IEA Heat Pump CENTRE
NEWSLETTER

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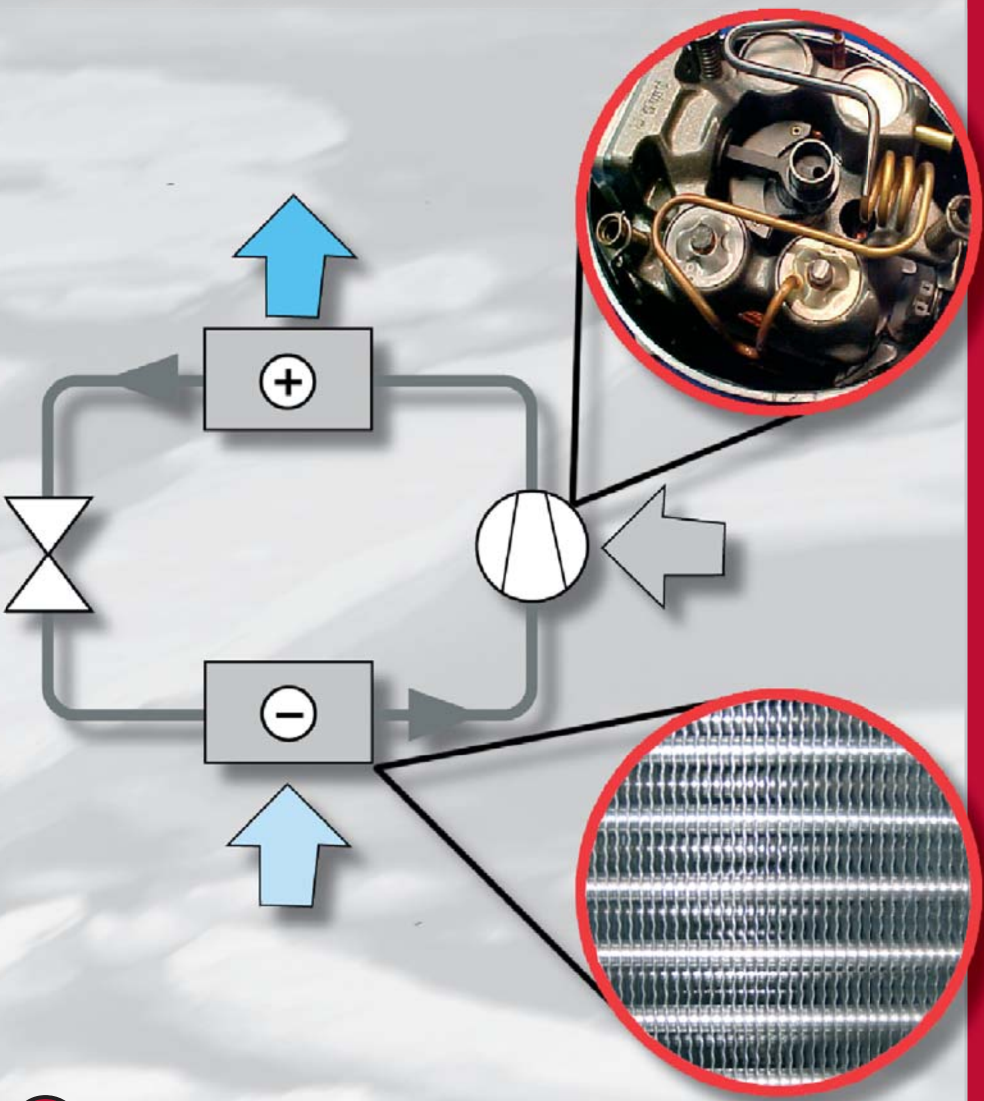
Heat pump components development trends

Microchannel heat exchangers

Compressors for Heat Pumps



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IEA **Heat Pump** CENTRE
NEWSLETTER

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In this issue

Heat pump components development trends

Dear readers,

Heat pumps are like chains – no better than the weakest link? There has been a constant evolution of the different components in heat pumps. One major success was the implementation of plate heat exchangers; are others perhaps waiting around the corner?

In this issue we look at development trends regarding different heat pump components.

Enjoy your reading.

Roger Nordman
Editor

Heat pump news

Features

Topical article

Non-Topical article

COLOPHON

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Heat pump component development trends

Hermann Halozan, Austria

The present development of the heat pump market is extremely interesting: in regions such as Japan and the US, where the market is dominated by air-to-air units, ground-coupled systems are obtaining an increasing share, while in regions such as Central and Northern Europe, which are dominated by ground-source systems, air-source systems have an increasing market share. Additionally, due to improved thermal insulation, cooling, which is common in Japan and the US, is becoming more interesting in Central and Northern Europe too. This requires an increase in efficiency of units and systems, not only in full-load operation, but also in part-load operation, which is more important for a high SPF than the full-load data alone.

A development in this direction is variable-speed compressor drive, in the small-capacity range using PMMs (permanent magnet motors) which also improve the efficiency of outside air heat pumps by increasing the efficiency of the drive, and for all capacities for reducing mixing losses caused by heat pump outlet temperatures higher than the supply temperature required. In the mean time, this type of compressor is also being used in ground source heat pumps: in addition to the reduction of mixing losses, the temperature drop from the ground to the coil can also be reduced, thus increasing the evaporation temperature and therefore the efficiency.

However, in addition to the compressor, increasing attention is being paid to parts such as heat exchangers, cycle control and auxiliary equipment such as fans and circulation pumps. One of these developments is improved cycle control by electronic expansion valves. Additionally, other control strategies are used, such as control of the discharge gas temperature and the condensate sub-cooling temperature, with both being very successful in the case of direct expansion ground source heat pumps.

Outdoor coils for outside air heat pumps are optimised with respect to minimum pressure losses for reducing the fan power requirement (even with permanent magnet motors with speed control combined with optimised fans), and with respect to frosting/defrosting losses. With variable-speed compressors, the size of the coil itself can be reduced significantly, as it is no longer dependent on the maximum heating/cooling capacity determined by evaporation and condensation temperatures, but is dependent on the maximum capacity at maximum speed.

CO_2 as a refrigerant seems to be achieving broader acceptance, especially for heat pump water heaters, and also for air conditioners. To improve the efficiency of these systems, a Japanese manufacturer has already shown a double rotary compressor with a rotary expander. Several concepts with ejectors as expansion devices are already on the market.

A new development in air conditioners is the separation of dehumidification and removing the cooling load. Dehumidification is carried out using a DEC system, removing the cooling load by a conventional compression system. This allows much higher evaporation temperatures and therefore much higher COPs. Moisture is driven off from the desiccant by utilising waste heat from the condenser.

Hermann Halozan,
TU Graz,
Austria

Columnist

20th Anniversary of the Montreal Protocol - 19th Meeting of the Parties of the Montreal Protocol

Sophie Hosatte, Canada

The 19th Meeting of the Parties of the Montreal Protocol, was held in Montreal, Canada, on September 16-21, 2007 in conjunction with the celebration of the 20th anniversary of this Protocol. About 190 countries and the European Commission attended this event, revealing the extraordinary collective and successful efforts in addressing the issue of the ozone layer depletion.

But another interesting result was that the elimination of CFCs and putting in place HCFC phasing-out have been considered as the Montreal's Protocol contribution to the Kyoto Protocol. More than 5,000 megatons (5 gigatons) equivalent of carbon dioxide (CO2) have already been eliminated as a consequence of the Montreal Protocol, representing more than 25% of the world's GHG emission compared to 1990. This is five times the Kyoto Protocol's target for reducing other GHGs by 2010. The Montreal Protocol, which was initially perceived as a threat for the critical refrigeration applications (e.g food and vaccine preservation) and by the refrigeration industry, revealed itself to be successful because of the unprecedented collaborative efforts of the international community (governments, academia, and industries) to meet the targets. The Refrigeration and Air Conditioning industry played an important role in the process, by continuously adapting the technologies, and benefited from these opportunities to innovate.

These results gave the participants enough confidence to accelerate the phase-out of HCFCs that are ozone-damaging chemicals but are also identified as strong contributors to global warming. The Parties agreed on an amendment to the Protocol to forward the initial deadlines of 2030 for industrialized countries and 2040 for developing countries to 2020 and 2030 respectively.

Heat pumping technologies, and particularly refrigeration and air conditioning, have the capacity to continue to reduce significantly their effect on the ozone layer and reducing GHG emissions. Several solutions have been put forward by the United Nations Environment Programme (UNEP) and the International Institute of Refrigeration (IIR) at the Montreal Conference. Refrigeration and air conditioning are the targeted areas where the natural refrigerants like hydrocarbons, carbon dioxide and ammonia, the reduction of synthetic refrigerant charges in systems, the utilization of low global warming potential HFCs and the improvements in energy efficiency, have the potential to further reduce significantly GHG emissions. The IEA Heat Pump Programme may play a significant role in supporting the development of technologies and knowledge and in their promotion for wider market uptake.

Sophie Hosatte, Canada
Natural Resources Canada
Chairman of the IEA Heat Pump Programme

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2. Combating Climate Change Given Big Confidence Boost in Canada www.unep.org/themes/climatechange/ozone
3. 19th Meeting of the Parties to the Montreal Protocol – Statement given by Didier Coulomb, Director of the International Institute of Refrigeration – Montreal – 16-21 September 2007

General

Heat pumps – ecological mischief?

This is what the German electricity company EWS (Elektrizitetswärke Schönau) asks in their paper on the competitiveness of heat pumps. Their answer to the question is that only with an SPF of 4 and higher, can heat pumps be regarded as OK. They base their conclusion on the following:

* In practice, heat pumps have SPF values of 2.7 to 4.2, but manufacturers talk about SPFs of 6 to 7.
* There is a high installation cost for the borehole
* In heat pumps with non-optimized components, a large share of the heating is supplied by electricity
* During its 15-year life, 60 % leakage emissions from a 2 kg R407c installation, plus the related carbon footprint of end-of-life scrapping, amount to about 1500 kg of CO_2.

To read the full paper (in German), go to: http://www.ews-schoenau.de/Download/files/EWS_Waermepumpen_Info.pdf

Source: CCI print 10/2007

France legislates for warmer summers

In the same way as Hong Kong and China have done, France has accepted a directive (2007-363) to shut down air conditioners when the temperature is below 26 °C. In the long run, it is expected that manufacturers will include a built-in function to follow this directive.

Source: Die kälte & klimatechnik 7/2007

1st International Heat Pump Symposium:

Complete success in Nürnberg

200 participants from eleven countries met at the 1st Nuremberg Forum

The International Heat Pump Symposium organised by DKV offered 200 experts from eleven countries an outstanding platform for information, trends and exchanging views. The "1st Nuremberg Forum" under the motto of "Possibilities and limits of heat pumps in existing private and commercial buildings" took place in the Exhibition Centre Nuremberg from 18-19 September.

About 200 participants from industry, business, associations and research institutes highly praised the German Refrigeration and Air Conditioning Society (DKV) as symposium organiser for the successful symposium in the attractive ambience of the Congress Center Nürnberg. On the two days of the event, 24 international speakers offered an impressive survey and outlook of markets, technologies and potentials of heat pumps for cutting the primary energy requirement of heating systems. The presentations and statements by the experts also provided an opportunity for stimulating and intensive discussions in large and small groups.

Current trends and developments in the heat pump market

The first day focused on general presentations of heat pump markets and developments in Germany, Austria, Switzerland, Sweden, France and China. It was pointed out that the sales figures for heat pumps in some of these countries are rising steeply. At the same time, there are considerable national differences in the use of heat pumps, especially regarding the use of air, ground or water as heat sources and the installation of heat pumps in new and existing buildings. The speakers also showed that the positive market development of the heat pump in individual countries is often closely associated with official support and incentive programmes. Supplementary information and information campaigns for architects, planners, installation contractors and end customers play a key role, too. It was also reported that a new European "Ecolabel" for heat pumps had been introduced in mid-September 2007.

Focus on energy efficiency

The second day was devoted to presentations of new energy-efficient components, products and systems from AL-KO THERM, Alpha-InnoTec, Copeland, Daikin, Johnson Controls, Kaut, Ochsner, Stiebel-Eltron and Viessmann. The presentations were supported by reports of experience with heat pump systems already installed in new and existing homes, blocks of flats and commercial and industrial projects. There was considerable discussion on refrigerants for heat pumps, performance figures and annual operating figures, but agreement prevailed on one point: The manufacturers of heat pumps are called upon to develop component and system solutions that are technically as simple as possible, robust and also low-cost, particularly in order to make even better use of the enormous energy-saving potentials in existing buildings in the future.

Next meeting: Chillventa Nürnberg 2008

The next International Heat Pump Symposium will take place in Nürnberg in October 2008 at Chillventa, the new International Trade Fair for Refrigeration, Air Conditioning, Ventilation and Heat Pumps. The Heat Pump Symposium takes place on 14 October, the day before the exhibition opens, and will be continued and enhanced by several forums and special events at Chillventa from 15-17 October.

Proceedings

All 24 presentations (German or English) at the Heat Pump Symposium are available for purchase on a USB stick, which can be ordered from the DKV office by e-mail: info@dkv.org or fax: +49 (0)7 11. 68 56-32 42.

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Poland Invited to Join IEA

The International Energy Agency (IEA) has invited Poland to become a new member country. At a regular meeting today in Paris, the Agency's Governing Board approved the accession request of the Polish government. "It is with great pleasure that we welcome Poland to the IEA", said IEA Executive Director Nobuo Tanaka. "Poland -- an EU member country since 2004 -- plays an important role in the transit of hydrocarbons to Europe and in energy co-operation in the region. Its geographic position means that its membership will greatly enhance the Agency's presence and energy security in Central and Eastern Europe."

Poland is the largest economy, energy consumer and energy producer in Central Europe. While a net importer and heavily dependent on crude oil and gas supplies from Russia, Poland is the third largest OECD coal producer.

2007 China-Japan joint meeting on heat pump and thermal energy storage

The China-Japan Joint Meeting on Heat Pump and Thermal Energy Storage was held from July 23 to July 26, 2007 in Tokyo at The Industry Club of Japan, and attended by about 60 delegates from China and over 100 delegates from Japan. The participants included policy-makers, researchers, engineers, universities and relevant industry experts from the electric utilities industry, building and HVAC system design companies, contractors, equipment manufacturers of heat pump and thermal energy storage systems, and Japanese and Chinese media. Officials from the Japanese Ministry of Economy, Trade and Industry and the Chinese Embassy also attended the seminars and dinner event at the meeting.

China, with the fastest growing rate of heat pump installation, especially Ground Source Heat Pumps, and Japan, with the highest number of water/ice storage systems, both showed their great interest in this meeting.

Twelve experts from China and Japan presented work in the afternoon of July 23 and full day of July 24. Seven were from Japan and five were from China. Both sides presented energy policies of both countries. Japan described a) the selection methods for heat pump HVAC systems, b) standardization and improvements in energy-efficient heat pump A/C systems, c) the energy-efficient technologies of water thermal storage and ice thermal storage equipment and systems, d) the technology of natural refrigerant heat pump water heaters, and e) an introduction to energy efficiency in public buildings. The Chinese representatives described a) the national certification method of energy efficiency in refrigeration & air conditioning equipment, b) the application of ground source heat pump systems, c) advanced products/systems in buildings, d) the integration of air-source heat pumps and ground source heat pumps, and e) the retrofit of the HVAC system of the China Central Television (CCTV) tower.

After the presentation, bilateral meetings were arranged between the two sides to discuss detailed steps to further collaborations and technology exchanges between China and Japan.

On July 25, the Chinese delegate members visited three technical sites. The first was Tokyo Electricity Power Research Center, where the group was shown an example of the company's energy conservation and recycle technology, in the form of the building's large temperature difference cool air distribution system with highly effective heat pump and ice thermal storage system, an automatic roll-up blind system with solar radiation sensor and auto-adjusting lighting system. The second was a large scale DHC project with a large water thermal storage tank (19 060 m3), and highly efficient chillers and double bundle heat pumps in the Harumi Island area. The Harumi project had reduced energy use by as much as about 51 %. The final site was the Hakozaki district heating and cooling system (Tokyo), using the water of the Sumida River as a heat source for heat pumps for heat-

ing and cooling office buildings and subway stations in the area.

On July 26, the Chinese delegates visited the heat pump and energy storage technology exhibition, called "Energy Solution & Thermal storage Fair '07 ", under the co-sponsorship of Tokyo Electric Power Co.(TEPCO), Heat Pump Thermal Storage Technology Center of Japan and the Federation of Electric Power Companies of Japan. This year's exhibition attracted well over 100 corporations. The exhibition was subdivided into four exhibit areas, including the Tokyo Electric Power Company (TEPCO) zone, the air conditioning and water heater zone, the kitchen zone, and the all-electric residence zone. The Chinese representatives showed great interest in the new equipment and technologies on display at the exhibits.

This year's meeting can be characterized by its large scale, its cutting edge technology, the high levels of attendees, and the breath of its technological reach in industrial applications. Attendees included representatives from government departments, academia, industrial design institutes, manufacturing firms, wholesalers and retailers. The meeting formats varied from large symposium-style presentations to small group one-on-one meetings. The meeting also included visits to major technology construction sites and attendance at Tokyo Electric's annual exhibition event, show-casing the latest heat pump and energy storage technology.

