Vol. 8, No. 2, June 1990

IEA Heat Pump Centre

NEWSLETTER

IEA heat pump centre

Contents

Front Cover
Design by Rosemarie Smith

International Energy Agency
The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme.

A basic aim of the IEA is to foster cooperation among the 21 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources and energy research, development, and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of 42 Implementing Agreements, containing a total of over 80 separate energy RD&D projects. This publication forms one element of this programme.

Editing:
Rosemarie Smith / Lucinda Maclagan
Design & lay-out:
Rosemarie Smith / Bureau van de Manakker, Maastricht
Illustrations:
Bureau van de Manakker, Maastricht.
Printers:
Hamers B.V., Sittard, the Netherlands.

ISSN 0724-7028

Editorial

Nowadays, there is an increasing awareness of the concern about the environment. The potential of heat pumps is being rediscovered and becoming an important issue for discussion. Heat pumps were placed in the limelight for four days at the 3rd IEA Heat Pump Conference in Tokyo. The conference underlined the potential heat pumps have for solving energy and environmental challenges, and it was this fact that attracted many participants from all over the world. There was such an enormous response in papers being submitted, that, for the first time, a poster session was also organised.

Since the previous conference, held in Orlando, development targets have been reached and many improvements have been made to the heat pump, especially by Japanese companies and organisations. Therefore, Tokyo was an excellent location for an international heat pump community conference.

As very interesting and high quality papers were presented in Tokyo, and we feel that heat pumps deserve great attention, this issue is being devoted to an overview of the papers presented, both at the oral sessions as well as the poster sessions, together with highlights of the presentations given at the conference. Important steps forward in heat pump performance have been made, stressing the energy saving potential of heat pumps, especially in residential and commercial applications. There is growing interest in absorption heat pumps, because these systems use 'friendly' fluids. However, the electric heat pump, is still the most successful type in the space conditioning market and a further growth is expected of these heat pumps, also within Southern Europe. Heating-only heat pumps are still under great pressure. There is belief in heat pumps and the immediate answer they can offer to alleviate the greenhouse problem. It is hoped that the appeal to governments and society to give the heat pump the chance it deserves will be honoured. The Chairman of the Organising Committee, Prof. J. Berghmans, has also contributed his conclusions from the conference, together with the resolution presented at the end of the conference, offering an important message to governments of the participating countries.
Y. Igarashi, from the Heat Pump Technology Center of Japan, has included an excellent summary of the organisational effort that went into the conference, the participants and the sessions held. Most of the papers, including the poster session papers, have been published in the conference proceedings (please refer to the Bibliography section for information on how to obtain a copy).

We hope that, by the 4th IEA Heat Pump Conference, decisive steps will have been taken on heat pumps, and that development will continue and important results achieved in the heat pump field. We also hope that governments and other decision makers will be inspired by the realistic possibilities heat pumps can offer in alleviating the greenhouse problem that the world is likely to face, together with the advantage heat pumps can offer as an efficient energy conservation device.

Jos W.J. Bouma
General Manager HPC

The 3rd IEA Heat Pump Conference 1990 - Tokyo

Review

J.Berghmans
Chairman International Organizing Committee 3rd IEA Heat Pump Conference

The 3rd IEA Heat Pump Conference recently held in Tokyo, Japan, led to a number of conclusions with respect to the progress made in the heat pump field, and thus to present and future application potentials.

Considerable technical progress has been made since the 2nd IEA Heat Pump Conference held in 1987, and in particular, in the area of compression heat pumps for space heating applications. The heat pump market in this area remains strong, but mainly limited to the U.S. and Japan. Other markets have not developed. Considerable interest was expressed, however, at the conference, with respect to the inclusion of heat pumps in industrial total energy systems.

As for the future potential of heat pumps, one should consider the greenhouse effect and the ozone layer depletion problem. The above problems limit the fluids which can be used in heat pumps. During the conference it was proposed that alternative fluids could be found and that only time is required for further investigation of these fluids in order to achieve sufficiently large production levels.

Photo of the 3rd IEA Heat Pump Conference

The potential for energy conservation and for diversification of primary energy sources of heat pumps, however, makes them very suitable to fight the greenhouse and ozone depletion problems. This resulted in participants adopting the following resolution :

Resolution

The participants of the Third IEA Heat Pump Conference, based upon the facts presented during the conference, draw the attention of their governments upon the very large potential of heat pumps with respect to energy conservation and the reduction of the greenhouse effect. Heat pumps are a proven technology in the domestic, commercial, as well as, industrial sectors. Their application could be vastly improved if the non-renewable character and environmental characteristics of primary energy sources were taken into full account.

The participants therefore urge their governments to take the necessary measures in order to promote heat pumps as a part of a comprehensive programme that leads to energy conservation and reduction of harmful atmospheric emissions. They should also be urged to intensify their R&D efforts in order to further improve the performance and application of heat pumps.

As Chairman of the Organizing Committee I would like to express the hope that this conference contributed to international collaboration in the area of heat pumps and thus to a solution against the environmental problems which the world is now facing. □

Organisation

Y. Igarashi, Conference Secretariat,
Heat Pump Technology Center of Japan

General

The 3rd IEA Heat Pump Conference was held at the Meiji Memorial Hall in Tokyo from March 12-15, 1990.

The Executive Committee meeting, held on June 3, 1988, in Rome, decided to set up the 3rd conference, for which the Heat Pump Technology Center of Japan was nominated as the Secretariat. The Organising Committee, composed of 10 representatives who came from the following supporting organisations:

- Energy, Mines and Resources Canada Ottawa, Canada
- Federal Ministry for Research and Technology Bonn, Federal Republic of Germany
- Ministry of International Trade and Industry Tokyo, Japan
- 1990 IEA Heat Pump Conference Organising Committee of Japan, Tokyo, Japan
- Netherlands Agency for Energy and the Environment, Sittard, The Netherlands
- Netherlands Organisation for Applied Scientific Research, Apeldoorn, The Netherlands
- Royal Norwegian Council for Scientific and Industrial Research, Oslo, Norway
- Swedish Council for Building Research, Stockholm, Sweden
- Swedish National Board for Technical Development, Stockholm, Sweden
- Swiss Federal Office of Energy Bern, Switzerland
- U.S. Department of Energy Washington, D.C., USA
- Electric Power Research Institute Palo Alto, USA
- Gas Research Institute Chicago, USA

Agenda

Various pre and post conference site visits were arranged. At the same time, a number of related meetings ran alongside - the Executive Committee Meeting, 7 Annex meetings and workshops, and the International Power Utility Heat Pump Committee Meeting. A reception was also held which was honoured by the presence of invited guests and the Vice Minister of MITI, Mr Saitou.

The number of participants to the conference exceeded initial expectations. Two reasons account for this: firstly, because it was not intended to devote the conference solely to the heat pump technology, but also to the environmental aspects. Non-IEA countries were invited to participate and give presentations as well. Secondly, because many applications for presentations were submitted, which resulted in a poster session being run alongside the oral sessions.

The actual number of registered participants was as follows:

Austria	4
Belgium	3
Canada	7
China	2
Denmark	2
Finland	2
France	9
FR Germany	15
Italy	2
Japan	338
Netherlands	11
Norway	10
South Korea	7
Spain	6
Sweden	16
Switzerland	7
Thailand	1
UK	1
USA	23
Total	466

Sessions

The oral papers (total 45) were presented in eight sessions and each poster session (total 50) with the same topics, was held at the same time, i.e.

I Opening Plenary Session

II Advances in Electric Heat Pumps

III Advances in Thermally Activated Heat Pumps

IV Industrial & District Heating Applications

V Environmental Aspects

VI Operating Experience, Economics & Marketing

VII National R & D Programmes, Governmental & Utility Roles

VIII Closing Plenary Session.

Opening Papers - Session I

G.J.A.M. Meijer

Welcoming Address

Mr M. Iwasa - Chairman of the 3rd IEA Heat Pump Conference Organising Committee of Japan

In his welcoming address, Mr M. Iwasa, stated that, in recent years, general interest in energy conservation and development of alternative energy sources had wained, but that interest in energy efficiency is increasing again because of the environmental problems. A recent Summit conference on global energy resources and environmental preservation concluded that "sustainable development" is necessary. "Sustainable development" refers to a process where the existing energy resources are used as efficiently as possible to make them last longer, and while the global environment and each nation's economic development are maintained, time is gained to develop new non-fossil energy resources and accelerate their commercialization.

Opening Address

Mr M. Sugiura, Director General of the Agency of Industrial Science and Technology of MITI

Mr M. Sugiura referred to the limited oil reserves and to the environmental problems. In 1978 MITI set up the "Moonlight Project" with the aim of promoting technological development for energy conservation. Since then, R&D projects, such as the "Super Heat Pump Energy Accumulation System", have been carried out, achieving substantial success. Since 1974 the IEA has been an important leader in promoting international cooperation, particularly in heat pump technology, where 15 nations are sharing their R&D efforts. Japan also recognizes that international cooperation in R&D is one of the most important means for meeting future energy and environmental challenges, and is committed to take an even more active role than before.

Prospects for International Energy Policy Co-operation

Mr J.P. Ferriter, Deputy Executive Director of the IEA

According to Mr. J.P. Ferriter, there are three main energy policy challenges which have to be faced in the 90s. He reviewed the prospects for international energy policy cooperation. These challenges are: the tightening of oil markets; energy and the environment; and the relations with non-IEA member countries.

- ***Tightening of Oil Markets***

  The use of oil in the OECD countries will concentrate more and more upon transport, while in the developing areas, it will be the motor of energy-intensive industrialization. Oil use for electricity production will decline relative to other energy sources. Assuming gradually rising prices, through the forthcoming decade, IEA projects the oil share in the total world energy market to drop from its current 40% to about 35%. Its volume usage, however, is expected to rise from over the current 3 billion metric tons per annum, to about 4 billion around the turn of the century. The current world excess production capacity for crude oil is estimated to be somewhere between 4 and 5 million barrels per day, whereas ten years ago it was somewhere in excess of 10 million barrels. Significant increases in production capacity are believed to take place in the future, however, amongst others as a result of the prospect of firmer prices. Thus, the IEA does not subscribe to the current pessimistic assessments regarding a third oil price shock as a result of exhausted crude production capacity.

  The evolving oil market situation will require that IEA countries act together to avoid any repetition of the events of the mid and late 70s. The kind of disruptions and dislocations that have to be faced in the 90s may be very different from those of the past. Within OECD, refinery capacity, for example, is being pushed to its limits in North America and Northern Europe. It is thus becoming increasingly difficult to cope with unforeseen refinery shut downs and surges in demand. Also, the present tanker fleet is likely to prove far from sufficient to meet the need to ship supplies of oil.

- ***Energy and the Environment***

  To meet the challenge of energy and the environment, international cooperation will be of vital importance, particularly in the field of R&D. The IEA believes that well-directed international R&D serves three purposes: first, it shortens the lead times for the development of new technologies; secondly, it spreads the risk in capital intensive technology projects; thirdly, internationally

developed technologies can have wider applicability than those developed in a narrow national context.

- ***Relations with Non-IEA Member Countries***

  The development of relations with non-OECD-countries will be of particular importance during the new decade. Half the world's energy consumption now takes place outside the OECD; in 1975 it was only 40 percent.

Conclusions

The IEA concludes that entering the decade of the 90s, the strategic goals remain the same:

- greater diversity in energy options, in particular, away from those sources that have undesirable consequences for energy security and the environment;
- improved efficiency in operation of the energy market;
- improved technology to render a range of energy options more economically acceptable.

"Heat Pumps - An Intelligent Response to the Energy and Environmental Challenge"

Prof. P.E. Frivik -the Norwegian Institute of Technology and Chairman of the Executive Committee of the Implementing Agreement on Advanced Heat Pumps

Prof. P.E. Frivik concluded the opening session with a presentation on the above topic. Below is a summary of his presentation.

Population Growth

One of the important factors to be considered in global energy use is the world population growth from 1 billion in 1800 to 5 billion in 1990, a figure which might level out at 10, or maybe worse, 14 billion, between 2050 and 2100. Growth is expected mainly in the developing world. The industrialized world is expected to stabilize to around 1 to 1.5 billion. The global use of coal, oil and natural gas has increased from 0.25 Gigatons oil equivalent in 1880, to almost 7 Gigatons in 1990.

Greenhouse & Ozone Layer Depletion Effects

The CO_2 concentration in the atmosphere has fluctuated between 235 and 310 ppm since the beginning of the christian era, whereas today the level has reached 335 ppm.

CO_2 accounts for 55% of the greenhouse effect. Its effect is due to the massive amount of CO_2 expelled into the atmosphere. CFCs contribute about 25% to the greenhouse effect and the remaining 20%, is contributed by both N_2O and CH_4, in total. Thus, with respect to environmental problems, CFCs are relevant not only because of their Ozone Depletion Potential, but also because of their Global Warming Potential. Table 1 shows the potentials of some CFCs relative to CFC 11. The proposed regulations in the Federal Republic of Germany foresee a prohibition against the sale of all equipment containing CFCs by 1998, and HCFC-22 by year 2000. Prof. Frivik believes that more attention should be paid to ammonia and propane as alternative refrigerants.

Table 1: Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) for Some Refrigerants

Chemical compound	Lifetime years	ODP	GWP
CFC 11	60	1.0	1.0
CFC 12	120	0.9 - 1.0	2.8 - 3.4
CFC 113	90	0.8 - 0.9	1.3 - 1.4
CFC 114	200	0.6 - 0.8	3.7 - 4.1
CFC 115	400	0.3 - 0.5	7.4 - 7.6
HCFC 22	15.3	0.04 - 0.06	0.32 - 0.37
HFC 134a	15.5	0	0.24 - 0.29
HFC 152a	1.7	0	0.026 - 0.033
NH_3		0	0
C_3H_8		0	0

Co-generation

Another energy efficient technology which has to be taken into account is co-generation. Figure 1 shows the power requirements per unit of heat and the total efficiency for refrigerating and heating. It follows that with respect to temperature lift heat pumps and cogeneration systems are complementary.

