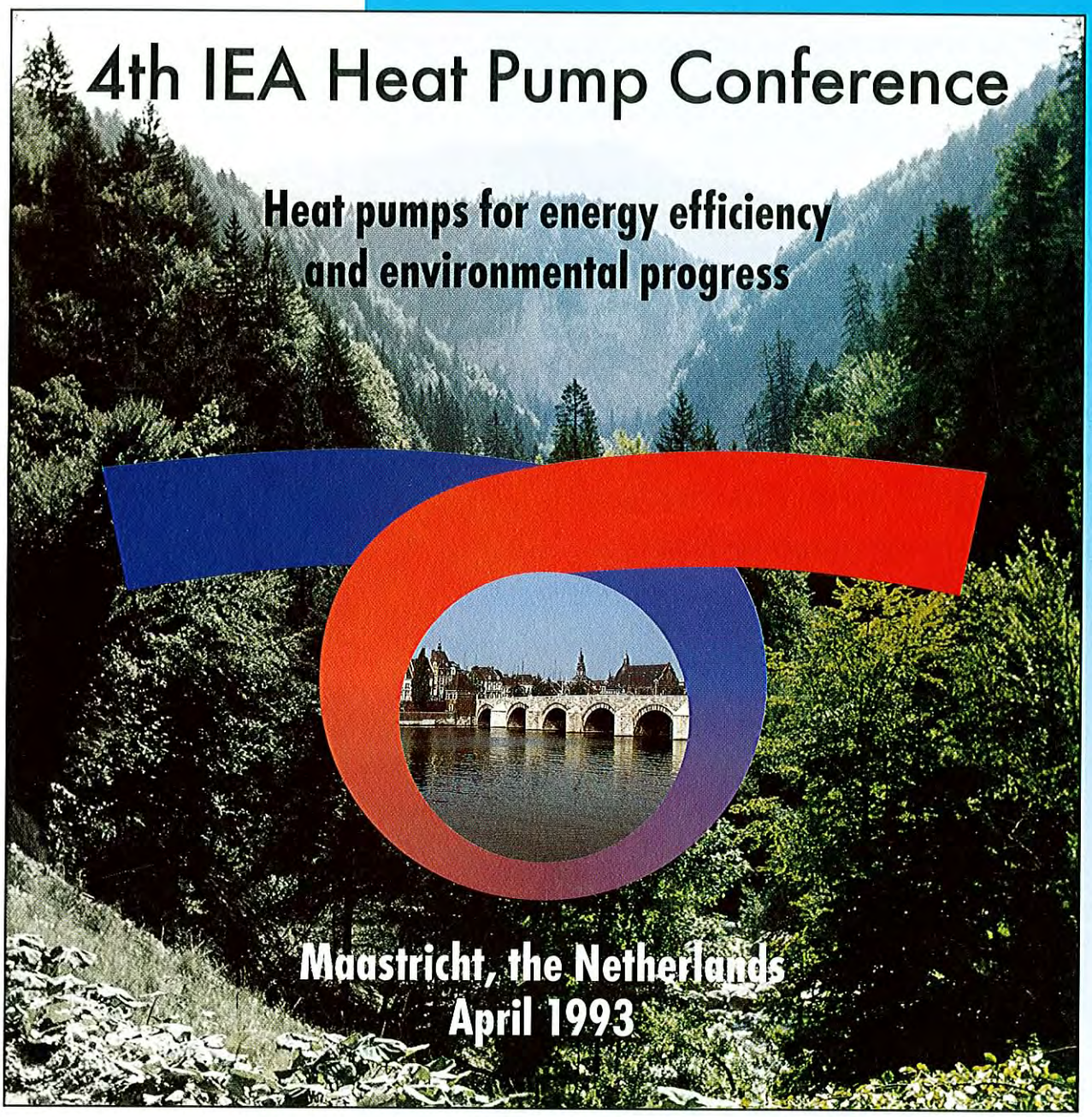
Vol. 11, No. 2, July 1993

IEA Heat Pump Centre

NEWSLETTER



IEA heat pump centre
OECD

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Front cover: The 4th IEA Heat Pump Conference - Maastricht takes centre stage in the drive to improve energy efficiency and benefit the environment. *(Photo Maastricht courtesy of Roel Vossen, Maastricht.)*

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 23 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects.

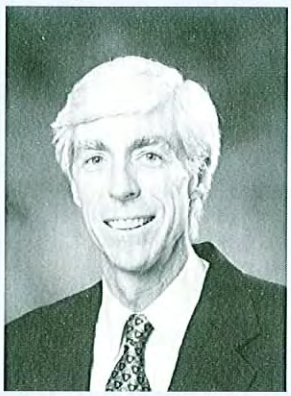
IEA Heat Pump Centre
The nine member countries of the IEA Heat Pump Centre (HPC) form a network for exchanging information on heat pump technology. By increasing awareness and understanding worldwide, the HPC aims to accelerate the implementation of heat pump technology as a means to reduce energy consumption and thereby to limit harmful environmental effects. This publication is one element of the HPC activities.

Any part of this publication may be reproduced, with acknowledgement to the IEA Heat Pump Centre, Sittard, the Netherlands.

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Progress through Interaction



This special issue of the Newsletter records the 4th IEA Heat Pump Conference held this April. As chairman of the Conference International Organizing Committee, it is my pleasure to take this opportunity to reflect on the success and impact of the event.

The raw statistics are straightforward. Over 250 people came to Maastricht for a four day programme of over 80 high-quality oral and poster papers. Three of the most influential people in the energy business made keynote addresses. The programme results were summarized in a lively final plenary session. Nearly two dozen people had a detailed look at the Swedish and Norwegian heat pump business on a week-long pre-conference tour. By these measures, the conference was a success.

Statistics don't tell the most important part of the conference story, however. A more comprehensive look reveals that the formal elements of the conference were bound together by a high level of ad-hoc personal interaction. Small informal group discussions typically involved researchers, policy makers, government managers and industry executives, often from several different countries. During these interactions, the participants dissected and interpreted the data and issues presented in the official conference programme from several national/regional perspectives.

The heat pump and refrigeration industry has moved from a history of relative stability into a period of great uncertainty and rapid change. The challenges facing the industry are global in scale. Solutions will have to be developed through unprecedented global collaboration among the technical, environmental, political and business stakeholders in this industry. An essential ingredient in this collaborative strategy is to examine solutions from various stakeholder perspectives and to develop, though personal contact, the mutual understanding needed for global solutions to emerge. This approach is essential if the industry is to make the transition effectively.

The final measure of success of the conference is the degree of attainment of the interaction described above. This proceedings, of course, are available and represent an excellent reference document. Everyone in the industry should have a copy. However, only those attending the conference can attest to the true level of success attained through personal interaction outside the formal presentations and events. As already described above, there is evidence, by this measure as well, that the conference was a success.

John Ryan
Department of Energy, USA.

News & Views

MITI looks forward to commercialization

Super Heat Pump Programme meets impressive targets

Japan - After nine years of research and development work, the 10 billion yen programme on 'Super Heat Pump Energy Accumulation Systems' (SHPEAS) was concluded in March 1993. The trendsetting Japanese programme met most objectives, including a near doubling of COPs and the coupling of heat pumps with high-efficiency chemical thermal storage systems.

When the objectives for the SHPEAS programme were first formulated in 1984, there was incredulity in some circles. Targets included a COP which was twice as high as customary in the early eighties, a heat pump output temperature of up to 300 °C, and the coupling of heat pumps with thermal storage systems which had yet been developed.

