUEL-DRIVEN SORPTION HEAT PUMPS	43	AT, **DE**, FR, IT, KR, SE, UK, US
HYBRID HEAT PUMPS	45	CA, DE, FR, **NL**, UK
DOMESTIC HOT WATER HEAT PUMPS	46	CA, CH, FR, JP, **NL**, KR, UK, US
HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS	47	AT, CH, **DK**, SE, UK
INDUSTRIAL HEAT PUMPS, SECOND PHASE	48	AT, CH, **DE***, DK, FR, JP, UK
DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB	49	AT, BE, **CH**, DE, NO, SE, UK, US
HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, **DE**, FR, IT, NL
ACOUSTIC SIGNATURE OF HEAT PUMPS	51	**AT**, DE, DK, FR, IT, SE,
LONG-TERM MEASUREMENTS OF GSHP SYSTEMS PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS	52	FI, NL, NO, **SE**, US, UK, DE
◖ ADVANCED COOLING/ REFRIGERATION TECHNOLOGIES DEVELOPMENT	53	DE, IT, KR, **US**
◖ HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS	54	IT, JP, KR, **US**
◖ COMFORT AND CLIMATE BOX	55	AT, IT, **NL**

◖ NEW

*) Operating Agent from Germany, but no other parties from the country participate.

The Technology Collaboration Programme on Heat Pumping Technologies participating countries are:
Austria (AT), Belgium (BE), 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).

Bold, red text indicates Operating Agent (Project Leader).

ANNEX 46 — DOMESTIC HOT WATER HEAT PUMPS

Domestic Hot Water Heat Pumps are traditionally seen as a standalone product, but the truth is more complex. Therefore, over the working period since 2017, the focus of the Annex has broadened.

Water heaters are one of the most complex product categories due to a large variety of product types, technologies, and fuels used for heating water. Not only ranging from individual to collective systems, but also introducing combined systems, hybrid systems and fresh water systems, with different terminology in different regions of the world.

As new buildings become more energy efficient, CO_2 emissions from hot water start to exceed those from space heating. Thus, the same level of detail should be applied to hot water system design as to the building envelope and ventilation systems. An important finding from the Annex work is that the way in which most energy models for current building processes consider hot water systems is too simplistic for newly build and deep renovation of dwellings.

Good models are needed for calculating and assessing systems for heating domestic water in buildings in order for policy to make the right choices at the macro level, based upon chain efficiency and designers, installers etc., to design an optimized system. Task 2 of this Annex has analysed this and concludes that there are a number of missing aspects:

- Many energy models for buildings use generic and old figures for the calculation, in which often flat-rate values are used, such as floor areas for the calculation of the use of hot water;
- Calculation for chain efficiency is often not used to compare alternative systems, or if used often show the same deviations as the standard calculation models;
- Innovative concepts are often not in the models (fresh water, booster, solar combi, etc.);
- A comparative calculation model for multifamily buildings is missing, considering the strategic control options.

In addition to this modeling challenge a number of important boundary conditions are being discussed and analyzed in the Annex, focusing on the needed future work and R&D on Domestic Hot Water Heat Pumps:

Refrigerants. Most widely used in DHW HPs are R134a, R410A. Both of these have a high GWP and are being phased out under the widely supported Montreal Protocol and Kigali Agreement. As alternatives, refrigerants and technical solutions for high temperature DHW applications (>65 °C) are desirable. Technical solutions can be cascade heat pumps and modifications to the refrigerant cycle, such as Enhanced Vapor Injection. No single refrigerant fulfils all the ideal requirements. There is a load of literature available, but not much on hot water heat pumps. The Annex stresses the importance of the TEWI factor, or the LCCP approach, to judge the applicability of refrigerants.

Legionella. Legislation is not harmonized between different countries. Existing legislation focuses mainly on thermal disinfection. Heat pumping technologies for single family buildings as well as in collective systems for Multi-Family buildings, sports centers, hospitals, etc., are well fitted and capable to deliver the required temperatures to cover the need for thermal disinfection. However, this higher thermal demand increases the CO_2 emissions for hot water production by around 5-10% and for heat pumps by up to 20%. Whilst the risks to human health should clearly remain a priority when setting regulations in this area, the impact on CO_2 emissions of an over-conservative approach suggest that further study in this area is required.

Test procedures and standards. There are a great number of test methods for heat pump water heaters in use in different regions of the world, with major differences between them. As a result, manufacturers have to undertake a different set of tests to be able to sell their products on the worldwide market. A harmonisation framework has been proposed for this purpose, including standardised physical tests and a development of simulation methods, in several stages. A first step has now been made by publishing the ISO Draft HPWH-19967-Part1-DIS registration by the Working Group 12 on Heat pump water heaters of the ISO Technical Committee 86/SC 6. Yet many of the test procedures seem to focus mainly on air source domestic hot water heat pumps, being the main stream of applied DHW HPs, while there is a large number of alternative heat pump technologies supplying domestic/sanitary hot water. For these, there are sometimes no standardized test procedures available, or if available, not acknowledged at the international level.

Collective systems. These occur in Multi Family Buildings (Annex 50) and District Heating Systems (Annex 47). Seemingly simple solutions are available for single family houses, but for collective systems solutions are more complex due to the demand for high temperatures in central distribution systems and the ownership relation in buildings. The low efficiency of collective DHW systems is well known by field practitioners. For many new residential buildings, hot water delivery times and water waste have been growing steadily with newer buildings. The sources of inefficiency can be found in every one of the diverse phases entailed by DHW systems: from the design of the piping structure and the sizing of equipment to the selection of the applied control strategies.

A great number of reports have been studied. In general, based on the sum of all losses, individual solutions, where hot water is generated where it is needed, are the best choice. Even in the development of the 4^{th} generation of district heating, the booster heat pump is considered the 'best solution', although there are different opinions about this.

In Task 1, an overview has been made of the state of the art showing a great diversity due to existing markets and cultural difference in hot water usage.

- Largest market is China (also for thermal solar);
- Japan, with 10% of market, is the second largest market (in numbers), mainly ECO Cute;
- US has a large potential in replacing Electric and Gas DHW storage tanks (typically still a market of split systems);
- In Europe, the market for double function heat pumps is growing, especially in countries with a need for space heating and a strong policy on Energy Zero and renovation.

These diversities will give different scenarios and will have different consequences for the R&D Road Map.

Except for Japan and China there is worldwide no clear government policy focusing on Domestic Hot Water Heat Pumps as a product. It is a common understanding that without governmental guidance (through legislation) the big potential of the market for Domestic Hot Water Heat Pumps will not be fully developed.

Example projects

Example projects are good installations and showcases. A large number of these are shown on the website, where a special page is made on heat pumps with CO_2 as refrigerant, showing some interesting videos. An interesting case is shown at a student accommodation located in the centre of the university city of Leiden.

There, two Mitsubishi Q-ton CO_2 heat pumps were installed for the sanitary hot water of the individual student homes. The building consists of identical blocks. Each accommodates 160 students and consumes 10 000 litres of sanitary hot water per day. One part still uses a gas boiler, while the other part uses the MHI's Q-ton system to supply hot water to the students. The Central Heat Pump is not only used for the supply of sanitary hot water but also to reheat the distribution circuit to follow the local anti-Legionella regulation. The installation is monitored and centrally controlled to optimise the system. Monitoring clearly shows that the morning peak demand of hot water in this student home is later than in 'normal' buildings. It also shows that control of these systems can optimize the energy use as often more debated lately in literature. Clear publicly available models to analyse the overall energy effects do not yet exist and are a challenge for Annexes 46 and 50.

Planned Workshops

Workshop at IIR Conference

A decision has been agreed upon by the Annex participants and the IIR-chair to have a workshop on the Annex 46 R&D Roadmap at the 25th IIR Conference ICR 2019 in Montréal. Speakers have been invited from the Annex participants and others not participating in the Annex.

Workshop at the 13th IEA Heat Pump Conference 2020 in Jeju. A special Workshop is planned for the Conference focusing on future developments with the prospect of continuation of the running Annex, or a new Annex. Officially the Annex 46 will then have ended but a lot of challenging work remains to be done.

Annex website

https://heatpumpingtechnologies.org/annex46/

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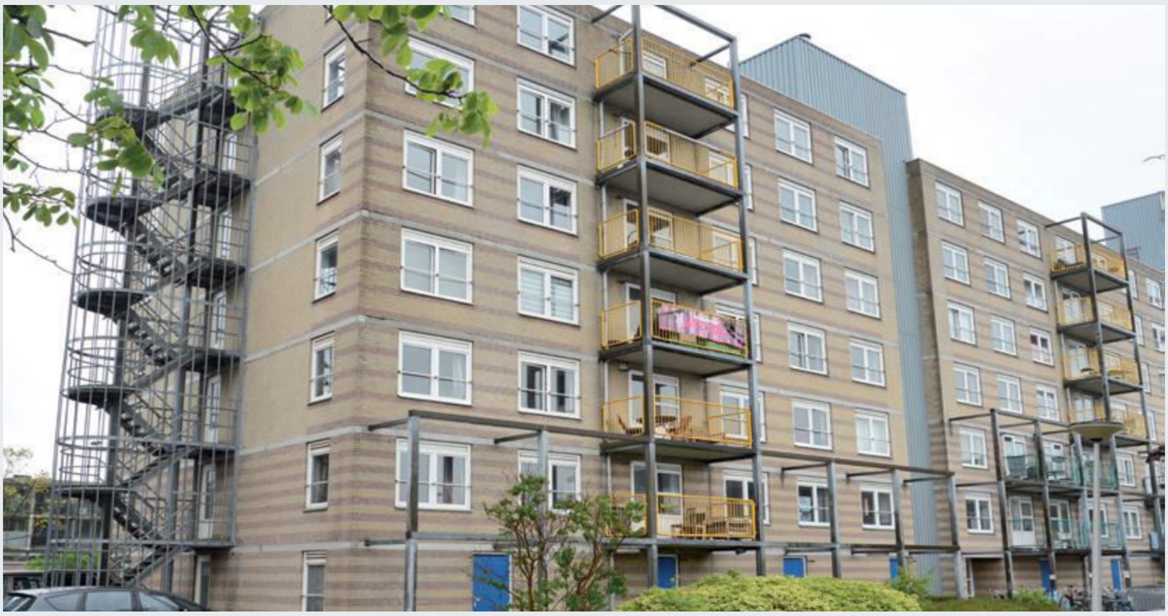

Fig. 1: Student accommodation located in the centre of the university city of Leiden, using CO_2 DHW heat pumps.

ANNEX 49 DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

As of January 1, 2019, the requirement of the recast of the EU Directive on the Energy Performance of Buildings (EPBD recast, current version of 2018) has been introduced and obligates the EU member states that all new public buildings have to comply with a Nearly Zero Energy Buildings (nZEB) requirement. Exactly 2 years later, by January 1, 2021, these requirements will be extended to all new buildings. Also worldwide, in the USA and Canada as well as in Japan and China, Net Zero Energy Buildings are the next step for the high-performance buildings of the future. However, what is understood by an nZEB and how ambitious an nZEB is compared to the state-of-the-art, varies between the EU member states. This is a fact which makes it hard for policy makers to compare the different ambition levels of the EU member states. For instance, in some member states a further step to higher performance requirements for new buildings has been taken, while other countries more or less remain on the already introduced performance level. For manufacturers, it is more difficult to develop performance standardized system solutions for the dedicated application in nZEB when the requirements differ between member states.

Heat pumps are a promising technology for nZEB due to the low loads and low temperature requirements, which lead to a high performance of the heat pump. Thus, Annex 49 is to evaluate the operation of heat pumps in nZEB. As further benefits, a heat pump can cover different building needs with the same generator, i.e. DHW and increasingly also space cooling needs. It also enables higher self-consumption rates of the installed on-site PV generation in nZEB, which can make the PV installation more economic in times of decreasing feed-in tariffs.

The work of Annex 49 is scheduled into four tasks: Task 1 summarizes the state-of-the-art of heat pumps in nZEB and is currently updated based on the definitions of nZEB introduced in the participating countries at the deadline at the beginning of 2019. Moreover, in order to facilitate the characterisation and comparison of ambition levels in different countries, a methodology is developed and tested based on simulations.

Task 2 covers integration options for heat pumps in nZEB, both on the source side and the sink side as well as for integration with other building technology components, such as thermal or electric storage, which can also enhance the energy flexibility of the building regarding grid interaction. Task 4, on design and control, is linked to the work in Task 2 on system integration.

In Task 3 different monitoring projects on residential and non-residential buildings are evaluated in the participating countries, and interim results are partly available. Task 3 also covers the testing and further development of nZEB components.

Task 4 deals with the design and control of heat pumps integrated into the building technology in nZEB.

In Switzerland, for instance, a 5-storey building with mixed commercial (basement, 615 m^2), office (1-2 storey, 615 m^2) and residential (3-4 storey and attic, 1520 m^2) use in the city centre of Pfäffikon, in the canton of Schwyz (SZ), has been monitored. The all-electric building is equipped with a high-performance building envelope at ultra-low energy house level, and a ground-source heat pump as core generator for space heating, DHW and space cooling with a heating capacity of 80 kW at B0/W35. However, the cooling operation, is mainly covered by free-cooling operation of the borehole field, which consists of 15 ground probes of each 150 m, so the heat pumps serve as back-up chiller in reverse operation in summer. Moreover, the ground is used for preheating/cooling of the mechanical ventilation system.

In order to meet a net-zero energy balance, the roof comprises a 26 kW_p monocrystalline solar PV system and, in the south, east and west direction, thin-film solar PV modules of a total installed capacity of 48 kW_p are integrated in the façades. The measured energy consumption mainly corresponds to the calculated design values of the building. The space cooling demand is yet a bit lower, since one of the server rooms has not worked as planned. However, the PV yield of the façade integrated modules has not reached the projected values. Therefore, despite a building envelope at ultra-low energy house level and good energy performance of the system technology with a measured overall seasonal performance factor of 5.2, the net balance based on the system boundary building technology (excluding plug loads) is not entirely reached. However, with better performance of the façade integrated PV, the balance would have been met.

The monitored systems are also partly simulated, to approve the energy balance and optimisation potentials identified in the monitoring.

Interim monitoring results in Annex 49 confirm that nZEB are high performing buildings. However, a lesson learned is that, depending on the balance boundary and building use, it can be hard to reach an nZEB consumption in larger buildings despite good performance of the building technical system, since the surface for the energy production at the building site is limited. Thus, nZEB may set ambitious targets for the building performance and energy generation on-site. Consideration of a group of buildings or neighbourhoods may be a viable solution to overcome limitations of the surface on the energy generation of single buildings. In addition, synergies of different load structures for energy recovery (e.g. combined cooling and DHW heating) may be used by groups of buildings.

A presentation and discussion of the latest results in the different Annex 49 Tasks took place at the 7th Annex 49 meeting in Obergurgl, Austria on February 25-27, 2019, which was amended by a lab visit at the University of Innsbruck, unit for energy efficient building.

Fig. 1: Different views of the monitored building Black & White in Switzerland, with mixed residential and office use.

Fig. 2: Group photo of the 7th IEA HPT Annex 49 working meeting held at the University Centre of the University of Innsbruck in Obergurgl

Annex website

https://heatpumpingtechnologies.org/annex49/

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ANNEX 50

HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW

The building sector is highly important for energy consumption in every country. Regarding the emission of greenhouse gases, it is one of the three most important sectors. Therefore, the massive reduction of CO_2 emissions from buildings and the long-term achievement of a climate-neutral building sector can be considered inseparable.

Applying heat pump technologies and renewable energy is more complex for multifamily buildings than for newly built apartments as multifamily houses bring along a range of heat demand characteristics. Firstly, the share of domestic hot water demand on the overall heat demand varies due to varying building standards as well as different climates. Secondly, the temperature level of the heating system is influenced by these aspects as well as by the installed heating transfer system. Henceforth, dealing with the variety of heat demand characteristic bears the challenge on the way to a broader spread of heat pumps in multifamily buildings.

Thus, Annex 50 focuses on solutions for multi-family houses with the attempt to identify barriers for heat pumps on these markets and how to overcome them. In respect to the demand of the participating countries new buildings and retrofit will be considered as well as buildings with higher specific heating demand.