Prof. Frivik stressed the importance of international cooperation in the field of heat pumps between the IEA Implementing Agreement and other international and national activities and bodies as shown in Figure 2.

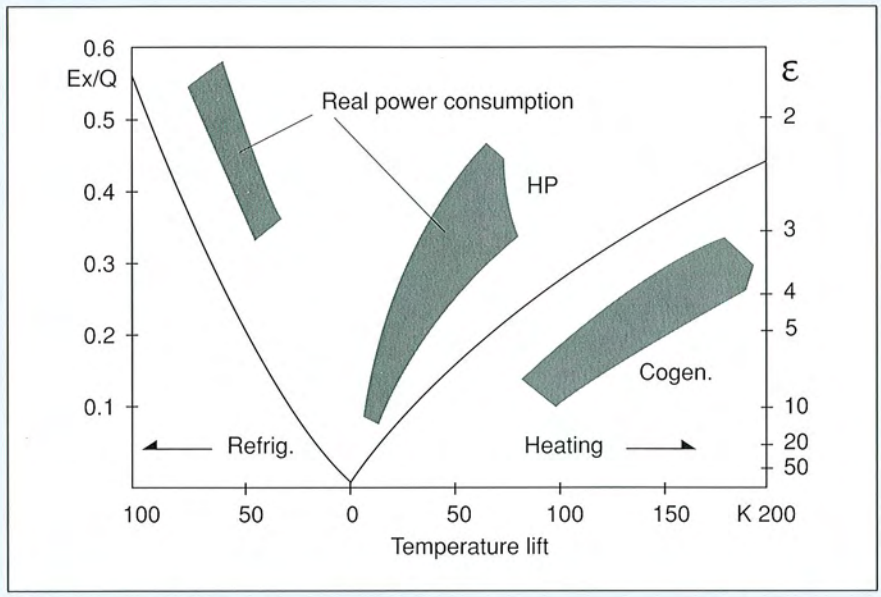

Figure 1: Power Requirements and Efficiency of Refrigeration, Heat Pump and Co-generation Systems

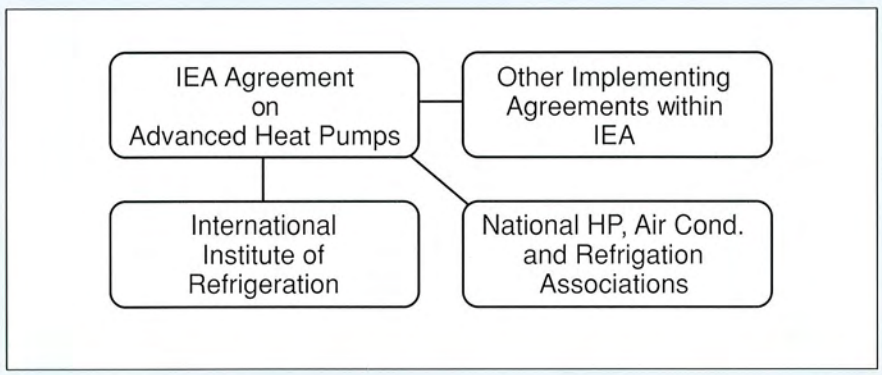

Figure 2: Co-operation between IEA Implementating Agreement on Advanced Heat Pumps and Others

Conclusions

A policy for the near future, with the objective of meeting the energy and environmental challenges, was defined by Prof. Frivik and included the following key political issues:

1. Individuals and society should be informed and educated on the quality of energy and its influence on the environment;

2. The importance of long range planning should be stressed together with a systematic approach to energy and environmental challenges, which should be unrelated to the daily oil price variations and to the payback concept. (For example: the Moonlight project);

3. Young and intelligent people should be encouraged to join heat pump research, development and applications in engineering schools, universities, companies and municipal and governmental offices;

4. Precise and reliable information and knowledge of what present day heat pump systems can do for the individuals, and for the society should be disseminated;

5. The "CFC" image from heat pumps, air conditioning and refrigeration systems should be removed as soon as possible;

6. The COP, SPF or energetic efficiencies of heat pumps should be increased by improving systems and components and by reducing supply temperature levels.

   Targets: at least 100% improvement in efficiency and

COP, SPF	6-8
Exergy efficiency	50%

7. Cost and reliability figures should be improved for small and large heat pumps to the "refrigerator level" and simple and sound constructions on how to integrate and maintain units in a heating system should be provided.

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**G.J.A.M. Meijer, HPC.*

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Advances in Electrical Heat Pumps - Session II

*G.J.A.M. Meijer

Non-Azeotropic Mixtures

Due to the CFC problem the interest for non-azeotropic mixtures as working fluids has increased considerably during recent years, this includes applications with small gliding temperatures. Heat exchanger design, reduction in heat transfer coefficients and change of composition in the case of leakage of fluid, have been considered problem areas in the application of these mixtures.

Based on a study, Chalmers University (Sweden) stressed the proper design of heat exchangers for the application of mixtures. The number of tubes should be chosen in such a way that the combined influence of the velocity on pressure drop and heat transfer coefficient results in a maximum COP. In order to achieve the full thermodynamic advantage with a mixture, the condenser and the evaporator should work in the counter current flow mode. This requirement becomes less important if the gradients are only a few degrees centigrade. Furthermore, it was concluded from leakage calculations that, in practical cases, the influence of fluid leakage on performance is marginal. The consequences of the reduction in heat transfer coefficients relative to pure fluids also seemed to be exaggerated according to the study. COP reductions were calculated to be approx. 5% at the most and even less if the temperature gradients were small. Though there are still some areas of uncertainty, the overall conclusion from the study was that mixtures can compete with both R12 and R134a in performance.

Two papers concerned experimental results on non-azeotropic mixtures. Experiments by Sharp Corporation (Japan) for R13b1/R152a, led to the conclusion that the COP is 20% higher than obtained with R22 for a water-to-water heat pump. The University of Tokyo concluded, on the basis of experimental and theoretical work, that with a mixture of R114/R22, an improvement of 18% in COP can be obtained compared to pure R114, provided that the heat transfer area is large enough.

Compression Absorption Heat Pumps

Compression absorption (hybrid) heat pump cycles which use NH_3/H_2O, can achieve a better performance than single fluid cycle heat pumps according to review by Chalmers University (Sweden) and Capenhurst Electric Research Centre (UK). This is particularly true for high output temperatures. Even for temperature gradients of 5 K, optimized cycles show superior performance over conventional systems. However, many technical problems still have to be overcome, such as design of absorbers and desorbers and a suitable compressor. The latter should either be of the unlubricated type or should use a lubricant that does not foam or form emulsions with water.

A compression absorption heat pump, using waste heat in the form of hot water of a chemical process, and which produces 3.2 bar 135°C steam and hot water, was expected to become operational by the end of February 1990. According to Thermo-Consult Heidelberg (FRG) the payback period is 3 years.

Reciprocating Compressors

In the field of components a new reciprocating compressor for unitary air conditioning and heat pump applications has been developed by Tecumseh Products (USA). The objective of this Quadro-Flex compressor was to

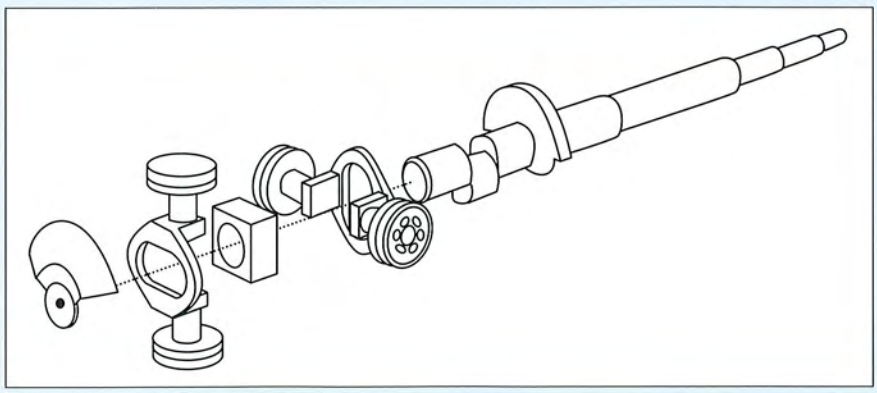

Figure 1: Piston and Counterweight Arrangement for Quadro-Flex

retain the features of conventional reciprocating compressors, such as reliability, adaptability to a wide range of applications, suitability for field erection and reasonable manufacturing costs. At the same time, the compressor should embody the gas dynamics and the vibrational characteristics of rotary compressors. The main features of the new design are:

- The use of 4 pistons separated by 90°, both in time and space, each coplanar pair being powered by a scotch yoke (see Figure 1). This configuration produces an imbalance which can be cancelled out exactly by a single pair of counterweights.
- Improved thermodynamics. The suction gas flows directly into a cavity behind the piston and from there, directly into the compression chamber, through which it passes in a unidirectional way. Thus, pre-compression heat pick-up is minimised.
- Inertia assisted suction valve closing. The inertia forces, due to piston motion, acting on the valve, which is mounted on the piston, give rise to a definite and optimally-timed closing action.
- Improved mechanical efficiency due to the scotch yoke mechanism.
- Variable speed capability since vibrational forces will be minimal.

The performance characteristics, such as low temperature capability and COP, are concluded to be on par with contemporary rotary and scroll designs.

Thermal Storage

Another development deals with a heat pump with thermal storage to enable quick room temperature build-up and defrosting. This inverter-aided room air-conditioner/heat pump was put on the market by Daikin Industries Ltd (Japan) in 1989. Thermal storage consists of phase change material - polyethylene glycol - arranged around the rotary compressor (see Figure 2).

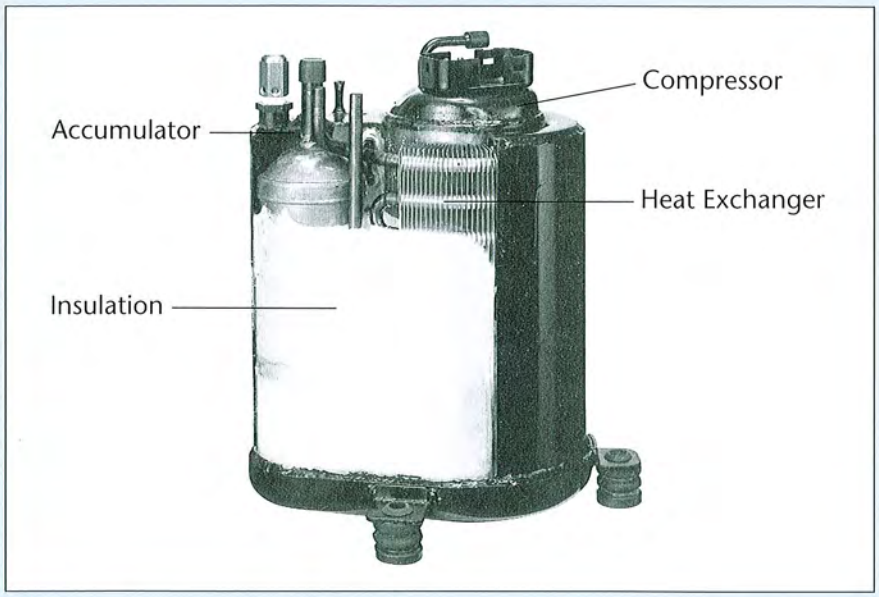

Figure 2: Compressor with Thermal Storage

Heat radiated from the compressor is transferred to the thermal storage by a finned tube heat exchanger. The thermal storage is used during start-up and during defrosting. During start-up a 50% reduction in time required to reach 45°C discharge air temperature is obtained. During defrosting a heating capacity of 3.5 kW is made available by the thermal storage which avoids a drop in room temperature.

Integrated heat capacity was improved by approx. 10% and the integrated COP by 5%. Sound characteristics were also improved. Installation space is the same as for a conventional heat pump/air conditioner.

Ground Source Heat Pumps

A number of papers in the poster session dealt with ground source heat pumps. The Institut für Umwelt Energie und Geotechnik (FRG) has run a test plant at Wezlar since 1985 and computer models have been developed to predict ground temperatures. Vertical heat exchangers with a brine circuit and also direct expansion heat exchangers are being investigated. R&D work, as part of Annex VIII, have led to optimal lay-outs, construction methods and long-term operation. Further work is needed for direct expansion systems. However, the present low fuel prices and high investment costs do not encourage further market penetration in Germany.

Ground temperature measurements and modelling campaigns in Switzerland (Polydynamics Ltd) resulted in an improved understanding of heat transfer phenomena in the ground.

A new anti-freeze solution for ground heat exchangers, based on potassium carbonate in water solutions, and with corrosion-inhibitor, is being investigated at the Royal Institute of Technology (Sweden). This brine has shown to be thermally and environmentally beneficial. The National Research Council of Canada has developed a novel horizontal ground heat exchanger and has run experimental tests. The basic concept was to activate a large mass of soil, employing a "large" (up to 60 cm diameter) spiral heat exchanger made of copper and high density polyethylene. Test results showed excellent performance and also indicated that large potential savings on installation costs are possible. It was concluded that such systems may be more economical than vertical ground source heat pumps in many practical situations.