The 2007 China-Japan Joint Meeting on Heat Pump and Thermal Energy Storage has helped each country to appreciated current developments in the other country. The meeting has also helped both sides to reach a mutual understanding of ways of popularising heat pump and energy storage technology developments and obtaining government subsidies. The bilateral exchanges also explored the feasibilities of future technology development and collaborations. This year's meeting has set a solid foundation for further bilateral exchanges.
Source: HPTCJ (Japan) and CABR (China)

Consensus Agreement Reached on Walk-in Coolers, Freezers Efficiency Standards

Commercial refrigeration manufacturers and energy efficiency advocacy groups recently announced that they have reached a consensus agreement on the first-ever federal energy-efficiency standards for commercial walk-in freezers and coolers that, if enacted by Congress, will begin affecting the design of new equipment in 2009. This agreement, which was negotiated over the last several months by the Air-Conditioning and Refrigeration Institute (ARI) and the American Council for an Energy Efficient Economy (ACEEE), is the latest in a series of successful negotiations between industry and energy efficiency advocates.

Under this new agreement, the signatories jointly recommend to Congress prescriptive design requirements to improve the efficiency of this equipment and direct the U.S. Department of Energy to develop performance standards by 2012.

The agreement covers coolers and freezers with an enclosed, walk in storage space of less than 3000 ft^2 that are refrigerated to temperatures above, at or below 32 degrees Fahrenheit, respectively. The agreement excludes products that are designed and marketed exclusively for medical, scientific or research purposes.

In 2005, three similar agreements were signed covering a number of commercial products including large-packaged air conditioners and heat pumps, commercial ice makers, and commercial refrigerators, freezers and refrigerator-freezers. Those agreements were included in the Energy Policy Act of 2005.

The Air-Conditioning and Refrigeration Institute (ARI) is the trade association representing manufacturers of air conditioning and commercial refrigeration equipment. An internationally recognized leader in developing standards for, and certifying the performance of, these products, ARI is also a major advocate for the heating, ventilation, air conditioning and refrigeration (HVACR) industry both domestically and abroad. Visit ARI at www.ari.org, or go to www.aridirectory.org for free information about ARI Performance Certified™ equipment.

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Source: www.ari.org

ASHRAE, DOE partner to improve energy efficiency

Under a new agreement, ASHRAE and the U.S. Department of Energy (DOE) will work to increase building energy efficiency standards for the year 2010 by 30 percent over 2004 standards.

A new Memorandum of Understanding commits ASHRAE and DOE to improving the efficient use of energy and the viable and widespread use of renewable energy sources and to minimizing the impact of energy use on the environment.

"DOE and ASHRAE have been working together in advancing energy conservation technology since the initial energy crisis of the 1970s," Kent Peterson, ASHRAE president, said. "This new initiative provides an opportunity for ASHRAE and DOE to expand our collective energy conservation efforts, our energy conservation education initiatives and strategic research program focus in leading our country and the world toward a sustainable energy future. The agreement further enhances ASHRAE's ability and resolve of being a global engineering engine of sustainability."

Under the agreement, ASHRAE and the DOE are committed to working together toward the following goals:

- Promoting and supporting the continuing development of ASHRAE standards related to energy efficiency, indoor air quality and sustainability
- Supporting implementation of ANSI/ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, through training programs.
- Supporting the development of guidance for exceeding the minimum efficiencies set by Standard 90.1, and new performance metrics and protocols for building energy efficiency and environmental impact.
- Cooperating in, and supporting, research into clean and renewable sources of energy, energy efficiency in buildings and equipment, and environmental impact of energy
- Cooperating in promotion of ANSI/ASHRAE standards adoption in International Organization of Standardization (ISO) standards.
- Working within the building community and related professions to encourage the interoperability of building-related software and integrated solutions to increase energy efficiency, health, and productivity in new and existing buildings.
- Ensuring sufficient numbers of qualified building design professionals by promoting and encouraging the study of mathematics and science to pre-college students, the study of building design within college curricula, and the pursuit of continuing education by practising design professionals.
- Providing and supporting technology transfer to building owners and management about the interrelationships between mechanical systems and building operating costs, noting energy, workplace performance, client satisfaction, and public safety.

Monitoring the operational, energy and environmental impacts of new counter-terrorism design features, and promoting minimization of those impacts.

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Source: www.ashrae.org

First heating law for renewable energy in Germany: Baden-Württemberg sets the example.

From 1st April 2008, new buildings in Baden-Württemberg must obtain 20 % of their heating requirements from renewable energy sources*. In its draft of an appropriate law, the government of Baden-Württemberg, is the first federal state to call for the use of solar, bio or environmental heating systems for use in water heating and space heating.

Existing buildings have a two-year transition period to complete their obligation in the case of heating renovation, the proportion of renewable energy sources in this case must be 10 %. The implementation of the law will be controlled by the building authorities.

*) The use of heat from the surroundings through heat pumps is assumed to be renewable heat if the following is fulfilled:
a) When an electrically driven heat pump in heating mode has an SPF of 3.5 or above.
b) When a heat-driven heat pump has an SPF of 1.2 or above.

The SPF value should be determined according to VDI 4650 (Stand: 2003-01).

Source: energy-server newsletter, Issue 73

Working Fluids

ASHRAE to fund CO_2 refrigeration research

For the first time, the leading US society for heating and refrigeration will support the development of CO2 (R744) in industrial refrigeration, with a USD90 000 grant to the Washington State University for its research on heat exchangers for subcritical applications.

ASHRAE will fund a two-year research project on carbon dioxide condensation in chevron plate heat exchangers. The study, to be carried out by the Washington State University Vancouver (WSU), will explore the use of the natural refrigerant CO_2 (R744) in low-temperature applications as an environmentally friendly alternative to current refrigeration systems.

It is the first ASHRAE fund ever awarded to a research project on CO_2 in industrial refrigeration. So far, the organization has sponsored only one study involving carbon dioxide for small-scale residential and light commercial systems. The latest grant was awarded to the Washington researchers to address the need of today's industrial refrigeration industry for more environmentally friendly solutions.

Given that several R744 refrigeration systems are already successfully operating in Europe, the Washington State University decided to reinforce the research into CO_2 in industrial applications for the US market. The proposed project will help to understand the physics of condensing CO_2 in complex geometries, such as plate heat exchangers, to optimize such heat exchangers for high-performance industrial cascade systems.

Amir Jokar, Assistant Professor at the WSU responsible for the project, hopes that the findings will help speed up the phase-out of ozone-depleting and high global warming substances in the refrigeration sector: "If we can use new technology to produce a less expensive way of condensing CO_2 for refrigeration purposes, especially in low-temperature applications, it could have an enormous global effect. We are very fortunate to have this research project now at WSU Vancouver."

Source: www.ashrae.org

New Standard 34 – classification of new refrigerants

Revisions to ASHRAE's Standard 34 should make it easier for manufacturers to prepare applications for refrigerant number assignment and safety classification.

ANSI/ASHRAE Standard 34-2007, Designation and Safety Classification of Refrigerants, establishes a simple means of referring to common refrigerants in place of chemical names, formulas or trade names. It also establishes safety classifications based on toxicity and flammability data. The 2007 standard contains a total of 16 new refrigerants.

The new standard contains revisions to the flammability classification and details on the flammability and fractionation testing procedures. These are intended to make it easier for manufacturers to prepare applications for refrigerant number assignment and safety classification, according to Bill Walter, Standard 34 Committee Chair.

In addition, a new section has been added specifying the criteria to determine recommended refrigerant concentration limits (RCL) in occupied spaces. The addition of RCL values will be useful in application of the refrigerants in the field.

"In general, incorporating the 23 approved addenda into one document makes the standard easier to read and understand, making it easier for users to determine the current requirements to get a refrigerant listed in the standard," said Walter.

The cost of Standard 34-2007 is $39 for ASHRAE members

Source: www.ashrae.org

Technology & Applications

ARI recently approved two new standards:

ARI 750-2007: Performance rating of thermostatic refrigerant expansion valves:
This standard establishes a single set of requirements for the testing and rating of capacity of thermostatic expansion valves, recommended standard maximum operating pressures for pressure-limiting type valves, recommended refrigerant designation and colour coding, and recommended standard connection sizes.

ARI 760-2007: Performance rating of solenoid valves for use with volatile refrigerants:
This standard establishes a single set of requirements for the testing and rating of refrigerant flow capacity and maximum operating pressure differential (MOPD) for solenoid valves using volatile refrigerants. Also included are requirements for external leakage and recommended line connection sizes.
Source: www.ari.org

Improved mobile air conditioning program I-MAC has met its four targets

The I-MAC program (Improved Mobile Air Conditioning Cooperative Research Program) which was started in 2005, aimed to reduce dramatically the environmental impact of HFC-134a in MAC. It has announced that it successfully met its four targets.

1. Reduction of direct system refrigerant leakage by at least 50 percent: it was demonstrated that this is feasible by using better parts.

2. Improvement of the system efficiency by at least 30 percent: it was demonstrated that energy used by the vehicle air conditioner could be reduced by over 30 percent using commercially available technology.

3. Reduction of system cooling loads by at least 30 percent: it was found that the inside temperature could be reduced by more than 6 °C by using solar-reflective paints and ventilation.

4. Reduction of refrigerant loss during servicing and at end of life by 50 percent: recommendations were presented that could cut refrigerant emissions in half. New refrigerant recovery, recycling, and leak-detection technology was introduced.

Combined, these achievements will save globally 2.4 million kg of HFC-134a, and reduce overall greenhouse gas emissions by 22 million tonnes CO2-equivalent.
Source: http://www.epa.gov/cppd/mac/#partnership

Radiative cooling in the Sub-Saharan desert

A new way of lowering temperatures without using electricity has recently been developed. Iterrae, a French company, has discovered a way of using radiative cooling, a phenomenon that takes place at night, when the Earth is cooled by the 0 K temperatures that can be found in outer space. A "Sahel granary", designed to keep grain cool, was constructed in Burkina Faso with the support of the UN and the World Bank. Radiative cooling is particularly effective on dry and clear nights, as air humidity acts as an insulant and the infrared radiation can transfer low temperatures more readily. Under these conditions, the radiation can be absorbed by a black body, in this case black anodized aluminium. With outdoor temperatures of 28 °C, it is possible to obtain an indoor temperature of 10-15 °C in a 100 m3 volume and on a 130 m2 surface area, the equivalent of 30-80 W/m2.

This system could be very useful for the storage of harvests and food in poorer, desert areas lacking power networks. However, in order to shave off the effect of temperature peaks, Y. and P. Fayet, who invented the system, use expanded graphite filled with a phase-change material (PCM) such as an alkane or paraffin, in order to store the cooling energy gathered at night. This innovative system has a huge potential for free, environmentally friendly cooling in developing areas, but is still very costly to implement at this stage.
Source: http://www.iterrae.org

The new market structure for boilers in the UK

In 2006, the entire market for domestic boilers reached a level just above that of 2004, despite evidence that the residential refurbishment market experienced negative growth in 2005-2006.

Comparing 2004 with 2006 figures, the sales volume for non-condensing boilers dropped by around 74 percent. By contrast, figures for condensing boilers rocketed, growing by more than 300 percent over the same period.

Boiler manufacturers were prepared differently for those changes, as significant shifts in market shares have occurred.

Sales of non-condensing domestic boilers will shrink further over the next couple of years to the extent that the non-condensing boiler is likely to become a niche product.
Source: www.bsria.co.uk

Reciprocating Compressors From Danfoss

BALTIMORE—Danfoss introduces the NTZ line of reciprocating compressors for R-404A and R-507 with high EER, low sound levels, and a

small footprint. The compressors are designed for low-temperature operation, which improves their COP and lowers energy consumption.
Source: The HVAC&R Industry for August 30, 2007 (e-newsletter)

New brazed plate heat exchangers

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

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

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

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

Other product advantages includes:
- Copper or nickel-brazed
- Welded or threaded connections
- Standard and high-pressure versions
- Low fouling
- 3-way design for heat pumps
- Low investment costs
- High corrosion resistance
- Easy to service

Source: www.danfoss.com

Boilers: the heat is on

After years of growth, sales of domestic boilers in the UK dropped by more than five percent after new regulations came into force. Is this the trend for the future, or will boiler sales recover?
The growing threat of climate change has led to unprecedented global agreements to reduce emissions of greenhouse gases. Foremost among these is the Kyoto Protocol, signed in 1997, which laid down emissions targets for the world's most polluting nations.

Further international and national regulations and carbon reduction initiatives followed; for example, the UK Climate Change Programme and the Energy Performance of Buildings Directive (EPBD). The Directive has placed an obligation on the UK radically to improve the energy efficiency of new and existing buildings.

The Building Regulations, specifically Part L that addresses the conservation of fuel and power, have responded to the need for step-changes in the energy performance of new and refurbished buildings. Part L covers a variety of energy efficiency measures in buildings, but one of the more significant measures is the amendment dealing with boiler efficiency.

In 2005, the minimum SEDBUK efficiency (Seasonal Efficiency of Domestic Boilers in the UK) in gross calorific value was raised to 86 percent for gas-fired boilers and 85 percent for oil-fired boilers.

These tougher requirements in Part L have sent shockwaves through the structure of the UK heating market, as they effectively require most new and replacement domestic boilers to be of a condensing type.

The de-stabilised market

After years of growth, sales of domestic boilers in the UK dropped by more than five percent. Besides a negative growth in the residential renovation sector in 2005 (over 75 percent of domestic boilers are sold into this segment), it is believed that some end-users possibly hesitated over whether to buy the more expensive condensing boilers, preferring instead to defer replacement.

However, 2006 sales figures show that changes in the Building Regulations did not lead to a continuing downward trend. 2005 was just a transition year, and end-users did not switch to alternative technologies such as heat pumps.

New Energy-Efficient Roof System

OAK RIDGE, Tenn.—A new roof and attic system being developed at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) is designed to reduce attic temperatures and reduce the amount of heat that gets transferred through the attic floor to the living space. The roof system consists of a proprietary inorganic phase-change material sandwiched between two reflective surfaces made of aluminum foil. This material is installed as a dynamic thermal barrier between the roof and attic area, creating separate air channels between roof rafters. According to ORNL, it reduces attic temperatures by about 22 °F (12 °C) on a typical summer day, and can reduce utility costs by 8 %.
Source: The HVAC&R Industry for August 30, 2007 (e-newsletter)

ASHRAE Research Investigates Photocatalytic Oxidation Technology

Air-cleaning equipment featuring new photocatalytic oxidation (PCO) technology is used to remove contaminants from indoor and outdoor air. New research from ASHRAE will provide a method for analyzing byproducts from PCO air cleaning devices, improving understanding of the technology.
Source: The HVAC&R Industry for August 30, 2007 (e-newsletter)

Boom time for beams

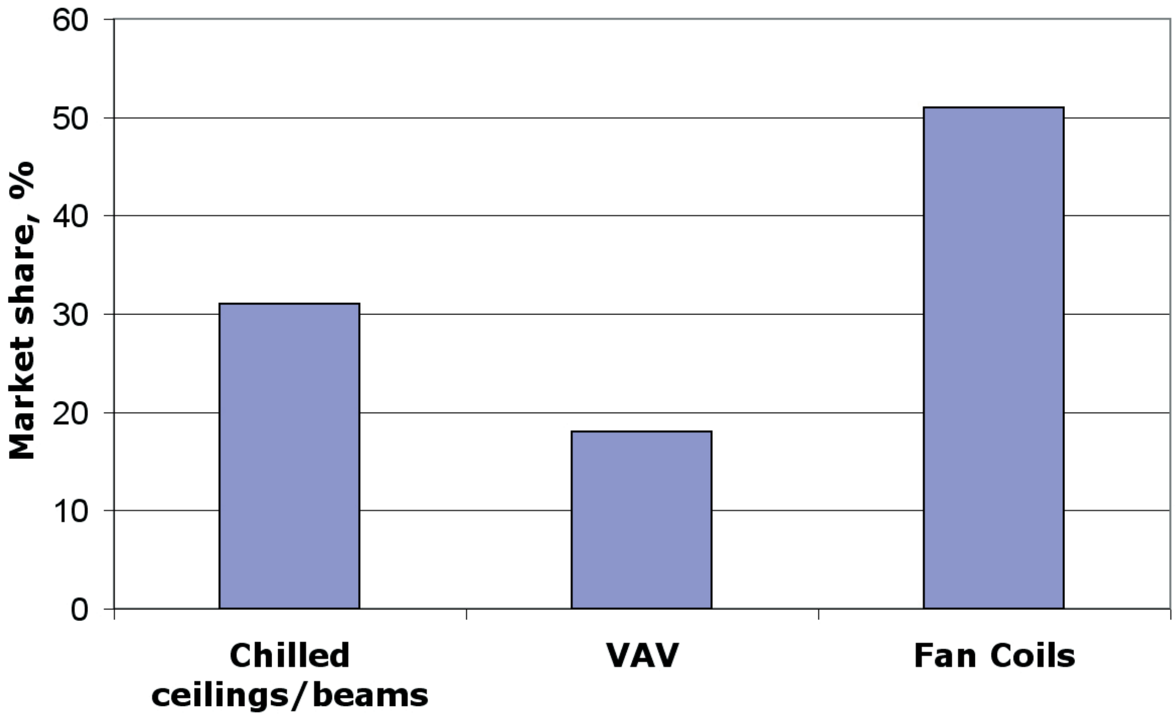
Chilled ceilings and beams have been around since the early 1990s, but it seems the market's perception is finally swinging in their favour.

Up until recently, the cooling capacity of chilled ceilings and beams was perceived as inadequate, and associated with high initial capital costs. However, continued product development and the increased number of projects incorporating chilled ceilings and beams is changing that view.

The market grew by 33 percent in 2006 compared with 2005, but BSRIA believes that this is just the tip of the iceberg: significant growth of around 40 percent is predicted from 2007, based on the known volume of orders. This will change the shape of the UK terminal unit market. In 2006, the UK market for terminal units was estimated to be worth around £54 million, including chilled ceilings and beams.