Targets

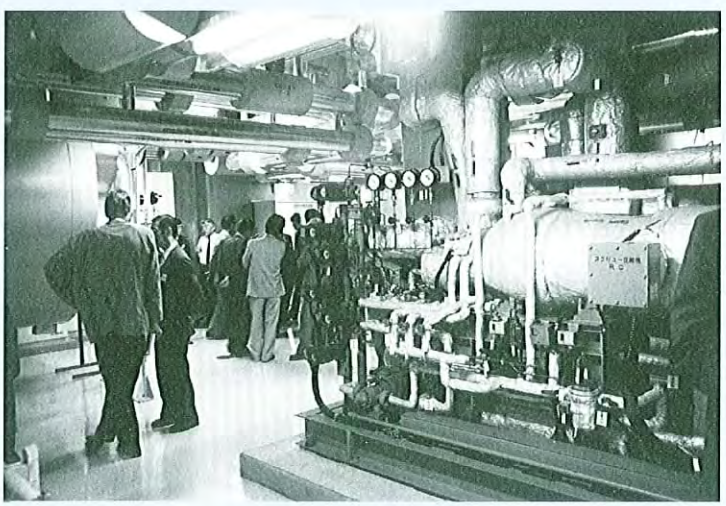
In spite of the fact that some aspects of the programme were recognized early on as uneconomic and cancelled, the extent to which targets have been achieved is impressive. A COP of over 8 was reached in a heat pump which delivered 85°C with a temperature lift of 35°C. Another high-performance heat pump achieved a heating COP of 6 and a cooling COP of 7 under Japanese Industrial Standard conditions. A pilot plant combining a heat pump with clathrate thermal storage was designed to 'surpass all existing systems in efficiency, electric load-levelling effect and other aspects of energy conservation', and did just that. Technologies developed in the course of the programme include advanced screw compressors, minimum temperature-difference heat exchangers, non-azeotropic mixtures as working fluid for high-efficiency heat pumps and chemical thermal storage systems.

An additional challenge had to be faced in the middle of the programme, when it became clear that the originally chosen CFCs had to be replaced by other refrigerants. It is recognized that even the current working fluids of the systems, mostly HCFCs, may have to be replaced in the future.

Key results of the programme were presented at the 4th IEA Heat Pump Conference, where Mr Yoshimura of MITI stated that he is now looking forward to the practical use and commercialization of the developed technologies. He expressed confidence that 'the results will contribute to energy conservation and are effective for reduction of CO_2 emissions' (see also page 33 of this Newsletter).

Workshop

More extensive results were presented at an international workshop held in May this year, which was jointly organized by the Heat Pump Technology Center of Japan and the IEA Heat Pump Centre. The workshop, 'Heat Pumps and Thermal Storage', was held in Fukuoka, Japan. It gave an international audience ample opportunity to discuss the results, and compare them with more conventional combinations of heat pumps and heat storage. The proceedings of the workshop will be published by the IEA Heat Pump Centre in September this year.



Workshop participants view a super heat pump with clathrate storage in Fukuoka, Japan.

It is now, of course, a major task for the Japanese industry to commercialize the concepts which have been developed under the programme. Only then will the potential benefits be realized. Prof. Tanasawa of Tokyo University, chairman of the workshop, noted commercial opportunities for the Super Heat Pump alone, but voiced

'pessimism' about the immediate economics of combined heat pump and chemical heat storage systems with the current low energy prices. Yet the growing concerns about the global and local environment made him 'optimistic in the long-range for combined systems'.

(Sources: Japanese National Team; IEA Heat Pump Centre.)

New programme underway in Norway

Norway - Following the success of Norway's Heat Pump Implementing Programme, which ran from 1989 to 1992, a new programme has been established. The new National Heat Pump Programme which runs until 1996 will carry out work under the New Norwegian Strategy Plan (1993-2000) which aims to ensure that heat pumps are installed where they are more competitive than other energy technologies, and to help develop the use of natural refrigerants. The programme director is Dr Ulf Rivenæs who is also the new National Team Contact for the HPC.

(Source: Norwegian National Team.)

'Heat pumps are essential for meeting CO_2 reduction aims'

Dutch heat pump programme launched

***The Netherlands** - The Dutch Ministry of Economic Affairs has begun a programme to build up knowledge and expertise on heat pumps in the period 1993-1995. Ultimately, the programme, subtitled 'A Programme aimed at Implementation' aims to increase the use of heat pumps until they reach the required share of the optimum mix of energy saving options.*

The programme illustrates a change of heart by the Dutch authorities which saw only a minor role for heat pumps in future energy systems. This was due to poor experiences with heat pump projects and the dominance of gas boilers for domestic heating in the Netherlands which are more economically attractive than heat pumps.

But since receiving advice from the Dutch National Team (see Vol.9, No.4, p. 31), the Ministry now foresees a much greater role for heat pumps. Firstly in niche markets in industry and in buildings where air conditioning is required. In the longer term, a much greater role for heat pumps is envisaged in conjunction with CHP (Combined Heat and Power) generation systems. Indeed, the programme report states that 'heat pumps are essential for meeting CO_2 reduction aims'.

The programme, which was launched in April this year, includes the following activities:

- To define and evaluate demonstration projects;
- To prepare Heat Pump Handbooks both for space heating and industrial applications;
- To develop standards and regulations, especially for low-temperature heating systems;
- To contribute to the HPC Analysis "Heat Pump Status and Policy Review";
- To stimulate the use of process-integration methods in industry and to participate in Annex 21 of the IEA Heat Pump Programme;
- To tune the various methods for technical-economic assessment and evaluation of energy saving systems;
- To participate in international activities;
- To have a symposium at the end of the programme (Spring 1996);
- To set up a data-bank for heat pump activities in the Netherlands;
- To develop coursemodules for various levels of technical education.

International cooperation is of prime importance. Fruitful cooperation has already begun with the Norwegian National Team including help in the making of handbooks. The Dutch National Team would welcome further ideas and suggestions for further international cooperation.

(Source: Dutch National Team.)

Joint Canadian/US standard comes closer

USA - The Air Conditioning and Refrigeration Institute (ARI) has agreed revisions to standards on packaged air conditioners and heat pumps that will allow joint publication of a standard by ARI and the Canadian Standards Association (CSA). ARI standards 310-90 and 380-90 will be combined as ARI 310/380-93 and published jointly with CAN/CSA-C744-93.

In another development, the ISO (International Organization for Standardization) has established a working group to develop international test methods for determining sound ratings for air conditioning equipment. The working group will be chaired by the USA and participation is expected from France, Germany, Italy, Japan and the UK.

(Source: Koldfax from the Air Conditioning and Refrigeration Institute, March 1993.)

Efficiency standards extend to commercial heat pumps

USA - The first energy efficient standards for HVAC equipment for commercial applications will go into effect from January 1st, 1994. The new standards will complement those introduced recently for residential heat pumps which set minimum cooling efficiencies of 10 SEER (COP = 3.4). Unlike the residential standards, the commercial standards are based on ASHRAE standard 90.1. The new standards are summarized in Table 1.

Table 1: Minimum efficiency standards.

Size	Heating	Cooling
air-source packaged		
<65 kBtu/h* (<19 kW)	HSPF = 6.8 (SPF = 2.3)	SEER = 10.0 (SPF = 3.4)
65-135 kBtu/h (19-40 kW)	COP = 3.0	EER = 8.9 (COP = 3.0)
135-240 kBtu/h (40-70 kW)	COP = 2.9	EER = 8.5 (COP = 2.9)
water-source packaged		
<65 kBtu/h* (<19 kW)	-	EER = 9.3 (COP = 3.2)
65-135 kBtu/h (19-40 kW)	-	EER = 10.5 (COP = 3.6)
135-240 kBtu/h (40-70 kW)	-	EER = 9.6 (COP = 3.3)

* For single-package units, the minimum efficiencies are:
For heating HSPF = 6.6 (SPF = 2.3)
For cooling SEER = 9.7 (SPF = 3.3)

(Source: EPRI Heat Pump news Exchange, Spring 1993.)