As the end user on the demand side, city councils and housing corporations owning large housing estates are important target groups. On the supply side, heat pump manufacturers, power companies, technical consultants as well as planners/installers will be addressed. Furthermore, political decision makers are of interest since governments setting the boundary conditions for future development for Energy Zero in 2050.

Results

The website is still growing. The page of the best practice sheets, that has been created to give an overview of all installations, is supplemented with new examples. The design of the documents is standardised: a description of the best practice, previous insights, key facts and a description of technical concepts. In addition to the sheets, an interactive map (see Figure 1) represents each example for best practices in different countries. Everyone can get access via: http://heatpumpingtechnologies.org/annex50/best-practices/

Users can click on a dot that each represent an example of a best practice and can get more information about why this example is successful. After clicking on the dot to get more information, a best practice sheet is available and can also be downloaded as a pdf-file. The sheets consist of a general description of the best practice, of lessons learned, of key facts and a description of a technical concept. The aim is to have as many examples as possible. This aim should be achieved by getting in contact with different institutions and partners that possibly have examples to show. All examples illustrate that there are many different ways of integrating heat pumps in multi-family buildings (multi-family buildings, hotels, schools etc.).

The collection of examples of Denmark, UK, The Netherlands and Italy are still in progress. In addition to the examples above, the website should be extended by examples that are not directly connected to Annex 50. In order to achieve this, there is an active exchange with other Annexes and groups that may provide examples, such as with the operating agent of Annex 49 "Design and Integration of Heat Pumps for nZEB".

The best practice sheets have led to a new way of communication. Examples of various countries have been collected. This collection results in the motivation of other institutions that also want to show their best examples. Therefore, not only the institutions that are participating countries of Annex 50, but also other institutions have been contacted. The aim of gathering many examples is nearly fulfilled and the aim of making these examples available was achieved in February 2019.

The uniform energy flow scheme was established in 2018 and is often used. Illustration 2 serves as an example for an energy flow scheme that has already been implemented.

Country	Location	Type of building	Size, number of apartments	Year
Austria	Weiz	Passive house	957 m² living, 10 apart.	2015
France	Marseille	New built private housing	2833 m² living	2015
	Nice	New built eco-district	20000 m² living, 280 apart.	2012
	Soissons	Social dwellings	841 m² living, 12 apart.	1975
Germany	Potsdam	Hotel	37 apart. plus restaurant	2013
	Kempen	MFB in old School	5 apartments	1881
	Düsseldorf	Quartis	10.200 m² living	2009
Netherlands	Amsterdam	Retrofitted MFB	1 157 apartments	2017
	Breda	3 new buildings	248 apart. + 3500 m² commercial	2012
	Den Haag	Newly built apart.	288 apartments	2013
	Leiden	Un-refurbished MFB	400 apart. + elderly home	2017
	Tilburg	New elderly home	285 apartments	2016
Switzerland	Daru	Existing MFB	7563 m² living, 68 apart.	1992
	Geneva	Existing MFB	4049 m² living, 53 apart.	1972

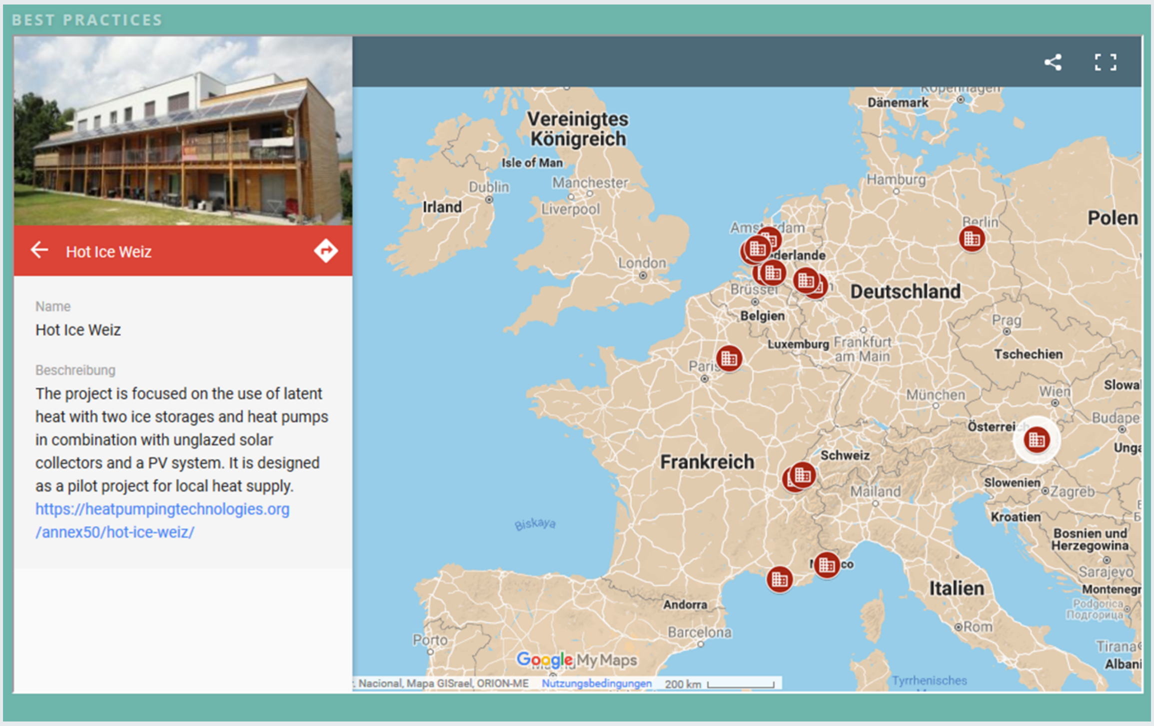

Fig. 1: Interactive Map of Best Practices. https://heatpumpingtechnologies.org/annex50/best-practices/

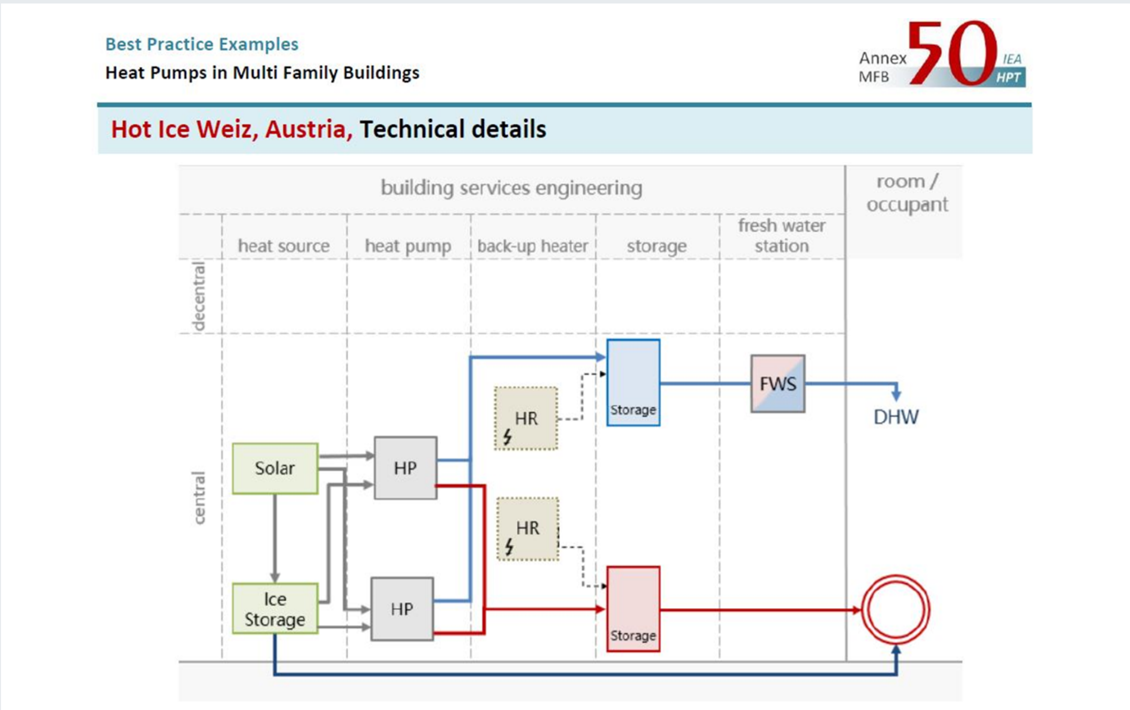

Fig. 2: Energy flow scheme that is part of the best practice sheet of "Hot Ice Weiz", Austria. https://heatpumpingtechnologies.org/annex50/best-practices/

Annex website

https://heatpumpingtechnologies.org/annex50/

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ANNEX 51 — ACOUSTIC SIGNATURE OF HEAT PUMPS

To further increase the acceptance of heat pumps, reduction of acoustic emissions is important. To minimize noise annoyance, more focus must be put on the acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. Placement of the heat pumps is also of utmost importance, as sound emissions exhibit a pronounced directivity. Especially, air to water heat pumps provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations, making acoustic improvements crucial due to their noise-producing components such as compressors and fans.

13 members of the IEA HPT Annex 51 team convened at DTI in Aarhus, Denmark for their 4th working meeting (see Figure 1). Results from the running measurement campaigns were presented and compared. The three heat pumps (an Exhaust-air Heat Pump Water Heater (HPWH), an Air-to-water Heat Pump and an Air-to-air Heat Pump) are "on tour" through Europe at the participating institutes. Their final tests are expected to take place during summer 2019. As an example of results, Figure 2 shows the calculated A-weighted sound power level of the Air-to-water Heat Pump at A7W35 condition over a period of 200 minutes. During this time, defrosting occurs three times with a typical interval of normal operation of just over one hour. Defrosting can be seen as a drop of electrical power consumption as well as of sound power level. The small electrical power and sound power level increase during defrost is attributed to running in reverse mode. The typical gradual increase in sound power level during the subsequent coverage of the heat exchanger with ice following a defrost is about 5 dB(A) in this operation mode.

The upper part of Figure 3 shows the frequency resolved sound power level around a defrost with a length of abound 330 seconds. During this time several light green and yellow "lines" can be spotted corresponding to the increase and decrease of the frequency of compressor and fan. In the lower part of Figure 3 the frequency resolved sound pressure level at one selected microphone position is shown. The 330 seconds range again corresponds to the period where the four-way valve is switched to allow for a reversed operation to heat up the heat exchanger for defrost. Various small acoustic bands can be traced changing their frequency (y-axis) originating from changes in the rotational speed of fan and compressor: first the compressor and fan stop (1) followed by the first switch of the 4-way valve (2); then the compressor restarts with reduced speed (3) in several steps for reverse mode and is stopped again (4); after the second switch of the 4-way valve (5), compressor and fan spool up to full speed (6) marking the start of normal operation. Comparing the results of the 60 different microphones positioned around the heat pump during the tests, a sound pressure level range of 5 dB(A) can be noted as the directional dependence of the sound emissions for the chosen Air to Water Heat Pump.

The documents on Introductions to Acoustic, Measurement Techniques and Regulations, which have been prepared under the task lead of Politecnico di Milano, Italy, are available on the IEA HPT Annex 51 team website. During the remaining time of the Annex 51, comments and additions are gathered and the updated documents will be put on the website by the end of the Annex mid of next year. Psychoacoustic tests, which will give input to the test design used in the Annex 51, are currently carried out by the Acoustic Research Institute of the Austrian Academy of Sciences.

A dissemination workshop "Acoustics of Heat Pumps" will be organized by the Annex 51 team in the framework of the 25th IIR International Congress of Refrigeration in Montreal, Canada, August 2019. The closing workshop of Annex 51 is planned to be organized at MCE2020 Mostra Convegno Expocomfort in Milano, Italy, March 2020.

Annex website

https://heatpumpingtechnologies.org/annex51/

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Fig. 1: The IEA HPT Annex 51 team at the 4th working meeting at DTI in Aarhus, Denmark. The group photo was taken in one of DTI's advanced climate chambers used for acoustic measurements based on ISO 3743-1 [Source: The IEA HPT Annex 51 team]

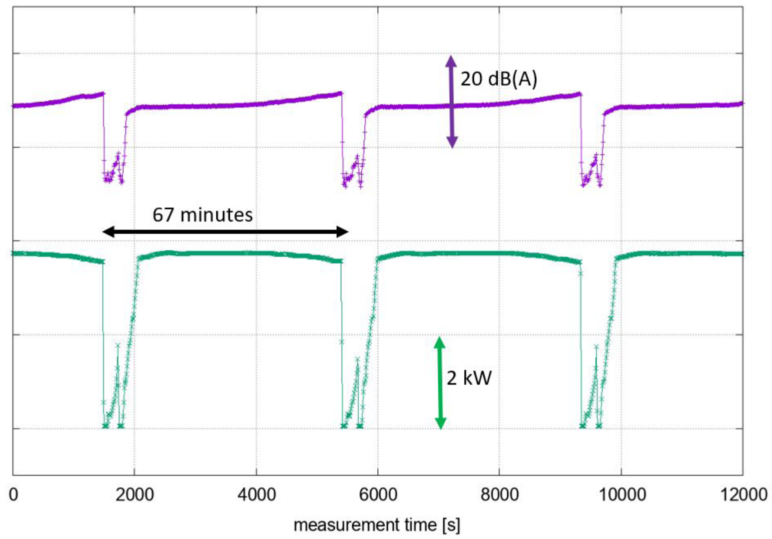

Fig. 2: A-weighted sound power level and electric power consumption of an Air-to-Water Heat Pump showing several defrosting cycles [Source: AIT, Austria]

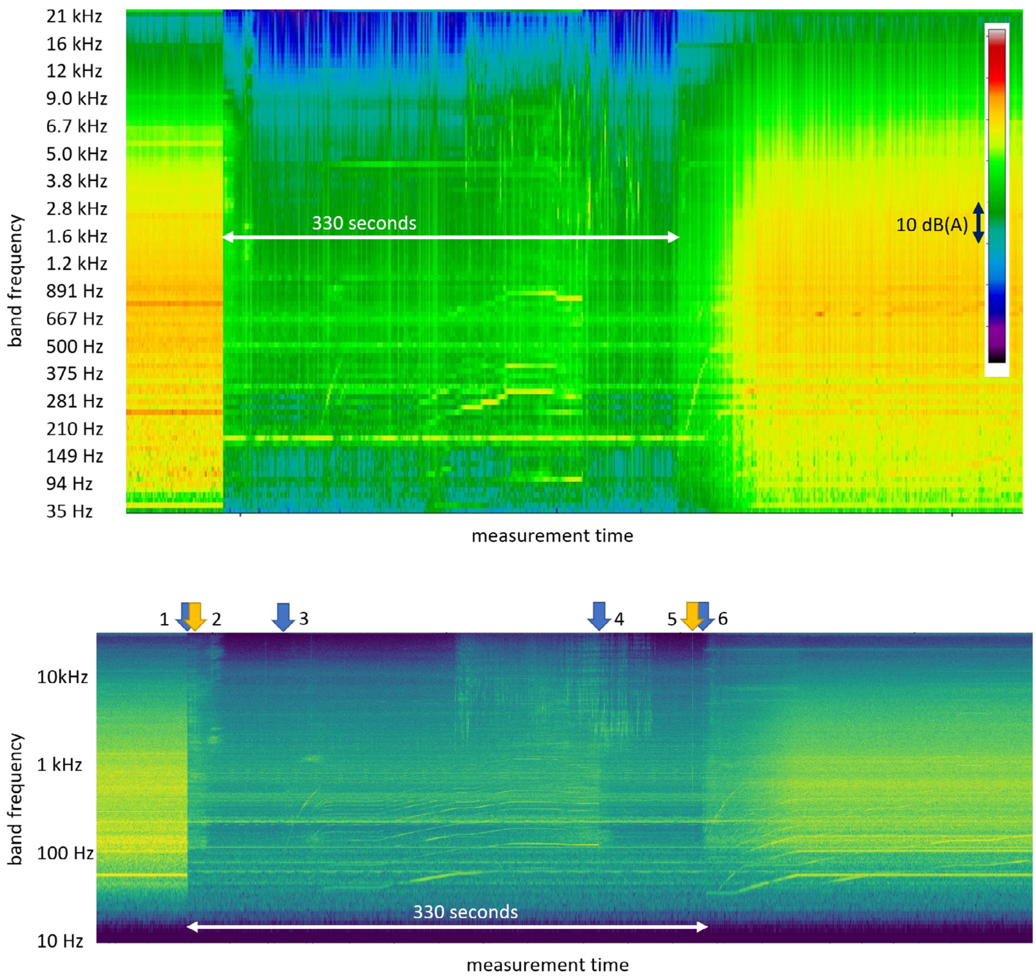

Fig. 3: A-weighted sound power level and electric power consumption of an Air-to-Water Heat Pump showing several defrosting cycles [Source: AIT, Austria]

ANNEX 52

LONG-TERM MEASUREMENTS OF GSHP SYSTEMS PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS

Bibliography points at the difficulty in GSHP system performance comparison

Along with the many case studies of GSHP systems, one of the first tasks of HPT Annex 52 – *Long-term performance monitoring of GSHP systems for commercial, institutional and multi-family buildings*, is to survey previous publications related to long-term performance monitoring of large GSHP systems. At the Annex 52's second experts' meeting in the USA in November 2018, a first compilation of an annotated bibliography on long-term performance monitoring of GSHP systems was presented. The bibliography then contained 37 publications related to long-term performance monitoring of larger GSHP systems.