An important driver is the demand for energy-efficient buildings prompted by tougher requirements in Part L of the Building Regulations. Chilled panels and beams are therefore being given higher priority by clients and consultants.

Another important factor is strong growth in the commercial building sector, with a 13.4 percent volume increase in 2006. The growth came from a 10 percent increase in the education, health and office sectors. BSRIA expects this growth to continue until the end of 2008. Conservative estimates put growth at eight percent in 2008 and seven percent in 2009.
Source: www.bsria.co.uk



Market

ECO CUTE Tops One Million Units

The Federation of Electric Power Companies of Japan (FEPCJ), the Japan Refrigeration and Air Conditioning Industry Association (JRAIA) and the Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ) announced last month that cumulative shipments of the ECO CUTE CO_2 heat pump water heater topped one million units as of September 25. Taking this opportunity, they have decided to launch a "Thank You for One Million ECO CUTE Units!" promotional campaign.

Since the ECO CUTE was first commercialized in May 2001, its sales have continued to increase, topping 50 000 units in June 2003, 100 000 units in January 2004 and 500 000 units in May 2006. Uptake of ECO CUTE units is continuing to spread smoothly.

Along with the noticeable improvement in heat pump efficiency, various types of ECO CUTE systems are now available, such as a multi-function type capable of being used for floor heating, a slim 2-tank system which can be installed in a narrow space, a compact single-piece type and one specifically designed for cold climates, thus giving customers more choice than before.

CGC Welcomes GeoExchange™ Application to Downtown Toronto

The Canadian GeoExchange Coalition (CGC) today joins industry members and developer Harry Stinson in welcoming the unveiling of the High Park Lofts project, Toronto's first high-rise multi-unit residential condo to use GeoExchange™ ground-source heating and cooling technology. Based on the experience of thousands of installations across Canada, Stinson expects the GeoExchange™ system drastically to lower energy bills for new residents.

"This project matters not only because it's in an urban setting or the first of its kind in Ontario. As a privately developed project, High Park Lofts illustrates the value which quality GeoExchange™ systems can deliver with well-structured financing: radically increased sustainability in our energy usage and in our buildings, and simultaneously radically higher productivity for our aging Canadian infrastructure" said Denis Tanguay, CGC President and CEO.

The unveiling of the project also points up the rapid growth that the GeoExchange™ industry is experiencing nationally. By CGC's estimate, the industry grew 40 % annually in 2005 and 2006, and is on track to repeat or exceed that number for 2007. This industry growth has occurred in tandem with development and roll-out of Canada's first-ever national quality programme for GeoExchange™, the CGC's Global Quality GeoExchange™ Program®.
Source: www.geo-exchange.ca

Gigantic French heat pump market growth

The French heat pump market grew by 112 % in 2006, to a total number of installations of 53 510 heat pumps. Although the French market is small per capita, the growth rate is matched only in Germany. Air-water heat pumps show the largest growth, by 139 %, and it is expected that this segment will overtake ground-source heat pumps quite soon.
Source: JARN magazine

Eco cute sales increase in Japan

The Eco Cute hot water heat pump continues to conquer the Japanese market, with 323 000 units sold in 2006. The market growth is exponential, and more products continue to come on to the market. The goal is to have accumulated sales of 5.2 million units by 2010 (target set by the government). Based on SHECCO technology, the Eco Cute uses CO_2 as refrigerant, so that there is no environmental effect of leakage.
Source: JARN magazine

Metal prices on the rise again

Since the beginning of this year, metal prices have continuously increased. Copper is soon to break the USD 8000 per tonne price, while aluminum has climbed to some USD 2700 per tonne. This will probably lead to future price increases in products as well.
Source: RAC Magazine, August 2007

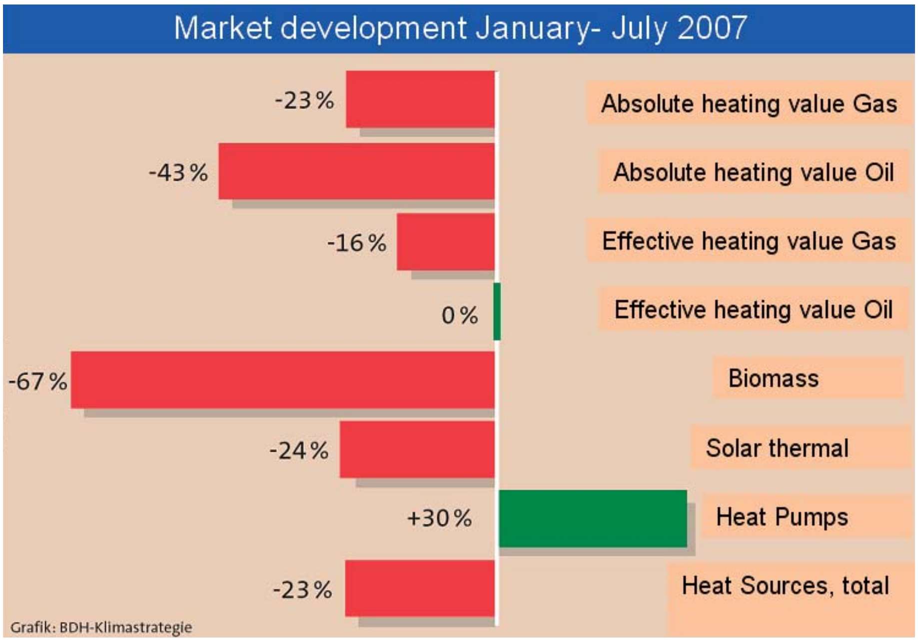
First accreditations delivered under the CGC Global Quality GeoExchange™ Program®

The Canadian GeoExchange Coalition (CGC) today announced the award of its first accreditations to geoexchange drillers, installers and residential designers. To be awarded CGC Accreditation, drillers, installers and residential designers must prove that they have received appropriate training (either CGC courses or recognised equivalents), submit relevant insurance and provincial licenses, and also prove that

they have field experience backed by customer references and clear manufacturer / distributor recommendations.
Source: www.geo-exchange.ca

Over two million heating systems in Germany are more than 25 years old

The owners of these old heating boilers are mostly unsure as to what their heating in the future will be like. The market analysis of the Association for House, Energy and Environmental Technology (BDH) has shown that investment in almost all heating types, including solar thermal heating systems, has reduced. However, heat pumps show a marked exception to this trend. *Source: energy-server newsletter, Issue 75.*



Ongoing Annexes

Bold text indicates Operating Agent.

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

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

Microchannel heat exchangers

Andrew Keogh, Carrier Air Conditioning, UK

Introduction

The air conditioning industry faces a constant challenge to provide higher efficiency levels and greater equipment reliability. This challenge is even more difficult to meet when the goal is simultaneously to maintain equipment size and limit potential cost impact.
Previous engineering solutions designed to satisfy these requirements have typically included such changes as improving individual components (e.g. higher efficiency compressors) or increasing the overall heat transfer surface area (e.g. a larger coil) to boost thermal performance. However, each of these enhancements tends to increase equipment size, cost, or both.

An alternative solution for air conditioning applications is microchannel heat exchanger (MCHX) technology for condenser coil design. This heat exchanger technology has been widely used in the automotive industry for many years, with considerable success. When compared to traditional coil technology, microchannel technology benefits include:

- Heat transfer and thermal performance improved by 10%
- 20% lower air-side pressure drop
- Refrigerant charge reduced by between 20 and 40%
- 50% reduction of coil weight
- Increased reliability as a result of better corrosion resistance
- No increase in chiller cost

Condenser coil construction

Conventional coil design

The standard round tube plate fin (RTPF) condenser coil has copper tubes mechanically bonded to aluminium fins. Figure 1 shows the typical arrangement. High thermal efficiency is achieved through direct metallic contact between the tube and fin. In non-corrosive environments, this arrangement generally provides excellent performance and long life. However, in corrosive environments, this type of coil is not recommended unless properly protected with pre-coatings or post-coatings, due to the likelihood of visible deterioration and poor long-term performance.

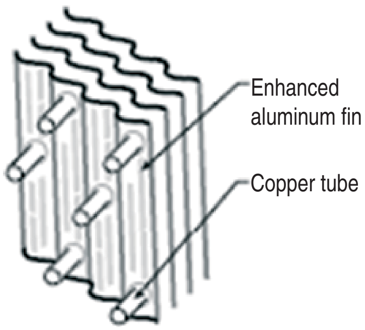


Figure 1 – Standard coil construction

Microchannel coil

In contrast to standard condenser coils, microchannel condenser coils are constructed utilising an all-aluminium brazed fin construction. A microchannel coil consists of three key components: the flat microchannel tube, the fins located between alternating layers of microchannel tubes, and two refrigerant manifolds. The manifolds, microchannel tubes and fins are joined together into a single coil in a nitrogen-charged brazing furnace. Overall product quality and integrity are maximized, since only one uniform braze in the furnace is required, as compared to 200 or 300 manually brazed connections on traditional copper/aluminium coils.
The refrigerant tube is essentially flat, with its interior sectioned into a series of multiple, parallel-flow, microchannels that contain the refrigerant (see Figure 2)

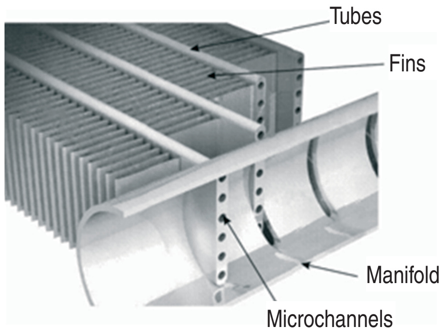


Figure 2 – Microchannel coil construction

Between the flat tube microchannels are fins that have been optimised to increase heat transfer (see Figure 3).

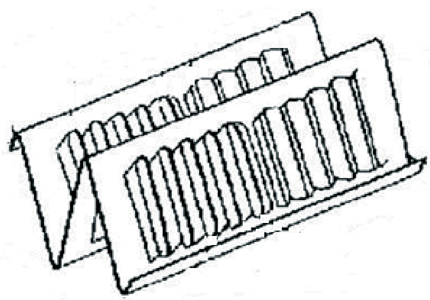


Figure 3 – Fin layout

Benefits of MCHX technology in air-cooled chiller applications

Thermal performance

The main reasons for the enhanced thermal performance of microchannel coils are the higher air-side heat transfer, the higher refrigerant-side heat transfer, and the high fin-to-tube surface contact. Microchannel flat tubes create a more favourable heat transfer boundary layer for improving air-side heat transfer coefficients, which improves overall heat exchange. In addition, the microchannel tubes promote better refrigerant-side heat transfer without excessive refrigerant pressure drops. Lastly, the metallurgical tube-to-fin bond increases the contact area between the fin and tube, thereby increasing the overall surface area and improving thermal conduction. Essentially, enhanced microchannel thermal performance has the potential to permit equivalent system design with up to a 25% reduction in overall coil size when compared to conventional coils.

Corrosion protection

Environmental exposure of air conditioning components can often lead to an undesirable outcome if the correct materials are not applied. Condenser coils are not immune to such factors, and therefore need to be protected from environments that may lead to localized and/or general corrosion. Premature corrosion of heat exchangers, particularly condenser coils, can result in unexpected performance degradation, poor aesthetics, and possible equipment failure. In order to minimize these effects, material selection and protection schemes must be considered.
The environment in which HVAC equipment is installed varies throughout the globe and in some instances, even within a local area. Corrosive environments include coastal or marine climates, industrial, urban or rural areas, localized micro-climates, and combinations of these conditions. Pollutants within these environments in combination with other factors such as wind direction, humidity, rain, fog, temperature, proximity to pollutant source and dust or particle contamination will result in the premature failure of improperly protected equipment.

The necessary conditions for galvanic corrosion occur when dissimilar metals, in contact, are exposed to an electrolyte. The environment readily creates electrolytes through the combination of moisture and atmospheric pollutants. An understanding of the environment in which HVAC equipment is being used is essential to the proper selection of materials and the choice of appropriate methods of protection.

Standard RTPF condenser coil construction utilizes copper tubes in contact with aluminium fins. The use of these two dissimilar materials in harsh environments can result in premature corrosion due to the galvanic couple inherent in this design. In this case, the aluminium fin is less noble (and therefore is less resistant to corrosion) than the copper tube, resulting in galvanic corrosion when the materials are exposed to an electrolyte. The result is attack to the aluminium fin, starting at the copper tube / aluminium fin interface. As the corrosion progresses, the performance of the coil is adversely affected due to the build-up of corrosion products at the tube/fin interface (due to the thermal resistance created from the build-up of corrosion products). The end result is poor performance, flaking aluminium fins and, depending on the degree of attack, complete removal of aluminium fin material from areas of the coil.

In order to minimize the attack to the standard RTPF coil, several options have been utilised. These include use of pre-coated aluminium fins to insulate the dissimilar aluminium and copper metals from one another; epoxy-coated aluminium fin/copper tube coils isolating the dissimilar metals from the environment; the use of mono-metal copper fin/copper tube RTPF coils, eliminating the possibility of galvanic corrosion, and the use of epoxy-coated copper tube/copper fin coils. The mono-metal design has the distinct advantage of eliminating the possibility of galvanic corrosion by avoiding the condition of dissimilar metals in contact. However, this design is not a solution for all eventualities, since some environments will attack even the copper metal, producing an undesirable result.

In contrast, the microchannel heat exchanger utilises several aluminium alloys, in combination with a metallic coating, for its construction. The aluminium tube alloy material is initially protected by a metallic layer specifically chosen to be less noble than the tube, fin and braze material, resulting in any initial corrosion occurring on this sacrificial layer. Furthermore, the coil is designed to minimize any remaining galvanic couples so as to provide the maximum life possible for the coil.

Use of the MCHX in areas in which the standard copper tube/aluminium fin RTPF coil design is typically employed will provide superior corrosion resistance. In addition, while

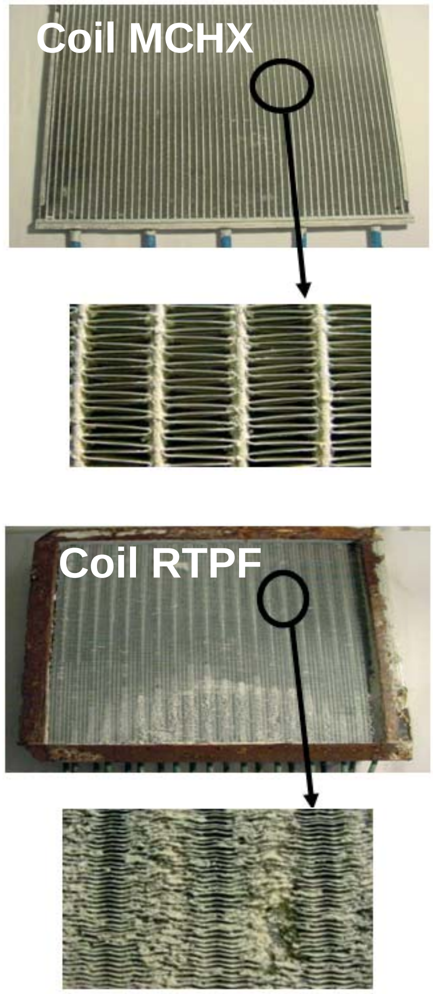


Figure 4 – Resistance to corrosion

RTPF coils are limited to non-corrosive environments, MCHX coils may be applied in mild marine and/or industrial locations. Figure 4 illustrates this point.

Environmental advantages

The superior thermal performance of microchannel coils can result in lower unit power consumption and hence reduced emissions of carbon dioxide from the power generation process. In addition, the refrigerant charge may be reduced by roughly 20 to 40% in a packaged unit application. This reduces the quantity of refrigerant that might potentially accidentally leak from the unit and contribute directly to global warning.

Structural robustness

The utilisation of traditional RTPF coils offers a potential for fin damage during manufacturing, shipping or installation. The protruding, unsupported aluminium fins are easily dented, resulting in an unsightly coil surface. If damage occurs, the aesthetic appearance of the coil surface is difficult to repair.
Because of the nature of the microchannel coil construction, the surface of the coil is extremely rigid and resistant to damage, even when significant impact is made.
In addition to structural resilience, the all-aluminium construction of the microchannel coil provides a significant weight advantage.

Serviceability

The structural rigidity of the coil surface allows pressure washing of the coil, which makes it easier to clean and which can lead to a longer coil life. Furthermore, although the rigidity of the coil makes coil damage or tube rupture less likely, the flat microchannel tubes are easier to repair than the round tube of aluminium fin coils used in the past. Proven and reliable methods, using repair kits and standard materials and tools, are available for field repair of microchannel coils, and provide dependable results.

Conclusions

For air-cooled chillers, when compared to traditional RTPF coils, microchannel heat exchangers offer considerable benefits, including:

- Improved heat transfer and thermal performance
- Increased coil and overall unit efficiencies
- Substantial refrigerant charge reduction
- Reduced coil size
- Enhanced structural robustness
- Increased reliability as a result of better corrosion resistance

Equally importantly, these benefits are obtained with no increase in the cost of the chiller.

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Development trends for heat pump components

Lorenzo Cremaschi, Oklahoma State University

Given the critical importance of energy and cost savings, the application of engineering and management principles has the potential to reshape the design of modern heat pump systems. Microchannel heat exchangers, ejectors, and injection-compressors are some of the latest more interesting developments in heat pump components that boost up the energy performance with respect to the basic heat pump cycle. In this article an overview of the current development trends for heat pump components is discussed and the performance improvement using novel, and sometimes complex and bizarre, heat pump cycles is summarized.