Heat Pump Modulation

Emerson Electric HVAC/R and Copeland Corporation discussed the application of new technologies to split system heat pumps, in the 2 to 5 tons range (7 to 17.6 kW) for the residential market in the USA. Economically speaking only advanced scroll compressors in the 10 to 13 SEER range (2.9 to 3.8 seasonal COP) will be the most effective. New technologies will be required to provide for cost-effective systems for the higher SEER values. Cost/performance studies show that continuous modulation of air and refrigerant flow, plus step modulation of compressors, will be cost-effective for high efficiency heat pumps in the 1992 time-frame. The addition of continuous modulation of compressors, via an inverter-driven, brushless, permanent magnet motor will ultimately be the most cost-effective approach. However, considerable technology development and volume production are necessary prerequisites. It is projected that by 1996 this technology and the market may have matured. With respect to comfort, independent adjustment of the blower speed by the control system will be an important improvement. Additionally, running the compressor and the blower at low speeds most of the time also dramatically reduces the system's noise level.

Key technologies needed to achieve this are further development of scroll compressors, of brushless permanent magnet motors and, once progress in this field has been made, the availability of low-cost electronics. Although electronics have already been commercialized in high volumes in Japan, and in limited quantities in the USA, costs are still too high for the mass US market.

Control System Hardware

Regarding control system hardware, ECR Technologies Inc (USA) has developed a liquid flow control (LCF) which replaces the expansion valve, and an active charge control (ACC), which replaces the accumulator, while maintaining an optimum refrigerant charge and increased efficiency. The LCF consists of an enclosed liquid/vapour reservoir with a hollow float controlling the outflow from, and the pressure of, the condenser, in such a way, that both sub-cooling of the refrigerant and blow-through of vapour are avoided. The ACC is a thermally insulated reservoir with a central tube in which the vapour from the evaporator enters as depicted in Figure 3. This vapour is mixed with liquid refrigerant, entering the central tube through an orifice. The outlet flow from the tube is deflected, in such a way that droplets fall back into the reservoir. Liquid arriving from the evaporator will be trapped in this way. In the event that superheated vapour enters the central tube, part of the mixed liquid is evaporated bringing more refrigerant into circulation within the system until the evaporator operates again in the non-superheat condition. The system has been tested with ground coupled and air-source heat pumps.

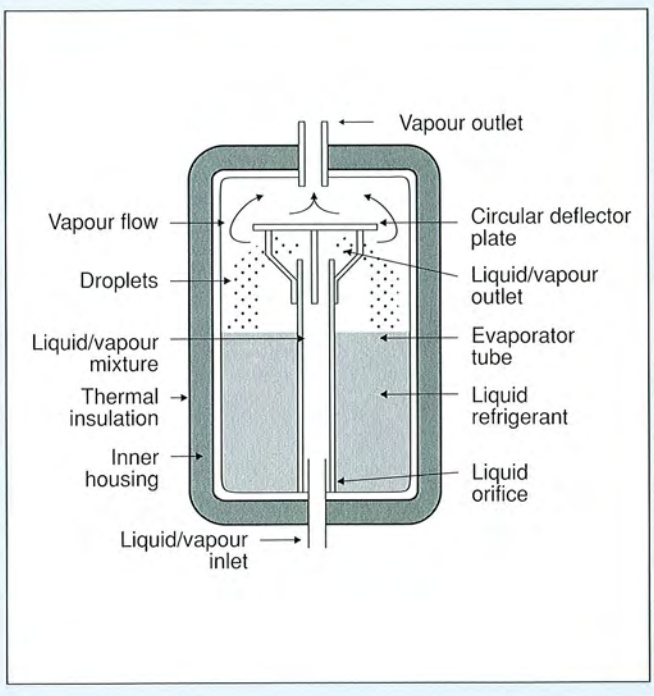

Figure 3: ECR Active Charge Control (ACC)

Design Programmes

With respect to design programmes SINTEF Norway has developed two computer programmes, PROSIM for plant design, and EVAC, for evaporator design. The latter is for calculating tube-in-fin air cooling evaporators which may be flooded, or of the dry expansion type. The programme predictions of overall heat transfer coefficients normally fall within 10% of laboratory measurements.

Summary

The need for CFC substitutes focusses increased attention on non-azeotropic mixtures, the same being true for compressor absorption heat pumps. A new horizontal ground heat exchanger has also been developed, in addition to further attained improved knowledge regarding ground source heat pumps. There are new components on the market which include a new reciprocating compressor and control system hardware which replaces the expansion valves and the accumulator. Furthermore, heat pump modulation appears to be the future development step for split system heat pumps in the residential market in the USA.

Author:
**G.J.A.M. Meijer, HPC.*

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Advances in Thermally Activated Heat Pumps- Session III

* C.B. Colenbrander

Presentations on advances in thermally activated heat pumps placed emphasis on new developments concerning gas-engine driven and absorption heat pumps.

Compression Systems

Gas-Engine Heat Pumps (GHP)

According to Osaka Gas Co. in Japan, the development of reliable and durable gas engines, has reached the stage where replacing the motors of electric-driven compressors of heat pumps/air conditioners, in the range of 5 to 50 kW, by gas-engines, is commercially attractive. The market in Japan is also accepting GHPs much faster than anticipated.

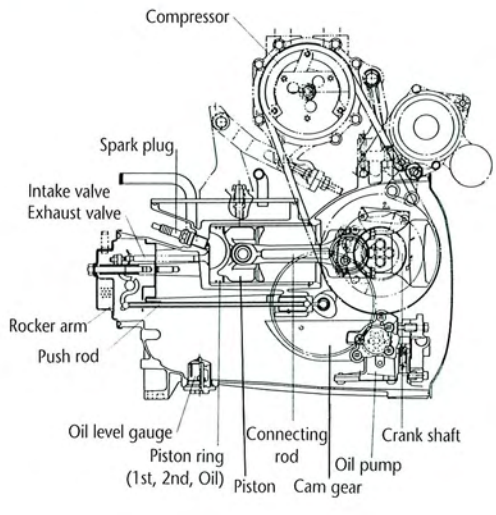
The Association for Gas Engine Heat Pump Systems formed by MITI, Tokyo Gas, Toho Gas and Osaka Gas, began development of GHPs in 1981. The technical problems which had to be solved were manifold and revolved mainly around the gas-engine, since most current GHP gas-engines are actually improved versions of automobile and diesel engines. A total of about 30 improvements were made and consisted of the following:

- improving the durability of the gas-engine by improving the valve system, ignition system and the lubricating system and thereby reducing maintenance costs. The cylinder head and crank case consist of a one-piece casing design in order to minimize costs.
- reducing the noise level by improving the intake/exhaust system and reducing vibrations.
- enhancing the torque/speed characteristics by optimizing the compression ratio and ignition and valve timing.

The enhanced gas-engines now have a 20,000-hour operational lifespan or a 10-year service lifespan. Figure 1 illustrates the gas-engine as developed by Yamaha Motor for the 4.7 kW GHP.

Other improvements to the GHP concerns the mechanical seal of the engine waste heat utilization system, exhaust gas heat exchanger, size reduction, further maintenance reduction by periodic checks and further noise and vibration reduction. With increasing capacity the GHP is still inferior compared to electric heat pumps in relation to volume and weight. Reliability of the GHP was tested in the field by installing about 400 trial units in consumer's houses. Results led to further improvement of the system.

Further enhancements are planned to reduce costs, improve the quality of exhaust gases, in particular, NO_x production, and provide better adaptation to existing air-conditioning systems.



Item	Description	Purpose
One-piece engine casing design	Cylinder head to crank case one-piece design using aluminium die casting.	Cost reduction and durability improvement
Engine-compressor assembly	Assembling the two components together via the common frame, supports the center of gravity with the provided anti-vibration measures.	Vibration reduction
Spherical combustion chamber	Installing the ignition plug at the center of the semi-spherical combustion chamber on the piston side, permits rapid combustion.	High efficiency (30%)
Low oil consumption	Designs the cylinder to be round.	Maintenance intervals lengthen

Figure 1: The GHP Gas-Engine

Control System

The US Gas Research Institute (GRI) and Honeywell Inc. reported on the development of a new control system for GHPs. One of the characteristics of a variable capacity GHP is the availability of recoverable engine heat. The control of this subsystem and other thermal subsystems to simultaneously optimize comfort, efficiency and reliability is, therefore, of prime interest. Both control strategy and prototype control hardware have been developed. Field testing is underway.

Stirling / Vuilleumier Cycles

There is renewed interest in the Vuilleumier and Stirling cycle, due to environmental concern and fuel economy. The same companies, involved in the development of reliable and durable gas-engines, are also investigating the replacement of electric motors by Stirling engines. Tokyo Gas Co., Toho Gas Co. and Aisin Seiki Co. reported on the development of a Stirling engine driving a conventional compressor heat pump. The Vuilleumier cycle circumvents the problem of CFCs. Mitsubishi Electric Corp. and Tokyo Gas Co. reported on a heat pump and air conditioner respectively, using a machine based on the Vuilleumier cycle.

Advanced Absorption

Oak Ridge National Laboratory (ORNL) presented an overview of advanced absorption technology development in the USA. The main topics regarding sorption machinery in the USA are advanced cycle absorption heat pumps/air-conditioners and double and triple effect H_2O/LiBr-absorption chillers and air-conditioners, combined with reduced manufacturing costs. In addition to the primary goal of the DOE sponsored research programme, namely, to conserve energy, benefits such as reduced CO_2 production and elimination of the use of CFCs, are also inherent assets of the absorption machines being investigated in the USA.

Columbia Gas Double-Effect Heat Pump

Following research in the 70's on single-effect absorption heat pumps/air-conditioners, it became clear that commercially attractive units should operate with more advanced cycles.

In the mid 70's, Columbia Gas System Service Corp., started development work on a heat pump/air-conditioner, working with a double effect cycle and with NH_3/NaSCN as the working fluid. In October 1986, the first semi-packaged prototype became operational. Based on a measured cooling COP of 0.8, it was calculated that a residential heat pump/air-conditioner, with a gas-fired COP of 1.7 in heating, and 0.85 in cooling, could be developed. Further development of a cost-effective residential heat pump/ air-conditioner is continuing, and Columbia Gas, is at present looking for a manufacturing partner.

Carrier Advanced Cycle Heat Pump

Carrier has demonstrated the technical feasibility of a dual loop heat pump/air-conditioner with NH_3/H_2O and H_2O/LiBr in the lower and upper loop respectively, with a heating COP of 1.76 at 8.3°C, 1.39 at -8.3°C, and a cooling COP of 1.02 at 35°C. The project has been concluded due to insufficient market potential at current energy prices.

Trane and Phillips Engineering Advanced Cycle Heat Pumps

Trane and Phillips Engineering are both working on a heat pump/air-conditioner based on the GAX-cycle (generator-absorber heat exchange) working with NH_3/H_2O. The unit of Trane is best suited to Northern climates and has a heating and cooling COP of 1.61 and 0.8 respectively. From measurements on a laboratory breadboard prototype it was concluded that the Phillips Engineering unit would have a heating and cooling COP of over 1.9 (8.3°C) and 0.8 (35°C) respectively. As of September 1989 an outdoor unit had accumulated 12,000 hours of operation. At present the Phillips Engineering residential heat pump/air-conditioner is predicted to have a selling price of $2,800 to $3,000 (1989 U.S. dollars).

GRI Advanced Cycle Heat Pumps

In mid 1983 GRI funded Batelle-Columbus Division to develop a dual cycle heat pump/air-conditioner with a 3-ton cooling capacity and a heating and cooling COP of 1.8 and .94 respectively. An integrated laboratory breadboard unit was built in 1985 and the target COPs demonstrated. Although several key components with innovative aspects were successfully demonstrated, the original schedule of large scale evaluation in 1987, with subsequent commercialization in 1989, was not met. Field tests are now scheduled for mid 1990. Some of the absorption technology derived from this project is also used for GRI's double-effect air-conditioner being developed by Batelle-Columbus.

Triple-Effect Chillers

With respect to chillers and air-conditioners, even the best double-effect chiller is not adequate enough to conserve energy compared to high efficiency electric chillers. Furthermore, ORNL has developed a triple effect cycle, which combines the potential of low cost with high efficiency. Figure 2 shows the triple effect cycle. It consists basically of 2 single-effect cycles (the 2 cycles being thermally coupled). Trane has licensed the triple-effect chiller, and together with the participation of GRI, is working on a project to develop triple-effect chillers for 150 tons and larger. The performance goal is to achieve a gas-fired COP of 1.5. Proof-of-concept demonstration is projected for 1991.

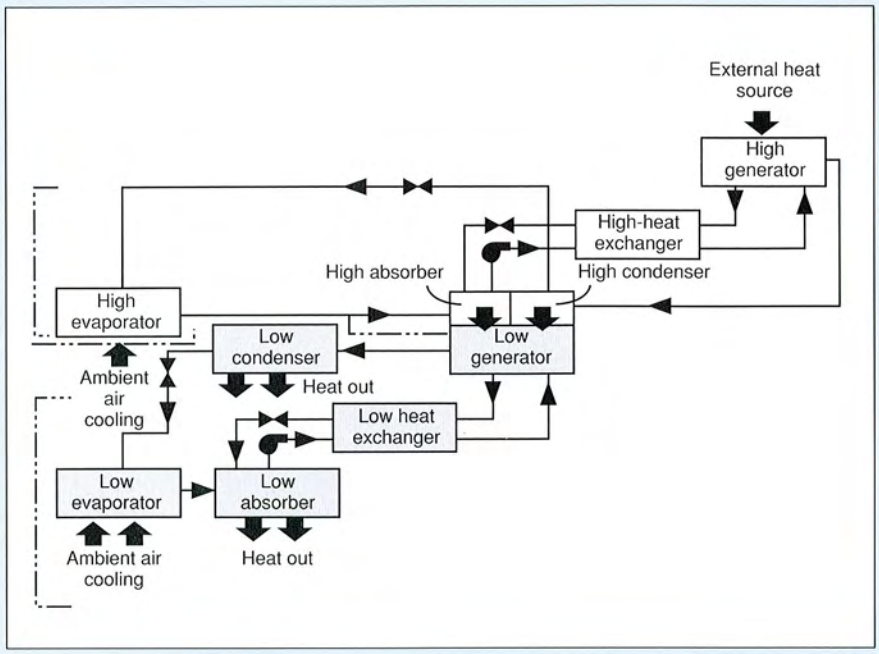


Figure 2: Triple-Effect Cycle

Working Fluids

In Japan the use of NH_3 as a refrigerant in machines for space heating and cooling is forbidden. Research therefore focusses on the use of other working pairs. Tokyo Gas Co. proposed an advanced absorption machine, using air as the heat source/sink. In the cooling mode the machine operates as a double-effect cycle. In the heating mode, the absorber and the evaporator, of the directly heated, high stage cycle, are not used. The high temperature stage operates then as a vapour boiler to provide the heat required for the low temperature stage. The refrigerant from the high temperature condenser is returned to the generator. The working fluid in the high temperature stage is H_2O-LiBr, and R22-DEGDME (dimethyl ether.diethylene glycol) is used in the low temperature stage.