Based on these 37 publications, 32 GSHP systems serving commercial, institutional and multi-family buildings with reported SPF and COP values were identified. 20 of these buildings are located in European countries, 11 in the USA, and one in China. The majority of the GSHP systems use vertical borehole heat exchangers in rock or soil, while a handful of the systems use groundwater, municipal wastewater or mine water as their source.

In the published literature, there is little consistency in the use of system boundaries for calculating SPF and COP values. In several cases, the system boundaries used are not clearly defined.

SPF and COP values for the 32 GSHP systems were compared using the system boundary schema defined by the EU project SEPEMO*. The SEPEMO system boundary schema was primarily defined for small residential heat pump systems in Europe, and thus does not reflect the complexity of larger GSHP systems that often provide both heating and cooling, sometimes simultaneously. Worth noting is the fact that the SEPEMO system boundaries for SPF_{H1} and SPF_{H2} correspond to SPF_{C1} and SPF_{C2}, while the boundaries for SPF_{H3} do not correspond directly to those for SPF_{C3}. SPF_{H3} includes auxiliary heating but not distribution pumps/fans, whereas SPF_{C3} includes distribution pumps/fans, but not supplementary cooling units. Hence if there is no auxiliary heating in the heating system, $SPF_{H2} = SPF_{H3}$, while $SPF_{C3} = SPF_{C4}$ for systems without supplementary cooling.

Five of the 32 buildings in the bibliography have distributed GSHP systems, delivering heating and cooling with fans integrated in the heat pump units, while the others have centralized GSHP systems. When comparing performance of centralized and distributed GSHP systems, the overall (H4 or C3) boundaries must be used, because the distributed GSHP energy necessarily includes fan power (Figure 2). For the case of the 32 GSHP systems in the bibliography, only about half the cases give the overall system SPF. The comparison of the buildings gives an SPF_{H4} range between 2.5 and 4.7, while the range for SPF_{C4} is 2.7-7.0. Uncertainty is analyzed for only two of the systems.

Using the results from the bibliography together with new performance data from the more than 30 on-going case studies within Annex 52, the aim is to define and analyze system performance for boundaries that better reflect the complexity and variations of larger GSHP systems worldwide. More publications will be added to the bibliography during the course of Annex 52, which will be a useful resource for participants as well as non-participants.

The third IEA HPT Annex 52 Experts' meeting will take place in Finland on May 23-24. Updates on the Annex 52 work and results are continuously posted on the Annex web site.

* Nordman, R. (2012). Seasonal Performance factor and Monitoring for heat pump systems in the building sector, SEPEMO-Build, Final Report. Intelligent Energy Europe.

Annex website

https://heatpumpingtechnologies.org/annex52/

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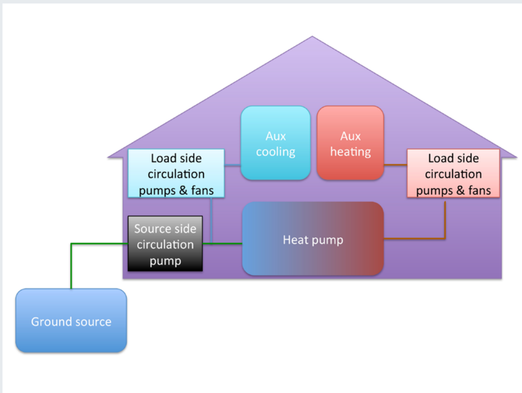

Fig. 1: Centralized GSHP

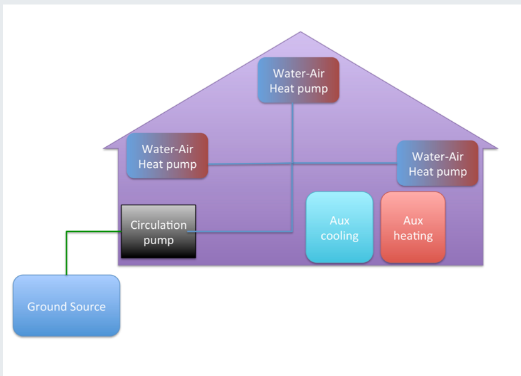

Fig. 2: Distributed GSHP

ANNEX 53 ADVANCED COOLING/ REFRIGERATION TECHNOLOGIES DEVELOPMENT

Growing populations and improving economies worldwide, especially in the developing world are projected to lead to huge increases in global demand for space cooling, dehumidification, and refrigeration. This will make reaching global energy and climate goals extremely challenging. In order to help address this challenge the HPT TCP started Annex 53. The primary driving motivation for Annex 53 is the projected 3x increase in global energy demand over the next 30-40 years for space cooling and dehumidification and for refrigeration (see Figure 1). It is acknowledged that this is a massive challenge and will require a combination of near- and longer-term actions to adequately address. Annex 53 focuses on longer-term RD&D to advance the efficiency of cooling and refrigeration systems. Technologies of interest include both those based on the well-known and widely used vapor compression (VC) systems and non-traditional cooling approaches being increasingly investigated.

An initial "kick-off" or planning meeting was held on January 11, 2019, in Atlanta, Georgia, USA just prior to the 2019 ASHRAE winter conference. Four technical projects were introduced, describing technology developments planned for inclusion in the Annex.

1. An ORNL (US) project based on the magnetocaloric (MC) concept in collaboration with the company General Electric Appliances (GEA), focused on development of a 100 W cooling capacity refrigerator (100 °F temperature lift [= 38 °C]). A key activity involves application of advanced or additive manufacturing techniques for fabrication of the MC regenerator concept (see Figure 2).

2. A project underway at the University of Maryland based on the elastocaloric (EC) cooling concept. The EC approach involves alternatively stressing and relaxing a solid metal tube or bundle, resulting in a temperature change in the material. A temperature lift of up to 22 K has been achieved experimentally.

3. Fraunhofer Institute (Germany) discussed MC and EC system developments utilizing heat pipes to move heat in/out of the MC or EC device (no pumps required). The respective project goals/applications are
a. MC heat pipe: deep freezer device for medical applications, and
b. EC heat pipe: residential heat pump.

4. The Korea Institute of Mining and Materials (KIMM) provided a presentation on a membrane-based air-conditioner (AC) project based on an advanced VC cycle using water as the refrigerant (Figure 3). The project goal is to develop a highly efficient AC system.

Annex 53 participants include Germany, Italy (announced just after the Atlanta meeting), South Korea, Sweden, and the US. Additional HPT member countries are invited to join the Annex – participation is open through 2019. As noted previously, the objective of Annex 53 is to develop technology solutions for higher efficiency air-conditioning/refrigeration systems to help minimize/reduce projected energy consumption increases. The Annex scope is broad, but the challenge is also huge; it is not likely that there will be only one or even only a few "right" solutions.

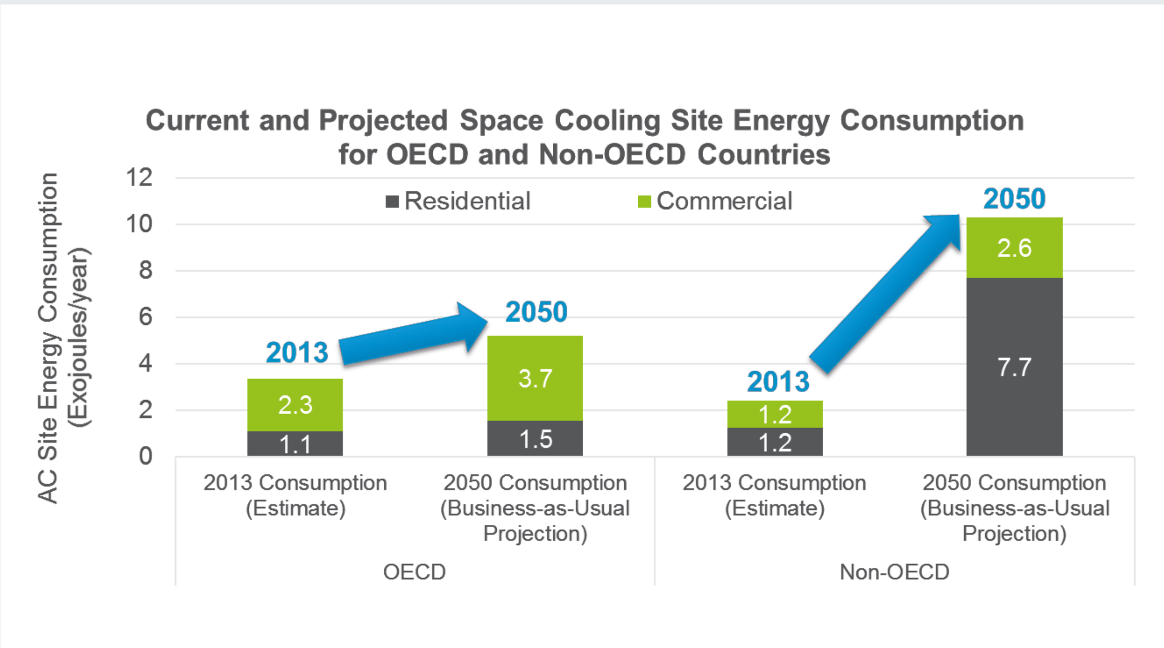

Fig. 1: Current and projected space cooling site energy consumption for OECD and Non-OECD countries. Source: Courtesy of Navigant Consulting, Inc.

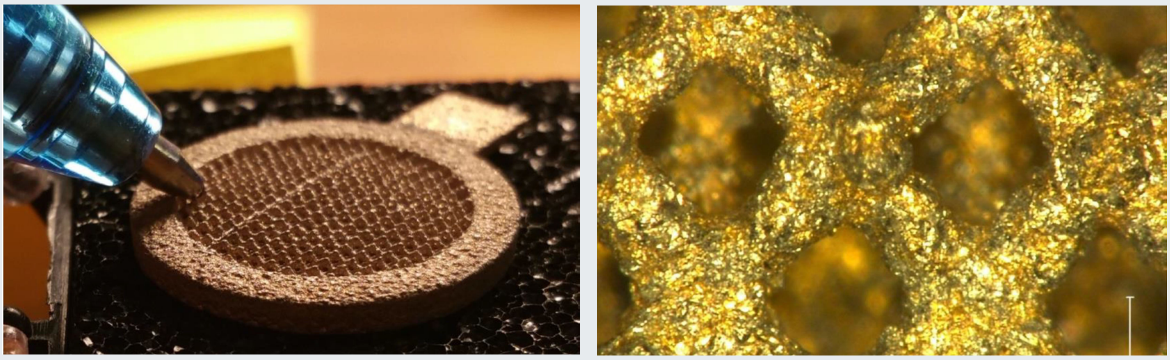

Fig. 2: Example of 3D printed MC regenerator component: full size part (left photo) and close-up of regenerator grid pattern (right photo). Source: Courtesy of Oak Ridge National Laboratory (ORNL).

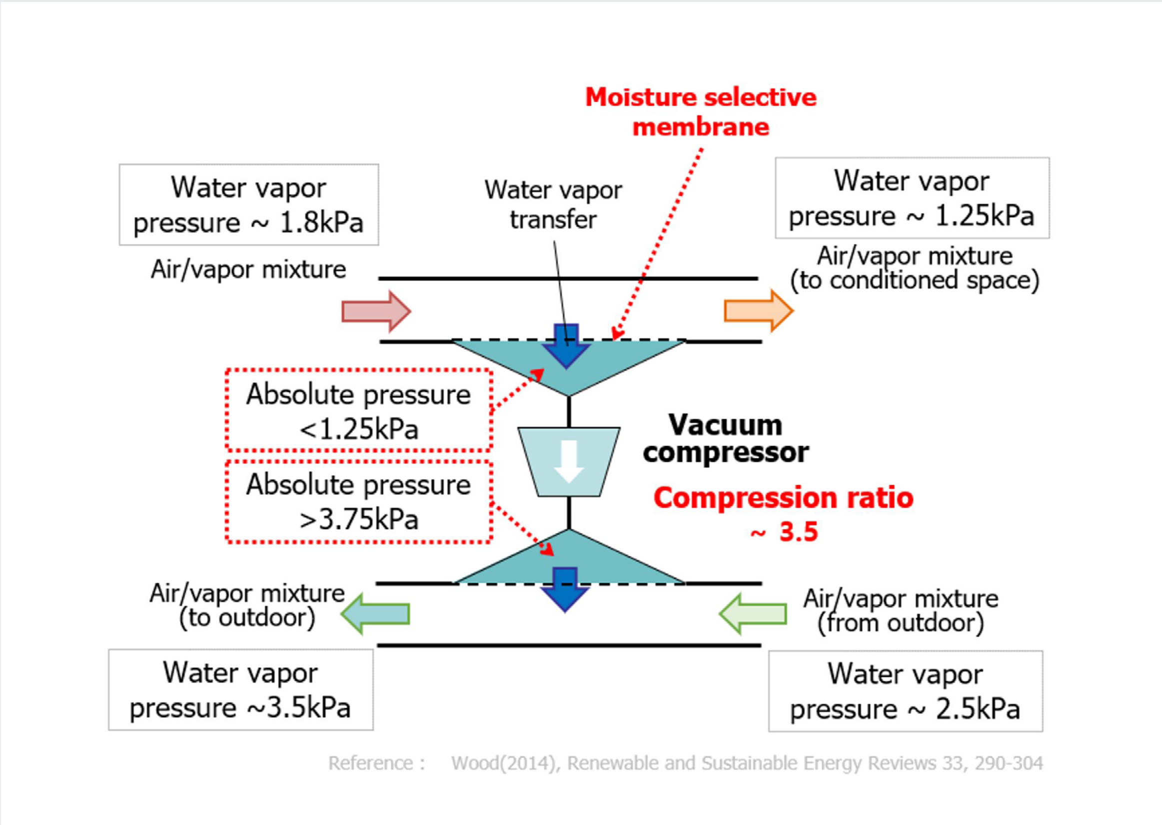

Fig. 3: Vacuum compressor membrane dehumidification concept.
Source: Courtesy of Korea Institute of Machinery and Materials (KIMM).