Introduction

A typical U.S. family spends $1,300 year on home energy bills and heating and air conditioning account for about 56% of the energy use [1]. The economic growth in the past decades has promoted the use of reversible heat pumps for cooling and heating space conditioning all year around but the basic heat pump systems are still quite inefficient. The basic vapour compression cycle for heat pump consists of four components: a compressor, an outdoor coil, an expansion device, and an indoor coil. Air-source heat pumps have Coefficient of Performance (COP) in the range of 2 to 4 and a corresponding Seasonal Energy Efficiency Ratio (SEER) of 9 to 13. In practice, what does a COP=3 for heating mean? In simple words it means that a heat pump may use only one-third as much energy as electric resistance heat (electric furnace and baseboards, for example) during mild winter weather. The current U.S. federal government's efforts aim to raise the minimum-efficiency standards for residential-type central air conditioning and heat pumps. Thus, the heat pump industry is looking for innovative design and control strategies to improve the energy efficiency of heat pump systems. From a component technology perspective, there are several ways to increase the energy efficiency with respect to the basic cycle. More sophisticated devices can be added to the basic cycle but often the cost becomes the most critical ingredients for the implementation of non-traditional technology. Ultimately, benefits to the heat pump end customers must be proven and significant through the entire life-cycle of the novel systems in order to justify their commercialization [2].

Body

Three main areas have seen major developments and they will be briefly discussed here: advanced heat exchangers for both small and large scale heat pumps, improved compression techniques, and efficient expansion devices for heat pump systems.

Heat exchangers in modern heat pump systems

In modern heat pump systems, the heat exchangers adopt enhanced heat transfer surfaces for both air and refrigerant sides. Conventional fin-and-tube coils are slowly being replaced by microchannel heat exchangers, which use flat multi port tubes and louvered fin design as shown in Figure 1. These heat exchangers are usually made of Aluminium and they reduce the volume and weight of condensers and evaporators. High overall heat transfer coefficients and large heat transfer area (due to the louvered fins), lead to a compact design while preserving similar or better performance than traditional fin-and-tube coils. Furthermore, the reduced volume minimize the refrigerant inventory, which ultimately lowers the direct contribution of CFC and HCFC refrigerants to global warming [3]. In heat pump applications, microchannel heat exchangers are mounted vertically (see Figure 1) to promote drainage of water vapour condensate in the corrugated fin bends and on the flat tube. While in cooling mode the increase in Energy Efficiency Ratio (EER) is in the range of 6 to 10%, during heating mode the energy per-

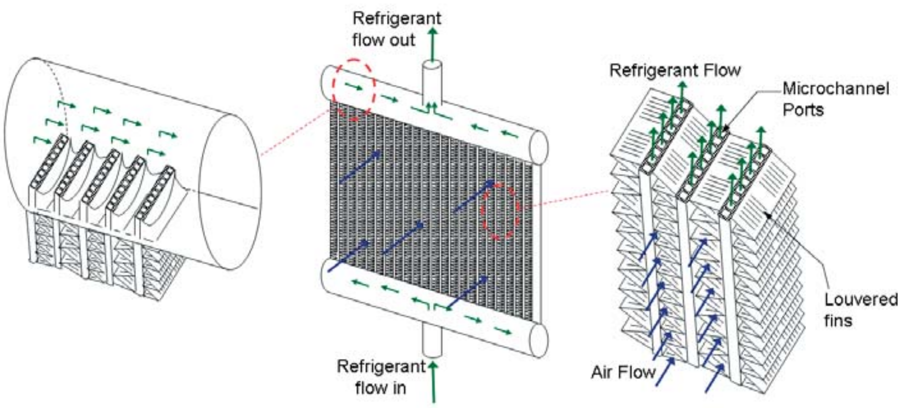


Figure 1: Schematic of a microchannel and louvered fin heat exchanger for heat pump systems

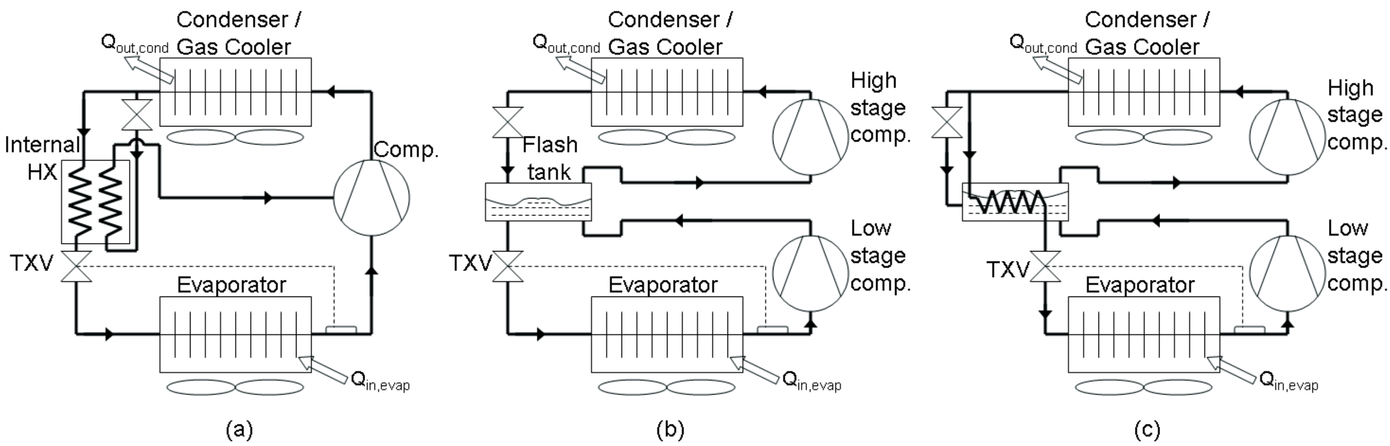


Figure 2: (a) Vapour-injection cycle; (b) flash tank cycle; (c) economizer cycle

formance of heat pump system with microchannel outdoor coils are generally lower due to a higher frequency of defrost cycles [4, 5]. Today, the most common choice is to employ microchannel heat exchangers in indoor coils and enhanced fin-and-tube heat exchangers (such as spine fin, swirl, and twisted tubes) in outdoor coils. This hybrid solution seems to provide higher energy performance both in cooling and heating modes with respect to each single technology used exclusively for both coils of the system.

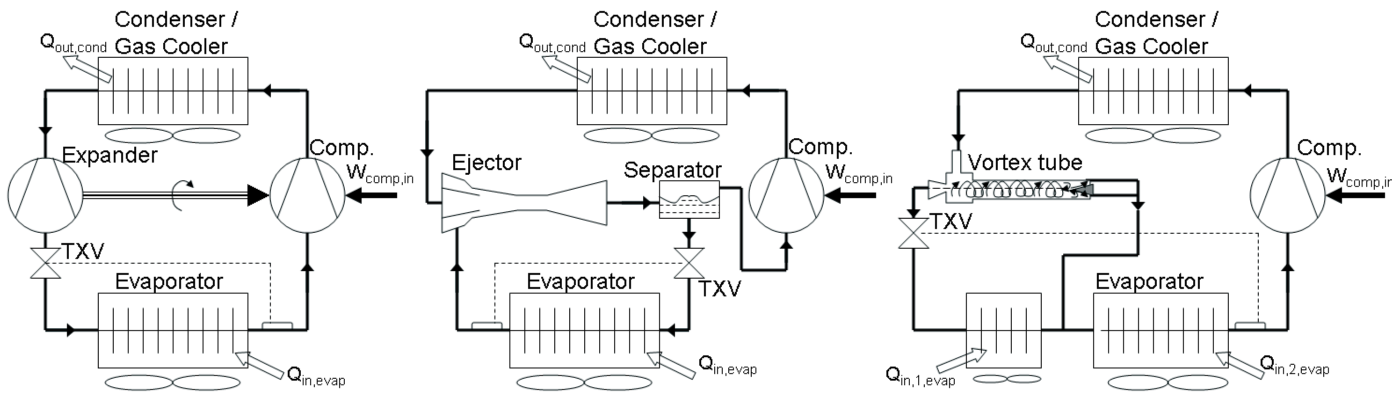
Compressors

Because heat pumps usually operate at elevated pressure ratios in comparison to the conventional air-conditioning installations, opportunities for energy efficiency improvement have been evolved from multi-stage compression techniques traditionally adopted in refrigeration applications, such as injection compressors and economizers. Novel injection techniques, similar to the one shown in Figure 2a, reduce the throttling and pumping losses of conventional vapour injection port design and improve the energy performance of about 5 to 24% with respect to basic heat pump cycle (BHPC) [6]. Heat pump systems with compressor flash-tanks (Figure 2b) are also being investigated by engineers. The heating capacity of these systems decrease along with the lowering the evaporating temperature but the decreasing rate is much slower than that of conventional air source heat pump systems [7]. Economizer cycles are also well-justified for high compression ratios and they benefit the system at very high and low ambient temperatures, provide superior dehumidification, and promote flexibility in multicircuit system configuration. Typical performance improvement of economizer cycles in AC applications (shown schematically in Figure 2c) is in the range of 5 to 8% and multicircuit system configuration offer a reduction in the heat exchanger cost as much as 25% [8].

Expansion devices

The conventional throttling valve is an inexpensive but inefficient device of the basic vapour compression cycle. Control of the heat pump systems is mainly performed by a thermal expansion electronic valve (TEV), which plays a primary role during the dynamic frosting and defrosting periods. Recent work in the engineering community focuses on replacing the throttling valve with expanders, ejectors, vortex tubes, and other work recovery devices that augment the energy efficiency performance with respect to the basic heat pump system. Expanders, which are usually mechanically coupled and integrated within the compressor shell as shown in Figure 3a, recover the expansion work of the gas that flows from high pressure condensers to low pressure evaporators. The benefits of the expanders (screw, scroll, rotary, swing piston, and reciprocating type) depend on their overall efficiency and current prototypes increase the system performance of about 28% (expander efficiency is around 30% max). Swing piston expanders achieve an isentropic efficiency up to 44%, which is one of the highest, and therefore one of the best, efficiency for these devices [9]. Ejectors are devices that use the kinetic energy of the flash gas to increase the suction pressure of the compressor inlet as schematically shown in Figure 3b. Ejectors efficiency depend on the pressure and entrainment ratios and if the working fluid is badly selected, despite having high entrainment ratios, the system might not function properly [10]. Researchers in the field have also proposed to replace the throttling valve by a Ranque-Hilsch vortex tube as shown in Figure 3c. The vortex tube makes use of an effect known as the Ranque effect and it has no moving parts. If a high-pressure gas is injected tangentially into a tube, a vortex is formed and the gas at the center of the tube is at a lower temperature and pressure than the gas near the tube wall. The gas can be extracted separately from these two regions, yielding heated or cooled gas. Hybrid compressors, refrigerant ejector cycles, and vortex tubes are still not widespread in the engineering community and more research needs to be done on these technologies to pioneer them into the next generation of heat pump systems.

A summary of the energy efficiency performance improvement for novel heat pump cycles is shown in Figure 4. In this figure, subcooling cycles, such as the ones that employ liquid-line/suction-line internal heat ex-



(a) (b) (c)

Figure 3: (a) Expander cycle; (b) refrigerant ejector cycle; (c) vortex tube cycle

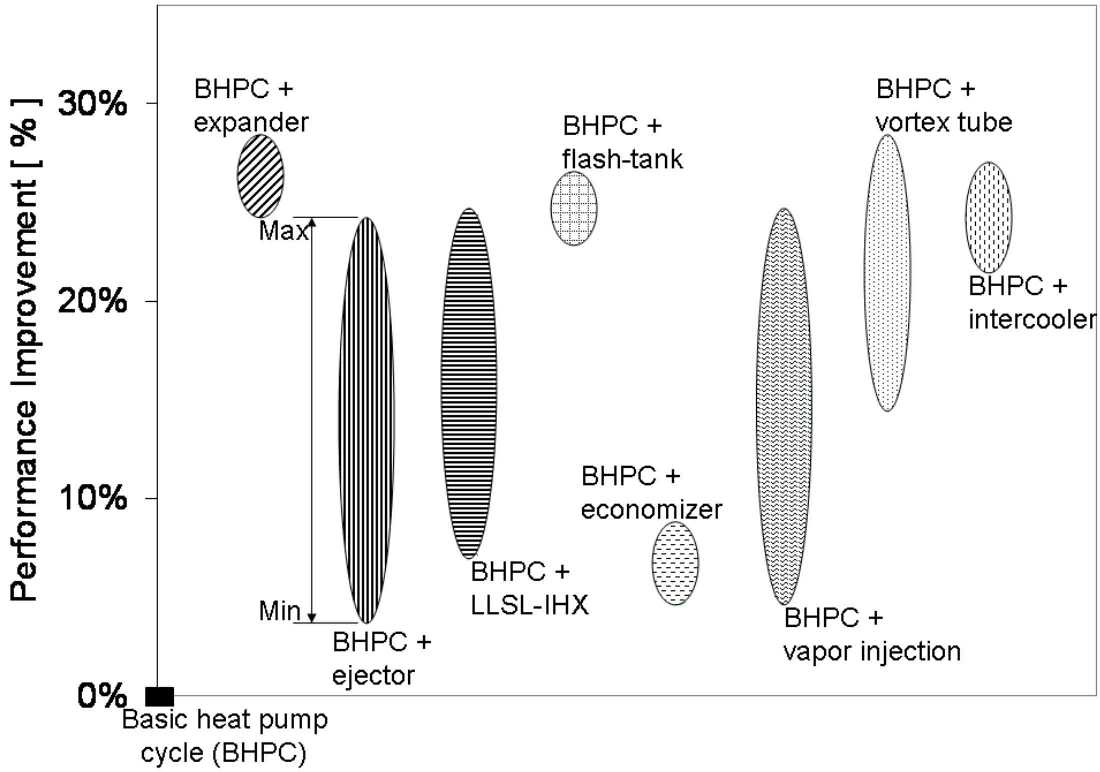


Figure 4: Summary of energy efficiency improvement for novel heat pump cycles

changers (LLSL-IHX), and two-stage compressor with intercooler [11] have been included in the performance comparison. The minimum and maximum coefficient of performance of each technology identify a range of performance improvement with respect to the basic heat pump cycle (BHPC). From the data in the open literature it seems that vortex tubes and expanders are the most promising ones. However, they are also the most expensive technologies and liable to suffer damage because of working with two-phase fluids. Economizers, subcooling cycles, and two-stage compressors with intercooler are the most popular in residential and commercial heat pump systems and their performance improvement range from 5 to 25%.

Conclusions

In recent years, a number of methods have been proposed to improve the energy efficiency of basic heat pump systems. Development trends have focused on three main areas, i.e. enhanced heat exchangers for indoor and outdoor coils, more efficient refrigerant vapour compression for high pressure ratios, and work recovery devices that reduce the expansion process irreversibility characteristic of throttling valves. Microchannel and louvered fins heat exchangers are commonly used in indoor coils while fin-and-tube technology is still the most effective one in outdoor coils operating in the actual service field. Vortex tubes and vapour injection compressors work well in heat pump installations due to relatively high pressure ratio during system operation but their development is in the early stage phase. Expanders seem also to be good candidate for the next generation of heat pump systems because they improve the coefficient of performance as much as 28% with respect to the basic heat pump cycle. However, expanders are still too expensive to justify their implementation in economically sustainable heat pump systems. Economizers and suction line heat exchangers increase the heat pump performance of about 5 to 25% and they are well-known in air-conditioning installations. Because of their popularity, simplicity to incorporate with existing system designs, and relatively low cost, economizers and suction line heat exchangers are likely to be employed as energy performance booster components in the next generation of heat pump systems.

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Compressors for Heat Pumps

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The overall efficiency of a heat pump system is highly dependent on the performance of the compressor. Compressors in heat pumps not only encounter a wider range of operating conditions than in traditional air conditioners, but also have two to three times longer run times per year than compressors for air conditioners [1]. The combination of higher pressure ratios and extended operating times present specific challenges for compressor manufacturers. The proposed solutions to these challenges are the subject of this article.

Introduction

The most significant difference in the demands placed on compressors for heat pumps versus compressors for air conditioners is the range of operating conditions encountered in the different applications. Heat pumps operate over a much wider range of conditions, which can include evaporating temperatures as low as -15°F (-26°C) due to low outdoor air temperatures and condensing temperatures as high as 110°F (43°C) due to restricted air flow over the indoor coil. This extreme condition results in a pressure ratio of 8.6 across the compressor for R-22, while the pressure ratio at standard air conditioning rating conditions (45°F (7°C) evaporating temperature and 130°F (54°C) condensing temperature) is only 3.4 for R-22 [1]. The high pressure ratio has several important consequences for the heat pump compressor, including increased bearing loads that must be accounted for in the bearing and lubrication system design. The increased pressure ratio also results in increased leakage losses because the leakage flow rate is driven by the pressure differential. Similarly, re-expansion losses are more significant because a greater mass of refrigerant is contained in the clearance volumes at a higher pressure. Both leakage and re-expansion decrease the volumetric efficiency of the compressor.

Another important consideration in the design of compressors for heat pumps is the frequent occurrence of part load conditions. While on/off cycling of the heat pump can provide simple, inexpensive control of the system under partial load conditions, it also results in increased wear on the system and inefficient operation during the transient start up and shut down periods. The inefficiency of operating at part load combined with the long operating hours encountered in heat pump applications makes it essential to design a compressor that can operate efficiently and with high reliability at both full load and part load conditions.

Compressor manufacturers have taken several approaches to address these challenges. While some research has focused on designing novel compression or capacity control techniques, other research has focused on improving the efficiency of existing compressor designs through means such as vapour injection. This paper will attempt to summarize the main developments in compressor technology for heat pumps.