Heat pump courses for the work force

Switzerland - Starting next year, employees in the building trade and other industries will be able to follow instruction courses on renewable energy technologies including heat pumps. TRE - an organization for renewable energies founded by unions from the manufacturing and building trades, have set out to educate the work force on renewable energy technologies. Courses are now being prepared for the following applications:

- vocational schools for around 15 different job categories;
- job development courses (for those seeking promotion to foreman or technician);
- refresher courses.

After a general introduction to all renewable technologies, the courses will focus on solar, ambient heat (heat pumps) and biomass technologies. This education drive has been organized in accordance with the Swiss energy programme - Energy 2000.

(Source: Dr H. U. Bruderer - Contact the Swiss National Team for more details.)

HCFC-22 phase-out is a hot topic in Austria

Austria - The prospect of a ban on HCFC-22 within seven years led to emotional discussion at the spring meeting of the Austrian Association of Refrigeration and Air Conditioning. Around 120 people from Austria and Germany were present at the University of Graz and many expressed concern on this issue. Representatives of DuPont, Hoechst, ICI and Solvay reviewed the legal situation which is expected to follow the phase out schedule of Germany, meaning a ban on CFCs in 1994 and on HCFCs in the year 2000. A presentation by German compressor manufacturer, Bitzer, gave an overview on possible options for using alternatives.

Other presentations included a report by Mr Ebner of Graz University of Technology on experimental work on direct-expansion ground-source heat pumps using deep wells. Mr Atzgerstorfer of ELIN spoke on the optimization of energy utilization by means of heat pumps and advanced control systems.

(Source: Austrian National Team.)

Venting ban comes into force

France - From December 1992, equipment engineers face fines of up to FRF 12,000 for venting CFCs, HCFCs or HFCs. The new decree makes recovery of these refigerants compulsory from all equipment containing more than 2kg. The decree also introduces compulsory certification for equipment servicing personnel.

Concern over the environmental impact of working fluids has also led to the formation of two clubs in 1993:

"Club de l'Ammoniac" involves the major French associations and representatives from industry in activities to extend the knowledge and development of ammonia as a refrigerant. It will provide guidance on regulations and legislation concerning the use of ammonia, and advise on installation, maintenance and safety procedures. Club members will participate in equipment development and provide technical and economic information on new ammonia applications. Further information is available from: Ms Lefebvre, AITF, rue Guillaume Apollinaire, 75006, Paris, France; Tel.: +33-1-4222-0034.

The second club, "Club Compresseurs/Fluides Frigorigènes de Remplacement" (Compressors and Replacement Refrigerants Club) comprises a group of five manufacturers who will collaborate on the selection of replacement refrigerants. The aim is to limit the number of replacement refrigerants chosen for use in France to a maximum of three. Further information is available from:
Mr. Folem-pin, 39-41, rue Louis Blanc, 92400, Courbevoie, France.

(Source: Revue Géneral du Froid, January/February 1993.)

Demand for space cooling in industries

Japan - An Japanese electric utility group has recently published the result of a study which shows the trend of the demand for space cooling in industries.

Generally speaking, the demand for energy in industrial use is much higher than in the domestic or commercial sectors and process heating covers much of this consumed energy. However, the demand for space cooling in industry is not negligible compared with process heating. The share for each industry depends upon the nature of the industry, as shown in Table 2. The average share through all industries is 3.9%.

Table 2: Percentage share of space cooling in industries.

Electric Machinery	:	80.5	Blast Furnace	:	2.1
Precision Machinery	:	22.4	Petro-Chemicals	:	1.5
Medicine	:	17.2	Electric Furnace	:	1.4
Fabric	:	7.8	Paper, Pulp	:	0.8
Food	:	7.7	Cement	:	0.8
General Machinery	:	5.9			
Automobile	:	5.4			
Glass	:	3.9	Average	:	3.9

ASHRAE takes action on global warming

USA - ASHRAE (The American Society of Heating, Refrigeration and Air-Conditioning Engineers) has formed a task group to assess the impact of the HVAC&R industry on global climate change and to plan appropriate technical activities. This measure, set out in a position paper approved at ASHRAE's winter meeting, shows the society's continued awareness of the role its members can play in reducing emissions of CO_2 and chlorofluorocarbon compounds. The paper emphasizes the need to assess the true impact of measures to limit global warming. So regulations on refrigerant substitution must take account of energy efficiency factors as well as the global warming potential of refrigerants.

In a separate position paper, ASHRAE has set out its views on the use of ammonia as an alternative refrigerant. The society maintains that increased equipment costs coupled with concerns about health and increasing regulation of ammonia-containing refrigeration systems will restrict the use of ammonia to industrial and commercial applications. Ammonia's use in the HVAC&R industry will only expand if alternative HFC refrigerants under development prove inefficient, unsafe, or too costly to manufacture. The paper acknowledges that ASHRAE has a significant role to play in encouraging proper and safe use of ammonia in terms of policy, research, standards, codes, guidelines, technology exchange and education.

(Sources: ASHRAE; Air Conditioning and Refrigeration News, February 15, 1993.)

Technology & Applications

Absorption heat pump tuned to perfection

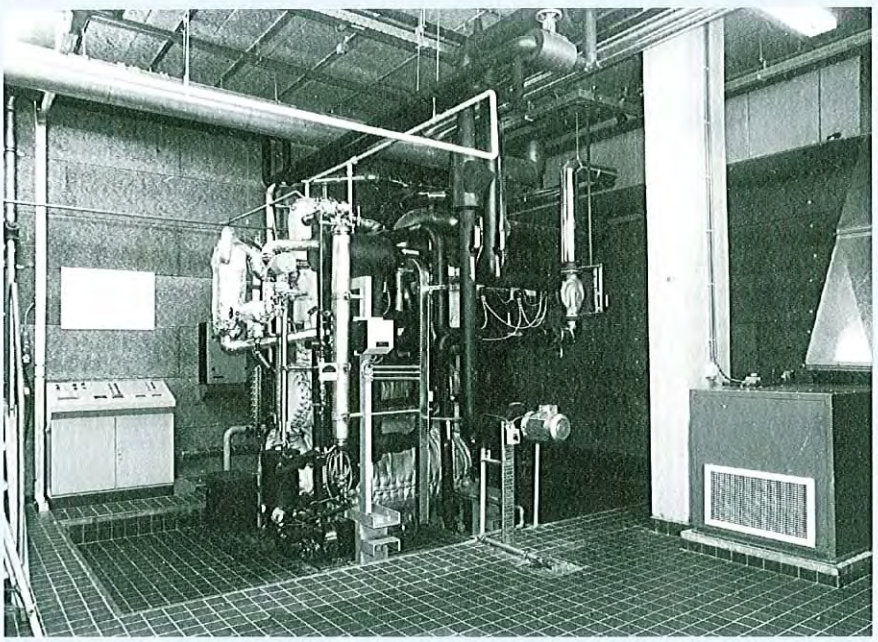
The Netherlands - Place and timing could not have been better. Only two weeks before the worldwide heat pump community gathered in Maastricht for the 4th IEA Heat Pump Conference, a revolutionary absorption heat pump was installed in Maastricht's provincial Government building - just minutes away from the Conference Centre. The 250 kW ammonia/water system, which uses the nearby river Maas as heat source, is expected to reach an annual PER (Primary Energy Ratio) of more than 1.5. The gas consumption of the building will be reduced by at least a third, or over 100,000m³ per annum.

The unit, developed by Colibri and built by the Dutch boiler manufacturer Rendamax, is arguably the world's most advanced absorption heat pump now commercially available. It features advanced plate-fin heat exchange technology, and a generator-absorber heat exchanger (GAX) is incorporated, which transfers more heat at lower temperature lifts. This benefits both the performance and flexibility of the system, which is able to operate at very high efficiencies at moderate temperature lifts, but can also reach high lifts with a more moderate efficiency.