Annex website
https://heatpumpingtechnologies.org/annex53/

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ANNEX 54 HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

Introduction

According to IEA, 350% of global air conditioning market growth is projected for next 30 years especially in developing countries due to their growing economy and warming climates. Therefore, this market growth will result in more consumption of high-GWP refrigerants unless we are able to switch current high-GWP refrigerant to low-GWP refrigerants sooner. Under this urgent circumstance, Annex 54 aims at promoting low-GWP refrigerant application to accelerate phase down of high-GWP HFCs. Annex 54 participants are Italy, Japan, South Korea, Sweden, and the US. Annex 54 started in January 2019 by holding the kick-off meeting in Atlanta, Georgia, USA, in conjunction with the 2019 ASHRAE winter conference. With 20 persons attending, three presentations were provided to share the overview of this annex and new research activities by chemical companies as follows:

1. The operating agent, Dr. Yunho Hwang, provided a short introductory presentation for Annex 54. He referred to the projected global emissions from refrigeration and air conditioning systems in 2030, as shown in Figure 1, to emphasize the urgent need for the phase down of high GWP refrigerants. He then shared the goals and tasks of the Annex 54. Annex 54 will focus on developing design guidelines of optimized heat pump components and systems for low-GWP refrigerants through the review of available low-GWP refrigerants, their properties and applicable standards, safety and flammability of refrigerants, and safe use of flammable refrigerants; optimization of heat pump components and systems for low-GWP refrigerants; analysis of the Life Cycle Climate Performance (LCCP) impact by the current design and optimized design with low-GWP refrigerants; market opportunity study for heat pumps with low-GWP refrigerants; and low-GWP refrigerants availability for 2030.

2. Mr. Joshua Hughes from Chemours presented "Low GWP Refrigerant Solutions for Heat Pumps". He shared Chemours lower GWP HFO solutions, including heat pump application as shown in Table 1.

3. Dr. Gustavo Pottker from Honeywell presented "Reduced GWP Refrigerants for Heat Pump Systems". He introduced R-466A (N41) as the first nonflammable, reduced-GWP replacement for R-410A in air-conditioning applications. He added that the energy efficiency and capacity of R-466A is equal to or better than R-410A.

After presentation, attendees discussed the presented topics and volunteered for participation in each task. Annex 54 will meet again during the 25th International Congress of Refrigeration in Montreal, Canada in August 2019.

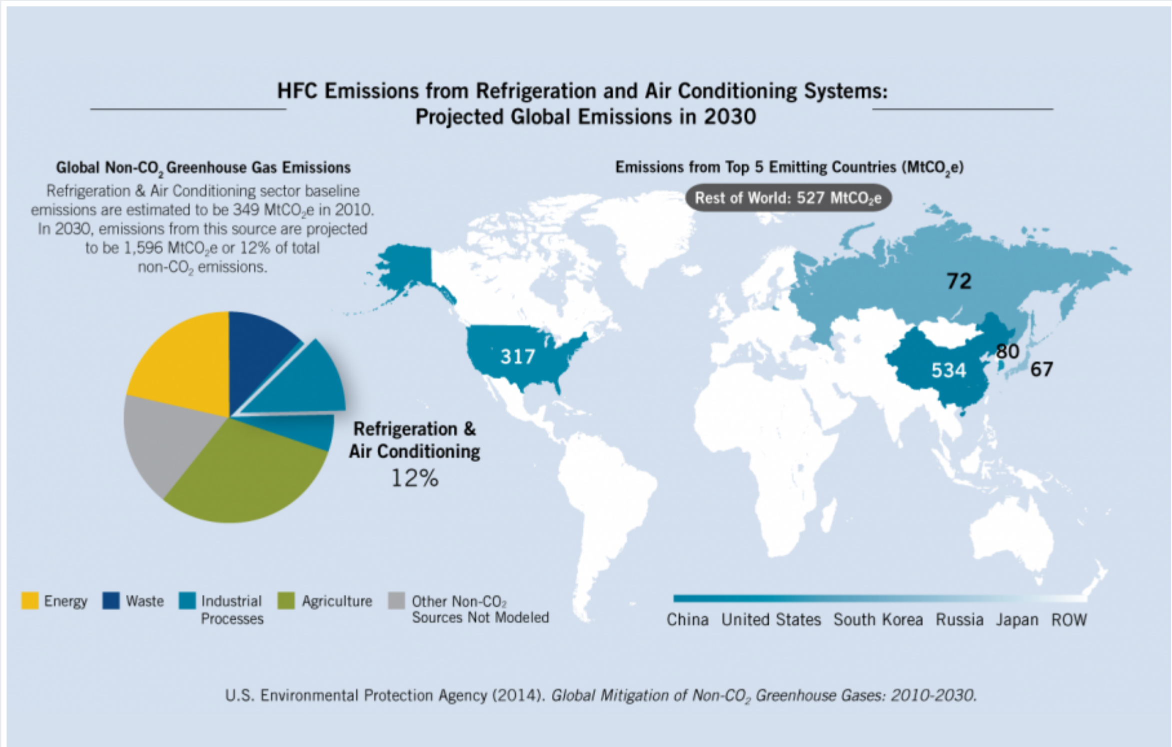

Fig. 1: Projected Global Emissions from Refrigeration and Air conditioning Systems in 2030 (source: US EPA, 2014 from https://www.epa.gov/sites/production/files/styles/large/public/2016-03/refrig_ac_pie_map.png)

Air Conditioning	R-410A	XL55 (R-452B)	XL41 (R-454B)	XL40 (R-454A)	R-22	XL20 (R-454C
GWP AR4 (AR5)	2088 (1924)	698 (676)	466 (467)	239 (238)	1810 (1760)	148 (146)
Capacity vs. R-410A	-	-1%	-2%	-25%	-30%	-37%
COP vs. R-410A	-	+3%	+3%	+2%	+9%	+3%
Evap Glide (K)	0.1	1	1	4	0	5
T Discharge (°C)	102	111	111	95	107	88
P Discharge (kPa)	3435	3243	3207	2615	2175	2261

Table 1: Table 1: Low GWP Refrigerant Solutions for Heat Pumps.

Annex website
https://heatpumpingtechnologies.org/annex54/

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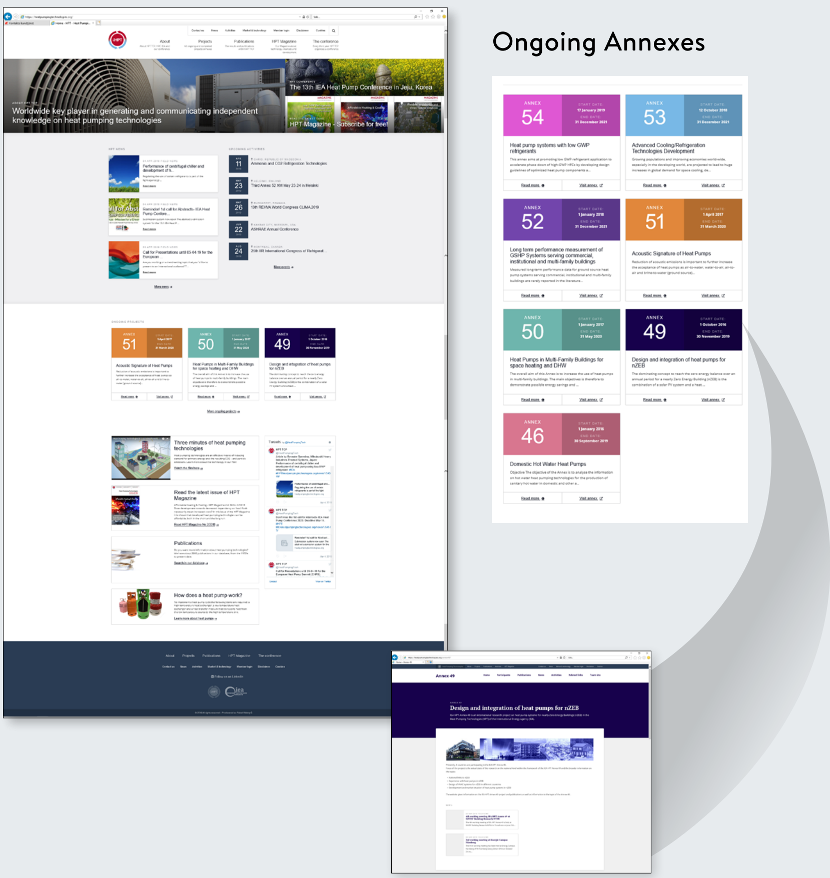
INFORMATION



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Market Report: Sweden

Per Jonasson, Swedish Refrigeration & Heat Pump Association, Sweden

Ever since 2008 the Swedish market for the heat pumping technology has steadily increased and is estimated to account for an annual sale of approximately 16 000 MSEK or 1500 MEUR in 2018 (1 EUR equals 10,5 SEK). The business can be divided into three segments: Air Conditioning 4 000 MSEK, Industrial/Commercial 4 700 MSEK, Heat Pumps 7 300 MSEK. Going from "busy", some ten years ago passing "hands full", the Swedish market situation since a couple of years can be defined as overheated. Contractors, mainly within refrigeration and air conditioning are overloaded with work, and there are no signs of any slowing down. On the contrary, the forecast for coming years indicates continued increase in sales within all segments. The largest challenge for all companies is the difficulty in finding and recruiting competent personnel. This goes for all types of professions, from management via white collar to service technicians.

Introduction

The Swedish RACHP market has been growing steadily for several years (Figures 1-4). Market drivers differ between on the one hand refrigeration and air conditioning (RAC), and on the other hand heat pumps (HP). The growth in the Swedish RAC business is influenced by two main factors: the F-gas Regulation and people's desire and financial capability for improved comfort and "luxury". For the HP industry, the influencers are cost and energy savings, and the construction of new houses and buildings.

The RAC business

In the past considered an unnecessary luxury, air conditioning in Sweden nowadays is more seen as a necessity. Last summer, with the highest temperatures ever reported for 260 years, clearly showed the consequences of bad air handling. Numerous incidents were reported, such as:

- destroyed and wasted food for millions of SEK, only for one single supermarket, due to insufficient and badly maintained cooling and freezing equipment. Something that happened all over Sweden, from south to north;
- hospitals (several) that had to cancel or postpone surgery due to condensation of water on surgery equipment;
- district cooling plants not able to meet capacity demands, ending up in sectional shut down of clients.

There are numerous examples. Therefore, the interest in AC and planning for installations or upgrades are steadily growing. This definitely will have a positive impact on future sales.

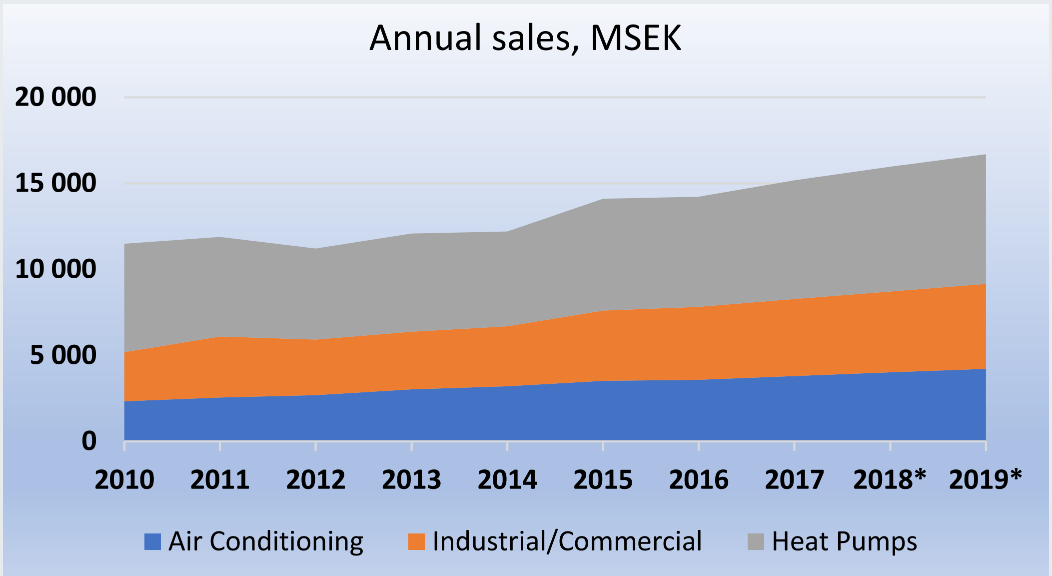

Fig. 1: Annual sales 2010-2019 (estimates for 2018 and 2019) for the three segments Air Conditioning, Industrial/Commercial and Heat Pumps. Source: Industrifakta AB and Swedish Refrigeration & Heat Pump Association (SKVP)*

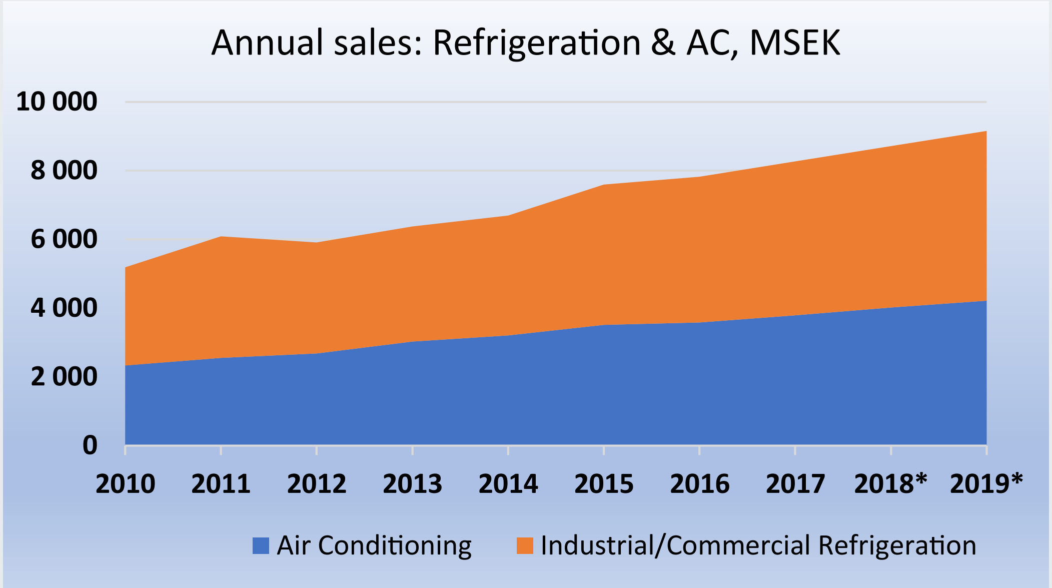

Fig. 2: Annual sales 2010-2019 (estimates for 2018 and 2019) for Air Conditioning and Industrial/Commercial Refrigeration. Source: Industrifakta AB

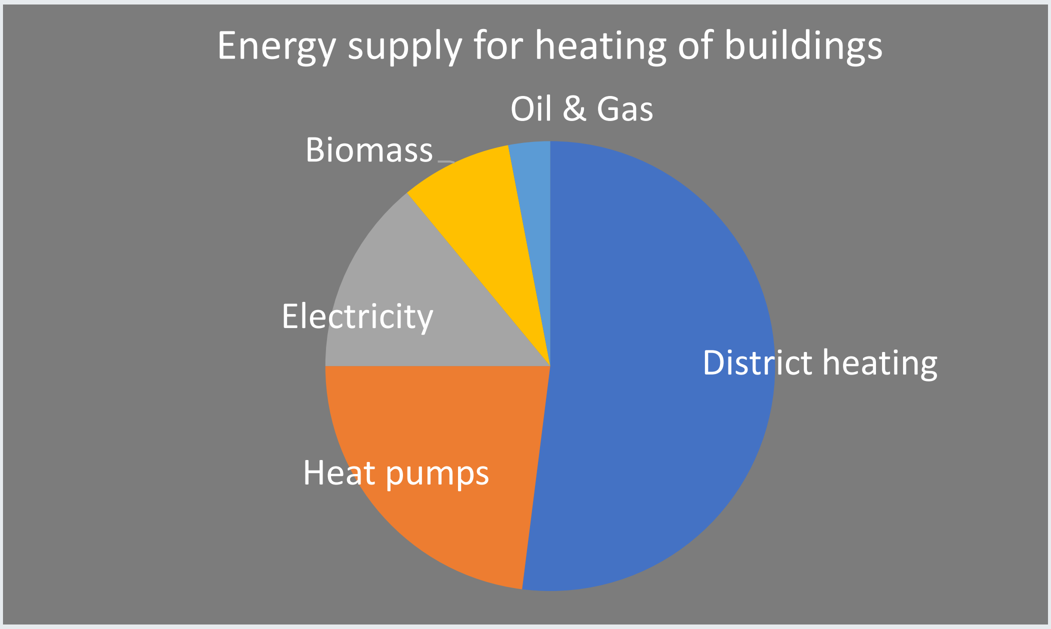

Fig. 3: Energy supply for heating of buildings in Sweden 2012. Source: Profu, Värmemarknad Sverige

The impact of comfort need, or "luxury behavior" is also seen within the commercial segment. A trend, not specific for Sweden, is that people have less time to spend on their household. Instead, individual "quality time" is highly valued. At the same time wealth is increasing, enabling a larger group of people the opportunity to a more "luxurious" lifestyle. As a consequence, air-conditioned or chilled areas and display cabinets for ready meals and pre-prepared foods are growing, resulting in the demand for more cooling and freezing equipment and larger cooling capacities. Also, the business for home deliveries is increasing, as are these companies' cold store facilities and distribution services.