Tokyo University reviews world wide data of working fluids and cycles. They have introduced a new absorption temperature amplifier cycle SRATA (Self Regenerated Absorption Temperature Amplifier). Cycle simulations were carried out for the working pair TFE/E-181. The cycle application should be investigated in the domain of low temperature levels of waste heat and large required temperature boosting values.

The combination of H_2O/LiBr still proves to be the best fluid pair in its range of possible applications as long as corrosion can be controlled. According to a German paper by GEA and the Technical University of Munich, H_2O/LiBr-solution temperatures in heat transformers and chillers should not exceed 150°C to 160°C. A vacuum tight construction, together with a correct combination of materials and corrosion inhibitor, are of utmost importance when using H_2O/LiBr. GEA is working on machines with new working pairs made up of organic compounds. It was stressed that heat pumps and heat transformers in industrial plants should be integrated correctly in order to optimize the potential of energy saving.

Exergy Analysis

A French paper by CNRS-ENSIC-INPL showed that all chemical heat pumps or heat transformers are double exergy converters. Exergy analysis has been applied on a few examples of processes in sorption heat pumps.

Summary

An intensive development programme on gas-engines specially dedicated to driving heat pumps has been carried out in Japan.

Stirling and Vuilleumier cycle and control systems development for gas-engine driven heat pumps is being reported on.

An overview is given of sorption development in the USA. The newest development is a triple-effect absorption chiller.

In Japan, development focusses on working pairs other than NH_3/H_20. Two new cycles are being proposed. The combination of H_20/LiBr is still considered the best fluid pair in its range of application - according to German work - provided that adequate construction and corrosion prevention measures are taken into account.

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Industrial and District Heating Applications - Session IV

*P.J. Collet

Industrial applications of heat pumps are still being negatively influenced by low fossil fuel prices and remain limited to specific applications. The CFC issue has become more of a problem to be reckoned with, but the promise of CO_2 reductions is now considered as an added incentive for heat pump use.

Notable features of district heating applications include the use of heat pumps for both heating and cooling, the application of thermal storage to make use of low off-peak electricity tariffs and greater emphasis being placed on improving energy efficiency.

Industrial Applications

Europe

An overview of industrial heat pump activities in Europe was given by the Fachinformationszentrum Karlsruhe (Federal Republic of Germany). Studies on the present status of industrial heat pump applications in Europe indicate the existence of 850 large heat pumps, with a total heat output of 2.49 GW, and these being, more or less, equally divided between open and closed cycle systems. This number excludes approximately 1000 smaller units used for wood and fish drying purposes. Figure 1 shows a breakdown of the large units, according to the application sector.

In order to improve the market situation and reverse the downward trend in the number of industrial heat pump applications, importance is stressed on the development of high temperature heat pumps (up to 200°C), improvement of knowledge in order to determine optimal applications, and, generally, upgrading the economics and reliability of components and systems.

Japan

With regard to the industrial application of large scale electric motor-driven heat pumps, the Ebara Corporation provides some comparable information on the market status in Japan. About 77 heat pumps are, more or less, equally divided between process, factory air-conditioning and primary industrial applications. Information is provided about the type of compressor being used, and the COP value as a function of heat output and operating temperature conditions. Emphasis is placed upon the utilization of industrial waste heat as a heat source. Approximately 90% of this waste heat is claimed to be at a temperature level below 45°C. Since the heat carrier is usually contaminated water, appropriate heat recovery techniques are being developed which include measures for avoiding corrosion, slime and scale adherence and the removal of foreign bodies.

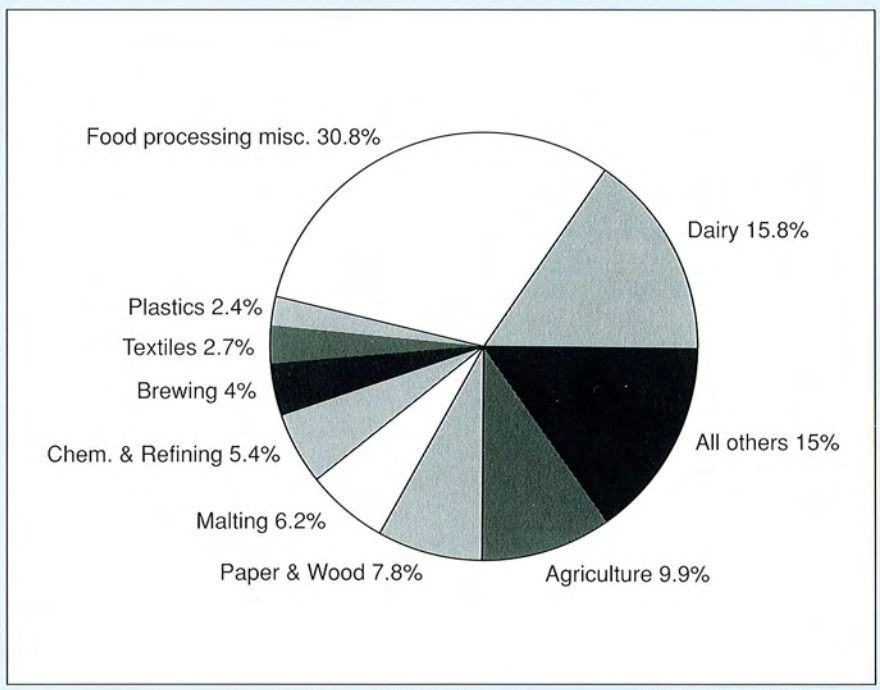

Figure 1: European Industrial Heat Pump Installations by Industrial Sector

Application in Drying Process

The incorporation of heat pumps being used in drying processes is discussed in a paper written by the Technical University of Norway. The application concerns mainly the drying of wood and fish products. In 8 IEA member countries, approximately 1100 units, with a total capacity of 60 MW, represent energy savings of 0.2 TWh/year. The market potential is considered to correspond to 10 TWh/year, representing 30% of the energy consumption for drying purposes. Advantages of the heat pump in lieu of direct-fired heaters, include estimated energy savings of up to 60 - 80%, environmental benefits with regard to elimination of the pungent odour given off by exhaust air and improvement of the drying quality in the case of temperature sensitive materials.

Wood drying by means of a high temperature heat pump is discussed in a paper by the Shanghai Institute of Energy Research (China), and describes a 4 kW compression cycle heat pump with a condensing temperature of 80°C and a COP of 3.8 to 4.6. Test results are given for the above heat pump operating in a furniture mill covering a drying period of one week.

Application in a Distillation Process

The application of a heat pump in a distillation process is described by the National Chemical Laboratory for Industry and the Chemical Technology Research Laboratory of Kobe Steel (Japan). A single compressor maintains a pressure difference between a rectifying and a stripping section that are thermally integrated. This concept is claimed to overcome the disadvantages of conventional heat pump methods and to achieve considerable energy savings. The paper describes the process concept and experimental test results showing the relationship between pressure and other parameters.

Development of Heat Pump with H_2O as Refrigerant

The Technical University of Munich (Federal Republic of Germany) carried out work on a test rig operating with H_2O as the working fluid. Above 110°C, this refrigerant has certain advantages that include high chemical and thermal stability, low cost, being non-hazardous and having a high specific latent heat. However, relatively large suction volumes and high discharge temperatures pose problems: these are counteracted by using a two stage liquid ring compressor, in which a heat transfer oil is used as the ring liquid.

Operating the rig at evaporation temperatures between 81°C to 100°C, and condensing temperatures between 121°C to 139°C, the measured COP is shown to vary from 2.5 to 4.2. These values correspond to between 0.285 and 0.35 of the theoretical Carnot COP.

District Heating Applications

Heat Recovery from Incineration Plant

With regard to district heating applications of heat pumps, a paper by CADDET Sweden describes a process for heat recovery.

The flue gases of the incineration plant are cooled down from 140°C to 40°C by being scrubbed with water. The energy contents of the 40°C water from the scrubber is upgraded in H_2O-LiBr absorption heat pumps i.e. it is used for heating up the district heating water from 60 to 72°C. The absorption heat pumps are driven by 5 bar steam, tapped from a turbine which forms a part of the incineration cogeneration plant.

With regard to energy efficiency, a comparison was made with possible types of heat pumps. The operating experiences are discussed and compared with those of similar plants in Sweden.

DHC Systems in Japan

In Japan the application of heat pumps for district heating purposes usually forms part of a combined heating and cooling system. For a DHC (District Heating Cooling) system, as described by the Tokyo Electric Power Co (Japan), emphasis is placed upon the use of river water as the heat source and heat sink. Preference is shown mainly for water to ambient air because higher energy efficiency can be obtained, together with relatively easy accessibility to the river waterfront. This paper emphasises measures taken to avoid corrosion and fouling of the waterside heat transfer surface. This depends mainly on the selection of materials which minimise the effect of corrosion (seawater replaces riverwater at high tide) and the application of an automatic washer to prevent slime formation on the inner side of the heat exchanger tubes.

Other DHC systems described by the Tokyo Electric Power Company and the Shimizu Corporation (Japan) show similar features. Hot and cold water storage is employed to obtain electricity off peak rate benefits by shifting heat pump operation from day time to night time hours. One such operational plant uses ambient air as a heat source. In another plant which is under construction treated sewage water will be used as the heat source. Other important aspects which should be considered are the heat pump remote-control operation and compactness of the installation.

A combination of heating and cooling and the application of thermal storage are also notable features of a heat pump system when used for an office building, as described by the Tohoku Electric Power Co (Japan). In this case, emphasis is placed upon the

feasibility of using ambient air as a heat source in cold and snowy districts. The measured COP is shown to be around 3 at outdoor dry-bulb temperatures of 6°C to 7°C. Defrosting operation causes a reduction in efficiency of 25%. Applying a thermal storage heat pump is economical due to the night time rate for electricity being one third of the day time rate. The higher cost of the installation is calculated to have a payback period of about 4 years.

DHC System with Decentralised Heat Pumps

A fundamentally different concept concerning heat pumps being used for district heating and cooling is presented by The Norwegian Institute of Technology. Heat is transported to individual buildings at about 20°C to 25°C, allowing the use of inexpensive plastic piping which does not require special insulation. Decentralized heat pumps in each of the buildings provide heating and cooling by using the distributed heat transport medium as the heat source or sink. The low temperature heat supply to the buildings is maintained by a large central heat pump and/or by waste heat injection along the way (Figure 2). The advantages that are claimed for this concept are supported by the results of a fundamental thermodynamic comparison between cogeneration and heat pump processes. These advantages include lower costs for the distribution network and cost advantages obtained by using heat pumps for both heating and cooling purposes. High energy efficiency would be the result of the decentralized heat pumps operating with water as a heat source/sink and producing heat at temperature levels tailored to individual building demands.

Modelling

The State University of Utrecht (Netherlands) proposes using exergy analysis as a means of attempting to optimize heat handling techniques in general. The basic aspects of the theory are explained together with applications on heat pumps. These include the optimization of the energy supply of a sugar plant It was concluded that the use of a heat pump would result in an additional saving of 10% of the exergy use.

More specifically concerning the heat pump is the modelling of the thermo and fluid dynamic behaviour of heat exchangers as part of vapour compression heat pumps. The Technical University of Munich (Federal Republic of Germany) explains the underlying thermo and fluid dynamic relationships and demonstrates the use of a model to determine the COP as a function of evaporator and condenser heat transfer surface areas.

Summary

With respect to industrial heat pumps overviews are given for Europe and Japan. Applications for drying of wood and fish products and in a distillation process are described. In Germany an industrial heat pump using H_20 as the refrigerant is being tested. Above 110°C this refrigerant has a number of advantages.

With respect to district heating applications, a DHC system in combination with heat recovery from an incineration plant district heating systems in Japan using river water, ambient air and sewage water respectively as heat sources and a DHC system with decentralised heat pumps are described.

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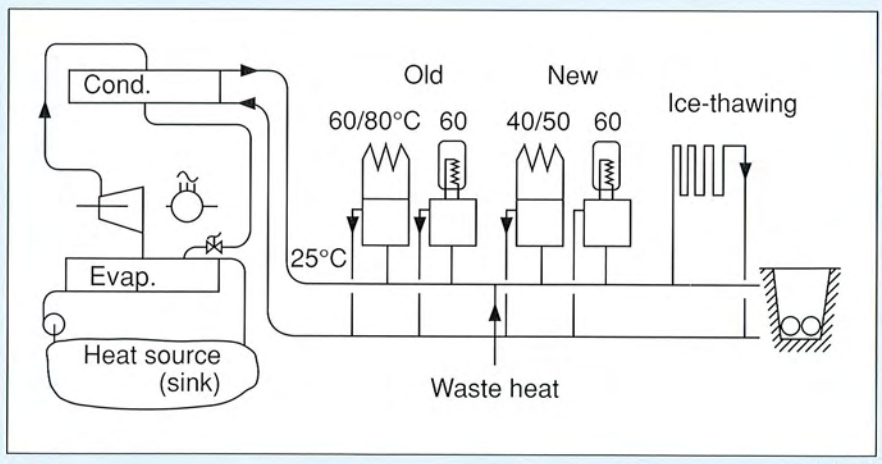

Figure 2: Remote heat source/sink system for decentralised heat pumps.