The following features enhance the economic performance of the system:

- Meets 30% of maximum heat load to maximize annual operating hours;
- Simultaneous cooling;
- Maximum efficiency through the use of a low-temperature heat distribution system, close control of return temperatures, and a relatively high temperature heat source.

The advanced absorption heat pump in its first application in the Netherlands.



The unit has re-kindled Dutch interest in the absorption heat pump, and is actively supported by the provincial gas and electricity utility 'MEGA', the Netherlands agency for energy and the environment 'NOVEM', and the national gas distribution company 'Gasunie'. Opportunities for further installations are being identified in schools, swimming pools and offices. Information on this heat pump was also given at the 4th IEA Heat Pump Conference, see page 31 of this newsletter.

(Source: Dutch National Team.)

Heat pumps successfully converted to propane

Germany - That propane is a zero environmental impact refrigerant with excellent thermodynamic properties is common knowledge. Equally common is the concern about the safety and, possibly, legal issues to be faced when using a flammable working fluid.

However, in Europe the opinion is gaining ground that the safety risk of a small amount of propane in a heat pump or refrigerator can easily be controlled. In any case, the amount is negligible compared with the liquid gas heating installations which are widespread in Germany. Propane/butane filled refrigerators have now entered the German market and are proving extremely popular.

At the same time RWE, the German electric utility most actively promoting heat pumps, is operating three test installations where the

refrigerant HCFC-22 has been replaced by propane. The first experiences are very positive - the only minor adjustment required was a fine tuning of the expansion valve settings. The test installations exhibit virtually unchanged characteristics, but a heat pump tuned to the specific properties of propane can have a better performance than a HCFC-22 installation and, significantly for Europe with its high-temperature distribution systems, a higher output temperature.

RWE reports that a few leading manufacturers have already shown a keen interest in the test results.

(Source: Wärmepumpe from IZW, Germany.)

Test rig emulates real life conditions

The Netherlands - As known, the performance of bivalent heat pump/boiler systems and monovalent heat pump systems is strongly influenced by the heating system environment. In particular, the temperature level of the heat delivering system (condenser) and of the generally climate dependent heat source (evaporator) are important. The 'Emulator' is a dynamic test rig which has been developed by Dutch research group IMET-TNO to emulate the heating system environment around a heat pump.

Both steady-state and dynamic heating system conditions can be physically generated and imposed on the heat pump system. The dynamic conditions are derived from advanced and rigorously validated building and heating system simulation models.

The test rig is equipped for all heat pump systems with condenser capacities up to 50 kW. The Emulator will be in operation by the end of this year. Those interested in using it should contact Mr Jan de Wit, Institute of Environmental and Energy Technology IMET-TNO, P.O. Box 342, 7300 AH Apeldoorn, the Netherlands. Tel.: +31-55-493-179.

(Source: Dutch National Team.)

Birth of a new concept in refrigeration

USA - Electric & Gas Technology Inc. (ELGT) of Dallas, Texas have filed a patent for an electronic "freon-free" refrigerator/freezer system which works without the conventional refrigerating circuit, eliminating the need for a compressor or working fluid. Cooling is achieved by passing an electric current (d.c.) through phase-change material (powdered chemical compounds) which removes heat from the cooling compartment and stores it as latent heat. Excess heat is removed by a water circuit and cooling fans. The temperature is controlled by varying the magnitude of the electric current. Defrosting is achieved by reversing the current for between 90 and 120 seconds per 24 hours. Power consumption for a 4.6m³ household refrigerator/freezer is between 650 and 940 Watts, depending on the selected temperature. The refrigerator has been developed in conjunction with the university of Nevada. ELGT, which is not in the business of producing refrigerator/freezers plans to offer a license for this technology to the refrigeration and air conditioning industry.

(Source: Ms Bette Rogers, Executive Vice President of ELGT; Fax.: +1-214-991-3265.)

Ratiometer measures refrigerant mixtures

USA - A portable instrument has been developed for easy measurement of CFC/HFC refrigerant mixtures in equipment such as heat pumps. The CFC/HFC Ratiometer allows a non-scientist to make a quick determination of the chemicals present, their mixture ratios and the amounts needed for recharging, just by pressing a few buttons. This is especially important now that mixtures such as CFC-12/HFC-134a are being used as intermediate steps towards environmentally benign working fluids. Developed by Oak Ridge National Laboratory, the device works by applying an electric field to a refrigerant sample and measuring the rate of charge particle drift. At around USD 1000, the instrument costs considerably less than a gas chromatograph (USD 5000) or a mass spectrometer (USD 20,000), the instruments currently used for the job.

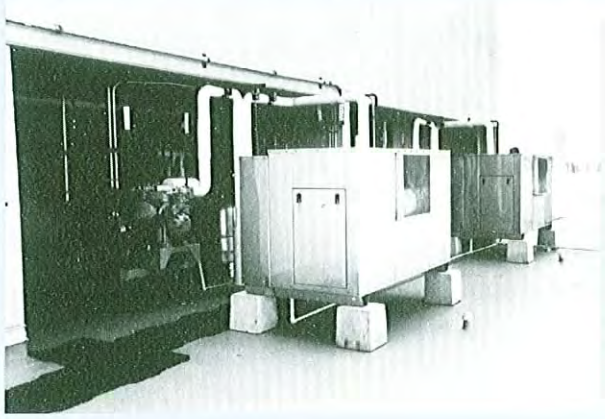
(Source: US National Team.)

Hot water heat pumps are big in Hawaii

USA - A 550 kW, four-unit air-to-water heat pump system is serving a 37-storey apartment block in Hawaii. Thought to be the largest air-to-water heat pump project in the USA, initial results suggest that energy consumption will be reduced to 17% of that consumed by the original gas water heaters, saving USD 94,000 per year.

Hot water heat pumps are, in more general terms, very big in Hawaii, serving nearly 20% of homes, mainly in multi-family flats. With Hawaii's temperate climate, hot water heat pumps often provide cooling as well, for instance for storage areas or elevator machine rooms. In some applications, hot water heat pumps are used in combination with conventional chillers: By supplying 15% of the chilled water requirements at peak loads, these heat pumps consume three times less energy than a conventional chiller and water heating system.

Not surprisingly there are no opportunities for space heating in Hawaii since it never gets cold. Industrial heat pump applications are also limited although one unit is used in papaya processing.



A 550 kW hot water heat pump system in Hawaii.

(Source: Mr Charles Senning, Hawaiian Electric Company Inc., P.O. Box 2750, Honolulu, HI 96840-0001, USA.)

New zeotropes cycle offers high COP

UK - A patented vapour-compression cycle design, for use with zeotropic refrigerant mixtures, provided substantial energy savings over a wide range of operating conditions, according to a recent paper by Professor Geoffrey Haselden and Dr. Jiufa Chen, of Leeds University Chemical Engineering Department. A simplified schematic of their proposed system is shown in Figure 1.

The geometry of the condenser and evaporator is designed to achieve annular two-phase flow of the refrigerant (thus increasing heat transfer) together with counter-current flow with the air stream. The evaporator is divided into two sections. The feed refrigerant mixture leaves the major section at approximately 90% vapour quality and passes to a low-pressure receiver from which residual liquid is gravity fed to the minor section of the evaporator. This split evaporator system ensures that all the evaporation surface is wetted by refrigerant under all loading conditions, improving efficiency.