The industrial refrigeration sector shows a more stable market. Growth is mostly seen in areas such as data centers, ice rinks and distribution centers, but in a more moderate pace.

Finally, the F-gas Regulation has, since it went into force in 2015, had a great impact on the whole sector, and will have for many years to come. Numerous are the plants and systems that need to be replaced, rebuilt or converted to new low-GWP systems and refrigerants.

As a result, the RAC business in Sweden has grown steadily by approximately 70% between 2010 and 2018.

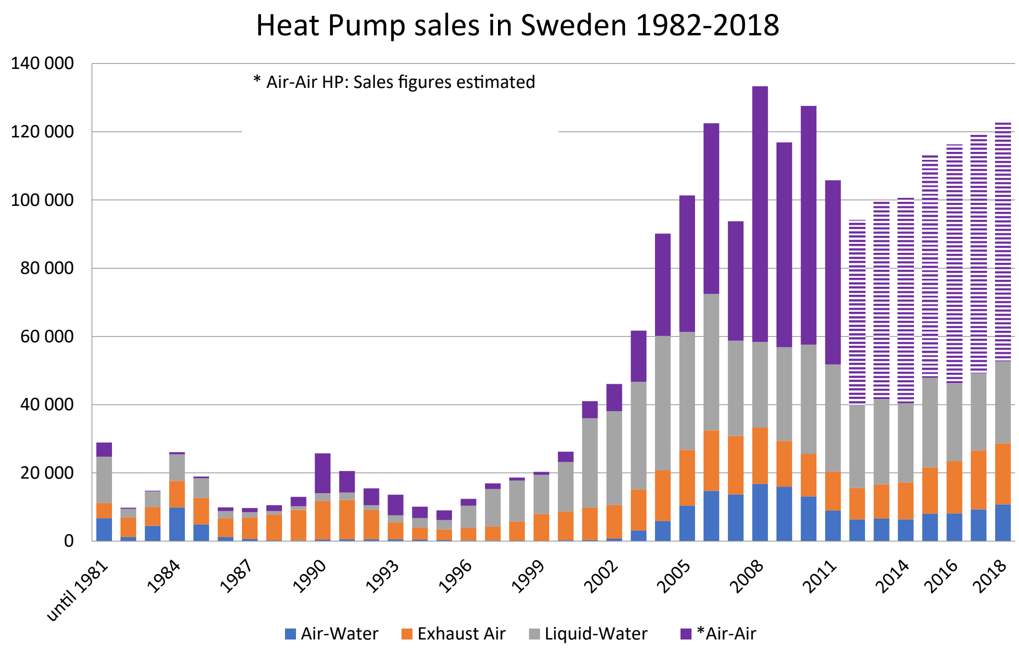

Fig. 4: Heat Pump sales in Sweden 1982-2018. Source: SKVP

The forecast for the next few years is that this trend with an annual growth of 5-7% will continue.

The HP business

The main reason for installing a heat pump (HP) is to save money. As a consequence, factors that influence this market differ completely from those for the RAC market. While the RAC technology is a "necessary evil" in order to operate your business, HPs have to compete on commercial conditions with gas or biomass boilers and district heating. Some examples of key arguments are "cost efficiency", "simplicity" and "reliability". Nowadays, also words like "sustainability" and "environmental friendliness" are of interest for potential customers; all "buzzwords" in favor of HPs.

A difference between the countries Sweden, Denmark and Finland compared to many other countries is the very large market share of district heating (DH) for heating of buildings. This, together with the unique position of HPs, makes the Swedish heating market rather special, with DH as the definite market leader with 53% of the market, followed by heat pumps with 22%.

Sweden is by far the country with highest numbers of HP installed per capita in the world (air-air HP excluded). With approximately 1,5 million heat pumps in operation (all types included), every second single-family house has some kind of heat pump installed, and for new constructions exhaust air heat pumps are considered as default. The contribution from HPs for heating of buildings is estimated to around 30 TWh annually.

After a significant reduction in 2011 and 2012 sales have increased every year and has now reached approximately 120 000 units per year, as shown in Figure 4. While ground source HP have been stable in sales, particularly exhaust air HP have had a very positive development during the last five years. The reason for that is the increased number of new construction of single-family houses. Almost all developers have this type of heating solution as their first choice.

Price level

Every year SKVP conducts a survey among its contracting members, Pulsen (the Pulse). The full report is available in English at https://skvp.se/aktuellt-o-opinion/statistik/pulsen/2018-eng

Figure 5 shows the reported total cost, VAT included, for a complete installation of various types of heat pump systems. Notable is the very small price increase shown for the period 2010 to 2018.

From an international point of view, the installation cost for, especially, ground source heat pumps has to be considered as very low. The main reason for these low prices is the industrialized way of performing the contracts. Installers together with borehole drillers form contracting teams executing only this kind of project – day after day.

Another question in the Pulsen survey for what reason the heat pump system was installed. Of special interest are the trends for "oil burners" and "old heat pumps".

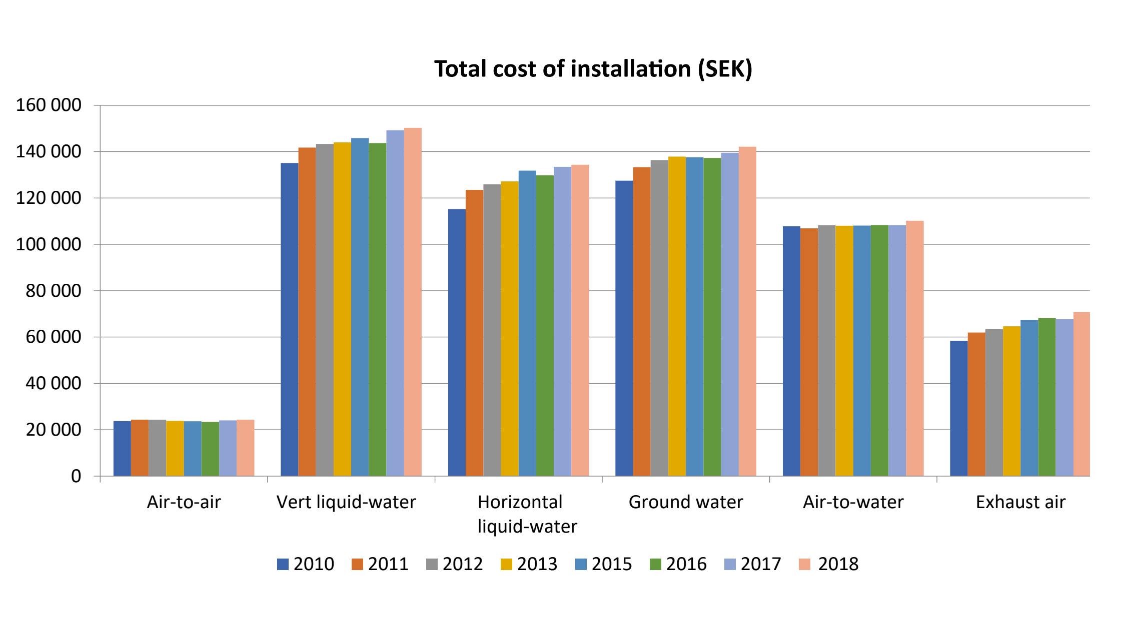

Fig. 5: Total cost for installation of various types of Heat Pump systems. Price based on turnkey contract for a single-family house with a heat demand of 20 000 kWh/year. Source: SKVP

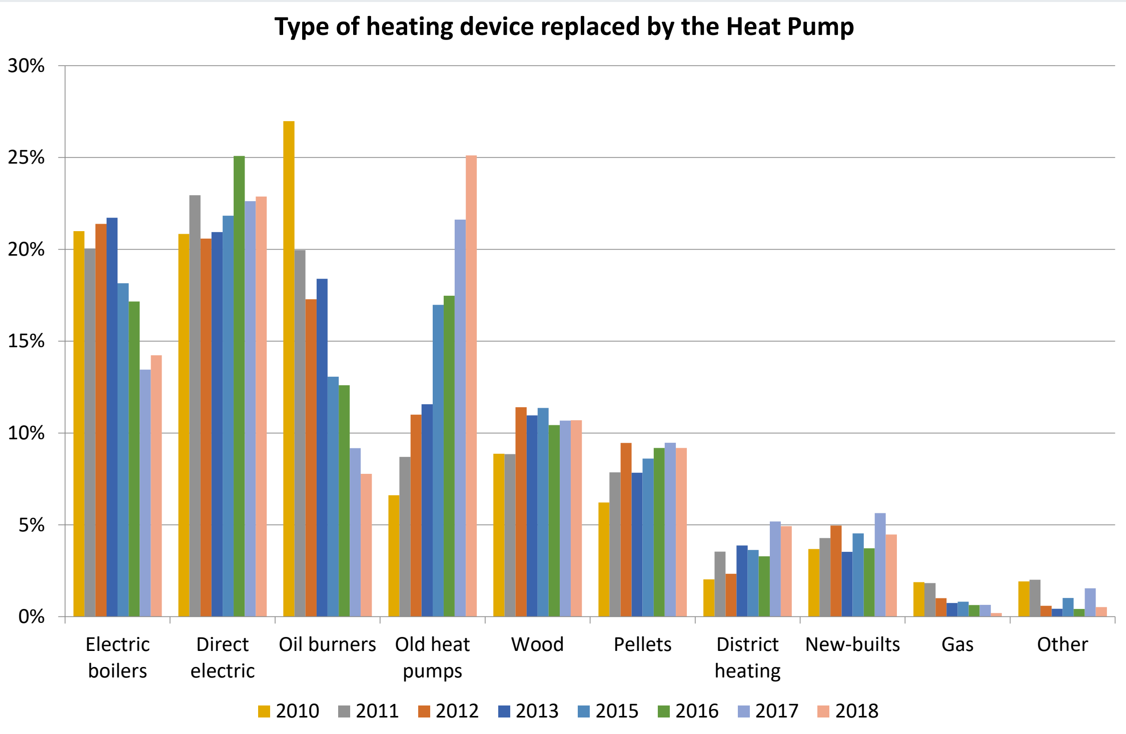

Fig. 6: Type of heating device replaced by the Heat Pump. Source: SKVP

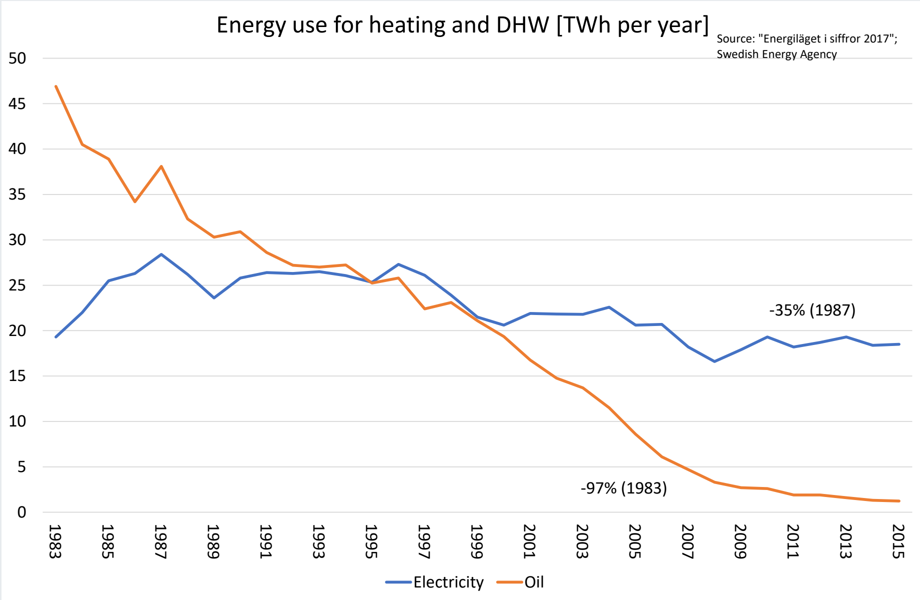

Fig. 7: Energy use for heating and DHW. Source: "Energiläget i siffror 2017", Swedish Energy Agency.

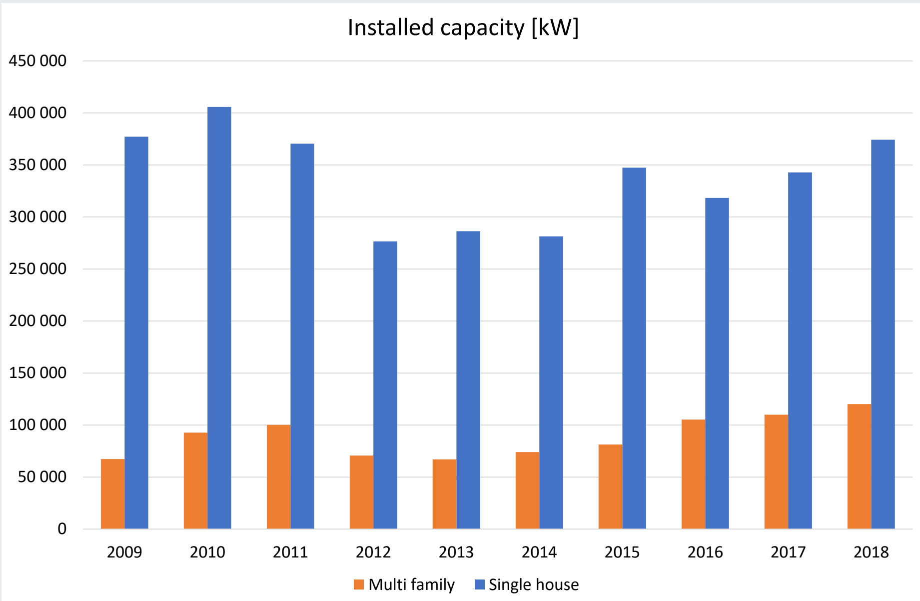

Fig. 8: Annual installed capacity in kW for multi- and single-family houses. Source: SKVP

As Figure 6 shows, the number of oil burners that are replaced decreases rapidly; a consequence following the fact that oil for heating more or less has disappeared in Sweden, clearly shown in Figure 7. Figure 6 also points out the loyalty we see by those who have an HP that needs to be changed (the "old heat pump" data in the figure). A large share of contracts executed by our installers consists of replacing an old HP with a new one. In other words - if you have an HP that is getting old, you do not change technical solution for heating your house – you stick to the HP.

It is also interesting to notice that despite the great number of installed HPs, use of electricity for heating and DHW has decreased by 35% from the peak year 1987.

Expectations for the future

Heat pumps is a mature product in Sweden. Every Swede has a heat pump or knows someone who has one. Despite this, expectations for the future are very positive. New constructed single-family houses are almost always built with heat pump as the heating source, Figure 8. And for multi-family houses, the transition from district heating towards heat pump systems continues. This is still in limited numbers of units, but the positive trend is clear.

Another very interesting market is the replacement business. All HPs sold in the early 2000s will soon have to be replaced. We can already see that the figures for replacements increase, but have not yet seen the boom.