Environmental Aspects - Session V

* P.E.J. Vermeulen

This session dealt mainly with the CFC issue.

HFC/HCFC Refrigerant Applications

A paper by SINTEF-Norway reviews the position of the new HFC and HCFC refrigerants in relation to different areas of application. To this end, details of thermodynamic properties and resulting cycle performance of R134a and R123 are presented and discussed.

In the field of domestic refrigeration, main candidates for R12 replacement are R134a and the near-azeotropic mixture of R22, R152a and R124. There is a growing interest in inflammable refrigerants, especially in R152a.

Refrigerant R22 is already being used more as the main working fluid in retail refrigeration and industrial refrigeration. R22 is expected to perform a similar role in transport refrigeration, although R134a and R125 may also play a role in this. Comfort air-conditioning systems in buildings use R22 equipment and R11 centrifugal chillers (of the large capacity). R22 is expected to take over part of the centrifugal/R11 market of the medium size type. R123 will replace R11 in these new models which have been especially adapted for R123. R134a is the intended successor for R12 for the new mobile air-conditioning systems, while mixtures may serve a role in servicing existing R12 systems.

Research on New Refrigerants

Two papers review the progress of research on the thermo-physical properties of the new refrigerants. Wakanabe Keio University, Japan and Hannover University, FRG, presented an extensive list of references on thermo-physical property research on environmentally acceptable refrigerants. Knowledge of R134a and R123 has increased significantly in the last two years.

The thermodynamics of both refrigerants are now greatly understood. However, knowledge on transport properties is still limited. The thermo-physical properties of other new refrigerants such as R141b, R124 and mixtures still remain relatively unexplored and more research still needs to be carried out.

The Japanese paper describes the research activities carried out all over the world, while the German paper gives details of the thermo-physical research programme in the Federal Republic of Germany.

Four additional papers dealt with research on specific refrigerants or specific refrigerant mixtures.

Dupont has proposed the use of ternary mixtures based on R22 and R152a, in combination with either R114 as a short-term solution or R124, as a long-term solution. This mixture is proposed to be used for some applications as a drop-in replacement for R12 (servicing of existing units). The ternary mixture (with R124) is recommended for use in domestic refrigeration, especially as a high efficiency alternative for R134a. Data has been presented to show that the mixture is more chemically stable than R12 and that it results in a marginally better performance. Mixtures are also proposed as CFC replacements in compression heat pumps: for example, R123/R141b for high temperature applications, R22/R152a/R124 for residential heat pumps, and R22/R23, R23/R134a or R22/R125 for low temperature heat recovery.

The interest in non-azeotropic refrigerant mixtures has changed to interest in mixtures containing environmentally acceptable refrigerants. A paper by the National Chemical Laboratory for Industry, Japan, presents data on the non-azeotropic mixtures, R134a and R123 as alternatives to the R12/R11 mixture. Basic thermodynamic properties have been studied at the laboratory. It is expected that the R134a/R123 mixture will show a similar performance as the R12/R11 mixture.

Daikin Industries (Japan) presented data on R134a testing in a refrigeration system. When tested at the same cycle temperature, R134a is slightly superior to R12. However, when compared under similar heat source conditions, superior performance is only possible when appropriate lubricants are used. Daikin used DEMNUM S-65, a fluorinated oil. If a mineral oil is used, an oil separator in the circuit is required to prevent a substantial drop in COP and capacity. The paper also addresses CFC replacements for high temperature duties. Pentafluoropropanal is proposed as a replacement to R114 as a working fluid for Rankine cycle heat recovery at temperatures above 200°C.

Since 1984 Electricité de France (EDF) has been working on the use of an inflammable refrigerant, R142b, as a working fluid for industrial heat pumps. The environmental effects of this refrigerant are similar to those of R22 (ODP: 0.06, GWP: 0.29, both relative to R11) and R142b and can, therefore, play a similar role as R22 in bridging the gap between existing ozone-depleting chemicals and future non-depleting chemicals. The paper presents a series of tests in heat pumps of various designs (open recipro-

cating, single screw, compound); up to 12,000 hours running time has been accumulated. These tests show that R142b can be used in industrial heat pumps for temperatures up to 90°C without greatly affecting the compressor efficiency.

Environmental Aspects of Heat Pumps

Papers by Chalmers University, Sweden and Oak Ridge National Laboratory, USA present a general discussion on the environmental aspects of heat pumps. The Swedish paper distinguishes between, firstly, the environmental impact of the equipment as such, secondly, the effects of extracting heat from the environment, and thirdly the environmental effects of using electricity.

The environmental impact of the equipment is caused by high noise levels and by CFC emissions. Many measures are being taken to eliminate CFC emissions, therefore, noise levels especially in larger units are expected to remain a problem. The extraction of heat from the ground or from ground water can cause negative impacts such as thermal influences on vegetation, leaks of anti-freeze fluids or deterioration in water quality. Air-source heat pumps have no other impact except noise and CFC leakage.

The environmental impact of using electricity depends heavily on the specific conditions of local power generation. The paper also presents a qualitative assessment of the environmental benefits of replacing certain methods of heat production by electric heat pumps in relation to the method of electricity generation (see Table 1).

The paper should be referred to for the underlying assumptions because these have a major impact on the resulting qualifications. It was concluded that, compared to heaters based on oil or coal, heat pumps would, in most cases, be beneficial to the environment. The ORNL paper focusses on the analysis of the role of heat pumps in reducing global warming.

Table 1: Outline of the Environmental Benefit of Heat Pumps Replacing Heat Production by Other Methods.

Environmental Benefits / Heat Replaced	Fossil Power			Water Power; nuclear		
	Local	Regional	Global	Local	Regional	Global
Oil, coal	+	+	O	+	+	++
Natural gas	O	O	O	O	O	+
Bio-fuels	++	O	-	++	O	O
Electric	-	++	++	-	+	O
Waste heat	-	-	-	O	-	O
Solar heat	O	-	-	O	-	O

Between 1967 and 1987, the world CO_2 emission associated with primary energy use, has increased from 3.3 to 5.5 gigatons of carbon per year. Strategic planning studies in the USA, Japan and Europe, indicate that there is no singular or clearly superior energy source technology which can solve this problem. The paper concludes that the best short to mid-term strategy for moderating the growth of CO_2 emissions is to increase the efficiency of energy use. Here, both advanced electric heat pumps and thermally activated heat pumps, are shown to be able to play an important role.

Current electric heat pumps use CFCs as refrigerants. CFC molecules are much more effective (i.e. 10,000 times) than CO_2, molecules in trapping heat in the atmosphere. Also, the rate of increase of atmospheric concentrations of CFCs is about 20 times that of CO_2 so the contribution of CFCs to the global greenhouse effect is steadily increasing. Because of their role in the dilution of the ozone layer, CFCs will be replaced by HFC and HCFC refrigerants. Although the Greenhouse potential of many of these new refrigerants is reduced when compared to CFCs, there remains a substantial uncertainty about what value of Greenhouse Potential will be "acceptable". There is therefore, a trade-off between the direct greenhouse effect from refrigerant emissions and the reduction of greenhouse warming from the increase of energy-use efficiency.

The applications of advanced heat pump technology for increased energy efficiency is also discussed in a paper by the Technical University Munich, FRG. The author has developed a method for comparing the efficiencies of systems combining different end uses such as heat and power or heating and cooling.

Scandiaconsult, in Sweden, presented results of a Swedish study into noise and noise reduction for large heat pumps. Field measurements have been carried out on 8 large heat pump installations in Sweden. Although, in general, the noise levels are low, it is advised to further improve noise levels by careful design. Measures for reducing sound levels are listed in the paper. As an example the Eagersjö heat pump plant (2.7 MW) is used to show that careful treatment of the noise aspects results in a very low noise level resulting in no complaints from the local people.

Summary

Knowledge about R134a and R123 has increased significantly. Interest in inflammable refrigerants such as R152a (in combination with R22, R114 or R124) and R142 is increasing. The environmental aspects being discussed, amongst others, relate to total environmental benefits of heat pumps, global warming and noise.

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Operating Experience, Economics, and Marketing - Session VI

*G.J.A.M. Meijer

Main themes which came forward in this session concerned heat pumps for cold climates, the contribution of heat pumps to improve electric utility load factors and the potential market for multi-functional heat pumps i.e. for cooling and/or sanitary hot water heating in addition to space heating. Requirements for building ventilation also open up a potential market for heat pumps using air as a heat source. Furthermore, heat pump reliability and expected life span figures were presented.

Heat Pumps for Cold Climates

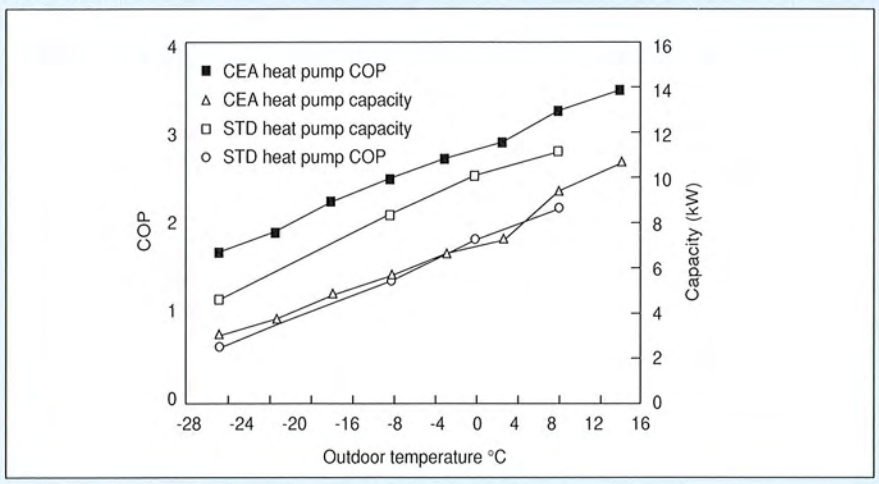
Air-Source Heat Pumps in Canada

In Canada, in spite of the cold winter, half the population live in regions with a 500 hours cooling need. It is this demand for air-conditioning which drives heat pump sales upwards.

CEA Cold Climate Heat Pumps

Ontario Hydro Corp., sponsored by the Canadian Electric Association (CEA), developed a cold climate heat pump. The prototype has been field-tested. Using 'off-the-shelf' components and moving the compressor and the electric controls to the indoor unit, it was possible to produce a machine that performed 15 to 20 % better than the contemporary standard at little additional costs. Performance is compared in Figure 1. Since cold climate heat pumps are considerably more effective, in particular, at low outdoor temperatures, this opens the possibility of reducing the electricity demand by 25 to 50%, even on the coldest days, thus improving the electric load factor. The cold climate heat pump can be applied in an all electric configuration (i.e. with electric resistance auxiliary heating) instead of a standard heat pump or can replace straight electric resistance heating. However, applying the cold climate heat pump in an "add-on" configuration to an existing gas or oil furnace is not energetically and economically very advantageous. At low outside temperatures, the furnace takes over so that the operating hours of the heat pump are curtailed.

Figure 1: Steady-state Performance Comparison between CEA Cold Climate Heat Pump and a Standard Heat Pump (both nominal 3kW electrical input at 8.3°C)



Unitary Bivalent Heat Pumps

Another new concept is a burner-assisted or unitary bivalent heat pump of which approximately 7,000 are installed in Canada and the Northern United States. It is a normal electric air- source split-system heat pump, equipped with a gas burner, located underneath the outdoor coil for auxiliary heating. When the burner is in operation (the flame mode), the unit continues to run as a normal heat pump with inactivated outdoor fan, but the flue gases, condensing on the coil, replace the outdoor air as a heat source. If defrosting is required during normal air source operation the flame-mode is re-activated. Only electricity is used for cooling. Further development, including domestic hot water production, is being undertaken.

Reliability / User Satisfaction

As to owner appreciation and the reliability of standard air source heat pumps, a survey by CEA showed that noise produced outside bothered only 12% of the owners and that 92% would buy a heat pump for their next house. The repair rate was 0.3 repairs per unit-year of operation, an improvement by a factor of 3 since the mid 70s. The most important causes of problems were refrigerant leakages on solderless couplings in the lines connecting the outdoor and the indoor units. Field-brazed connections seemed to have less leakage occurances.

Medium Size Heat Pumps (50-500 kW) in Norway

Heat pumps for cold climates were also discussed by SINTEF (Norway). Since a large part of the population lives in coastal areas and the Gulf Stream keeps the average water temperature between 4 and 7°C, the most important heat source in Norway is sea water, followed by outside air. Ground-water, soil/rock and waste heat are also used. Operational time is the most important design factor regarding profitability of the heat pump. Therefore, the most interesting use of medium-sized heat pumps in the 50 - 500 kW range is in apartment buildings and commercial and industrial buildings, where the demand conditions are often favourable. Examples are:

- Hospitals, homes for the elderly, hotels, gymnasiums and swimming pools which have a great demand for sanitary hot water in addition to the demands for space heating.
- Office buildings and hotels etc., for which the increased internal heat load from lighting and computer installations have resulted in a cooling demand in addition to heat requirements.