The expansion device is also significantly redesigned. It employs a double orifice float valve to keep the condenser drained and to generate a steady two-phase discharge appropriate to the required refrigerant flow rate. A few results obtained on a

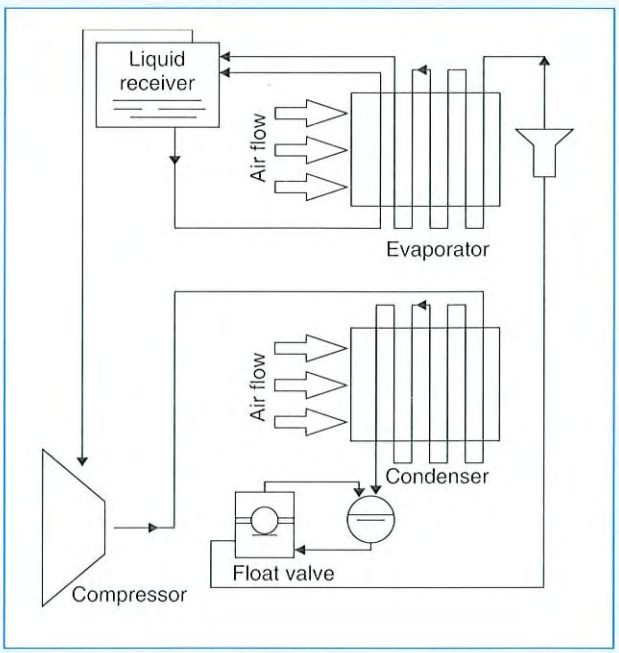


Figure 1: Vapour-compression cycle for use with zeotropic refrigerant mixtures.

test unit with the zeotropic blend HCFC-22/142b (50/50) have been reported. For a typical air conditioning application, where the cooling duty was 19 kW (air cooled from 26.6°C to 12.0°C, at 28.2°C ambient temperature), the measured compression work was 3.0 kW, giving a COP of 6.0. This gave a power savings of 37% compared to a conventional HCFC-22 unit, operating at the same conditions.

For more information, contact Dereck Riley at: University of Leeds Innovations, Ltd., 175 Woodhouse Lane, Leeds LS2 3AR, UK.

(Source: Tech Update from the Air Conditioning and Refrigeration Institute, March 1993.)

Pilot GSHP uses 100 m deep earth probe

Greece - Demonstration of a 7 kW (heating) ground-source heat pump (GSHP) has recently begun in a house with 120 m² floor area. Developed by Interklima SA (the Greek HVAC society) in cooperation with the National Technical University of Athens, the water-to-water electric heat pump uses a 100 m deep closed-loop earth-probe set. It is expected to cover 40% of the building's total heating and cooling load including hot water heating. In the heating mode, space heating stops when hot water is needed. In the cooling season, simultaneous cooling and hot water production is possible.

The pilot project will evaluate operation with pure water and with a water/glycol mixture in the evaporator loop. The system will be optimized to exploit the storage capacity of the ground by means of interseasonal heat recovery. The compact unit features a hermetic reciprocating compressor and coaxial heat exchangers, and uses HCFC-22. A COP of 4.2 has been predicted.

(Source: Dr Michaelis Karagiorgas, Interklima S.A. Athens, Greece. Tel: +30-1-6611136; Fax: +30-1-6612767.)

Markets

AWT: 'Heat pump market stagnates, but at a very low level'

Low profile for heat pumps at major German HVAC fair ISH

***Germany** - The 1993 ISH in Frankfurt, Germany's largest fair for heating, climatization and sanitary ware, was once again overwhelming, drawing more visitors and exhibitors than ever before. But on heat pumps the fair maintained an uneasy silence. Bert Stuij of the IEA Heat Pump Centre reports.*

The ISH is very big indeed. Ignoring the recession, it drew 210,000 visitors, a new record. The seemingly endless halls were filled by 1882 exhibitors, also an all-time high. Impressive statistics. But looking at the ISH from a heat pump perspective it is clear that massive overall statistics do not tell the whole story. In fact, the fair was characterized by an uneasy silence with the distinct impression that major players in the heat pump market are holding their breath. Some key manufacturers from Japan and the USA were even absent. The vital issues for the heat pump industry appeared to receive scarce attention. The phase-out of HCFC-22, nowhere as near as it is in Germany, hardly resulted in a vigorous presentation of climatization systems with alternative refrigerants. Propane as working fluid has gained acceptability in German society since its introduction in refrigerators, but manufacturers at the ISH appeared as yet hesitant to consider its application in commercial air conditioners and heat pumps (although elsewhere interest has been reported, see pp. 8 & 9 of this newsletter).

German manufacturers of heat pumps such as Stiebel Eltron and Siemens seemed at the fair almost evasive about their products. Buderus, Germany's largest supplier of heating technology, gave ample attention innovative heating systems at its massive stand, but did not feature heat pumps. Ochsner, the successful Austrian heat pump manufacturer, was testing the German waters, but confirmed limited commercial interest. A manager of "Absorptions Wärme Technologie", the only German manufacturer of small absorption heat pumps left, noted that 'the market is not only stagnant, but is unfortunately sitting at a very low level'.

Looking beyond the ISH, many positive signs for heat pumps in Germany are emerging. More and more utilities are stimulating their application, and heat pumps now feature prominently in regional energy policies. In 1991, the sale of heat pumps in Germany rose for the first time since 1980. But the distinct impression from the ISH is that the industry has yet to be convinced.

(Source: IEA Heat Pump Centre.)

Air-to-air heat pump shipments up 4.5%

USA - Figures from ARI (the Air Conditioning and Refrigeration Institute) show that despite a downturn in the air conditioning market, air-to-air heat pump shipments rose by 4.5% to nearly 800,000 units (see Figure 2). This reverses much of the 5.5% fall of 1991 and was better than the 3% growth predicted a year ago. While around 50% of installations were replacements, heat pump sales benefited from an increase in house building in the South, where over four in ten new houses employ heat pumps. It's also thought that the growing number of utility rebates for efficient equipment has benefited the heat pump. Today, air-to-air heat pumps in the USA number more than 3.6 million. The average sales-weighted cooling SPF in 1992 was 3.1, due largely to the minimum efficiency standard of 10 SEER (cooling SPF of 2.9) imposed last year by the US government.

PTHPs up 5%

Shipments of packaged-terminal (through-the-wall type) heat pumps (PTHPs) have increased by 5% to 84,200 units (see Figure 2). This rise was achieved despite a slump in the hotel and office building markets where these units are applied.

20,000 GSHPs installed

The Air Conditioning and Refrigeration News estimates that more than 20,000 residential ground source heat pumps (GSHPs) were installed in 1992 along with a few hundred in the commercial sector. These water loop type heat pumps have benefited from substantial rebates (often USD 3000 or more) from electric utilities. Figures available for water-source heat pumps show a 5% decline in shipments in 1992, although this is mainly due the falling demand for the old-style closed-loop systems in high-rise apartments, condominiums, and small or medium-sized offices.

Hot water heat pumps

Although more than a dozen electric utilities are offering rebates to residential and commercial customers, the market for hot water heat pumps is tiny. One factor is uneasiness among HVAC and plumbing contractors who don't want to become involved in each other's trade.

Exports down

Exports of self-contained heat pumps fell 16% in 1992 to 52,814 units The value of these exports declined in 1992 with small units (< 17.6 kW) down 16% to USD 29.9 million, and large units down 2% to USD 9.0 million. This is in sharp contrast to more general figures on US exports of air conditioning and refrigeration equipment. These show a rise of 23% in 1992 due largely to growing markets in Asia, South America and Eastern Europe. Table 3 shows figures for the main heat pump export markets for the USA.

	thousand units
Canada	15.1
Germany	3.6
Chile	3.5
United Arab Emirates	3.3
Israel	2.6
Egypt	2.6
Argentina	2.2
Panama	2.0
(Figures from US Department of Commerce for self contained heat pumps.)	

Table 3: US heat pump exports.

Imports up

In contrast, import of self-contained heat pumps to the USA rose 40% in value. The biggest rise was for small units (< 17.6 kW) which rose 51% to a value of USD 51.8 million.