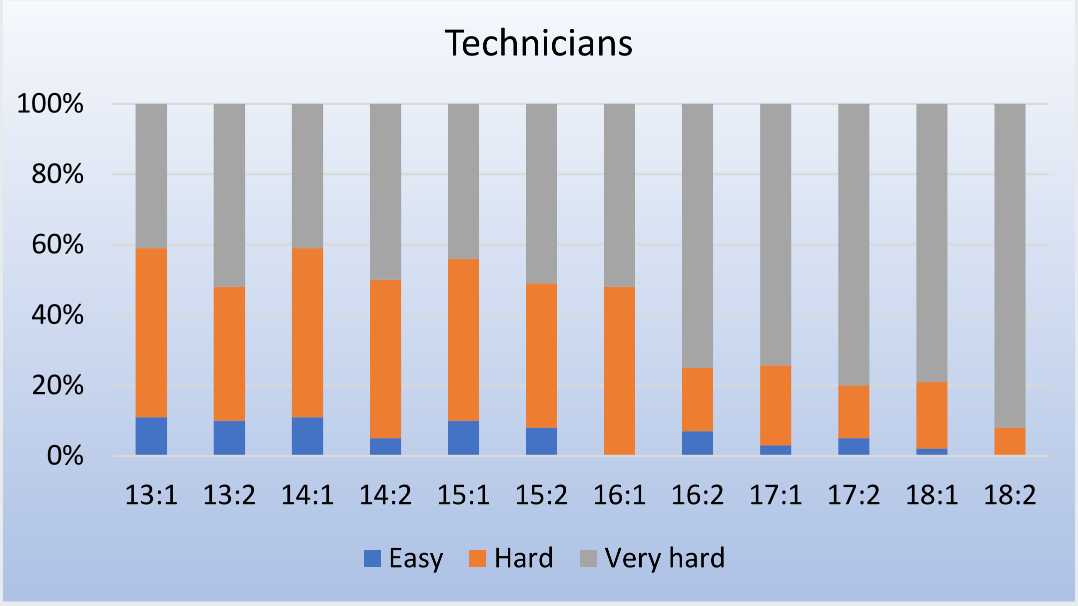

Fig. 9: Difficulties in finding technicians to recruit from year 2013, first half year (13:1), to second half of 2018 (18:2). Source: Industrifakta AB

Challenges

The main challenge for the whole RACHP business in Sweden is lack of resources.

Twice a year a research company (Industrifakta AB) makes a survey among the members of the Swedish branch organisation SKVP. Among questions on business climate, trends and sales volumes, they also ask how easy or difficult it is to recruit employees within the three categories “management”, “white collar” and “technicians”.

Since many years the answers have indicated difficulties in finding employees, Figure 9. But bad has turned worse, and in last survey 92% replied “very hard”, 8% “hard” and 0% “easy” in finding technicians to recruit. The corresponding figures for management were 87/13/0% (very hard/hard/easy) and white collar 85/15/0%.

The problems in finding and recruiting skilled employees have now reached such a magnitude that it hurts the development of the industry. Several companies avoid to quote for projects as there is no one to put on the job, and the transformation from high-GWP refrigerants to low within the F-gas regulation is ongoing at too low a pace.

Conclusions

The RACHP businesses in Sweden is performing extremely well – to some extent too well. Sales figures are steadily increasing, clearly above inflation. Estimated annual sales in 2018 are expected to be approximately 16 000 MSEK or 1500 MEUR, divided into the three segments Air Conditioning (4 000 MSEK), Industrial and Commercial (4 700 MSEK), Heat Pumps 7 250 MSEK. The forecast for the coming years is also very positive, with no signs of slowing down.

There are mainly two market drivers for the RAC business: the F-gas Regulation and people’s wish and financial capability for improved comfort and “luxury”.

The HP industry, on the other hand, is influenced by cost and energy saving, and the construction of new houses and buildings.

Expectations for the years to come are that sales will increase. The only threat is the problem of finding skilled personnel. This goes for all types of professions, all from management via white collar to service technicians.

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Low Charge Evaporators for Industrial Heat Pumps

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Energy usage and its impact on the environment has become an important topic in today's world. One way to handle this issue, on a larger scale, is to use heat pumps for district heating. With the Kigali amendment to the Montreal protocol there are not many options at hand regarding suitable refrigerants. They will be either low GWP nonflammable olefin-based gases or natural refrigerants such as ammonia. The former is expected to be expensive and the latter is toxic. To cope with this challenge, engineers must devise systems that are highly efficient and at the same time carry low refrigerant charge.

Introduction

The heat exchanger business has seen dramatic changes in the last 100 years - shell and tube to micro-fin coils. There have been two distinct businesses that have been prolific users of heat exchangers. Firstly, the oil and gas (OG) industry, and secondly, the refrigeration and air-conditioning (RAC) industry. The OG industry's thrust has mostly been in the area of shell and tube heat exchangers, with very little improvement, whereas the RAC industry has been at the forefront of introducing new technologies, be it shell and tube or plates or coils. There is an obvious reason for this. The OG industry is extremely conservative and tries to shy away from any new technology. On the other hand, the RAC is an extremely competitive industry and tries to strive for better products at lower cost, which can hold lower refrigerant charge, especially after the regulations, such as the Montreal and Kyoto protocols. Low charge issues in particular have become a key factor. Since heat pump business has been gaining importance in the last decade or so, with a driving pitch for higher coefficient of performance (COP), low refrigerant charge, lower global warming impact both direct and indirect, there have been several new developments in the field of heat exchangers, especially the evaporators. This paper will shed some light on this important topic.

Industrial Heat Pump

The basic concept of the use of industrial heat pumps is very simple: use surplus heat from a refrigeration system to heat a community (district), to avoid direct combustion of fuel. The energy used in running the compressor need to be lower than the direct fuel burnt, which also in turn reduces the carbon footprint or carbon impact factor. In order to achieve this, a refrigeration system need to be highly efficient with high COPs. One key player in this puzzle is the evaporator. It is a known fact that for every 1 °C rise in saturation temperature there is close to 2% improvement in the COP of a system. The same applies to the condenser side, but here we will only discuss the evaporator.

Types of evaporators

There are two types of heat exchangers available in the market for use in industrial heat pump applications:

- Shell and Tube
- Plate which are further divided in three sub categories
    - » Plate and Frame
    - » Shell and Plate
    - » Brazed

Each of the above types has its advantages and disadvantages. As mentioned above we will only discuss the latest types that have the features of holding low refrigerant charge and at the same time are high performers, operating with close approach temperatures. Low charge has two main advantages. Firstly, the refrigerant cost, especially for the current high prices of newer low Global Warming Potential (GWP) refrigerants. Secondly, toxicity, for natural refrigerants such as ammonia, which has excellent features such as zero GWP and Ozone Depletion Potential (ODP) but usually is subject to special local regulations and ventilation criteria.

Shell and tube type

Currently there are three types of low-charge shell and tube evaporators that are most suitable for large industrial scale heat pump applications. They are:

Direct expansion: A typical direct expansion (DX) evaporator as shown in Figure 1 has refrigerant in the tubes and the fluid being cooled in the shell. The main advantage of this configuration is the ability to work with low charge

Fig. 1: Shell and tube DX evaporator

per kW capacity. The disadvantage is that the fluid being cooled is on the shell side and mechanical cleaning is not possible. The second disadvantage is that because of control related issues they are not available for larger capacities, so for those applications banks of multiple units are required. Oil management could also be an issue, especially in case of immiscible oil/refrigerant combination. Several boiling correlations are available in the open literature such as Shah (1982).

Spray: A spray evaporator also has low charge characteristics and the key mechanical advantage is that the fluid being cooled is in the tubes, so cleaning is possible. The disadvantage is that for better heat transfer a pump is required to spray the refrigerant onto the bundle surface. Improper wetting can result in lack of heat transfer and optimal capacity will not be attained. A typical spray evaporator is shown in Figure 2. Zeng et al. (1995) proposed the following correlations with a non-dimensional heat flux, φ, for a dimensional heat flux, q''. To account for the effect of saturation temperature, a reduced pressure ratio was also added to the correlations as follows (for an explanation of symbols, se list at the end of the article):

$$Nu = 0.0568\ Re^{-0.0058}\ Pr^{0.193}\ p_r^{0.323}\ \varphi^{1.034}$$

$$Nu = h/k\ (\upsilon^2/g)^{1/3}$$

$$Re = 2\Gamma_f/\mu$$

$$\varphi = q''D/(T_{cr} - T_s)k$$

Fig. 2: Shell and tube spray evaporator

Shell side DX: this is the latest innovation and has the combined qualities of both of the above. The refrigerant is direct expanded on the shell side and therefore there is no requirement for a pump, and because the fluid being cooled is in the tubes, cleaning of tubes is possible. Figure 3 shows a typical evaporator of this type. It holds low refrigerant charge, oil management is simple and because no liquid maintenance is required, the control system is simple too. Ayub et al. (2017) presented the following correlation for ammonia which has been found equally applicable to other refrigerants:

Fig. 3: Shell and tube "Shell Side" DX evaporator

$$\mathbf{h_{tp} = 70\ q''^{\,0.9-0.4p_r^{0.1}}\ p_r^{0.55}(-\log p_r)^{-0.6}\ e^{-0.075T_{sup}}}$$

In order to further reduce the size of shell and tube evaporators, various enhancement techniques could be applied, such as high nucleate boiling surfaces that are currently available on the market.

Plate type

There are basically three types of plate exchangers that are candidates for heat pump applications. They are:

Semi-welded plate and frame: two adjacent chevron plates are welded to make up a cassette or module. This keeps the refrigerant confined within the welded cavity and eliminating a flow gasket. Figure 4 shows a typical semi-welded plate and frame exchanger. However, it is not a gasket-free unit. There is a slight misconception in the industry regarding welded plates. Many users believe that the plate pairs are 100% welded together. Unfortunately, that is not the case. In order to maintain the refrigerant flow, only O-ring gaskets maintain the seal, i.e., for every single cassette, there are still two O-Ring gaskets. These gaskets are around the ports where the velocity is maximum and hence highly prone to a leak—most of the leaks reported by the operators have been around the ports. Some advantages are compactness and expandability; a negative feature is higher maintenance cost due to potential leakage issues. Recently Ayub et al. (2019) presented a universal correlation for evaporator applications as follows:

$$Re_{eq} = \frac{G_{eq}D_h}{\mu_l}$$

$$Bo_{eq} = \frac{q''}{G_{eq}h_{fg}}$$

$$G_{eq} = G\left[(1 - x_m) + x_m\left(\frac{\rho_l}{\rho_g}\right)^{0.5}\right]$$

$$Nu = \left(7 + 4.5\,\beta/\beta_{max}\right)Re_{eq}^{\left(-0.3\frac{\sigma_{Ref}}{\sigma_{ammonia}}+3\right)}\ Bo_{eq}^{-0.2}$$

Shell and Plate: Shell and plate combines the advantages of shell and tube and plate and frame technologies, with high mechanical integrity inherent to shell and tube and the superior thermal characteristics of the plate and frame. A plate pack is welded together in such a way that the shell side is isolated from the plate side, and there is no gasket for sealing purposes except an O-ring for a body flange in the case of a removable plate pack. Figure 5 shows a shell and plate exchanger. One key disadvantage is its vulnerability to weld leakage in case of a weak weld as shown in Figure 6 which shows a normal weld and a weak weld that leaked after a few cycles of operation. The design criteria are the same as plate and frame.

Brazed Plate: Figure 7 shows a typical compact brazed exchanger. Because of size limitations they are not geared for large capacity industrial heat pumps. They are fully brazed and therefore do not require gaskets. Fluid mixing can only occur in case of plate puncture. They cannot be mechanically cleaned and are thus limited to non-fouling applications. Design criteria are the same as plate and frame.

Comparison

A quick comparative analysis was performed for all the above cases as shown in the table below. A typical sea water-based heat pump application was considered for a 1000 kW evaporator capacity with sea water inlet and outlet temperatures of 8 °C and 4 °C, respectively. Ammonia at saturated temperature of 2 °C. Except for the capacity, the terminal temperatures are exactly the same as at the world's largest ammonia heat pump in Drammen, Norway (Ayub, 2016). The material in contact with sea water was titanium.

Type	Charge (kg)	Price ($, 2019)
DX- Tube	65	59,516
Spray	90	82,477
DX- Shell	46	68,732
PHE (with drum)	209	61,460

Conclusion

A brief comparative analysis of various types of heat exchangers used as evaporator in an industrial heat pump application is presented. The two major types of exchangers are shell and tube and plate type. Each type has sub-categories depending on its usage and geometry characteristics. Each type also has pros and cons that need to be considered carefully at the time of selecting the equipment. The key design criterion is the selection of appropriate two-phase boiling coefficient. The paper presents correlations for each type that can be useful for design engineers. In the wake of environmental issues, especially after the Kigali 2016 amendment, the entire refrigeration industry is striving for low charge systems. This paper provides a brief analysis of charge/kW for each heat exchanger type. The latest shell and tube with shell side direct expansion turned out to be the optimal in this category.

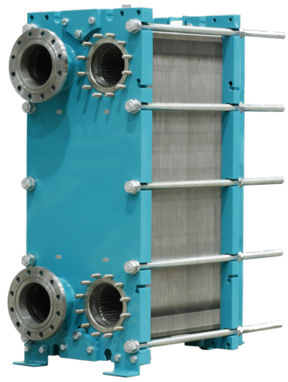

Fig. 4: Semi-welded plate and frame exchanger

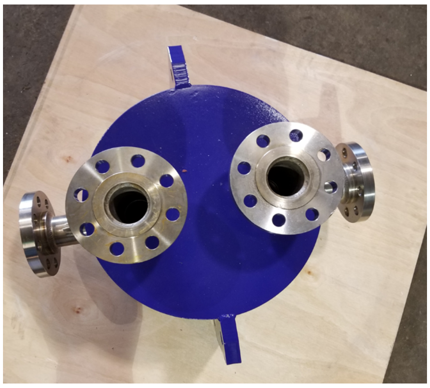

Fig. 5: Shell and plate exchanger

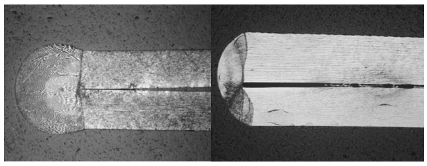

Fig. 6: Normal and failed weld

Fig. 7: Brazed plate exchanger

Nomenclature

Bo	Boiling number
D	Tube outside diameter
G	Mass flux, kg/m^2-s
g	Gravitational acceleration, m/s^2
h	Heat transfer coefficient, W/m^2-K
h_{fg}	Latent heat, kJ/kg
k	Thermal conductivity, W/m-K
Nu	Nusselt number
p_r	Reduced pressure
Pr	Prandtl number
q"	Heat flux, W/m^2
Re	Reynolds number
T	Temperature, K
x	Quality
Γ_f	Liquid flow per unit tube length, kg/m
ρ	Density, kg/m^3
β	Chevron angle, degree
μ	Dynamic viscosity, N-s/m^2
υ	Kinematic viscosity, N/s^2
φ	Non-dimensional heat flux
σ	Surface tension, dynes/cm

Subscript

ammonia	Ammonia as reference refrigerant
cr	Critical
eq	equivalent
g	gas phase
h	hydraulic
l	liquid phase
m	mean
Ref	Working refrigerant
max	maximum chevron angle, degrees
s	Saturation
sup	superheat
tp	two phase

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Experimental Analysis of Falling Film Evaporator Applied in Centrifugal Chillers

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A new type of evaporator, falling film, was tested, allowing low refrigerant charges. Under certain conditions, the heat transfer performance was better than a for traditional flooded evaporator. The effects of different refrigerant charges, tube pass arrangements and refrigerant types on the falling film evaporator were analyzed. The results showed that with the increase of refrigerant charge, the heat transfer performance was improved gradually, but the trend was gradually slower. The bottom-to-top tube pass arrangement provided a better performance than the top-to-bottom tube pass arrangement. The falling film evaporation centrifugal chiller with R1233zd (E) provided a higher COP when the refrigerant charge reached a certain amount.

Introduction

With the increasingly serious environmental problems, refrigerant replacement and reduction continuation technologies have become important concerns of the current air conditioning industry. Compared to traditional flooded evaporators, the horizontal tube falling film evaporator not only has higher heat exchange performance, but also has the advantages of less refrigerant charge, smaller heat transfer temperature difference, and reliable oil return. With the promotion of new refrigerants, in large or medium-sized chillers, the falling film evaporator may gradually replace the flooded evaporator. At present, many studies have been published on the falling film evaporator and new refrigerants, but most of them focus on the parameters of the liquid distributor, the distribution of the liquid film outside the tube, the flow pattern between the tubes, and single tube experiments [1-6]. There are few studies on the research of the whole unit.