Body

While the scroll compressor is now widely used in heat pump applications, the transition from reciprocating to scroll compressors did not become widespread until the 1980's. Bush and Elson [2] analyzed the benefits of scroll compressors over reciprocating compressors in their 1988 paper, starting with a graphical comparison of the efficiencies of rotary, reciprocating, and scroll compressors, which is reproduced in Figure 1. While reciprocating compressors have fewer mechanical losses, Figure 1 illustrates that the continuous compression process of scroll compressors and the absence of valves result in significantly reduced flow and leakage losses in scroll compressors. The low leakage rates in scroll compressors result in high volumetric efficiencies that remain nearly constant over all operating conditions. In contrast, the leakage and re-expansion losses in reciprocating compressors are more significant at higher pressure ratios, as discussed previously, and thus result in reduced volumetric efficiencies at higher pressure ratios.

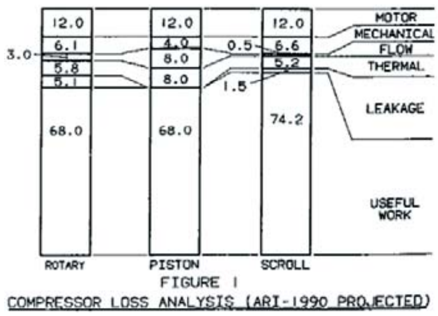

Figure 1. Compressor loss analysis reproduced from reference [1].

Bush and Elson also provide a graphical comparison of the performance of a scroll compressor over a range of conditions to that of a reciprocating compressor with the same capacity at the 95°F (35°C) rating point. This comparison is reprinted in Figure 2, showing that the heat pump with the scroll compressor provides more heating capacity at low ambient temperatures, and thus requires less supplemental heat than the system with a reciprocating compressor. When cooling is required at ambient temperatures below 95°F (35°C) both compressors have excess capacity, but the scroll less so than the reciprocating compressor, resulting in less cycling. Above 95°F

(35°C) the scroll compressor provides more capacity, better meeting the cooling demands of the system.

Other advantages of the scroll compressor are the reduced noise, vibrations, and gas pulsations due to the continuous compression process, and increased reliability due to fewer moving components. The scroll compressor also tolerates liquid refrigerant flooding, especially when a complaint design is used that allows the scrolls to separate in the case of excessive flooding. For this reason, the scroll compressor design can also use liquid or vapour injection to its advantage, as will be described below.

The purpose of incorporating liquid or vapour injection into a scroll compressor is twofold; it has the potential to both increase the efficiency of the overall heat pump system, and also to decrease the discharge temperature of the refrigerant, thereby reducing wear on the compressor and breakdown of lubricants. Figure 3 presents the results of a simulation by Wang et al. [3] to study the effect of refrigerant injection on the efficiency of a scroll compressor. The figure shows how the ratio of the indicated efficiency of the compressor with injection to the indicated efficiency without injection varies with the injection pressure, which represents the point in the scroll at which the refrigerant is injected. The graph shows that, in general, an optimum injection point exists, and that the potential for injection to increase the compressor efficiency is more significant at higher pressure ratios, as might be expected.

While the advantages and disadvantages of the reciprocating compressor and the scroll compressor both with and without refrigerant injection have been discussed, the focus thus far has been on the efficiency of the compressor at a certain operating set point. As mentioned in the introduction, however, heat pump applications require that the compressor not only operate efficiently and reliably under design conditions, but also over a wide range of conditions. When the heat pump capacity exceeds the heating demand, the simplest form of capacity control is on/off control of the compressor. However, the compressor does not operate at its maximum efficiency during start up or shut down, and cycling not only causes variations in the heated space temperature, but also places excessive wear on the compressor.

One very appealing alternative to cycling the compressor on and off is to use variable speed control. This capacity control option matches the system capacity, determined by the speed at which the compression process occurs, to the demand using inverter control of the compressor speed. Particularly in rotary compressors, where leakage contributes significantly to the compressor inefficiencies, benefits can be achieved by operating the compressor at a slower speed. At the slower speed, leakage effects are reduced and the compressor operates more efficiently.

One limitation on the inverter controlled system is the range over which the compressor can operate with low noise and vibration. Particularly with rotary compressors, the operating range can be restricted due to "vibration, noise, and shaft whirling associated with rotational imbalances" [4]. For this reason, the twin rotary compressor, which uses two compression chambers arranged in an angle 180° out of phase, has certain benefits. The balanced rotation of this configuration allows the twin compressor to operate at lower frequencies than its single cylinder counterpart, as shown in Table 1. This comparison of Toshiba's compressors shows that a twin rotary compressor with the same displacement as a single compressor can operate over a significantly wider frequency range.

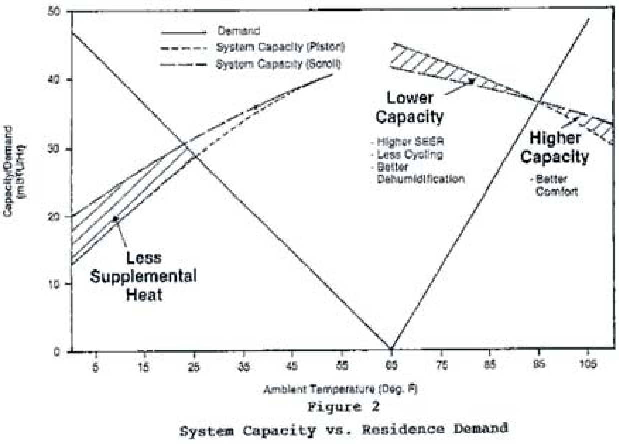

Figure 2. Comparison of system's ability to meet cooling and heating demand with scroll or reciprocating compressor from reference [1].

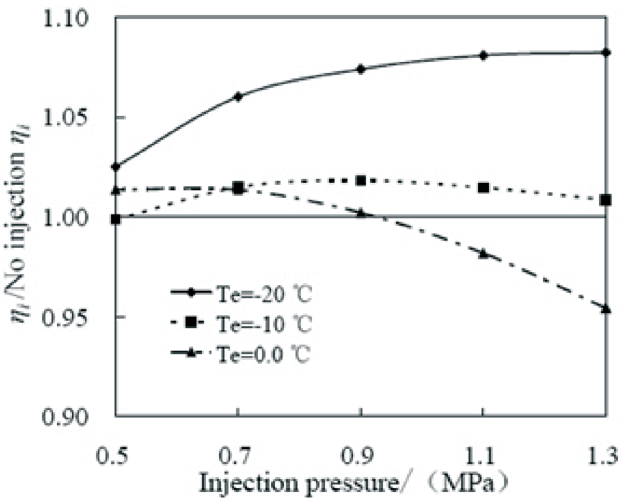

Figure 3. Comparison by Wang et al. [3] of scroll compressor indicated efficiency with injection to efficiency without injection.

Specifications for compressor

Specification	Twin-rotary compressor	Single-rotary compressor
Cylinder diameter ×Stroke (mm)	41×3.5	41×4.0
Number of cylinders	2	1
Displacement(cc/rev)	13.3	13.1
Motor output (w)	750	750
Variable frequency range (rps)	12~150	30~135
Total hight ×Case outside diameter(mm)	272×115	272×115

Table 1. Comparison of single and twin rotary compressor performance by Okoma et al. [4].

The digital scroll compressor is an example of another approach to capacity control that can be applied to heat pump systems. The digital scroll compressor uses a solenoid valve to control the pressure in a modulation chamber [5]. When the solenoid is closed, the modulation chamber is held at discharge pressure, thereby forcing the orbiting scroll into compliance with the fixed scroll. When the solenoid valve is open, the pressure in the modulation chamber is reduced and the orbiting scroll separates from the fixed scroll to unload the compressor. By opening the solenoid valve for specific amounts of time during the compression process, the scroll can operate at anywhere from 10 to 100% of its full capacity. This precise, continuous capacity control is ideal for an application such as heat pumps, which encounter such widely varied conditions. Compared to a traditional air conditioning system, the seasonal energy efficiency ratio of a system with a digital scroll compressor is about 20% higher, corresponding to significant energy savings that would be even greater for a heat pump system [5].

A variable displacement compressor that has lower initial cost than variable speed control has been proposed by Goodnight et al. [6]. For a single cylinder reciprocating compressor, a device has been designed that changes the length of the compression stroke depending on the direction of rotation of the crankshaft. This provides two levels of operation depending on the demand on the system. While the proposed modification to the reciprocating compressor is feasible from a manufacturing prospective, the disadvantage of this configuration is the time required to reverse crankshaft rotation direction, which results in some start up inefficiencies. However, this capacity control solution is still one of many that should be considered for improving the ability of compressors to match the widely varying loads of heat pumps. Goodnight et al. [6] report that a 15% improvement in efficiency can be achieved by installing a variable speed compressor in place of a standard compressor, and the efficiency improvement can be increased to up to 40% when the system components are tailored for operation with a variable speed compressor.

Conclusions

As heat pumps become more widespread and the demand for energy efficient equipment continues to increase, the need for compressor technologies tailored to heat pump applications will continue to grow. While these developments may take the form of novel compression concepts well suited for high pressure or variable speed operations, they may also include modifications of existing compressor designs. One proposed modification that has already proved successful in air conditioner installations is the use of refrigerant injection to improve the efficiency of scroll compressors. Similarly, the potential of the twin rotary compressor to operate efficiently under varying speed conditions was demonstrated.

The use of capacity control will also continue to increase in heat pump applications. While many forms of capacity control are already in use for reciprocating compressors in various applications, new alternatives, such as Goodnight et al. two-step control, may provide the balance of control and cost effectiveness needed for the heat pump application. Another promising form of capacity control is the use of a digital scroll compressor, which can operate at 10 to 100% of its full capacity.

This paper has summarized some of the developments in compressor technology that may find applications in the heat pump industry. With increasing energy conscientiousness pushing greater standards in energy efficiency, optimization of each aspect of the heat pump system, and in particular the compressor, will prove essential in the coming years.

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Trends in next-generation heat exchangers for heat pump systems

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Development of air conditioning products to address environmental and air pollution concerns is now an imperative for the industry. Heat exchangers, which are widely used in room air conditioners, packaged air conditioners, heat pump water heaters and other applications, are one of the most important components and affect the performance, reliability (quality) and cost of the product. This paper, therefore, describes trends in the development of heat exchangers by air conditioning manufacturers, focusing on actual cases.

Introduction

In the air conditioning industry, heat pump systems are mainly used in air conditioners and heat pump water heaters. Figure 1-a) shows the outline of air conditioning products and a system circuit diagram. Figure 1-b) shows a heat pump water heater. "Heat pump water heater" refers to models, such as the Eco-cute, jointly developed by electric power companies and water heater manufacturers. The heat exchanger is the key system component in both air conditioners and water heaters.

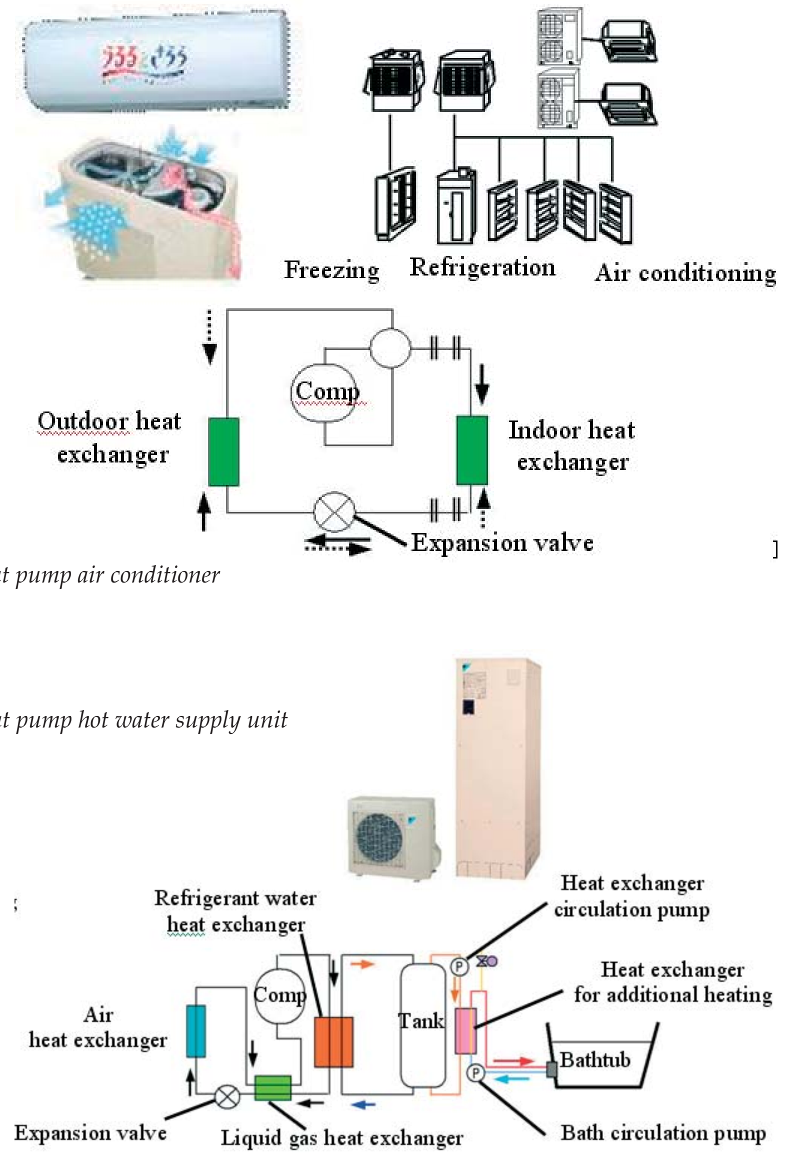
The revised Law Concerning the Rational Use of Energy in Japan requires manufactures of air conditioners to improve the energy efficiency of their products. Development of products incorporating heat exchangers of improved performance is therefore essential, and competition in this field has become fierce in recent years.

This paper examines trends in the development of heat exchangers by air conditioning manufacturers, focusing on actual cases.

Trends in various types of heat exchangers

Heat pump air conditioner

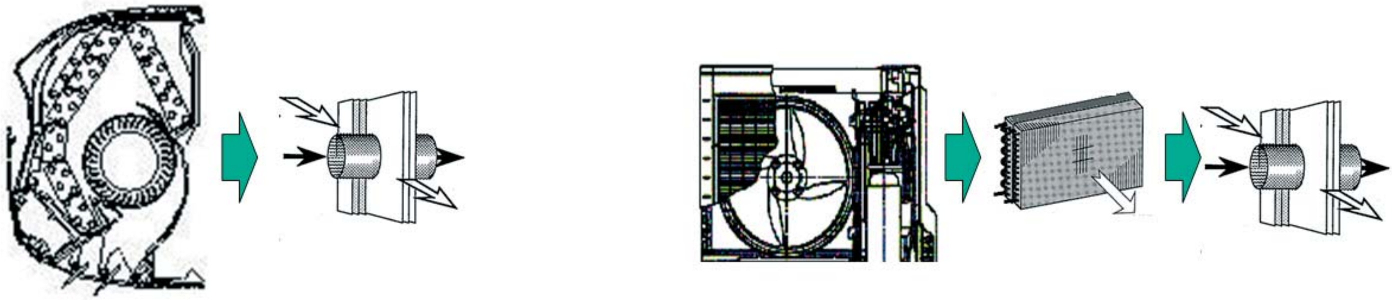
Heat exchangers for air conditioners are roughly categorized into those for indoor units and those for outdoor units. Cross-fin heat exchangers consisting of copper tubes and aluminum fins are under development



a) Heat pump air conditioner

b) Heat pump hot water supply unit

Figure 1: A heat pump system from an air conditioning manufacturer (air conditioner and hot water supply system)



(a) Indoor heat exchanger (b) Outdoor heat exchanger
Figure 2: Air conditioner heat exchanger

separately for both indoor and outdoor units. Those for indoor units are categorized into main heat exchangers and auxiliary heat exchangers. Many recent products are equipped with auxiliary heat exchangers to enhance the performance. Cross-flow fin heat exchangers, shown in Figure 2, are used for air conditioners. Figure 2-a) shows an indoor heat exchanger, and Figure 2-b) shows an outdoor heat exchanger. Heat exchangers are largely divided into two types: those for indoor use and those for outdoor use. They consist of aluminium fins about 0.1 mm thick, and copper pipes 6 to 9.5 mm in diameter. Recent heat exchangers product development is driven by structural design technology to optimize air flow and refrigerant flow, while also considering noise level, water spray at the heat exchanger and heat exchanging performance.

Heat pump water heater (Eco-cute)

The heat source of the Eco-cute works on a principle similar to that of the outdoor unit of an air conditioner, and is categorized as both an air heat exchanger and heat exchanger to heat water. Air heat exchangers are cross-fin heat exchangers like those of the outdoor unit of air conditioners, and exchange heat between a refrigerant and the air as an evaporator. To improve their performance, the shape of the heat exchanger tube and that of the fin must be optimized. A heat exchanger to heat water is designed to heat water through exchange of heat between water and the refrigerant heated by adiabatic compression by a compressor. Various manufacturers have developed their own structures and forms, and are striving to improve their efficiency by expansion of the heat transfer area, optimization of the groove shape, etc. However, problems of clogging due to the structure and water flow speed are a concern.

Technological trends in next-generation heat exchangers for heat pump systems

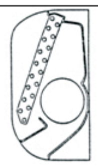
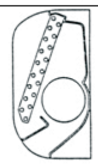
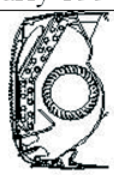
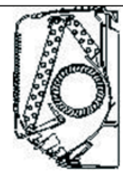
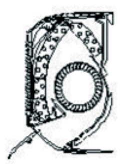
This section examines possible future trends of various heat exchangers for heat pump air conditioners and the Eco-cute, focusing on heat exchangers for room air conditioners and the Eco-cute.