(Sources: Air Conditioning and Refrigeration News, March 29, 1993, Koldfax from ARI, April 1993.)

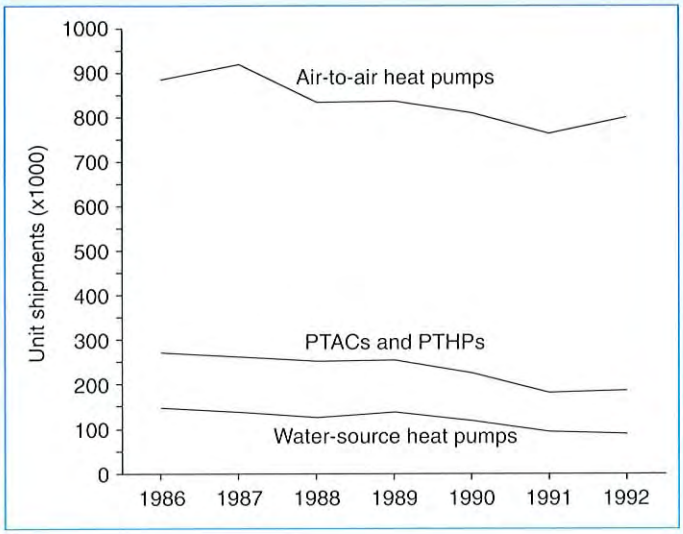


Figure 2: Heat pump shipments in the USA.

New survey on DHC systems

Japan - Based on the registration of heat supplying businesses, government figures give a new picture of district heating and cooling (DHC) systems in Japan. The 102 DHC sites throughout the country use 111 heat pumps, 282 boilers, 39 heat exchangers, 361 chillers and 89 storage tanks. In terms of capacity, heat pumps share 8% of the heating load and 10 % of the cooling load.

(Source: Japanese National Team.)

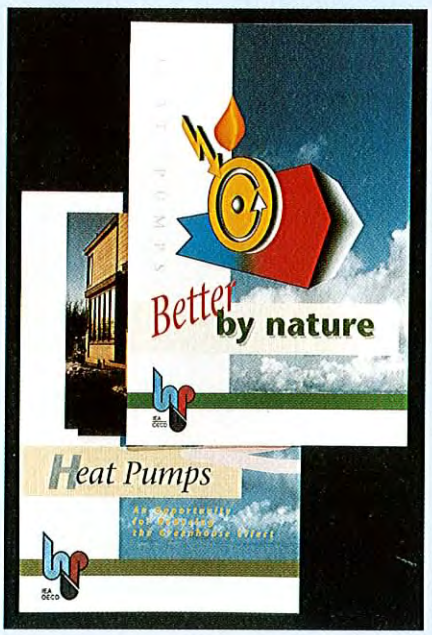
IEA Heat Pump Programme

Better By Nature: HPC launches its promotion campaign

Under the slogan, 'Better by Nature,' the Heat Pump Centre's campaign to promote the use of heat pump technology has been set underway. A brochure, 'Heat Pumps - Better by Nature' is now available and will be sent to those people who can help bring about an upturn in heat pump implementation. The main target groups are policy makers in governments and utilities. Jos Bouma, the HPC's General Manager explains:

"While the technology has made great strides in recent years, heat pumps will only be successful when more people understand their benefits. In particular, there must be more awareness in governments and utilities of the role heat pumps can play in meeting energy saving and environmental objectives. The IEA Heat Pump Centre's promotion campaign aims at heightening this awareness."

The brochure provides clear illustrations of the energy and emissions savings achievable with heat pumps. Examples of the way governments and utilities are already supporting heat pumps in some parts of the world are given, along with the views of several key players in the energy and environmental field. The brochure explains the basic working principle of the heat pump and describes how heat pumps can be applied in buildings and industry.



Additional promotional material from the HPC includes a set of posters and a brochure released last year: 'Heat Pumps - An Opportunity for Reducing the Greenhouse Effect.'

Two brochures have also been produced to stimulate interest in the IEA Heat Pump Programme. More details are given on page 45. All those concerned with the implementation of heat pumps are invited to participate in this campaign by providing the HPC with the names of people who should receive promotional material.

(Source: IEA Heat Pump Centre.)

Annex 18 announces "Refrigerant Olympics" winners

At its meeting in April, Annex 18 (Thermophysical Properties of the Environmentally Acceptable Refrigerants) settled upon the equations-of-state that will form the basis for properties bulletins for HFC-134a and HFC-123. Dubbed the "Refrigerant Olympics," the evaluation process compared seven equations-of-state. For HFC-134a, the equation-of-state of Tillner-Roth and Baehr of Universität Hannover, Germany was selected. For HFC-123, the equation-of-state developed by Younglove at the National Institute of Standards and Technology in the United States was chosen. Both of these equations are accurate over wide ranges of temperature and pressure. The selections were based on thorough evaluations conducted by two independent examiners - the Center for Applied Thermodynamic Studies at the University of Idaho in the USA and the IUPAC Thermodynamic Tables Project Centre at Imperial College in the UK. As a result of this process and the approval of the IEA Annex, it is anticipated that these equations will become the internationally accepted standards for the properties of HFC-134a and HFC-123. These equations will be made known to a wider audience through scientific papers giving details of the equations as well as property bulletins with extensive tables. The IIR (International Institute of Refrigeration) has expressed interest in publishing the property bulletins; in addition, members of the Annex will work to have these formulations adopted by their respective national refrigeration societies.

(Source: Mr Mark McLinden, National Institute of Standards and Technology, USA.)

New Annex on the table

The IEA Heat Pump Programme continues to look for new activities to further the application of heat pumps for environmental benefit. An exciting new area for heat pump technology is in the use of chemical processes for transport, conversion and storage of thermal energy. A meeting held on 26 May in Fukuoka, Japan made the first steps towards starting up a new Annex on this topic. Further discussions will take place at the Programme's Executive Committee Meeting in October.

(Source: IEA Heat Pump Centre.)

Session 1 - Plenary Opening

Mike Steadman, IEA Heat Pump Centre

On Monday 26th April, around 275 participants from over 25 countries, gathered at the Maastricht Exhibition and Conference Centre for the 4th (tri-annual) IEA Heat Pump Conference. A wide spectrum of professions were represented, including researchers, manufacturers, energy experts, utility managers and government officials.

Already in the opening speeches of the conference, it became apparent how widely heat pumps are viewed as a promising technology for limiting the environmental impact of energy use.

* * *

In his welcoming speech, **Mr Stan Dessens**, the Director General for Energy at the Dutch Ministry of Economic Affairs took up the theme of the conference - "Heat Pumps for Energy Efficiency and Environmental Progress". He looked forward to a time when heat pumps would enable a 30 - 40% reduction in CO_2 and NO_x emissions generated by space heating systems in Europe as has been suggested in detailed studies. But is this prediction a view of Utopia or reality?

Next Generation

Clearly, the Dutch view the heat pump for buildings as a "next generation" technology and do not expect widespread application until after the turn of the century. Currently, the Dutch are turning to other technologies, such as cogeneration, in their energy conservation programme. They aim to reduce CO_2 emissions by 3-5% of the 1990 values and improve energy efficiency by 2% a year. But the years 2000 to 2020 will see a dramatic increase in heat pump penetration which could contribute over half of the energy savings that need to be achieved to meet European goals for CO_2 reduction. Mr Dessens went on to say that "energy savings could be feasible with a heat pump which exceed the energy savings of cogeneration by a factor of three." He emphasized the need to avoid a blinkered view of heat pump technology and to consider heat pumps as an integrated part of all energy conservation opportunities. He summed up by stressing the importance of international cooperation and hoping that the participants can help turn Utopia into reality.