In Norway the market potential for heat pumps is estimated at 15 - 20 TWh/year.

Operational experience in the case of a heat pump for heating and cooling of a hotel, with sea water as the heat source, was presented, in which titanium plated heat exchangers were used. The heat pump was dimensioned to cover the cooling demand of an extension of the hotel. Thus designed, it is possible to cover most of the heat demand of both the existing hotel building and the extension. The payback period of the investment costs to upgrade the refrigeration plant for heat pump operating conditions was about 2 years.

Another example deals with air as a heat source for a 55 kW heat pump in a municipal high way office. Refrigerant circulation between evaporator and separator is due to gravity. During defrosting liquid refrigerant flows down by gravity from the roof-top evaporator to the condenser. The liquid is evaporated in the condenser, and the refrigerant flows upwards to the evaporator again, while by-passing the compressor.

Large Heat Pump Plants in Sweden

Further experience with large heat pumps in Northern climates was discussed by Skandinavisk Thermoekonomi (Sweden). The trend in Sweden is towards indirect heat extraction, regardless of the heat source. Despite its high corrosiveness, $CaCl_2$ appears to be the best choice for the brine when outdoor air is the heat source. K_2CO_3 could also be used. One of the advantages is that with a brine, large installations contain less than 20% CFCs relative to a direct expansion plant.

With respect to the CFC issue it is important to note that experience has shown that R22 can be used up to the outgoing water temperatures close to 80°C.

Ground-Coupled Cold Climate Heat Pumps in Japan

Hokkaido Electric Power Company has developed and field-tested ground coupled heat pumps designed to provide a constant heating capacity even in the coldest climates. Field demonstrations in 10 cities on the Island Hokkaido confirmed the viability of this type of heat pump for cold districts. COPs of 2.3 to 2.8 were obtained. A drilling machine was also developed which achieved a large reduction in installation costs. Depending on the hardness of the soil, the vertical tubes are directly inserted into the ground by pressing and rolling.

The conclusion is that, in spite of the achieved investment cost reduction, the installation costs are still too high for ground-coupled heat pumps with brine coil to compete with air source heat pumps. A further reduction of capital cost by developing direct expansion systems is necessary and is being investigated.

Use of Waste Heat from Subway System

A unique example of a heat pump application in cold climates is the use of waste heat from the subway system for road heating in the town of Sapporo. The system was developed by Mitsubishi and Hokkaido Electric Power Co. During the night time when the subway is closed, the system operates as an ambient air source heat pump.

Status of Unitary Heat Pumps in North America

The current market status of unitary heat pumps in North America was reviewed by Lennox Industries Inc. The share of electric heat pumps in new single family houses in the USA has dropped from 30% in 1985 to 26% in 1988. This development is primarily due to a significant drop in new houses in the southern states, where heat pumps are most popular. The national electric utility load factor declined from 62% in 1985 to 59.7% in 1988. Since add-on heat pumps can improve the load factor, some utilities offer special incentives for this type of investment.

In 1988, for the first time, the average seasonal COP (SEER) of new heat pumps, operating in the cooling mode, was slightly higher than for cooling-only air conditioners.

New technology introduced includes variable speed reciprocating compressors, scroll compressors, triple-integrated heat pumps (including hot water heating capability) and systems incorporating thermal energy storage. A double-fuel single package unit for rooftop applications in the 7.5 - 10 tons range was also field tested and market tests are planned for 1990.

The Air-Conditioning and Refrigeration Institute has now included estimated national average heating and cooling operational costs (along with adjustment factors for application sizing and regional geographic location) in their directory of unitary products.

A new survey by EPRI showed that more than half of the residential heat pumps, installed in specified areas, under surveillance, were still in operation after 19 years of service.

Market Niches

A review of market niches in Europe was given by the University of Technology of Graz (Austria). The variety of heat pump systems on the European market is a result of the different climatic conditions, different energy supply structures of European countries, and the development of energy prices during the last 20 years. The oil price drop struck a final blow to the heat pump market in Europe.

In the residential market monovalent heat pumps are cost-effective only when installed in new buildings with low temperature distribution systems. Bivalent systems are only economic when the heat pump can fulfill additional needs such as cooling or heat recovery from exhaust air. Market niches exist in the Nordic countries and France for exhaust air heat pumps, as opposed to Central and Southern Europe, where presently no regulations concerning building ventilation exist. Domestic hot water heat pumps are also popular in Europe and use waste heat from the boiler in winter time and ventilation air in summer time.

In the commercial/industrial building sector heat pumps for both heating and cooling and for shifting waste heat to temperature levels required, are of commercial interest, e.g. for department stores and office buildings. The most promising market segment in this field is the integrated system, used in hospitals and health resorts. In this application the heat pump is only part of a sophisticated and complex system (Figure 2).

Practical experiences obtained with heat pump systems in commercial buildings were given in poster session papers by Japan, Sweden and France.

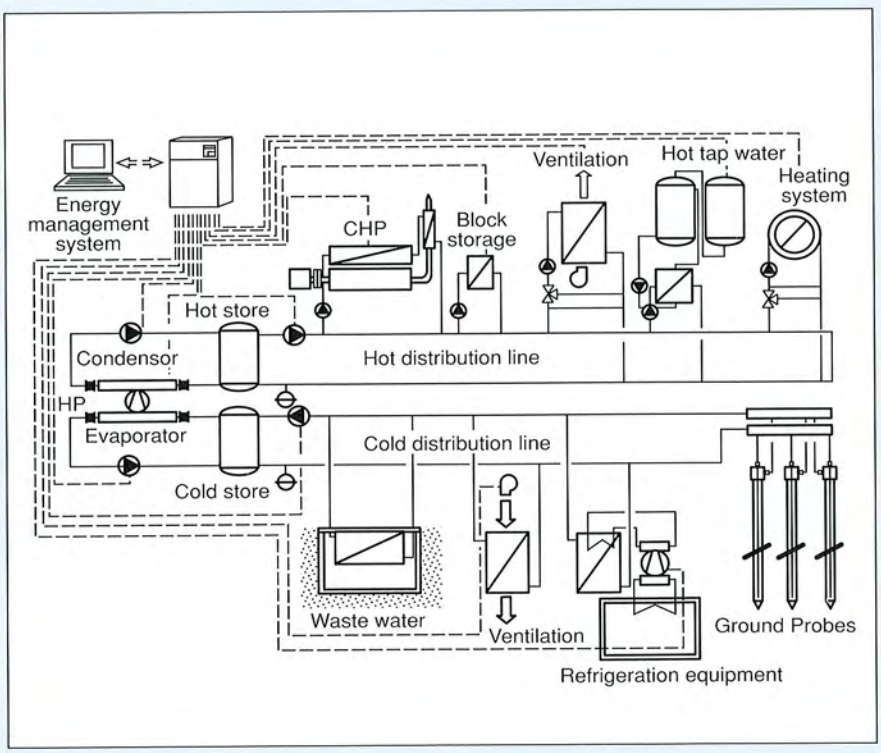


Figure 2: Components of an Integrated Energy System

Solar Collector-Assisted Heat Pump in Japan

Another system which has been applied in commercial buildings is a solar collector-assisted heat pump, developed by Kajima Corp. (Japan). The uncovered collector functions as a solar collector and as an outside air source evaporator when there is insufficient sun light. It acts a heat sink during night time and has been tested and found suitable for cold climates as well. No separate defrosting is required. Although many components have been improved since 1985, the conclusion is that the system is not economically viable yet. So far, it has been applied to high quality buildings where economics were not the primary concern. There is still room for further cost reduction.

Summary

A lot of progress has been made and operating experience gained in Canada and the Northern USA with new air source heat pumps specially designed for cold climates. US and Canadian surveys show that owner appreciation and the lifetime of residential heat pumps are good and that reliability has been considerably improved over the past few years. Also, Scandinavian experiece with medium and large plants is good. Introduction of electric heat pumps can improve the electric utility averaged annual load factor, though for different reasons.

In most cases the market potential of heat pumps depends upon whether there is a demand in addition to control heating which can be fulfilled by the heat pump, e.g., cooling air-conditioning, domestic hot water production, simultaneous cooling and heating, and utilisation of ventilation heat.

Author:
**G.J.A.M. Meijer, HPC.* □

National R&D Programmes and the Roles of Government and Utilities in Advanced Heat Pumps and Protection of the Environment - Session VII

*J.W.J. Bouma

North America

Major technical advances for improving heat pump performance have been carried out in North America since the 2nd IEA Heat Pump Conference in 1987. Considerable progress has been made in advancing the development of engine-driven heat pumps, including internal combustion engines (free-piston, reciprocating, and rotary) and Stirling engines (both kinematic-Stirling and free-piston Stirling). Advances in developing new refrigerants have also been made. These advances include developing highly-efficient alternative refrigerants to replace CFCs and investigating potential savings with non-azeotropic refrigerant mixtures.

The importance of heat pumps to electric utilities was stressed (in a paper presented by EPRI) together with a report on EPRI's research programme to develop heat pumps with improved efficiency and electrical load characteristics. The US electric utility industry has experienced a decrease in system annual load factors (ratio of average demand to maximum demand) partly due in large to the increasing demand for comfort air-conditioning. With about 75% of the new homes air-conditioned in 1988 (and an even higher fraction of the new apartments), electric heat pumps can play an important role in reducing the cost of electricity to customers by improved plant utilization resulting from a more balanced annual load.

EPRI's research programme in heat pumps is aimed at developing improved equipment for both the residential and the commercial sector customers. Examples of recently completed projects, which have resulted in commercially available products, are the variable speed-water heating integrated heat pump for residential applications and a dual-fuel (bivalent) unitary heat pump for commercial buildings. An active research programme in ground source heat pumps focussed on equipment improvements and installed cost reduction.

The environmental and resource conservation effects of heat pumps are also under investigation at EPRI. With the push of the Federal Government's minimum efficiency standards and the public's growing concern about global warming, the future for efficient electric heat pumps looks very promising, indeed.

Korea

In a Korean paper, insight has been given into heat pump R&D projects in residential space conditioning and industry. Interest for heat pumps as an energy saving and environmental protection device has increased in the last few years.

The Korean Government has now started a heat pump technology programme as part of the long-term Energy R&D Programme for 1989. Attention is focussed on the chemical heat pump, high temperature compression heat pump, modelling of the absorption heat pump, engine-driven heat pump, cold climate compression heat pump and heat pump dryers.

Of special interest was the report on a heat transformer in the chemical industry. The imported transformer, installed in 1986, has operated successfully and the investment costs were paid back after 1.2 years. It produces 5 ton saturated steam at 127°C, using 98°C waste steam from 3 polymer strippers as driving energy. Heating capacity is 3 MW and the COP is 0.5.

F.R. Germany

In F.R. Germany the dominating criteria in energy policy and RD&D programmes are now economy of supply systems and an environmentally justified use of fossil fuels. Increased energy conservation is aimed at through the use of indirect instruments, such as a tax on gas consumption and a tax increase on mineral oil.

Market forces and reactions to energy price developments are considered to be the main mechanism for a rational energy use. In order for the markets to react with the available solutions however, new technical approaches and solutions should be pursued. An important role of the government in this is to create an innovative climate and framework to boost R&D forces in the economy.

During 1974-1988 the Federal Ministry of Research and Technology funded 72 heat pump R&D projects which amounted to DM 68.5 million. The funding breakdown showed DM 14 million for electrical heat pumps, DM 40 million was used for engine-driven heat pumps and DM 14.5 million for absorption heat pumps.

Market penetration of electrical heat pumps in F.R. Germany is shown in Figure 1. After the two oil shocks market penetration remained lower than expectations. This is explained by failures made during market introduction, i.e. manufacturing of heat pumps with inadequate components, insufficient maintenance, insufficient installers capability and

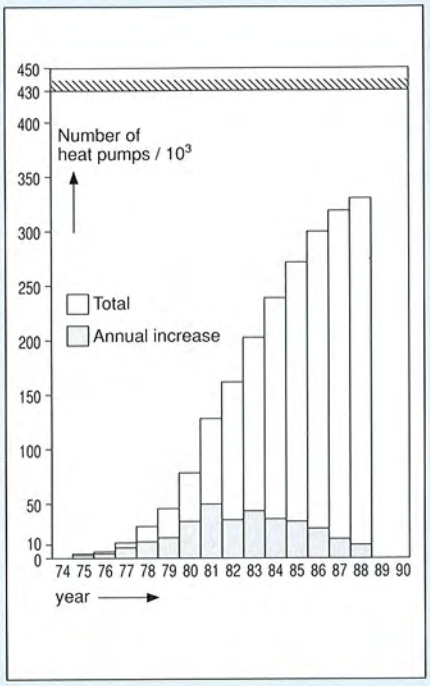


Figure 1: Development of Heat Pump Market in FRG

unrealistic cost savings perspectives claimed by sales people. Hot water heat pumps, however, show annual sales figures of 20,000 to 30,000 units. Engine-driven heat pumps of large capacity type, 100 kW and over, are used for apartment buildings and commercial buildings, although cogeneration is a competitor here.

Absorption technology is expected to be applied increasingly in air-conditioning and refrigeration, if heat in excess of 100°C is available and for medium and large scale plants. The two technologies available in the market are ammonia/water systems for refrigeration and water/lithium bromide systems for air-conditioning and cooling.

Absorption technology is also being provided for use in the residential, commercial and industrial (heat transformer) sector. It is believed that sorption technology can provide a short-term alternative for CFC using compression systems in these sectors.

It was concluded that there is no reason for neglecting the heat pump despite the present low energy prices. Technical developments show progress, e.g. in the field of prefabricated wall-integrated concrete heat exchangers in buildings using monovalent electrical heat pumps, and therefore, the Federal Government will continue to support amongst others, heat pump technology.