Heat exchangers for air conditioners

Table 1 shows the historical change in the layout of indoor units of representative models of room air conditioners manufactured by Daikin [1]. As the table shows, heat exchangers of indoor units have become larger year by year, and have evolved to the present form, whereby they surround the fan. This has made providing sufficient air passage more difficult, and has complicated the layout of components. Reliability in terms of air flow, noise level and water spray must be taken into consideration. As Table 1 shows, heat exchanger tubes have become thinner, from φ9.52 to φ7, and heat transfer performance has been improved by the adoption of grooved tubes and slit fins. Since 1995, energy efficiency and a compact exterior to enable more flexible installation have become more important, and development efforts have focused on improving efficiency through increased volume of heat exchangers. However, as Table 1 shows, the introduction of multi-stage heat exchangers, starting in 1990, had the effect of changing the layout - with a larger heat exchanger - without having much effect on the volume of the product. Heat exchangers are expected to become more integrated in the future.

Technological development of heat exchanger tubes, fins and their materials, and improvements in performance, reliability and cost are likely to become increasingly important in heat exchangers for air conditioners.

Table 1. Change of layout of indoor units

Year	1970's	1980's	Early 1990's	1993 onwards	1995 onwards	1999 onwards
Structure						
Heat transfer pipe	φ9.52 Flat	φ9.52 Flat	φspiral Trapezoid ditch	φspiral Trapezoid ditch	φspiral Trapezoid ditch	φspiral Trapezoid + slim ditch
Fin	Plate fin	Slit fin	Louver fin	Louver fin	Louver fin	Louver fin

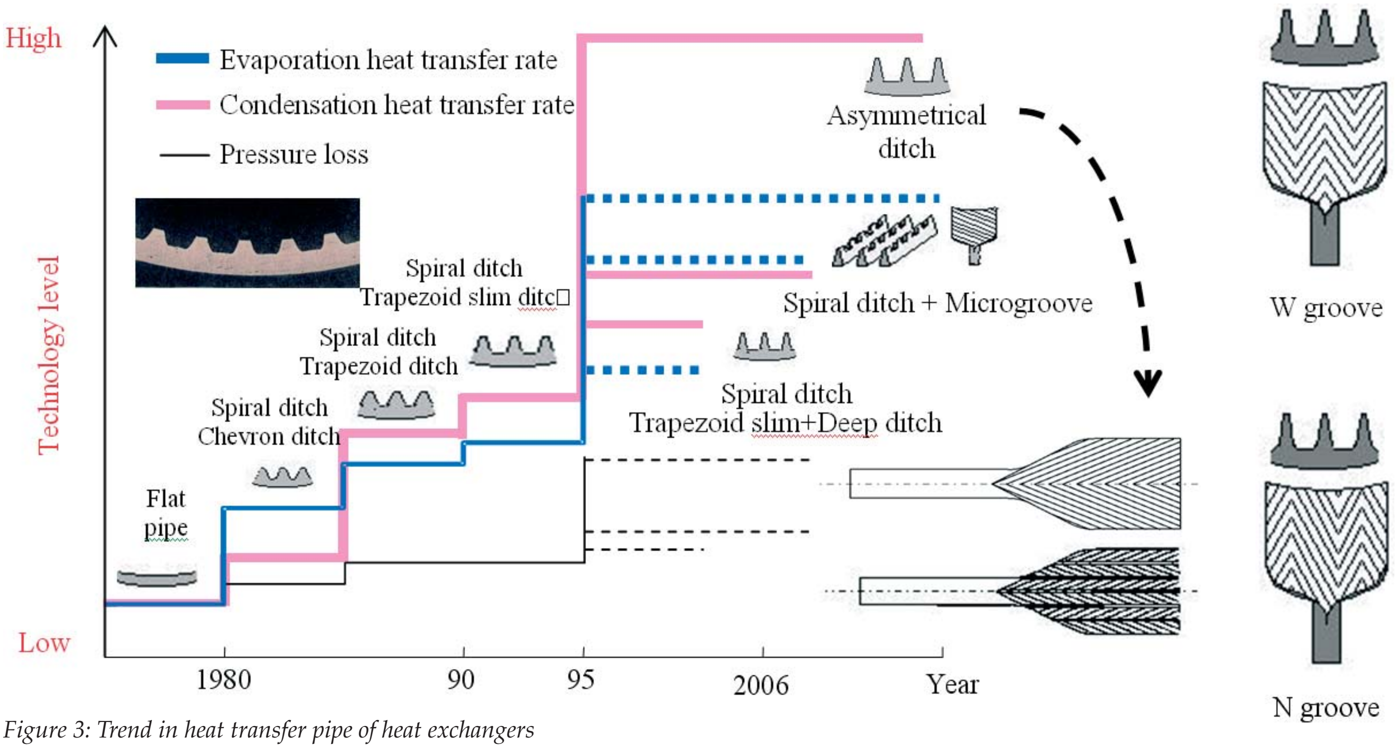


Figure 3: Trend in heat transfer pipe of heat exchangers

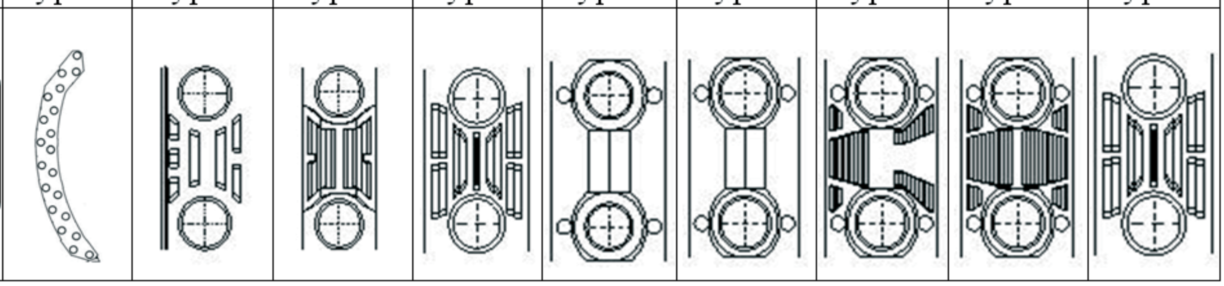
Figure 3 shows the historic change in heat exchanger tubes for air heat exchangers. By 1995, they had evolved from the smooth tubes used before 1980 to tubes with processed (grooved) inner surfaces with improved heat transfer area and characteristics. Improvements in processing and manufacturing technologies have helped further to enhance the heat exchanging performance. Since 1995, and in response to the adoption of substitute refrigerants R410A and R407C, research and development of heat transfer technology and improvements in processing to improve heat transfer and energy efficiency have led to better performance. New shapes of welded pipes, such as those with a W groove or N groove, have been developed to suit the characteristics of specific refrigerants. In the future, further advancement of processing technology to incise the groove is expected further to enhance heat transfer efficiency, but cost may be a concern.

Table 2 also shows the historical change in the fins of air heat exchangers in indoor and outdoor units. Table 2 shows that fins of air heat exchangers of indoor units have become slimmer as the tubes have become thinner, and various slit shapes have been introduced. This has been necessitated by factors other than performance, such as air flow noise and other practical factors, including cost. The shapes of fins of outdoor units have also evolved, due to the need to improve defrost performance during heating operation and to reduce operating noise. In the future, further advancement of overall system optimization is needed, including fin processing technology, cost reduction, optimization of fin pitch, and improvement of tube expanding ratio.

Heat exchangers of heat pump water heater (Eco-cute)

Heat exchangers to heat water are especially important as the next generation of heat exchanger for the Eco-cute. In order to prevent refrigerants and refrigerant machine oil mixing with the water, Daikin's heat exchangers to heat water has a thin tube carrying the CO_2 coiling around the core tube carrying the water, and both tubes are brazed together. The heat transfer coefficient to the water is much smaller than that of the CO_2, so in this type of heat exchanger to heat water, improvement of the heat trans-

Table 2. Trend in heat exchanger fin

Use	Indoor				Outdoor				
Type	Type A	Type B	Type C	Type E	Type A	Type B	Type C	Type D	Type E
Fin shape (Line pace Step pace Fin pace)									

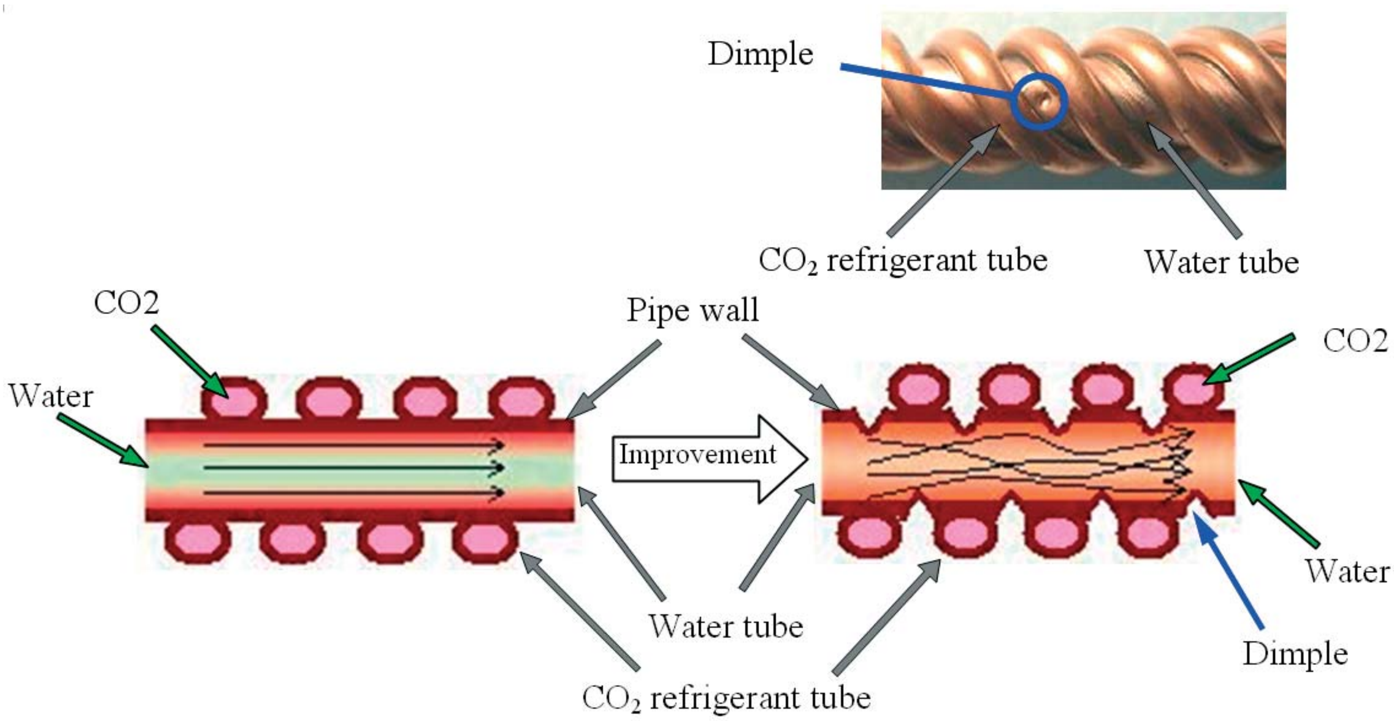


Figure 4: Improvement of a heat transfer rate of a water heat exchanger

fer coefficient to the water is the key to improving performance [2]. In the 2006 model, the water tube is dimpled to promote heat transfer and optimize the flow of water, in order to improve performance. As Figure 4 shows, water in the dimpled tube is turbulent, which results in efficient mixing of high temperature and low temperature water compared with conventional heat exchangers to heat water, in which the water flow is smooth.

Conclusions

The above investigation of development trends in heat exchangers in air conditioning based on actual cases reveals the following key points for future development:

1. Air heat exchangers: more compact, higher performance, lower cost, measures against water spray.
2. Heat exchangers to heat water: higher performance, higher defrost performance, better reliability, more compact, lower cost.

In the future, development of breakthrough technology in performance, practicality, cost, materials and other aspects is needed.

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Packaged Air-Conditioners Suitable for Cold Areas

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Introduction

Annual domestic (Japanese) shipments of packaged air-conditioners were 624,000 in 1999, and reached 808,000 in 2005, showing a favourable increase. Of the shipped packaged air-conditioners, those intended for shops and offices accounted for 81%. However, shipments of packaged air-conditioners for Hokkaido and Tohoku District amounted to over 47,000 in 2005, and are also on the increase recently. Heat pump air-conditioners have been almost inadequate, because their heating capacity is reduced with falling outside air temperature, which requires electric heaters and stoves to supplement the insufficient heating capacity of conventional heat pump air-conditioners.

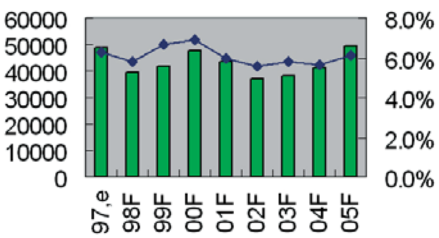

Figure 1. Trend of Industrial Air-Conditioner Shipments to Cold Districts

We have improved the heating performance at low temperatures in extremely cold districts, and have taken measures to protect against freezing for use in cold districts. Further expansion of the market is predicted if electric air conditioning can be introduced in cold districts by introducing air-conditioners that are suitable for use in cold districts. We have therefore developed and released 3-, 4-, 5-, and 6-horsepower (rated cooling capacity of 7.1 kW, 10 kW, 12.5 kW, and 14 kW respectively) air-conditioners for shops and offices in cold districts. We describe the technologies employed in the developed air-conditioners for cold districts below.

2. Elements Necessary for Outdoor Units for Use in Cold Areas

2.1 Technical Issues

The following are the main technical issues for air-conditioners when used in cold areas.

1. Ensuring the heating capacity at a low temperature
2. Extending the outside air temperature heating operation range to the low-temperature side

   Increasing the compressor's compression ratio

   Extending the operating temperature range of electric components
3. Improving the defrosting performance and defrost timing
4. Improving drainage of defrosted water and preventing freezing

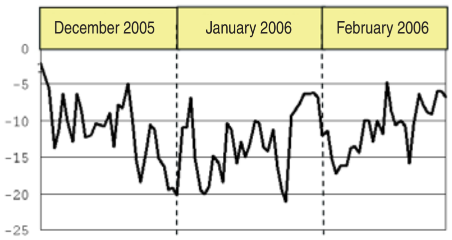

Figure 2. Lowest Temperatures in Asahikawa

Figure 2 shows the lowest temperatures in Asahikawa city in last winter, including days with a lowest temperature of below -20 °C. Therefore, air-conditioners must have adequate heating capacity for use at temperatures down to -20°C, with operation at lower temperatures being guaranteed.1)

We introduce the technologies employed in the type with rated cooling capacity of 12.5 kW (5 h.p.) in the following.

2.2 Ensuring Heating Capacity at a Low Temperature

Ensuringe the necessary heat exchanger capacity at a low temperature is the primary means of improving the heating capacity at low temperature. However, since there are several restrictions on product size, mass, the size of the heat exchanger etc., any measures to improve the heat exchanger performance at low temperature must be done with minimum increase in its size.

The heat exchanger employed in this air-conditioner type has a frontal area about 15 % larger than the normal type to ensure heat exchange performance at a low temperature. In addition, the structure of its components was devised to enhance the heating performance. Figure 3 illustrates the structure.

The heat exchanger has larger refrigerant paths than in the normal type in this class, in order to reduce the pressure loss during heating operation, as well as to ensure a no-frost area at the bottom where temperature is controlled in order to prevent frost formation during heating operation. For the 5-horsepower types, this heat exchanger has 10 paths, as compared to six paths or so for the normal type.

The heat exchanger performance depends on factors that are different in the cooling operation and heating operation. In cooling, the acceleration of heat exchange by flow rate is effective. In heating, pressure loss using the refrigerant flow is effective. Thus the heat exchanger for general air conditioners is designed to provide the necessary performance for both cooling and heating modes. However, outdoor units for cold districts require large heating capacity. Especially at a low temperature, the pressure loss increases due to a large specific volume of refrigerant and the heat exchanger performance correspondingly falls off. In the development of this type, we employed more paths in the heat exchanger than in the conventional equivalent type to reduce the pressure loss.

We also employed a high-static pressure fan that shows characteristics of less airflow reduction even when the airflow resistance rises due to frost formation in cold areas. Figure 4 shows a view of the fan impeller: Figure 5 shows the fan characteristics, where airflow increases as the static pressure increases but without any increase in noise level.

With these improvements, the outdoor heat exchange performance in the heating mode with maximum capacity can be ensured.

In addition, a low-pressure sensor is installed on the low-pressure side for efficient operation at a low temperature. The refrigerating cycle is controlled while constantly monitoring a low pressure with this sensor to fully exercise the power under the operating conditions. With respect to the compressor, a large-capacity DC twin rotary compressor with an air volume of 42 cc was employed to ensure the low-temperature capacity. The rotary compressor has a motor suitable for high-speed operation. Motor speed is increased during operation at a low temperature in order to enhance the performance, but is decreased in a normal temperature range or with a partial load in order to ensure the energy-saving performance.

Furthermore, the rotary compressor generates a suction pressure pulsation which increase the refrigerant circulation turbulence. This will also increase the heating capacity at a low temperature.

2.3 Compression Ratio of the Compressor

In heating operation, the temperature on the high-pressure side determines the discharge temperature to the air-conditioned room, while the temperature on the low-pressure side depends on the outdoor temperature and the outdoor heat exchanger capacity. A certain level of temperature is necessary for comfortable heating.