Richness

Dr. Kenneth Friedman of the IEA, addressed the participants on behalf of the IEA. He stressed the significance of non-OECD nations to energy policy, since energy consumption in these countries is now one half of global consumption and rising. The IEA sees the use of waste energy as a critical goal for saving energy and one that can be facilitated by heat pump technology. More efficient energy use will also stretch resources and ease pressure on energy markets. The IEA feels that in the long term, the richness of applications for heat pumps will make them a targeted next-generation technology for the heating and cooling area.

Keynote Adresses

Keynote speakers from UNEP (The United Nations Environment Programme), Mitsubishi Heavy Industries Ltd and the IEA addressed the conference. Their speeches are summarized in the following pages.

Mr Dessens: "Heat pumps can contribute over half of the total energy savings that need to be achieved"

Keynote Address: Environment

Rajendra Shende, United Nations Environment Programme

Mr Shende began his environmental theme by summarizing the shift in environmental policy in the recent past. He noted that the sixties policy of merely diluting pollutants to a harmless level was followed by pollutant treatment in the seventies and recycling in the eighties. Today, the emphasis is on prevention of the generation of waste and pollutants. At Rio in '92, 'sustainable development' was introduced as a core concept of Agenda 21 meaning: 'meeting the needs of present generation without compromising the ability of the future generation to meet their own needs'. Mr Shende had a message for decision makers and stake-holders in industry:

"The bottom lines in the balance sheets are not burdened due to environmentally sound processes. In fact, ecology strengthens economics to sustain development."

Mr Shende then went on to examine the present state of the environment.

Ozone Depletion

"Ozone levels measured a few months back were 105 Dobson units over the Antarctica as compared to a world average level of 300 Dobson Units. Observations in the last quarter of 1992 showed that the ozone hole now extends for 15 million square km which makes it 15% larger than the area of the hole measured in 1991. Indeed, ozone depletion is now wider, is deeper and takes place in both hemispheres, in the winter as well as in spring and summer. There are no longer quasi biannual oscillators which mean that it now takes place every year and earlier than expected. Incidence of UV-B radiation have been observed in conjunction with the Ozone Depletion.

The yellow signal of the 1980's has now nearly turned red. The situation is getting worse by the hour.

The world responded at Copenhagen last winter by agreeing to further advancing the schedule of ODS [Ozone Depleting Substances -Ed.] phase-out. For the first time in the history of civilization, the substances invented by man will soon be phased out for the protection of the environment. Within 32 weeks from today [December 1993 -Ed.] we will be closing the shutters of Halon producing plants and at the same time 75% of the production of CFCs will cease in the developed world."

Global Warming

"The current rate of net increase of CO_2 in the Earth's atmosphere is 0.5% per year which represents a net increase in carbon of about is 3000 million tonnes per year. Together with CFCs, methane and nitrous oxide emissions, this increase has caused the global mean temperature to rise by 0.3 to 0.6 °C over the past 100 years. The five warmest years in the human history have been in the last decade.

The yellow signal is glaring. Many feel that it has not turned red. But should we wait for that to happen? Uncertainties are intrinsic in any science. But those uncertainties cannot be an excuse for inaction, specifically when the consequences are prohibitively costly."

Challenges and Opportunities

Mr Shende then considered the challenges posed by these concerns and noted the importance of global partnership and the role of the IEA and UNEP. For heat pumps, the environmental challenge has already lead to many new developments for using ozone-benign fluids and reducing the emissions of CO_2. These developments have lead to other benefits such as better efficiencies and improved operational convenience, which more than compensate the



Mr Shende: "Ecology strengthens economics to sustain development"

resources spent. UNEP appreciates the efforts to utilize waste heat as input for heat pumps while recognizing that utilizing waste heat formed due to inefficient heat generating equipment is really an end-of-pipe solution and calls for remedying the root problem.

Clearly there is a need for good environmental management. Mr Shende went on to explain UNEP's role:

"In many cases information about environmentally sound technologies already exists. There is a need to have knowledge sharing networks to disseminate such information. We catalyze such networks. OzonAction Information Clearing House and International Cleaner Production Information Clearing House are such knowledge sharing systems which have various elements like computerized information exchange system, publication of technical documents, newsletters, etc. There is also a need to impart training to use the shared knowledge for societal benefits. UNEP's activities have a training and education thrust. Dissemination of information and providing training will contribute to 'capacity building' which is particularly important in the case of developing countries who intend to follow environmentally sound technologies. UNEP IE/PAC is one of the implementing agencies to assist developing countries in their plans and actions related to the phase-out of Ozone Depleting Substances.

UNEP also facilitates the technical co-operation between developed and developing countries in the area of ozone benign technologies. The Heat Pump Industry through IEA has already started collaborative programmes in the area of environmentally sound options.

Technology transfer now should give way to technology co-operation and technology partnership. Time has come not to hold the cards too close to the chest. We have to forge global partnership. Our OzonAction Programme would provide you with the assistance to facilitate such partnership with developing countries through our information exchange networks. At UNEP, as the Executive Director Ms Elizabeth Dowdswell, puts it, 'we strive for preventive diplomacy to get countries to recognize the need for co-operation in utilizing scarce resources and ensuring that the co-operation does happen'.

If the concept of Agenda 21 is to gain momentum, industry will be required to set out on totally different ways of development. Fortunately, these ways have economic and social spin-offs. Environmental Management should be an essential element of "*sustainable development* and *sustained use of natural resources*".

Mr Shende ended his address by describing an event related to the sustained use of natural resources:

"The great Mahatma Gandhi at the turn of the century was asked if he would like a free India to become like Great Britain. 'Certainly not' he replied, 'if it took Britain half the resources of the globe to be what it is today, how many globes would India need?'"

Speaker:

Mr Rajendra M. Shende
OzonAction Programme Coordinator
United Nations Environment Programme (UNEP),
Industry and Environment Programme Activity Centre,
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75739 PARIS CEDEX 15, France.
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Keynote Address: Future Vision of Heat Pump Technology and Global Environment

Yoshitake Makise, Japan

Mr Makise opened his keynote address by highlighting a number of ongoing technological developments, which are increasing the environmental significance of the heat pump. He mentioned new refrigerants which reduce ozone depletion, rising COPs which reduce fuel use, higher output temperatures which improves the heat pump's applicability, and the development of systems which make more effective use of unused energy.

Heat Pump Use in Japan

Focussing on Japan, Mr Makise illustrated the impact of a rising heat pump penetration on fuel consumption and associated emissions. "Table 1 shows the estimated heat pump use in Japan. The Heat Pump Ratio is a ratio between supply by heat pump and total heat demand. The Heat Pump Ratio was 1.6% in 1985. In year 2000, the Heat Pump Ratio will be 8.8% at present conditions and can be



Mr Makise: "The global environment should be preserved to enable sustainable development"

increased to 16.2% when heat pump usage is accelerated by technological development and government policy. This will reduce energy consumption by about 2%; $C0_2$ discharge by about 4%; $S0_x$ discharge by about 5% and NO_x discharge by about 3% and can save energy and improve the global environment."

Performance Trends

Taking compressor technology as an example, Mr Makise described how heat pump performance is continuing to improve:

"Hermetic compressors for heat pumps have achieved 30% higher efficiency during the past 20 years. In the year 2000, by the following measures, improvement by 20% can be made and a COP of 4 in ARI [Air Conditioning and Refrigeration Institute, USA -ED.] conditions may be obtained:

- Improving motor efficiency;
- Decreasing mechanical loss by using new materials and refrigerant oil with lower viscosity;
- Improving mechanical structure."