It was stressed that success in the market also depends on informing potential consumers on the features of this technology to overcome uncertainties caused by former errors and to create a climate of confidence. This is a task for manufacturers, with the utilities and their governments in close cooperation.

Japan

Energy conservation in all sectors is of vital importance to the Japanese economy. In addition, as one of the worlds largest energy consumers, Japan is convinced that energy conservation is a key to abate global environmental problems. To support an energy saving policy, legal measures and promotional and educational activities are considered essential. Equally important is the development of new technology. Energy conservation R&D has been embedded in the 'Moonlight Project', launched in 1978 by the Agency of Industrial Science and Technology, AIST. It comprises 6 programmes, of which the 'Super Heat Pump Energy Accumulation System' is one of the large-scale programmes. This project started in 1984 and will be concluded after 8 or 9 years, with a total budget of approximately 10 billion Yen. The basic idea behind the project is to develop efficient advanced heat pumps utilizing low-tariff electricity during the night time, storing the heat produced at high density and using this energy in the day time when heat demand is high. Heat can be used to air-condition large buildings, supply hot water on a large scale and to heat and cool houses and heat industrial processes. In addition, the system provides load-levelling capabilities for electric utilities. Details of the project are shown in Newsletter Vol. 7, No. 4.

The objective of the project is the development of 1 MW scale pilot plants, each consisting of a highly efficient heat pump and a chemical storage unit, and a conceptual design of a 30 MW system. The project has recently been evaluated. To that end tests of various bench plants have been carried out in Tsukuba Science City under comparable conditions. NEDO, (New Energy and Industrial Technology Development Org.) who supervised the project, reported upon testing of a 100 kW class heat pump and 10 Mcal chemical heat storage system. A heating COP of 5.5 (10/45°C) and a cooling COP of 6.3 (7/32°C) were reported for the 100 kW class heat pump. The unit is equipped with a new rotor profile screw compressor, plate fin type condenser and evaporator and a two-stage economizer. A non-azeotropic mixture (R22/R114) was used as a refrigerant. In view of the

Table 1: Targets for Total Systems

Applications		Output Temp. °C	Energy Effic. (COP)
Air-conditioning of office buildings	: Heating	45	4.5
	: Cooling	7	5.3
District air-conditioning	: Heating	45	4.3
	: Cooling	7	5.3
	: Hot water supply	85	6
Industrial processes	: Heating from wasted heat	ca. 150	>2.3
		ca. 300	>2.3

depletion of the ozone layer substitutes for these fluids will be used as a next step. The heat storage test plant uses gas clathrates. A heat storage density of 30 kcal/kg material has been achieved, with a heat recovery ratio of 62%.NEDO concluded that the objectives of the project will be achieved together with the targets of the total system (see Table 1). Final results of the interim evaluation will be published at a later date.

Japanese concern for the environment was stressed at the conference, for which a 6 billion Yen project on the global greenhouse effect in 1990 was announced. Amongst other things it will comprise new refrigerants and CO_2 technology.

Utilities in Japan also play an important role in heat pump technology. Electric utilities are promoting district heating and cooling systems with heat pumps. These applications improve load-levelling. In addition residential, commercial and industrial use of heat pumps are actively promoted, including development of cold climate applications.

Gas utilities also make efforts towards technological development of heat pumps. They have succeeded in developing the world's first small air-conditioner powered by a gas-engine. These units are expected to be widely used as a result of low operating costs. Furthermore, small air-cooled absorption type air-conditioners for domestic use are under development, as are large capacity absorption heat pumps that use sewage or river water as a heat source.

Europe

An overview of current and future heat pump R&D in Europe was presented in a paper by the IEA Heat Pump Centre. The environmental concern in relation with heat pumps (CFC, CO_2) is a driving force of growing importance for heat pump R&D in many countries, since heat pumps can tremendously help to abate the greenhouse problem through energy conservation. The present heat pump situation in Europe is described in the paper, together with results of the national and the European Communities heat pump programmes. Countries concerned are Norway, Sweden, Denmark, The Netherlands, F.R..Germany, France, Austria, Switzerland, United Kingdom and Italy. As a result of falling oil prices, the European heat pump industry has diminished dramatically since 1986 and so has their R&D effort. Present R&D activities by industry focuss on finding solutions to meet the obligation of applying new refrigerants and improving existing products.

R&D funding by governments has decreased as well in comparison with the early 80s. However, through the increased environmental concern, many countries in Europe and the Commission of the European Community have extended heat pump R&D programmes. Key research elements are improvement of the cost/efficiency ratio of heat pumps, widening the application, and development of harmless refrigerants.

Investment cost reductions are pursued through development of cheaper and more efficient components like compressors and compact heat and mass exchangers. Efficiency is improved through new cycle development, non-azeotropic mixtures, cycling of heat pumps and component development. Development of new refrigerants replacing chloro-fluorocarbons and investigation of their impact on efficiency and hardware take place in many countries.

A growing interest in adsorption and chemical heat pumps is also visible in Europe.

It was concluded that substantial effort and funds are involved in working on these topics and therefore, international cooperation and coordination on a global level in heat pump R&D is essential, since the environmental issue is pre-eminently an international problem. The IEA-Heat Pump Centre provides the means to assist in achieving the solution to some of the problems.

Summary

R&D in North America, Korea, Japan and Europe and the role of utilities in the USA and Japan have been reviewed. In North America advances have been made for improving heat pump performance, development of combustion engine systems and for developing new refrigerants. The electric utilities in the USA believe that heat pumps are very important for the annual load factor and research programmes aim at further efficiency improvement.

Awareness of the energy saving potential of heat pumps is growing in Korea. A comprehensive technology programme has been put to work. In F.R. Germany absorption technology is considered promising as it can provide a short-term alternative to compression systems in air-conditioning and refrigeration. Also monovalent electrical residential heat pumps still have chances. In Japan progress has been made with the long-term "Super Heat Pump Energy Accumulation System". After an interim evaluation it was concluded that the targets will be achieved. Electric heat pumps are actively promoted by electric utilities, especially for district heating and cooling. Gas utilities focus on small gas-engine driven air-conditioners.

Although the heat pump industry in Europe has diminished and funding by governments and the European Commission decreased, there is a renewed interest and effort put into development of heat pumps, driven by environmental concern.

Author
**J.W.J. Bouma, HPC.* □

Closing Remarks of the Conference

J.W.J. Bouma, HPC, Sittard

The Chairman of the international organizing committee, Prof. J. Berghmans, in his conclusions, stated that there are two challenges with regard to the theme of the 3rd IEA Heat Pump Conference. First, the challenge to the heat pump itself, due to the environmental impact produced by chlorofluorocarbons and, secondly, the challenge for the heat pump to inhibit the greenhouse effect through energy conservation.

Primarily, compression heat pumps suffer from an environmental disadvantage, but alternative fluids will become available to cope with this problem. However, time is needed to solve remaining problems involved and to be able to produce replacement refrigerants in the volumes required. Absorption heat pumps using 'friendly' fluids, such as ammonia/water, a heavily discussed and interesting topic at the conference, are advantageous compared to existing compression heat pumps, . Again, the many papers presented, showed the energy conservation potential of heat pumps, especially for domestic and commercial buildings. Therefore, the chairman advocated for careful analysis of the global energy conservation potential of compression and sorption heat pumps.

Knowing that heat pumps are able to meet at least part of the environmental challenges, the question was raised how this could be achieved. In other words, what systems on the market are most successful. Undoubtedly, the electric compression systems come first. Considerable progress in performance has been made since the Orlando conference 3 years ago. In addition, new gas-engine driven heat pumps have been succesfully introduced into the Japanese market due to favourable gas/electricity price ratios and tariffs.

As far as application is concerned, (simultaneous) heating and cooling and space conditioning dominate this area. Although not reported at the conference, space conditioning heat pumps are also surfacing in Southern Europe in the last few years. It was stated that space conditioning applications will remain the most potential market in the near future. In Europe, market conditions may be improved by creating more uniformity and openness in 1992. The price of electricity in EC countries might then develop in a favourable direction for heat pumps. It was noted that industrial applications of heat pumps have suffered seriously as a result of energy price development.

The market development for heating-only heat pumps was typified as disappointing. In addition, it was stated that there were no strong indications that this situation will change in the near future, as this is an economic problem. This situation is typical for European countries, where heat pump R&D budgets have decreased in the last few years, in contrast with, for example, Japan.

It was concluded that this unfortunate situation should be rectified especially where there is proof that heat pumps can contribute to solve present environmental problems. Relying upon the free market forces will not improve this situation, and it was felt that at present, there is a lack of financial support to further improve heat pump systems and develop advanced technology. Therefore, a strong appeal was made by the Chairman to society and to the governments of countries present to amend this situation.

The participants agreed to conclude the conference by issuing the resolution as presented in the article by the chairman. □

Conferences

· Call for papers

4th Intl. Conf. and Exh. on Application and Efficiency of Heat Pump Systems in Environmentally Sensitive Times
Oct. 1-3, 1990 / Munich (Fed. Rep. of Germany)
Contact: BHRA, The Fluid Engineering Centre: Ms. L. Grove Cranfield, MK 43 OAJ Bedford, UK
Tel.: +44 234-750422
Fax.: +44 234-750074.

Exhibition Heating & Ventilation
October 23-25, 1990 / London, UK
Contact: Trenton Group Ltd., Trenton House, Imperial Way, Croydon, CRO-4RR, UK
Tel.: +44 81-680-7525.

Exhibition for Plumbing, Heating and Air Conditioning
November 21-24, 1990 Hamburg (Fed. Rep. of Germany) Contact: Hamburger Messe und Kongress GmbH, P.O. Box 302480, D-2000, Hamburg 36, FRG
Tel: +49 40-35690.

Symposium Innovative Applications of Absorption Machinery
January 19-23, 1991 / New York (USA) Technical Committee 8.3 is sponsoring the above symposium at the ASHRAE Winter Meeting. Contact: Reinhard Radermacher, Associate Professor, Department of Mechanical Engineering, The University of Maryland, College Park, MD 20742-3035, USA,
Tel.: +1 301454-8876,
Fax: +1 301 454-8957.

***New Challenges in Refrigeration**
August 10-17, 1991 / Montreal (Canada) Contact: Coordinator Steve Bettner. XVIIIth International Congress of Refrigeration, 3600 Casavant Boulevard West, St. Hyacinthe, Quebec, Canada, J2S 8E3,
Tel.: +1 514 773-1105,
Fax: +1 514 773-8461.
Application due by: 1 Oct., 1990;
Final date: 1 Dec., 1990.

News and Views

Market Development

Ground-Source Heat Pump Market Development in the USA

Indiana
The Public Service Company of Indiana's (PSI) promotional programme, which seeks to increase ground-source heat pump usage, is reported to show good results. The Estridge Group, developer of the 126-home "Walden Pond" subdivision in Carmel, Indiana equipped each home with a ground-source (geothermal: GT) system in 1989. EPRI is providing technical assistance and support to the Walden Pond project. It is estimated that the homeowners will save US$ 400 per year on heating and cooling costs compared with using gas furnaces and electric air-conditioners. The programme allows utilities to increase revenue and marketshare and to produce a better load curve. *(Source: EPRI Heat Pump News Exchange, Spring 1989)*

Pennsylvania
In the USA the first metered space conditioning service using closed-loop ground-source heat pumps in commercial applications now has 3000 tons of capacity in operation. HEATAC Systems, Lester, Pennsylvania is projecting sales for 1990 at over US$ 1 million. The three year old venture has installations in fast food restaurants, retirement villages, elderly care facilities, medical buildings, low-rise office buildings, schools and a residential condominium complex. HEATEC bears the cost of installation, operation and maintenance over a 20-year maintenance contract and charges the customer for space heating, cooling and water heating service. Savings are passed along to HEATAC's customers. Since the capital cost of a ground-source unit is greater than for other systems, ideal candidates for the service are buildings with a 16- to 24-hour per day usage. *(Source: EPRI Heat Pump News Exchange, Spring 1990.)*

European Market Survey

In anticipation of the 1992 market integration within the European Community (EC), an EC-wide market survey of HVAC products is being held, to be published in 6 product reports. The product groups are: Domestic heating; Commercial/Industrial and Multi Family heating; Plumbing; Controls; Air-conditioning; Ventilation. Heat Pumps are dealt with in the product group "air-conditioning". The market survey concerns aspects such as market size and market structure, most important suppliers, distribution and sales channels, developments in 1983-1990 and prospects for 1990-1995, price levels, overview of end-users and applications, government policy and regulations, market barriers (incl. codes and standards), advices on market penetration. Data are being collected by 12 institutes, one in each of the 12 EC countries. Each report will contain a chapter about EC policy concerning codes and standards. Each buyer of at least one product report will also receive 12 country appraisals regarding general economic and more specific aspects such as building investment, contact persons, government services, trade fairs etc. Reports (in English) are expected to be published by June 1990. They will be available to manufacturers and suppliers for their own use. Approx. price indications are: 1 product group US$ 4000, 6 product groups US$ 7000-8000. Contact: Mr J.A. Giles, Building Services Research and Information Association, Old Bracknell Lane West, Bracknell, Berkshire RG 12 4AH, UK.
Tel.: +44-3444-26511,
Fax.: +44-3444-87575
(Source: Heating & Ventilation, March 1990, No. 3.)

Products

Development of Large Absorption Chillers Heaters by Sanyo

Sanyo is involved in the development of a super-large 5000 RT class absorption chiller/heater intended for large district heating/cooling projects. At present, there are many large district heating/cooling projects under planning in Japan - Kansai New Airport (36,000 RT class), Rinku town (45,000 RT), Nanko Redevelopment (17,500 RT), Haneda New Airport (28,000 RT) etc. The gigantic unit being designed is 10.7x5.9x5.8 m in size and weighs 180 tons.