For this reason, compressors of conventional machines are operated with a high compression ratio at a low temperature in cold districts, which may reduce the operational efficiency, increase the stress on the compressor

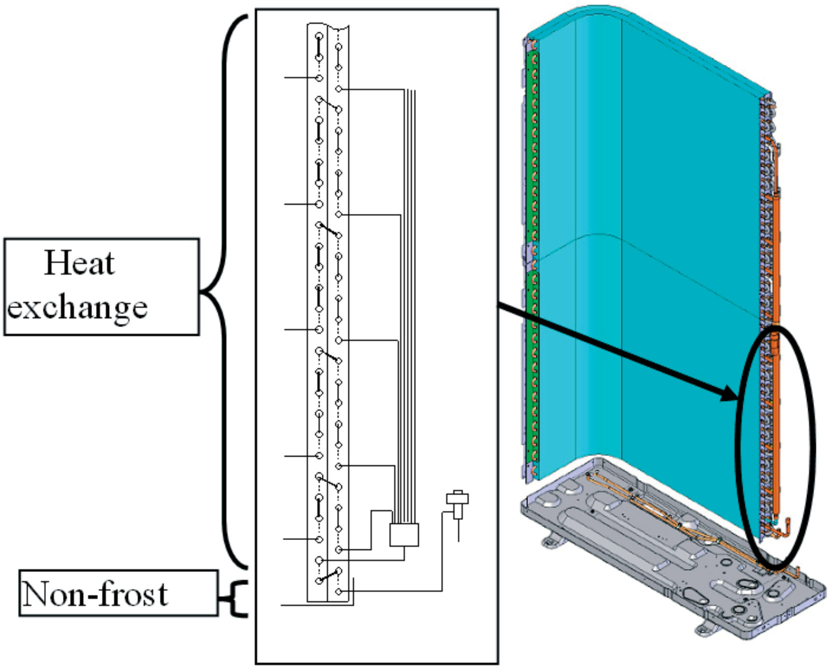

Figure 3. Structure of Heat Exchanger

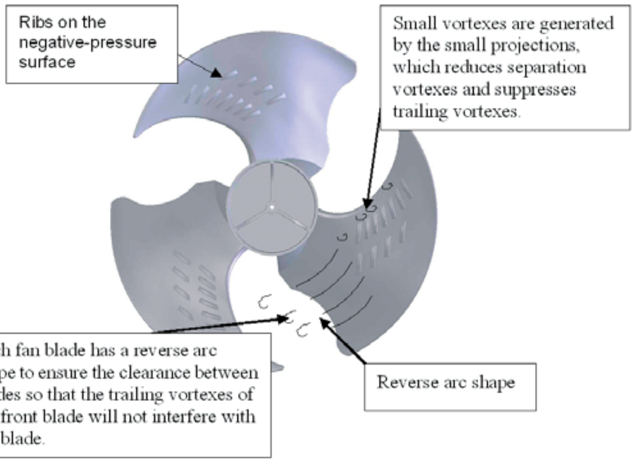

Figure 4. View of High-Static Pressure Fan

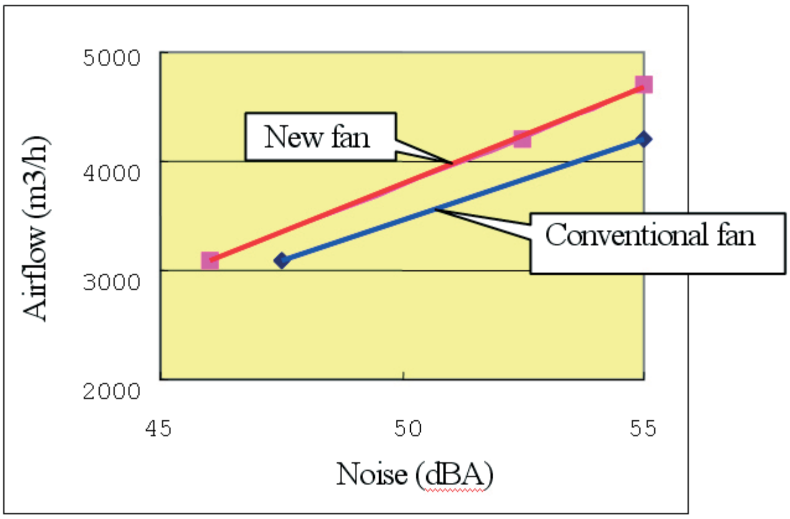

Figure 5 High-Static Pressure Fan Characteristics (Single Fan)

itself, and/or degrade the long-term reliability.

The improvements in the outdoor heat exchanger performance described in Section 2.2 have made it possible to ensure the heating capacity and decrease the compression ratio by operating the low-pressure side at a relatively high temperature even at a low outdoor temperature, which enables efficient operation.
In addition, efficient operation is achieved by controlling the compressor's rotation speed and the refrigerating cycle with a low-pressure sensor that directly measures the low pressure, and with a temperature sensor to detect a high pressure.

With respect to the electric components, an operating temperature range down to -25 °C is guaranteed by several measures, such as by operating a part of the components even while the air conditioner is not working for self-heating in order to maintain the inside temperature higher than the outside air temperature, as well as by selecting bearing grease for the motor and other components for use at a lower temperature.

2.4 Improving the Defrosting Performance and Defrost Timing

The defrosting function is essential for use in cold areas. Since there are significant regional differences in the Japanese climate, the required defrosting performance must also allow for regional differences. Furthermore, for use in cold areas, additional defrosting performance is required in order quickly to recover from performance deterioration due to frost formation.

As a heat source for defrosting, the heat of the pressurized refrigerant immediately before defrosting, and the heat generated through the compressor's power consumption, must be used effectively. To this end, this type employ a circuit to circulate the refrigerant by bypassing the indoor unit to maintain the refrigerant circulation amount during defrosting, this provides a configuration that allows efficient defrosting.

Figure 6 shows a schematic diagram of the refrigerating cycle that features the bypass circuit, including a solenoid valve that opens during defrosting.

If the piping length is long (as for industrial use), the defrosting performance deteriorates due to pressure drop in twice the distance to the indoor unit and to insufficient refrigerant amount. This new type enables efficient defrosting while ensuring the circulation amount. Thus the defrosting time has been reduced by 25 % compared to the conventional type under the same conditions.

The frost formation amount per unit time varies significantly, depending on regional differences, and there ought to be no frost formation at low outdoor temperatures due to the associated low absolute humidity. In actual operation, however, defrosting may occur due to natural phenomena, such as snowfall or rapid temperature/humidity change. Therefore, various studies have been conducted for the defrost timing.

In general, the defrost timing is controlled by monitoring the outdoor heat exchanger temperature or by using a combination of this temperature change and the timer. Another means of control, using the outside air temperature, is also considered. This type includes these controls, but has an additional control to decrease the frequency of defrosting by extending the heating operation time, because the absolute humidity is low and frost formation amount is small under the low-temperature condition.

2.5 Improving Drainage of Defrosted Water and Freeze Prevention

When air-conditioners are used in extremely cold districts, defrosted water often refreezes on the drain pan.

If the refreeze grows, the lower part of the heat exchanger is covered with ice, and then the ice melts. The repetition of this freeze and melting may damage the heat transfer tube at the bottom of the heat exchanger. Measures for this problem are important for use in cold areas. As a solution for this problem, a measure has been taken to maintain a part of the heat transfer tube at the bottom of the heat exchanger at a temperature free from frost formation.

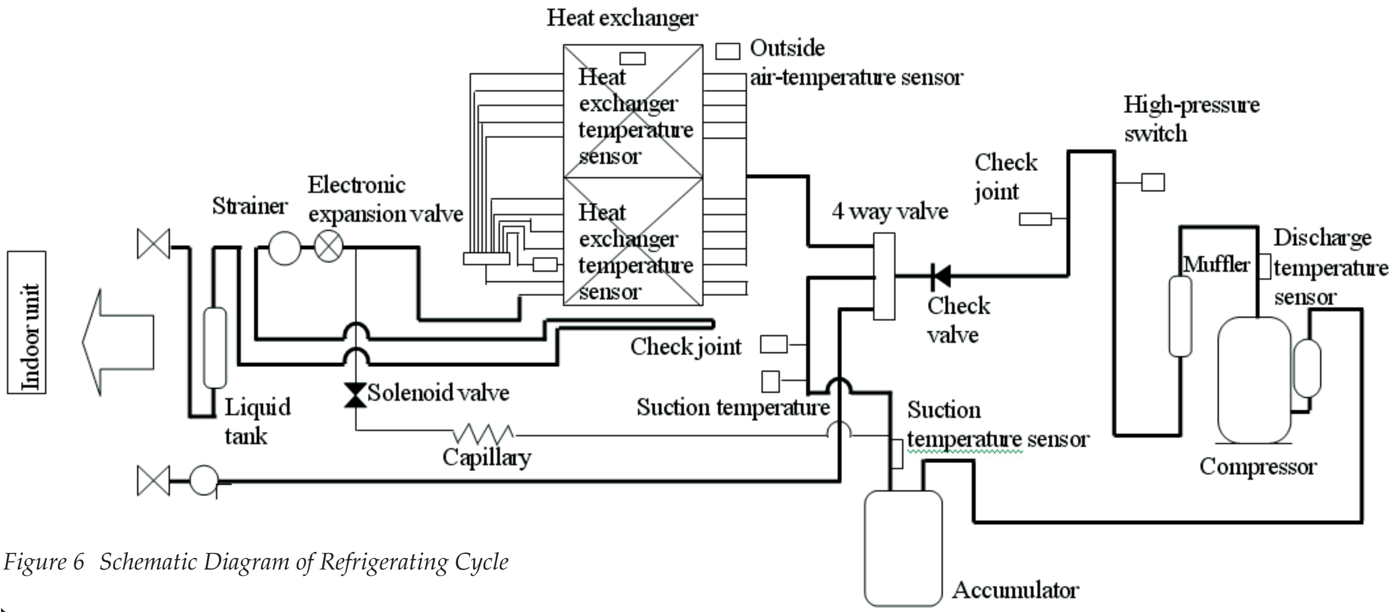

Figure 6 Schematic Diagram of Refrigerating Cycle

This measure has been proved to be effective by field operation results.

However, freezing on the drain pan cannot be prevented only with this measure. Therefore, as shown in figure 6, this type has employed another measure to prevent freezing on the drain pan by laying the warm pipe at condenser outlet near the drain port on the bottom plate of the outdoor unit, which functions as a drain pan in this type.

Figure 7 shows the freeze prevention pipe, and Figure 8 shows a photo of the lower part of the heat exchanger after three weeks' continuous operation at an outside air temperature of -20 °C and high humidity. This photo shows that no frost has formed at the lower part of the heat exchanger, and that drainage is properly performed.

2. 6 Throttle Control

With respect to the throttle control, the superheat is controlled using the compressor suction pressure (with the low-pressure sensor) and the compressor suction temperature (with the suction temperature sensor).

In addition to this, other controls are provided to respond quickly to status changes, including a control to adjust the throttle with a constant based on the amount of rotational speed change if the compressor rotation speed has changed, and a control responding to the discharge temperature, as well as a control to prevent the compressor from overheating.
However, to ensure the heating capacity at a low temperature, a control that is available for the low-temperature operation is also required.
In general, to ensure the heating capacity at a low temperature, more throttle control than usual is needed, and therefore fine control is required. To this end, we consider employing an expansion valve that allows fine control for a slight flow amount, and providing fine throttle control by changing the control constant depending on the situation. Thus this type achieves fine throttle control by adjusting the amount of throttle change at a low temperature.
However, it is essential to respond promptly to the outside air condition in the ever-changing operating environment in order to meet the conditions. As far as throttle control modes for low temperatures are concerned, further studies are required, including examinations of actual operating conditions at sites in detail.

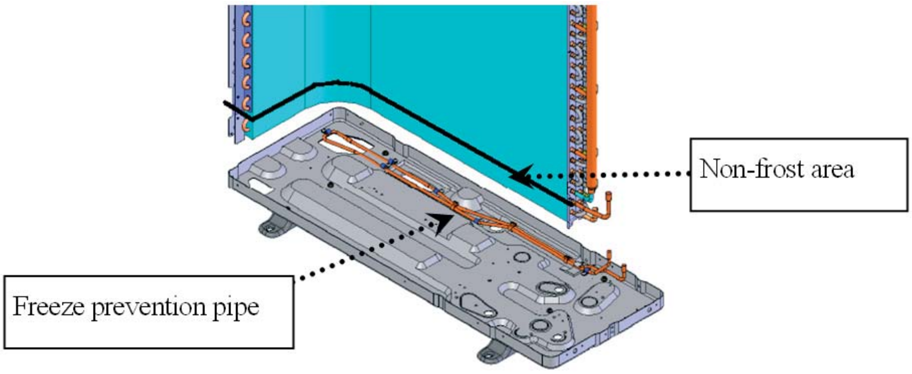

Figure 7 Non-Frost Area and Freeze Prevention Pipe at the Bottom of the Heat Exchanger

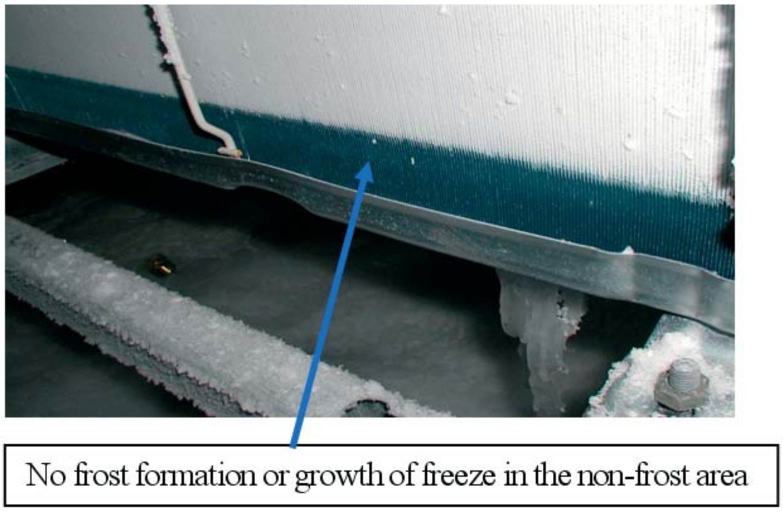

Figure 8 Lower part of the heat exchanger after the 3-week continuous operation at an outside air temperature of -20°C and a high humidity

3. Product Specifications

Two products that employ these technologies were released: one is “Super Power Eco Dantaro” by Toshiba Carrier Corporation, and the other is “Super Tokudan” by Sanyo Electric Co., Ltd.

Table 1 lists the main specifications of these products, including characteristics that show no decrease in the heating capacity until a low temperature of -15 °C. This has been achieved by increasing the maximum compressor speed as the outdoor temperature falls. With this control, the compressor is run at high speed only at low temperatures, where the suction pressure and the power consumption are low. Therefore, the heating capacity at a low outdoor air temperature is ensured when used with the equivalent maximum current as for normal air-conditioner types.

In the development process, we conducted long-term operations under extremely cold conditions and on-site evaluation tests. As part of these operations and tests, we focused on checking phenomena during and after long-term and intermittent operations under extremely cold conditions, as shown in Figure 8, and then reflected the results in the product specifications.

Figure 9 shows the exterior and perspective view of the outdoor unit of the air-conditioner. The internal component layout is designed in the same manner as for conventional types. The fan chamber is partitioned from the machine chamber, the compressor is installed at the bottom of the machine chamber, and electric devices including an inverter are installed at the up-per part of the machine chamber. The fan chamber is designed to ensure effective heat exchange performance.

In addition, a lot of techniques to ensure the reliability in operation at a low temperature are incorporated in the products, such as (1) the adoption of a large-sized accumulator, (2) the activation of the inverter even while the air-conditioner is not working to energize the motor coils of the compressor to maintain the temperature of the inactive compressor and electric components, as a means to prevent the refrigerant from accumulating in the inactive compressor, and (3) the installation of a check valve to the compressor discharge side to prevent the liquid refrigerant from entering the compressor from the heat exchanger.

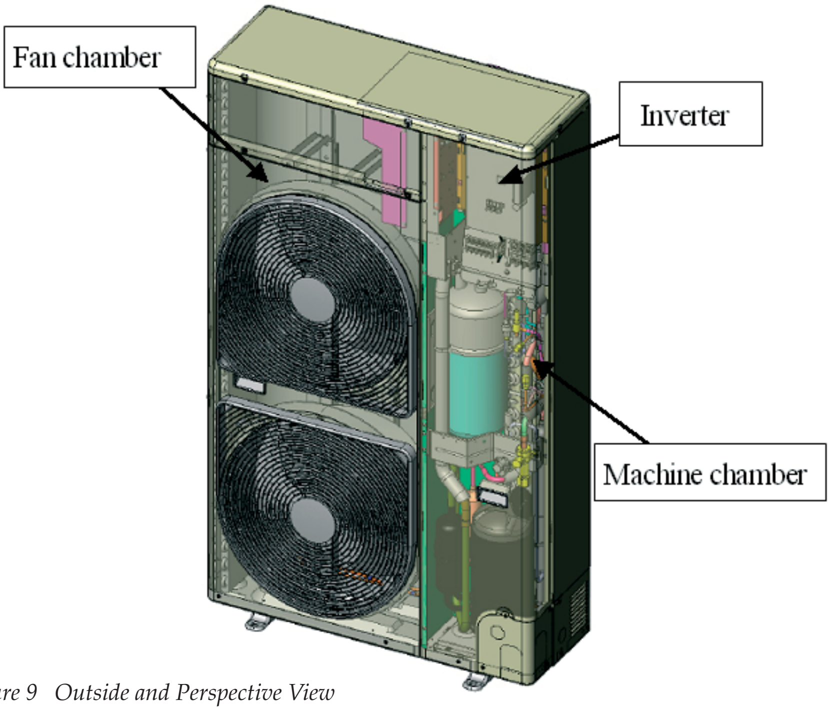

Figure 9 Outside and Perspective View

4. Conclusion

The use of high-efficiency electric heat pump air-conditioners in cold Hokkaido and Tohoku District allows provision of a safer heating means than the commonly used heating from directly burning primary-energy sources, such as oil heaters, and also allows a reduction in CO_2 emissions.