This paper analyzes the performance of the falling film evaporation centrifugal chiller through unit testing. It can provide a background for design, production and promotion of falling film evaporator in chillers.

Experimental setup

Structural description of evaporator

As shown in Figure 1, the internal tube bundle arrangements of the flooded evaporator and that of the falling film evaporator are very different. For the flooded evaporator, the position of the top tubes is at about the center of the shell, and the tube bundles are arranged symmetrically from the left to the right. The refrigerant inlet is arranged at the bottom of the shell, and the gas outlet is at the top. In the falling film evaporator, the falling film distributor is at the top of the evaporator, and the tube bundles under the distributor are arranged

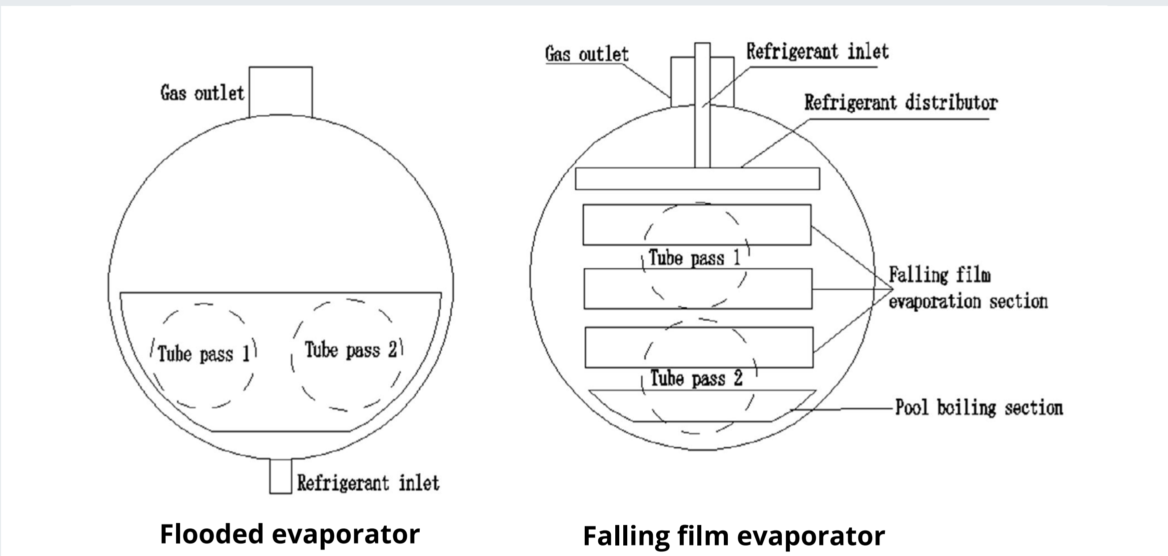

Fig. 1: Schematic diagram of tube bundle layout

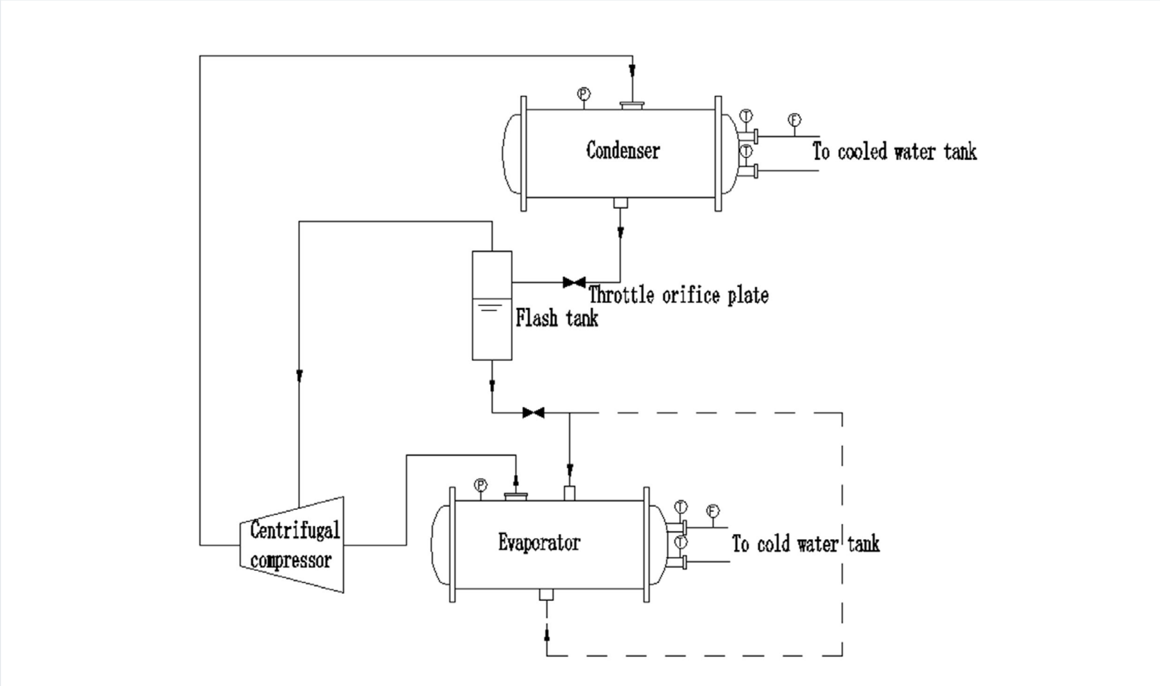

Fig. 1: Schematic diagram of tube bundle layout

symmetrically from top to bottom. The refrigerant inlet and gas outlet are both at the top of the shell.

Experimental apparatus

The sample unit was tested on a 600 RT chiller test bench, as shown in Figure 2. For the falling film evaporator, the refrigerant inlet is at the top, while for the flooded evaporator, the refrigerant inlet is at the bottom (as shown by dashed lines).

Testing conditions

The testing conditions of the evaporator are shown in Table 1.

Enhanced tubes with the same specification and type have been used in all experimental evaporators. The enhanced tubes have a diameter of 19 mm and total heat exchange area of 47.11 m^2. The testing conditions of the unit under nominal conditions based on GB/T 18430.1-2007 are shown as Table 2.

Test sequence	Type of centrifugal Chiller	Refrigerant charge	Tube pass arrangement
1	R134a, flooded evaporator	350kg	left in and right out
2	R134a, falling film evaporator	variable refrigerant charge	Top in and bottom out (top-to-bottom)
3	R134a, falling film evaporator	variable refrigerant charge	Bottom in and top out (bottom-to-top)
4	R1233zd(E), falling film evaporator	variable refrigerant charge	Bottom in and top out (bottom-to-top)

Table 1: Testing conditions of the evaporator

Type of centrifugal Chiller	Evaporator		Condenser	
	Volume flow rate (m^3/h)	Outlet Temperature (°C)	Volume flow rate (m^3/h)	Inlet temperature (°C)
Flooded evaporator (R134a)	211.0	7.0	264.5	30.0
Falling film evaporator (R134a)	211.0	7.0	264.5	30.0
Falling film evaporator (R13233zd(E))	211.0	7.0	264.5	30.0

Table 2: Testing conditions of the unit under GB nominal conditions

Device	Type	Precision
Digital power meter	WT230	±0.1%
Temperature measuring element	Pt100	±0.1 °C
Electromagnetic flow meter	AXF200G	±0.35%
Pressure sensor	AKS33	±0.5%

Table 3: Main testing devices used in the experiments

Cooling capacity (kW)	COP	Evaporation temperature (°C)
1148.0	5.92	5.6

Table 4: Experimental results of flooded refrigeration chiller

Experimental equipment

The main testing devices used in the experiments are shown in Table 3.

Calculation formula

The overall heat transfer coefficient K is calculated as follows:

$$K = \frac{Q}{A \times \Delta T_m}$$

$$A = \pi \times d_o \times L \times N$$

$$\Delta T_m = \frac{T_{in} - T_{out}}{LN\left(\frac{T_{in} - T_o}{T_{out} - T_o}\right)}$$

Where:

Q Heat exchange rate, kW;

A Total heat exchange area, based on the outer surface area of the enhanced tube, m^2;

d_o Outer diameter of the enhanced tube, m;

L Effective length of the enhanced tube, m;

N Number of enhanced tubes;

ΔT_m Logarithmic mean temperature difference, °C;

T_{in} Inlet temperature of chilled water, °C;

T_{out} Outlet temperature of chilled water, °C;

T_o Evaporation temperature, °C.

Results and discussion

Experimental results of flooded evaporation chiller

Experimental results of the flooded evaporation chiller with 350 kg refrigerant charge are shown in Table 4.

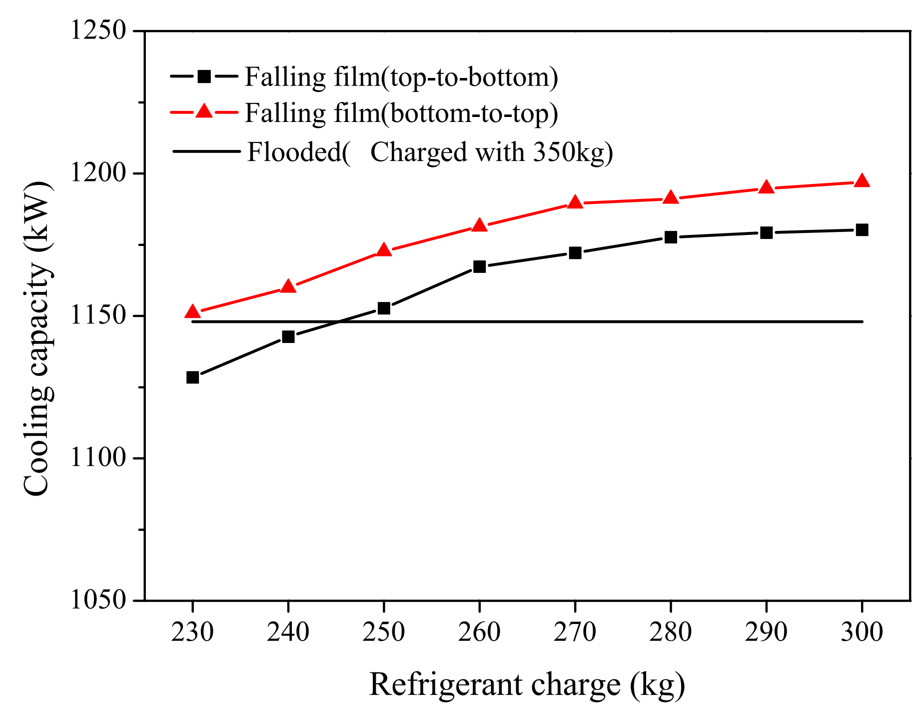

Fig. 3: Comparison of refrigeration capacity as a function of refrigerant charge

Experimental results of falling film evaporation chiller

The flooded and falling film evaporators were tested under the same conditions. The performance of the falling film evaporation chiller, with different tube pass arrangements, including top-to-bottom and bottom-to-top, and of the flooded evaporator, are shown in Figures 3-6.

As shown in Figures 7-10, the cooling capacity, evaporation temperature, COP and overall heat transfer coefficient all increase with the increasing refrigerant charge. However, the cooling capacity and overall heat transfer coefficient of the chiller with R1233zd(E) under the same refrigerant charge are lower than those of the chiller with R134a over the full span of refrigerant charges studied, but they increase rapidly with the increasing refrigerant charge, and the differences between the two refrigerants gradually decrease. The evaporation temperature and COP of the chiller with R1233zd(E) are lower than those of the chiller with R134a when the refrigerant charge is small, but they exceed those of the chiller with R134a when the refrigerant charge reaches a certain value.

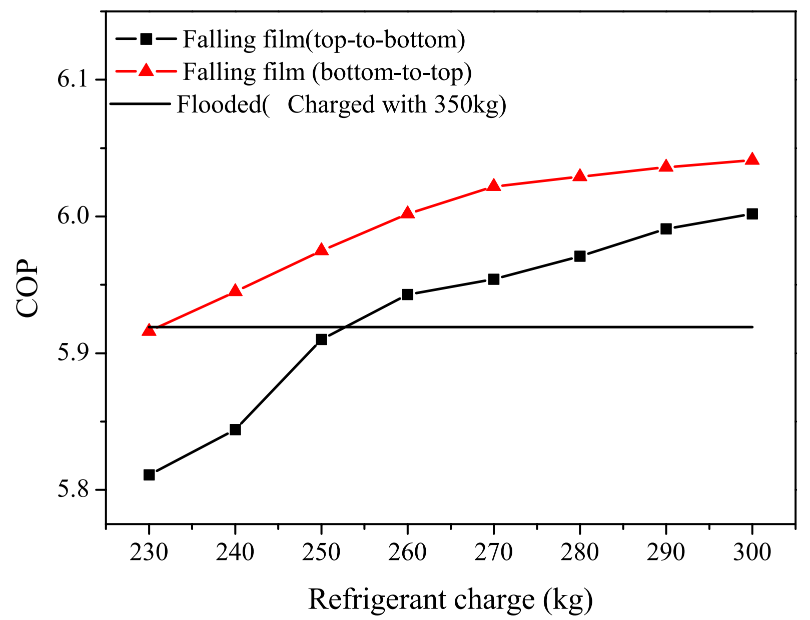

Fig. 4: Comparison of COP as a function of refrigerant charge

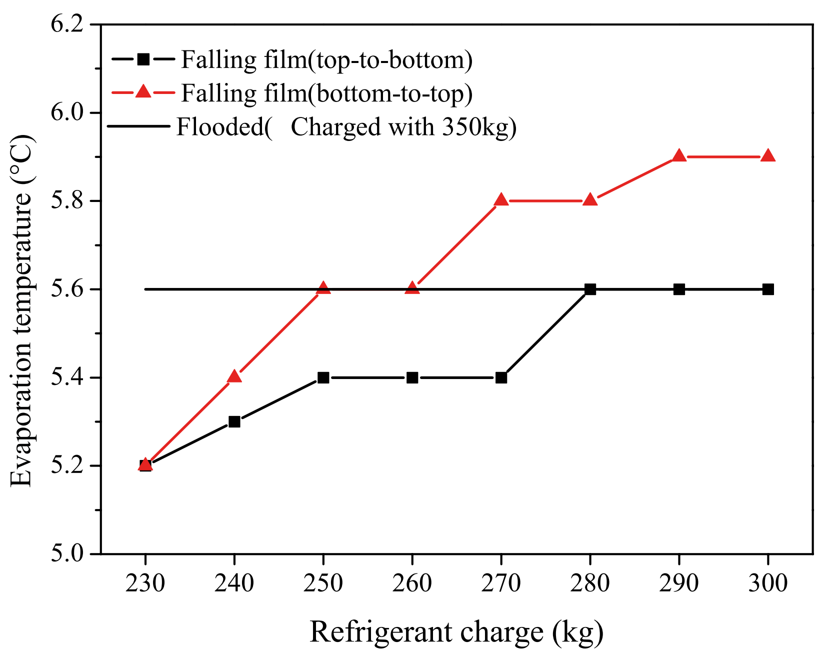

Fig. 5: Comparison of evaporation temperature as a function of refrigerant charge