Sanyo also intends to increase the monthly production of large absorption chillers/heaters (over 80 RT) from 50, at present, to 80 units. Furthermore, with the announcement of new medium-size (50-80 RT) models in Dec. 1989 to be mass produced instead of conventional production to order, Sanyo intends to achieve an annual production of more than 1,000 of small-/medium-size units *(Source: Japan Air Conditioning, Heating and Refrigeration News, Febr. 1990.)*

Applications

Heat Pump for Space Conditioning Treasure House for Plants

At Kew Gardens in London the Centre for Economic Botany is housed in an innovative building. It houses a collection of plant materials that have some benefit for mankind, e.g.seeds which are thousands of years old from the pyramids. The collection needs to be kept under controlled conditions. The building consists of a single-storey structure, much of it underground. The soil covering the building and most of the upper part insulates it from the vagaries of the climate. A heat pump provides energy, exchanging heat with the ground water to cool the building in summer and warm it in winter. The heat pump system is monitored to check its

performance. A COP of 3.6 is aimed for. The heat pump can control the temperature inside the building to within 2°C and humidity to within 5%.
(Source: New Scientist 17 March 1990, pp. 57-60.)

Refrigerants

Alternative Fluorocarbon Toxicity Testing

The first toxicity results on several alternatives to CFCs were presented by the Programme for Alternative Fluorocarbon Testing (PAFT) at a recent European Symposium of the Toxicology Forum in Toulouse, France. The results indicate that the three leading products, R123, R134a and R141b, do not show significant signs of toxicity. The results provide a basis to expect that the 3 materials show no adverse effects in carcinogen tests. Final results will be available in 1992 to 1993. Results on R124 and R125 will be available in 1994 to 1995.
(Source: Int. Journal of Refrigeration, Vol. 13, March 1990.)

Production of CFC Substitutes

Allied Signal Inc., Morris Township, New Jersey, has started up a pilot plant to produce environmentally safe CFC substitutes, and has announced plans for a commercial plant. The multi-ton pilot plant, located at the company's Buffalo, New York, research laboratory, will produce R134a for evaluation in various applications, including residential, commercial and industrial refrigeration.

DuPont supplies about a quarter of the world's CFCs. DuPont Company, Wilmington, Delaware, will build its first commercial-scale manufacturing facility for R123a substitute for R11 in industrial refrigeration and other uses. The $20 million plant, to be located in Maitland, Ontario, Canada, is scheduled for start-up in late 1990. It will supply initial and market quantities beginning in 1991. ICI, began production of R134a in Britain this year and has another plant planned for 1992 in St. Grabiel, Louisiana.
(Source: ASHRAE Journal Jan. 1990 and New Scientist, 14 April 1990.)

The International Institute of Refrigeration's (IIR) 4th Informatory Note on CFCs and Refrigeration

On November 29, 1989, the IIR submitted its 4th informatory note on CFCs and refrigeration to the United Nations Environment Programme (UNEP). The note gives recommendations to be considered in the process of amending the Montreal Protocol text.

The main recommendations are:

- allow the use of R11 and R12 for small hermetic systems to be continued until cost-effective and reliable alternatives are available;
- permit the use of R22 beyond the year 2000;
- ask Governments to take legislative measures to control the CFC emissions during construction, maintenance and repair of equipment;
- cooperate with the IIR as it is particularly qualified to provide opinions on refrigeration technology.

IEA

The International Heat Pump Promotion Centre (IPC)

Preparations for cooperation - which were announced in Newsletter Vol. 8, No. 1, - have led to a contract between the HPC and IPC. Following the decision of the Executive Committee in October 1989, the HPC provides operational support by cofunding IPC's 1990 programme.

Operating under contract to the IEA-HPC, the IPC was initiated in 1989 with authorization and support from the Austrian Government at the Energiesparhaus Graz. IPC's objectives are to promote a greater awareness and utilization of energy and environmentally beneficial heat pump systems. As the need has been recognized to involve industry and utilities, in addition to governments, in promotional actions, the IPC endeavours to offer a framework for joining the efforts of these sectors in a cooperative venture to communicate and stimulate broader use of heat pump technology.

In carrying out its objective, the IPC will organize and administer a programme of activities such as development of educational and promotional products, publications and training material; establishment and promulgation of an extensive public relations and communication programme and will serve as a clearing-house for collection and dissemination of promotional material for heat pumps.

W. Hochegger

The IPC will be administered by W. Hochegger as Executive Director. Programme oversight will be provided by a Board of Directors comprised by IPC client representatives and individuals with international prominence in the energy technology field.

G. Groff

Summary of Technical Annexes per April 1990

Annex	VIII	IX	X	XII	XIII	XIV	XV	XVI	XVII	XVIII
Austria				+				+		
Belgium		OA		+*		+	+			
Canada	OA				+		OA	+	(+)	+
Denmark						+			(+)	
FRG	+	+		+	+	+				(+)
Finland		+								
Italy				OA				+		
Japan		+		+*	+	OA	+	+		(+)
Netherlands		+						OA		
Norway					+			+	+	(+)
Sweden		+	+		OA	+		+	OA	+
Switzerland	+	+		+					+	
UK										(+)
USA	+	+	OA	+	+	+	+	+	(+)	OA
Status	cr	cr	cr	cr	cr	cr	cr	cr	cr	p

* country is not involved in extension
(+) = participation not yet confirmed
cr = current
p = proposed
OA = Operating Agent

Explanation of Annexes:

VIII	Advanced in-ground heat exchange technology for heat pump systems.
IX	High temperature industrial heat pumps.
X	Technical and market analysis of heat pumps.
XII	Modelling techniques for simulation and design of compression heat pumps.
XIII	State and transport properties of high temperature working fluids and non-azeotropic mixtures.
XIV	Working fluids and transport phenomena in advanced absorption heat pumps.
XV	Heat pump systems with direct expansion ground coils.
XVI	Heat Pump Centre
XVII	Experiences with new refrigerants in evaporators.
XVIII	Thermophysical properties of the environmentally acceptable refrigerants.

The Board will be chaired by G. Groff,President of Marquardt Inc. USA , previously Director of Corporate Research for Carrier Corporation,and Product Manager for Carrier's European and Transcontinental Operations.

Membership in the IPC will be by three-year subscription at either a sponsoring level or participating level. The first highlight in IPC's 1990 programme will be a joint workshop with the Heat Pump Centre on market impediments of space conditioning heat pumps in Graz on 26 and 27 September, 1990, announced in Newsletter Vol. 8, No. 1.

Bibliography

Refrigerants

New Data on Ozone -safe Refrigerants

1. Thermodynamic appraisal of alternative refrigerants in connection with CFC-restrictions. J. *Morgenstern, I. Ebinger, J. Senst, D. Vollmer Luft- und Kältetechnik, 1990, No. 1, pp 41-44 (German)*

2. Experimental and theoretical research of the refrigerants R134a (CH_2F-CF_3) and R123 ($CHCL_2CF_3$). *R. Döring, H. Buchwald, Klima-Kälte-Heizung, 1990, No. 3, pp 108-112 (German)*

New data on ozone-safe refrigerants will continue to appear for some time. Döring and Buchwald carried out experiments on vapour pressures, pVT values and liquid densities for both R134a and R123. The paper describes the set-up of experiments and presents analytical functions fitting the data of the above mentioned thermo-dynamic properties.

Morgenstern et. al. compare performance data of R134a with those of R12 for ideal refrigerating cycles. Attention is also given to R22, R124 and NH_3. The calculations make use of a numerical model for the prediction of thermodynamic properties which, for R134a, are validated against the data of Baehr and Kabelac. Results on condensation pressure, pressure ratio, COP, specific capacity and volumetric capacity are plotted relative to R12 as a function of condensation and evaporation as an attractive substitute and its comparative properties are described. The remaining requirements of economic and safe operation are described together with measures needed for commercial applications, and collaboration, with the authors, is

invited for the systems development into a marketable form.

Special Issue 1989 ASHRAE CFC Technology Conference

International Journal of Refrigeration, Vol 13, No 2, , March 1990 (English)

This issue of the Intern. Journ. of Refrig. is devoted to the conference at the US National Institute of Standards, Gaithersburg, MD, USA, September 27-28, 1989. This meeting was designed to present the known information in several areas and outline work needed in these areas.

The following 10 of the 13 papers presented at the conference have been published:

- The chemistry of stratospheric ozone: its response to natural and anthropogenic influences, M.J. Kurylo
- Compatibility requirements for CFC alternatives, H.O. Spauschus
- Beyond CFCs: Extending the search for new refrigerants, W.L. Kopko
- Expanded applications for ammonia - coping with releases to atmosphere, W.F. Stoecker
- UNEP assessment of the Montreal Protocol: Refrigeration within the framework of the technology review, L.J.M. Kuijpers
- Overview of alternatives to CFCs for domestic refrigerators and freezers, J.L. Boot
- Commercial refrigeration and CFCs, E.B. Muir
- CFC alternatives for thermal insulation foams, I.R. Shankland
- CFC research programmes in Western Europe, H. Kruse
- Impact of CFC curtailment on refrigeration and mitigation research in Japan, K. Ushimaru.

Installations

NEW HOPE FOR THE HEAT PUMP? Electrical heat pump with foundation/absorber and integrated exhaust-air heat recovery

1. *W. Scheu, Technische Werke der Stadt Stuttgart, Waermetechnik nr. 11, 1989 (German)*
2. *H.J. Fröhlich, Architect, Waermetechnik nr. 12, 1989 (German)*

The first article gives a description of the monovalent heat pump system and an economic analysis. The heat source is the foundation of the house and the surrounding ground. To that purpose water-glycol tubes are cast into a steel-concrete foundation slab under the house and also water-glycol tubes have been laid in the adjacent ground during the building of the house. Ventilation of the house is via the special foundation construction. Thus, the ventilation air also serves as a heat source. Heating of the house is by a floor heating system.

The conclusion of the economic analysis, taking into account the subsidies applicable in the Federal Republic of Germany, is that this heat pump can compete with conventional heating of single-family houses. Market penetration can not be achieved however, since heat pumps do not have a good image and the subsidy scheme is too complicated to explain to people. The second article gives a summary of the measurements carried out during two heating seasons. An overall Seasonal Performance Factor of 2.74 was achieved. This includes auxiliary equipment.

Studies

Thermal Heat Pumps and Membrane Technology

C.B. Colenbrander et. al. Report Netherlands Organisation for Applied Scientific Research TNO, Sept. 1989, ref nr. 89-277 (Dutch).

The results of a feasibility study, carried out by TNO and Ingenium BV, are reported concerning the applicability of membranes in absorption heat pumps. The conditions for which the heat pump was evaluated were: 500 kW air-to-water, bivalent application, heating of buildings by means of radiators (70/57 system), being backed-up by means of a normal central heating boiler. The most import evaluation criteria were a COP of 1.5 or greater, and a maximum investment costs of Dfl. 10,000. The report gives a review of the possible membrane processes. The applications studied were pervaporation in the generator of a NH_3/H_2O absorption heat pump and vapour permeation and pervaporation in the generator of a CH_3NH_2/H_2O absorption heat pump.

The conclusions drawn were:
- it is not considered feasible to attain spectacular higher efficiencies by the application of polymere membranes
- some constructional advantages are possible
- membrane heat pumps would need a long development trajectory

The report (price Dfl 75.) is available at TNO, Postbox 342, 7300 AH Apeldoorn, The Netherlands.. Contact:Mr J.J.M. Post.

Meetings

Heat Pumps - Solving Energy and Environmental Challenges
T. Saito, Y. Igarashi
Proceedings of the 3rd IEA Heat Pump Conference, Tokyo, Japan, 12-15 March 1990 (English)
Published by Pergamon Press, 1990.
ISBN 0-08-040194-5

U.K - Pergamon Press plc, Headington Hill Hall, Oxford OX3 OBW, England

U.S.A. - Pergamon Press, Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A.

PEOPLE'S REPUBLIC of CHINA - Pergamon Press, Room 4037, Qianmen, Hotel, Beijing, People's Republic of China

FEDERAL REPUBLIC of GERMANY Pergamon Press GmbH, Hammerweg 6, D-6242 Kronberg, Federal Republic of Germany

BRAZIL - Pergamon Editora Ltda, Rua Eáa de Queiros, 346, CEP 04011, Pariaso, Sao Paulo, Brazil

AUSTRALIA - Pergamon Press Australia Pty Ltd,. P.O. Box 544, Potts Point, N.S.W. 2011, Australia

JAPAN - Pergamon Press, 5th Floor, Matsuoka Central Building, 1-7-1 Nishishinjuku, Shinjuku-ku, Tokyo 160, Japan

CANADA - Pergamon Press Canada Ltd., Suite No. 271, 253 College Street, Toronto, Ontario, Canada M5T 1R5

Proceedings DKV-Annual Meeting 1989

(German) (Volume 2)
Published by DKV,
Pfaffenwaldring 10,
D-700 Stuttgart 80, FRG.
ISBN 3-922-429-64-5

The DKV (German Refrigeration and Air-Conditioning Assoc.) published 4 volumes of proceedings about its 1989 Annual Meeting in Hannover. Volume 2 deals with refrigeration and heat pump technology, i.e., basics, installations and components. Air-conditioining technology is handled in Volume 4.

For a selection of topical papers, please refer to Newsletter Vol.8, No. 1, pp. 30.

Future Issues 1990

Vol./No.	Topic	Deadlines
8/3	Combustion engine-driven heat pumps (practical experiences, developments, field monitoring).	July
8/4	Sorption heat pumps (residential, commercial, industrial applications, practical experiences, developments).	October 1

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