These products are considered to be effective for not only these districts but also for users who requested high heating capacity at a low temperature, and for districts that have problems of defrosting performance due to the high winter humidity. The best feature of these products is that they work efficiently even at a low temperature of -15 °C or -20 °C while exhibiting high heating capacity. We expect the release of these products will increase their use in cold areas.

From the perspective of the environment, energy saving and a reduction in CO_2 emissions are the essential issues. We will continue to contribute to society by supplying air-conditioners with the improved heat pump basic characteristics.

Nobuo KAWAI, Advanced Air-Conditioning Research and Development Center Co., Ltd.
Tooru KUBO, Toshiba Carrier Corporation
Tatsuya TANI, Sanyo Electric Co., Ltd.

Table 1Main Specifications (When Connected to 4-way Air Discharge Cassette Type Indoor Unit)

		3 h.p.	4 h.p.	5 h.p.	6 h.p.
Rated cooling capacity	(kW)	7.1	10.0	12.5	14.0
Rated cooling power consumption	(kW)	1.50	2.28	3.11	3.90
Cooling energy consumption efficiency		4.73	4.39	4.02	3.59
Rated heating capacity at normal temperature	(kW)	8.0	11.2	14.0	16.0
Rated heating power consumption at normal temperature	(kW)	1.81	2.57	3.13	4.00
Heating energy consumption efficiency		4.42	4.36	4.47	4.00
Rated heating capacity at low temperature (outside air temp.: 2 °C)	(kW)	11.5	14.2	16.3	16.8
Rated heating power consumption at low temperature (outside air temp.: 2 °C)	(kW)	4.48	5.25	5.72	5.94
Heating capacity at low temperature (outside air temp.: -15 °C)*1	(kW)	11.5	14.2	16.3	16.8
Heating capacity at low temperature (outside air temp.: -20 °C)*1	(kW)	10.3	12.0	14.3	14.8
Year-round energy consumption efficiency		5.4	5.4	5.3	5.0
Outdoor unit dimensions	(mm)	1340H × 900W × 320D	1540H × 900W × 320D		
Outdoor unit mass	(kg)	95	95	116	116

Reference

1) Japan Meteorological Agency Climatic Statistics data (on the website)

An overview of the industry and the market for heat pumps in Korea

Dr. Seong-ryong Park, KOREA

The heat pump is one of the most effective among technologies for carbon dioxide reduction. Nevertheless, the popularity of heat pumps is not so common because of geographical, economic and technical problems. In Korea during the winter season the ambient temperature is very low (about -5 °C), and electricity is expensive. Direct heating from a boiler costs less than that of a heat pump system. Continuous efforts have been made by researchers for the last decade to overcome these obstacles. Nowadays, heat pumps systems for specified locations such as cold areas, multi-zone and module-based systems with high performance are available in the market. Also, the development of IT (Information Technology) has enabled optimized control techniques to be developed, and the application of heat pump systems has become easier. Government policy favours GSHPs. At present, the heat pump market and industries are quite promising in Korea.

Introduction

The HVAC market of Korea has been expanding for the last three decades. The systems related to HVAC industries have progressed from conventional systems to advanced systems with higher performance, compactness, and easy installation with multi-purpose applications. Among these systems, a heat pump system is regarded as being one of the most effective systems for heating and cooling applications due to its high performance, with multiple functions and moderate operating cost. In addition, heat pumps can use various heat sources such as ambient air, underground water, river water, ground surface water, sea water, exhaust gas, geothermal energy, and so on. As the concerns about global warming problems grow, heat pump systems have attracted attention as an alternative system that can reduce the generation of carbon dioxide. According to statistics for 1997, annual generation of carbon dioxide reached up to 22 billion tons, where 30 % is from indoor air conditioning and 35 % from industrial generation. In other words, 6.6 billion tons of carbon dioxide per year is from indoor air conditioning. Assuming that the heat pump systems supply 20~30 % of indoor air conditioning, the generation of carbon dioxide can be halved by residential and commercial heat pump systems. The minimum reduction from industrial processes is 0.2 billion tons, up to 1.2 billion tons of carbon dioxide if only heat pumps were used. This is about 6 % of the global carbon dioxide production, with the heat pump being the most effective one among those technologies for carbon dioxide reduction. In the current issue, we would like to introduce the market and industry for heat pumps in Korea.

Body

According to statistics from BSRIA/JARN(2002), the HVAC market is worth 34 billion USD worldwide, with the heat pump accounting for 16 billion USD, i.e. 47 % of the market. The United States, China, and Japan are the 1st, 2nd, and 3rd ranked countries in the world market sales, with 64 % of HVAC products and 73 % of heat pumps. In these nine countries of Korea, Italy, Spain, Taiwan, Australia, and France etc, sales reach 76 % of HVAC products and 86 % of heat pumps, respectively

Air source HVAC systems in Korea are mostly classified into two groups: split room air-conditioner (SRAC) and split packaged air-conditioner (SPAC) which accounted for 86 % of HVAC systems in 2005. However, heat pump systems have only 2 % (38 million USD) of market share. The water source heat pump market share is worth 74 million USD, but mostly biased toward gas engine heat pump (GHP) systems for schools and public buildings. Recently, the multi-zone air-conditioning heat pump system market is growing fast by LG Electronics and Samsung Electronics.

Due to the policy by the Korean government of accelerating the utilization of alternative and renewable energy, newly constructed public buildings should employ construction facilities utilizing alternative and renewable energy. Table 2 shows the obligation of public buildings legislated in Feb. 2005 concerning alternative and re-

Table 1. Statistics of heat pump market in Korea (Unit: count, 1,000 USD)*

Year	Money (USD) Electric Heat Pump				Gas Engine Heat Pump			
	Quantity (unit)		Money (USD)		Quantity (unit)		Money (USD)	
	Product	Sale	Product	Sale	Product	Sale	Product	Sale
2003	262	275	4,246	4,171	3,211	17,849	53,578	68,444
2004	N/A	N/A	N/A	N/A	2,555	2,998	90,755	93,169
2005	0	37	0	699	20,897	20,810	37,664	42,292
2006	994	773	8,280	8,142	1,084	9,417	14,296	76,689
Sum	1,256	1,085	12,526	13,012	27,747	51,074	196,293	280,594

**Data based on Korea Refrigeration and Air-Conditioning Association, Aug. 2007.*

newable energy. After the legislation, geothermal energy was preferred from the application point of view, and installation of ground source heat pumps (GSHP) has been increased. GSHP sales increased from 670RT in 2003 to 12,720RT in 2007, as shown in Table 3.

Widespread use of heat pumps has not been achieved yet. Since the average winter temperature in Korea is very low (about -5 °C), and electricity is expensive, direct heating from a boiler costs less than that of a heat pump operation. To overcome these obstacles, continuous efforts are being made by researchers. The heat pumps available now are designed for use in different zones such as, cold area heat pumps, multi-zone heat pumps and module-based heat pumps, and have higher component performance. The rapid development of IT (Information Technology), has enabled development of optimized control techniques, and the application as well as optimization of heat pump systems has become much easier.
The advanced heat pump technology along with the policy on alternative and renewable energy resources will expand the heat pump market in Korea.

Conclusion

In order to spread the advanced heat pump applications widely, the appropriate political support is necessary, in addition to efforts to increase markets. The policy should be employed based on the wide and trusty database from the market and technical history. At present, it is encouraging for Korea to join IEA HPP as a member country, though a bit delayed for its industrial scale. IEA HPP can help the related public welfare organizations, companies, and customers of Korea to identify their roles for the heat pump industry. Eventually, IEA HPP will help the government to employ a policy supporting the social subjects in the background.

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Table 2. Requirement for public buildings to utilise alternative and renewable energy

Directed organization	Newly constructed buildings with floor area exceeding 3,000 m2 by government organization, local government, government-invested organization, and government-funded institutes
Directed building	Public buildings, cultural and conventional facilities, medical centers, sports complexes, social welfare facilities, memorial parks, leisure facilities, hotels and accommodations, recreational facilities, and office buildings
Requirement	Minimum 5% of the total construction cost

Table 3. Total GSHP capacity in Korea

Year	Capacity (RT)
2001	88
2002	207
2003	670
2004	1,768
2005	2,331
2006	7,656
2007	12,720

Table 4a. Capacity of GSHP in terms of users (2005 base)

Category	Capacity (RT)
Residential	39
Public	261
Educational	570
Social welfare	569
Industrial	307
Commercial	243
Others	342
Total	2,331

Table 4b. Capacity of GSHP system in size (2005 base)

Unit capacity (RT)	Capacity (RT)
< 10	68
10~50	186
50~100	920
100~200	857
> 200	300
Total	2,331

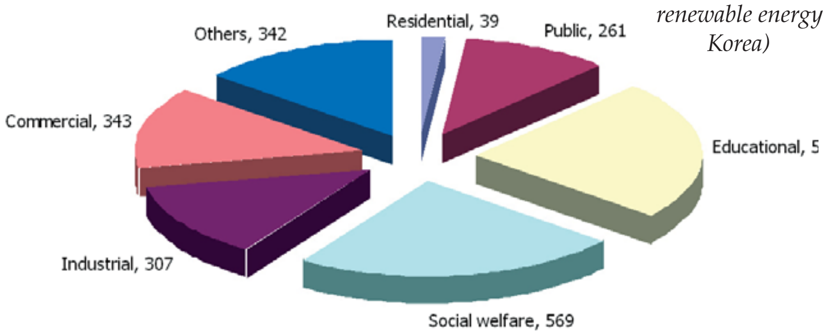

Figure 1. Capacity of GSHP supply in Korea by category (Korea Energy Management Corporation, 2006, "2005 statistics on alternative and renewable energy in Korea)

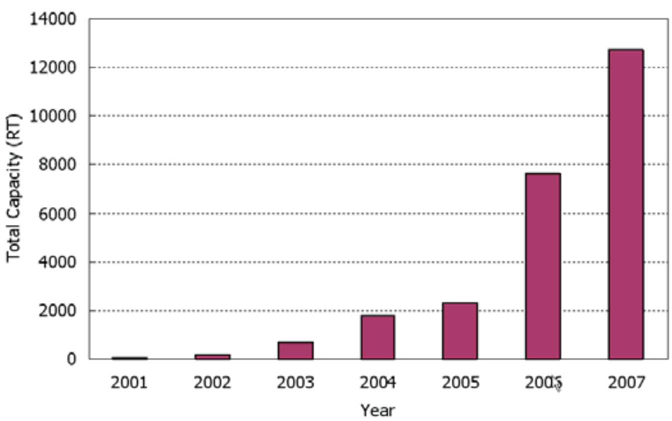

Figure 2. Total capacity of GSHP supply in Korea

To be released on 7 November 2007 by the International Energy Agency: **World Energy Outlook 2007 - China and India insights**

China and India, the world's fastest growing energy markets, are the special focus of the 2007 edition in the award-winning World Energy Outlook (WEO) series. How quickly will demand in these dynamic economies rise? How will it be met? And what impact will their energy choices have on the rest of the world?
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Energy use in the new millennium - Trends in IEA countries
At the Gleneagles Summit in July 2005, G8 leaders identified climate change and securing clean energy and sustainable development as key global challenges. They agreed that we must transform the way we use energy and that we must start now. Improved energy efficiency is essential to meeting this goal. The G8 leaders therefore asked the IEA to provide analysis of energy use and efficiency developments in buildings, appliances, transport and industry.
This publication is a response to the G8 request. Looking back, it shows how changes in energy efficiency, economic structure, income, prices and fuel mix have affected recent trends in energy use and CO_2 emissions in IEA countries. The results are a "wake-up call" for us all.

Since 1990, the rate of energy efficiency improvement in IEA countries has been less than 1 % per year – much lower than in previous decades, and not nearly enough to stem the growth of CO_2 emissions. If we are to tackle climate change and move towards a sustainable energy future then this rate will need to double. We must – and we can – do better!
By means of in-depth energy indicators, Energy use in the new millennium: Trends in IEA countries provides important insights to policy-makers about current energy use and CO_2 emission patterns that will help shape priorities for future action.

ARTI releases new research reports
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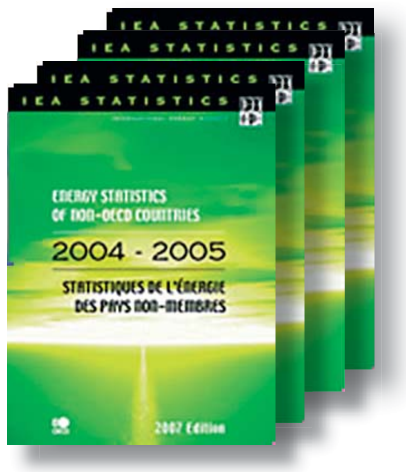
Renewables Information 2007
Renewables Information provides a comprehensive review of historical and current market trends in the OECD. This reference document brings together in one volume essential statistics on renewables and waste energy sources. It therefore provides a strong foundation for policy and market analysis, which in turn can better inform the policy decision process to select policy instruments best suited to meet domestic and international objectives.
Source:www.iea.org

Energy Statistics of Non-OECD Countries, 2004-2005



This volume contains data on energy supply and consumption in original units for coal, oil, gas, electricity, heat, renewables and waste for over 100 non-OECD countries. Historical tables summarise data on production, trade and final consumption. The book includes definition of products and flows and explanatory notes on the individual country data.

In Energy Balances of Non-OECD Countries 2004-2005, the sister volume of this publication, the data are presented as comprehensive energy balances expressed in tonnes of oil equivalent.
2007 Edition, 786 pages, ISBN 978-92-64-02768-8 (paper) 978-92-64-03730-4 (CD-ROM), paper €110, PDF €88, CD-ROM €500 (2007)
Source: www.iea.org

Electricity Information 2007
Electricity Information provides a comprehensive review of historical and current market trends in the OECD electricity sector, including 2006 preliminary data. This reference document brings together in one volume essential statistics on electricity and heat. It therefore provides a strong foundation for policy and market analysis, which in turn can better inform the policy decision process toward selecting policy instruments best suited to meet domestic and international objectives.
Source:www.iea.org

Updated Design Manual Published by ASHRAE
An updated Air-Conditioning Systems Design Manual, which bridges the gap between engineering theory and practical application, is available from ASHRAE. The manual was first published in 1993 to assist entry-level engineers in the design of air-conditioning systems. The update includes new materials dealing with design process, indoor air quality and green design.

"The manual fills the void between theory and practice," Walter Grondzik, P.E., editor of the guide, said. "It bridges the gap between real-world design practices and the

theoretical knowledge acquired in academic courses or textbooks. Such courses and books usually focus on theoretical calculations and procedures – the manual focuses on applications."

Changes to the guide include addition of information regarding:
- The various stages of the design process (conceptual design, schematic design and design development) and the role of HVAC&R systems design in each stage;
- The commissioning process;
- Indoor air quality, now noted as a major design intent for HVAC systems design;
- Green design for HVAC systems in high-performance buildings.

It also uses International System of Units (SI) throughout.

The book is the second in the ASHRAE Professional Series, published jointly by ASHRAE and Butterworth-Heinemann/Elsevier.

The cost of the Air-Conditioning System Design Manual, Second Edition, is $89.95, ($71.95, ASHRAE members).

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2007

ASHRAE's IAQ 2007 - Healthy & Sustainable Buildings
15 - 17 October
Baltimore, Maryland, USA
http://www.ashrae.org/publications/detail/15187

2´nd International Conference SOLAR AIR-CONDITIONING
18 - 19 October
Tarragona, Costa Dorada, Spain
Organisation Commitee:
Das Ostbayerische Technologie-Transfer-Institut (OTTI e.V.)
Regensburg, Germany
Tel: +49 941 29688-29/-37
E-mail: gabriele.struthoff-mueller @ otti.de
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SMACNA Annual Convention
21 - 25 October
Las Vegas, Nervada, USA
http://www.smacna.org/

The 6th International Conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings - IAQVEC 2007
28 - 31 October
Sendai, Japan
iaqvec2007 @ sabine.pln.archi.tohoku.ac.jp
www.iaqvec2007.org

20th Anniversary, IGSHPA's Technical Conference and Expo
29 -30 October
IGSHPA - The International Ground Source Heat Pump Association
Oklahoma City, Oklahoma, the USA
www.igshpa.okstate.edu/conf/2007conf.htm

New Ventures in Freeze-drying
7 - 9 November
l.rey @ aerial-crt.com
Fax: +33 (0)3 8819 1520
http://www.aerial-crt.com

ARI Annual Meeting
10 - 13 November
www.ari.org

Deutsche Kälte-Klima-Tagung 2007
21 - 23 November
Hannover, Germany
www.dkv.org/dkv-tagung_2007.htm

IOR Annual Conference
29 November
The British Institute of Refrigeration
www.ior.org.uk

2008

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

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

Interclima
5 - 8 February
Paris, France

HVAC& R Japan
12 - 15 February
Tokyo, Japan

ACREX 2009
15 - 17 February
Bangalore, India

In the next Issue

Combining heat pumps and other technologies

Volume 25 - No. 4/2007

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

IEA Heat Pump Programme

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

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

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

Mission

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

IEA Heat Pump Centre

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

The IEA Heat Pump Centre is operated by

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IEA OECD heat pump centre

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