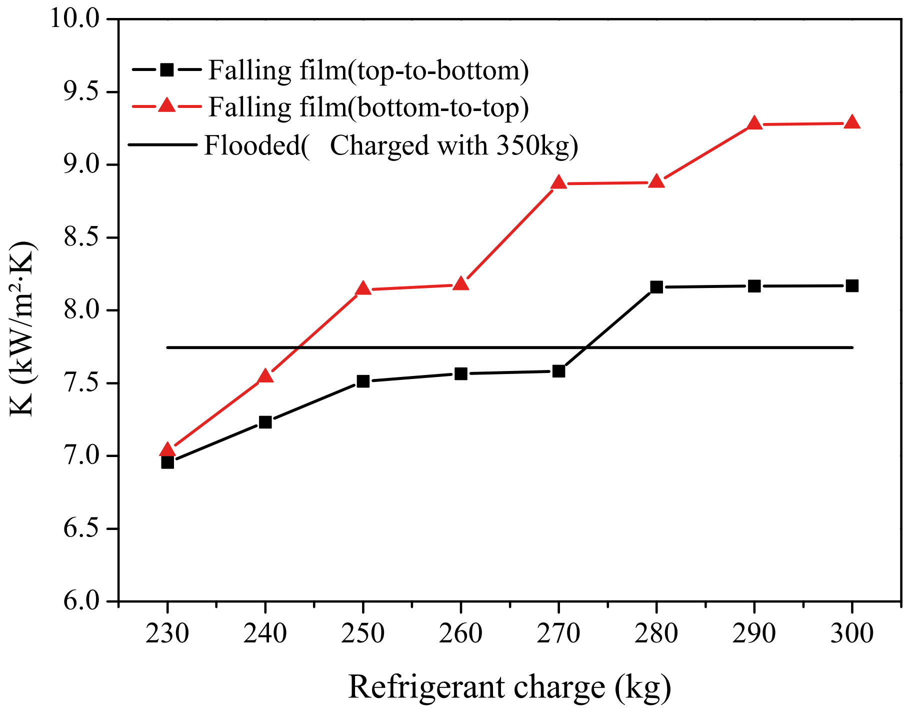

Fig. 6: Comparison of overall heat transfer coefficient as a function of refrigerant charge

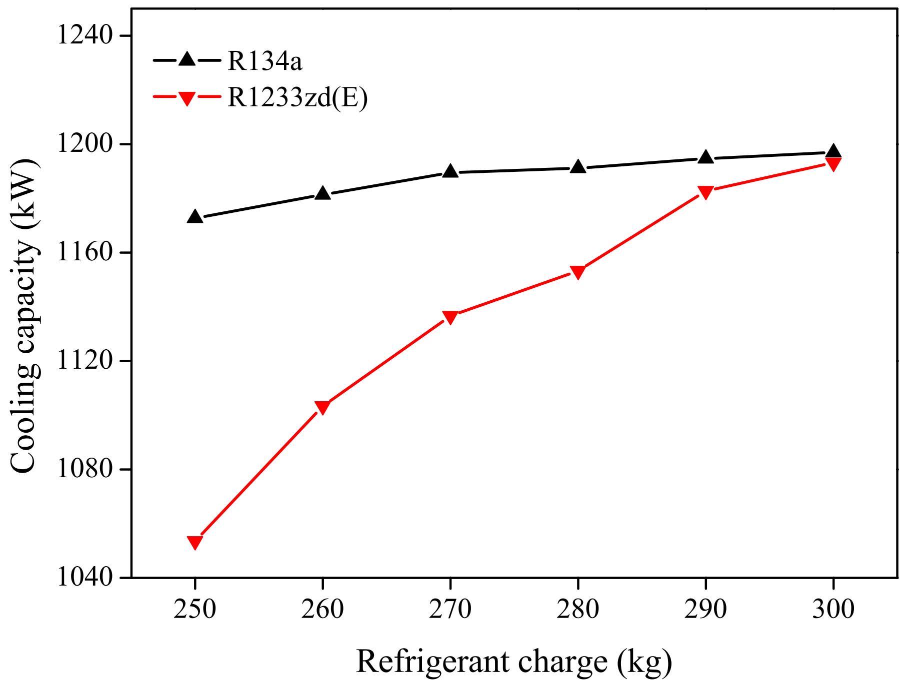

Fig. 7: Comparison of refrigeration capacity for different refrigerants

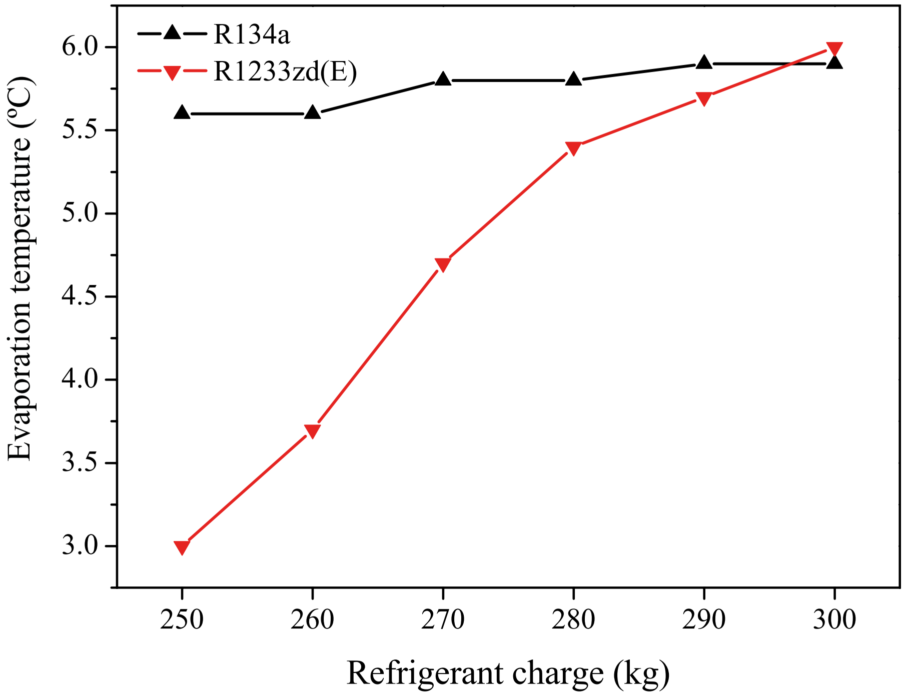

Fig. 8: Comparison of evaporation temperature for different refrigerants

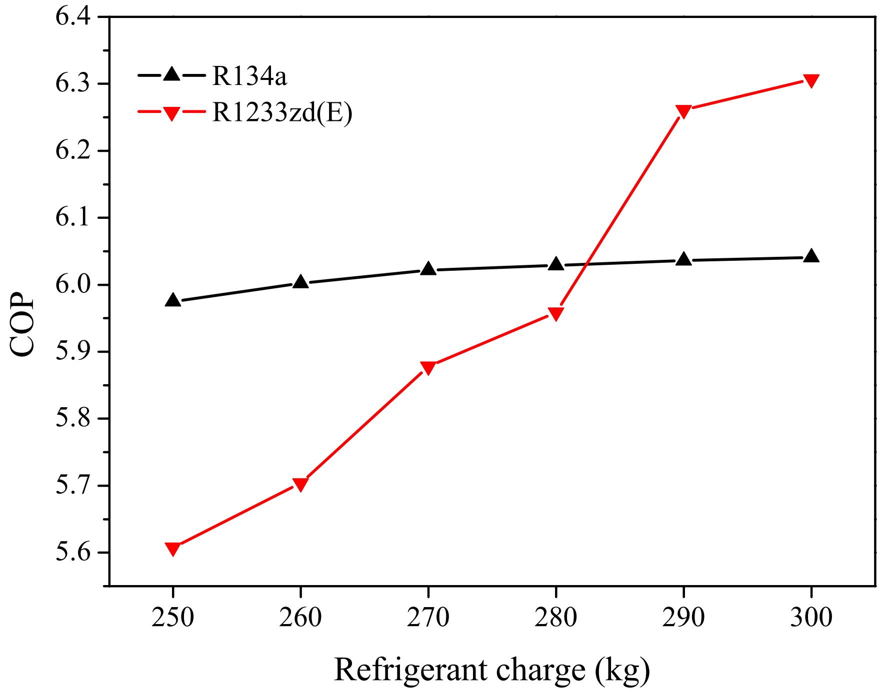

Fig. 9: Comparison of COP for different refrigerants

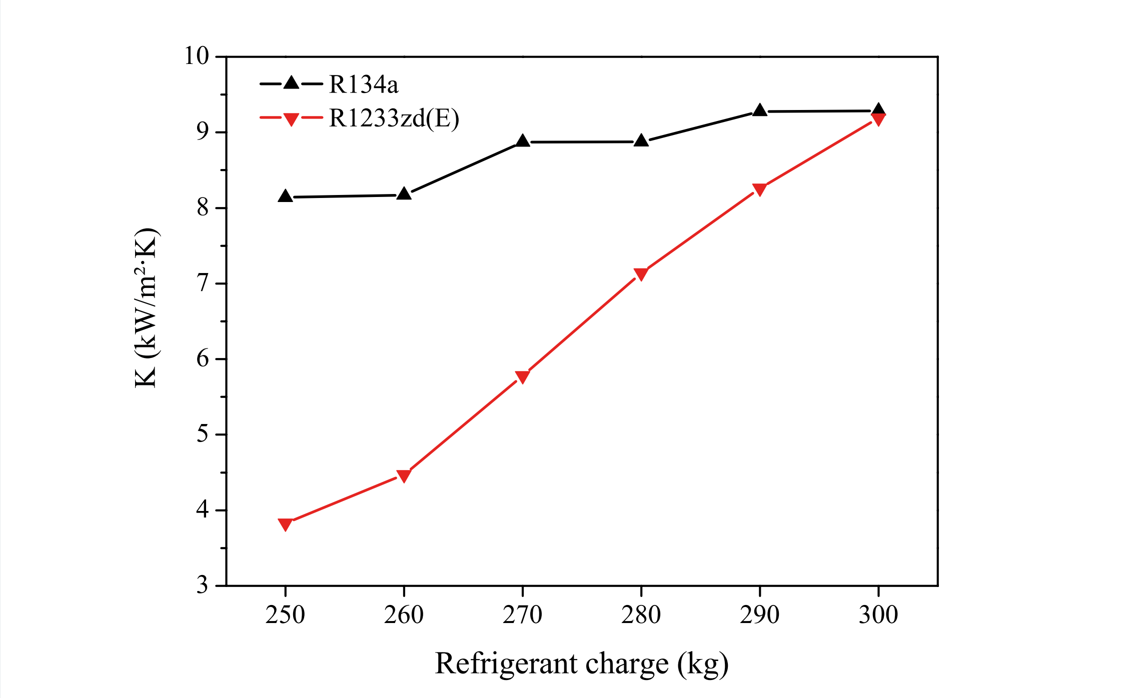

Fig.10: Comparison of overall heat transfer coefficient under different refrigerants

Conclusions

By experimental analysis on the falling film evaporation chillers, the following conclusions can be drawn:

1) As the refrigerant charge increases, the cooling capacity, COP and evaporation temperature of the falling film evaporation chiller gradually increase, but the growth trend decreases;

2) For the falling film evaporation chiller, the bottom-to-top tube pass arrangement gives better performance than the top-to-bottom tube pass arrangement;

3) Providing the same refrigeration capacity, the falling film evaporation chiller needs less refrigerant charge than the flooded evaporation chiller. When the tube pass arrangement of bottom-to-top is adopted, the refrigerant charge can be reduced by 34%;

4) The falling film evaporation chiller with R1233zd (E) has a lower cooling capacity than the chiller with R134a for the same refrigerant charge. And the evaporation temperature and COP of the chiller with R1233zd(E) exceeds the chiller with R134a when the refrigerant charge reaches a certain value.

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11-13 April
Ammonia and CO_2 Refrigeration Technologies
Ohrid, Republic of Macedonia
https://www.mf.edu.mk/web_ohrid2019/ohrid-2019.html

8-9 May
ATMOsphere Australia
Melbourne, Australia
http://www.atmo.org/events.details.php?eventid=77

15-16 May
Heat Pump Forum
Brussels, Belgium
http://www.hp-forum.eu/

26-29 May
13th REHVA World Congress CLIMA 2019
Bucharest, Romania
https://www.ashrae.org/conferences/ashrae-endorsed-conferences/13th-rehva-world-congress-clima-2019

11-12 June
EUREKA 2019
Bruges, Belgium
https://www.eureka-hvacr.eu/

18-20 June
EU Sustainable Energy Week Policy Conference
Brussels, Belgium
https://eusew.eu/about-conference

22-26 June
ASHRAE Annual Conference
Kansas City, Missouri
https://www.ashrae.org/conferences/annual-conference

24-30 August
25th IIR International Congress of Refrigeration
Montreal, Canada
http://icr2019.org/

28-29 August
5th International HVAC/R Congress
Atlantico, Colombia
https://www.ashrae.org/conferences/ashrae-endorsed-conferences/5th-international-hvac-r-congress

2-4 September
Building Simulation 2019
Rome, Italy
http://buildingsimulation2019.org/

9-11 September
11th International Conference on Compressors and their Systems
London, UK
https://www.city.ac.uk/compressors-conference

25-27 September
2019 ASHRAE Building Performance Analysis Conference
Denver, Colorado, USA
https://www.ashrae.org/conferences/topical-conferences/2019-ashrae-building-performance-analysis-conference

22-23 October
European Heat Pump Summit 2019
Nuremberg, Germany
https://www.hp-summit.de/en

24 October
HPT TCP National Experts' meeting
Nuremberg, Germany
For more information, please contact your HPT National Contact https://heatpumpingtechnologies.org/contact-us/ or Johan Berg, HPC johan.berg@ri.se

9-12 December
2019 Buildings XIV International Conference
Clearwater Beach, Florida, USA
https://www.ashrae.org/conferences/topical-conferences/2019-buildings-xiv-international-conference

2020

1-5 February
ASHRAE Winter Conference
Orlando, Florida
https://www.ashrae.org/conferences/2020-winter-conference-orlando

15-17 April
6th IIR Conference on Sustainability and the Cold Chain (ICCC 2020)
Nantes, France
http://www.iifiir.org/clientBookline/recherche/NoticesDetaillees.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=exploitation&iNotice=7&ldebut=

11-14 May
13th IEA Heat Pump Conference 2020
Jeju, South Korea
http://hpc2020.org/

7-10 June
9th International Conference on Caloric Cooling and Applications of Caloric Materials (Thermag IX)
College Park, Maryland, USA
http://www.iifiir.org/clientBookline/recherche/NoticesDetaillees.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=exploitation&iNotice=9&ldebut=

27 June – 1 July
ASHRAE Annual Conference
Austin, Texas, USA
https://www.ashrae.org/conferences/ashrae-conferences

13-16 July
Purdue International Compressor Engineering, Refrigeration & AC, High Performance Buildings Conferences
West Lafayette, Indiana, USA
https://engineering.purdue.edu/Herrick/Conferences/2020

26-29 July
Rankine 2020 Conference – Advances in Cooling, Heating and Power Generation
Glasgow, United Kingdom
http://www.iifiir.org/clientBookline/recherche/NoticesDetaillees.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=exploitation&iNotice=7&ldebut=

14-16 September
Indoor Environmental Quality Performance Approaches - Transitioning from IAQ to IEQ
Athens, Greece
https://www.ashrae.org/conferences/topical-conferences/indoor-environmental-quality-performance-approaches

6-9 December
14th IIR-Gustav Lorentzen Conference on Natural Refrigerants (GL 2020)
Kyoto, Japan
http://www.iifiir.org/clientBookline/recherche/NoticesDetaillees.asp?VIEWALL=TRUE&ToutVisualiser=1&INSTANCE=exploitation&iNotice=10&ldebut=

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Industrial Heat Pumps–
Good examples from ongoing Annex
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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.

Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)
International collaboration for energy efficient heating, refrigeration, and air-conditioning.

Vision
Heat pumping technologies play a vital role in achieving the ambitions for a secure, affordable, high-efficiency and low-carbon energy system for heating, cooling and refrigeration across multiple applications and contexts.

The Programme is a key worldwide player in this process by communicating and generating independent information, expertise and knowledge related to this technology as well as enhancing international collaboration.

Mission
To accelerate the transformation to an efficient, renewable, clean and secure energy sector in our member countries and beyond by performing collaborative research, demonstration and data collection and enabling innovations and deployment within the area of heat pumping technologies.

Heat Pump Centre
A central role within the HPT TCP is played by the Heat Pump Centre (HPC). The HPC contributes to the general aim of the HPT TCP, through information exchange and promotion. In the member countries, activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on heat pumps and the HPT TCP, contact your National Team on the address above.

The Heat Pump Centre is operated by RISE Research Institutes of Sweden.

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