Alternative Refrigerants

Mr Makise highlighted the aims and achievements of AREP (the Alternative Refrigerants Evaluation Programme) and stressed the importance of striking a balance between ozone depletion, global warming potential and energy efficiency when selecting alternatives to HCFC. He commented on some of the HFC alternatives investigated under AREP as follows:

- HFC-134a: Already available, and good efficiencies will be reached. An immediate alternative.
- HFC-32/125/134a (30/10/60 wt%): A non-azeotrope alternative with good potential efficiency. How to cope with leaks needs consideration. A medium term alternative.
- HFC-32/125 (60/40 wt%): A high pressure azeotrope. Easy to handle but requires an equipment redesign. Miniaturization is possible. A long term alternative.

Table 1: Estimated heat pump use in Japan.

(Unit: %)

Case		Residential		Commercial		Industrial		Heat Pump
		Heating	Hot Water	Heating	Hot Water	Heating	Process Heating	Ratio
(1985)		8	-	13	-	-	-	1.6
2000	Max	64	17	68	9	68	5.0	16.2
	Min	40	7	39	3	39	2.3	8.3

Note: Heat Pump Ratio is the ratio between heat supply by heat pump and total heat demand in Japan

Max: When accelerated by government policy and by technological development
Min: at present conditions

Vision

Drawing the wider picture, Mr Makise then described the Japanese Government's 'Global and Long-Term Vision Extending over the Next Hundred Years'. The Japanese government has announced a revival plan for a greener earth by which the world CO_2 discharge is controlled to or below 6 billions tonne (the 1990 level) over the next hundred years by the promotion of various measures. The measures are categorized according to effectiveness as energy saving, substantial clean energy introduction, revolutionary environmental technology development, CO_2 absorption source extension, second-generation energy technology development. Only energy saving is promising in the next 10 to 20 years which will only serve to reduce the *rate* of increase in CO_2 levels. Consistent with this vision of a greener earth, a number of technological development programmes have been initiated.

Super Heat Pumps

The first one of these programmes discussed by Mr Makise was the 10 year, 10 billion yen budget, Super Heat Pump Energy Accumulation System Programme, which will be concluded this year. For heating/cooling, two times the existing efficiency has been confirmed in a Lorentz cycle pilot plant using the non-azeotropic refrigerant of HCFC-22/142b and a two-stage economizer system with a screw compressor. Another system developed under the programme realized a heating COP of 8.1, at a heat source temperature of 50°C and an output temperature of 85°C by a Lorentz Cycle with 3-stage condensation and 4-stage turbo-compressor, and by using non-azeotrope HCFC-123/HFC-134a.

Using Unused Energy

Mr Makise then described the Japanese programme 'Technological Development to Utilize Unused Energy' which is being carried out in cooperation with the Ministry of International Trade and Industry (MITI) and private organizations under a 1 billion yen budget for a 7 year period from 1991 to 1997.

The development of a heat pump system using river water is estimated to realize a 34% energy saving compared with a conventional air-source system. Features include plate heat exchangers, a high-density heat transfer system and ice storage.

Another system under development includes an absorption chiller driven by high-temperature steam from a garbage incinerator. A 25% energy saving is estimated compared with a conventional system using a steam driven absorption chiller for cooling and a steam/water exchanger for heating.

Mr Makise expects the programme to "realize an increase in heat utilization efficiency by leaps and bounds and contribute to the reduction of consumption and load-levelling for private-use energy."

Broad Area Energy Utilization

Another Japanese programme of interest is the Broad Area Energy Utilization Network System which looks at industrial waste heat utilization in urban areas:

"Part of the New Sunshine Project, this programme has been planned by MITI at 50 billion yen by year 2000. Technology such as a heat pump utilizing night electric power, waste heat recovery by chemical heat pumps utilizing hydrogen absorbing alloys, and multiple function heat supply by hydrogen absorbing alloys needs to be established."

Summary

To sum up, Mr Makise listed the following points:

- "Heat pumps are one of the key technologies to achieve sustainable development and to solve problems concerning energy and environment simultaneously.
- Refrigerants for heat pumps can be replaced by alternative refrigerants such as HFC which have an ozone depletion potential of zero.
- Heat pump efficiency can be made two times the current efficiency by developing technology such as Lorentz cycle using non-azeotrope refrigerants.
- Owing to the development of high-density heat transfer technology, triple-effect absorption heat pumps and high-efficiency 'turbo' type heat pumps, a total system making effective use of unused energy can be developed to realize energy savings.
- In order to develop efficient utilization of energy in the future by establishing new infrastructure such as eco-energy urban systems, the use of high-efficiency type electric heat pumps should be promoted along with the development of chemical heat pumps utilizing hydrogen absorbing alloys.
- It is the duty of advanced nations to rapidly transfer to developing nations various environmental protection technology, thus promoting ozone layer protection and global warming prevention."

Speaker:

Mr Yoshitake Makise
President of the Heat Pump Technology Center of Japan and Executive Vice President of Mitsubishi Heavy Industries, Ltd., Japan. Tel.: +81-3-3212-3111; Fax: +81-3-3212-9855.

Keynote Address: Meeting Energy Demand by Energy-efficient Technologies - a Market Approach

Helga Steeg, International Energy Agency

Speaking on the final day of the Conference, Mrs Steeg began by discussing developments and challenges in the energy sector as they are expressed in the IEA's latest report 'World Energy Outlook to 2010'. This shows that the world's energy supply will remain essentially carbon based, with a projected share of fossil fuels of 90 per cent in 2010:

"Energy use in the OECD countries will rise, but it will rise even faster outside the OECD. By 2010 we foresee that the OECD will account for less than half of the world's energy consumption. How can we achieve sustainable economic growth throughout the world, maintain a secure energy supply and - at the same time - improve environmental protection?"

While all these questions present many political challenges, the IEA has a clear role in addressing the latter two questions. According to Mrs Steeg, 32% improvement in energy intensity of final consumption achieved by IEA member countries since 1973 can most probably not be repeated unless there are considerable and drastic energy price increases or more stringent regulations.

Heat Pumps

Mrs Steeg had some important remarks on heat pumps:



Mrs Steeg: "Energy prices should reflect real costs and thus enable markets to work"

"It is quite clear to me that advanced heat pumps do belong to those technologies which can exploit the energy savings potential. To me it seems that they have, of course, a potential for the residential building sector, but that their development and application for commercial and public buildings seems more important, since space heating and air-conditioning systems are a major user of electricity in commercial buildings. Also, industrial heat pumps seem to offer the most immediate commercial applications. With some research and development such as in the field of super heat pump systems, high-temperature and high-performance heat pumps with natural gas-driven compression or directly-fired absorption and with chemical heat storage - just to mention some items - heat pumps would appear to be one of the key next-generation technologies for the heating and cooling area.

With the use of substitutes to the CFCs and environmentally benign refrigerants, heat pumps should above all reduce the environmental consequences of energy production per unit of end-use service provided in a way that need not interfere with or alter the desired performance characteristics of such service."

Mrs Steeg also noted the benefits of heat pumps as highlighted in the IEA HPC's analysis 'The Impact of Heat Pumps on the Greenhouse Effect.'

Realistic

"Despite these positive factors one has to be realistic. A widespread lack of knowledge about this technology as well as high investment and maintenance costs are still a major obstacle to their application. Institutional and market constraints have still to be overcome.

The IEA has always attached great importance to a free market approach within all energy sectors. Making markets work, unleashing competitive forces, encouraging trade for goods and technologies, removing fuel subsidies, getting prices right and improving the transparency of costs - in my view - would also contribute to exploiting the potential for energy-efficient technologies.

I am well aware that reliance on market forces alone, however, is unlikely to achieve the necessary level of efficiency improvement implicit in most environment-oriented energy policies. Innovative and bold approaches to energy efficiency programmes are

needed. These have, however, to be based on careful analyses. Therefore - before embarking on intensive programmes of this kind - governments should be aware of the costs of new technologies and the actual energy efficiency potential they offer. Such market information is an essential prerequisite to evaluating the effectiveness of efficiency programmes and to developing policies to accelerate energy efficiency improvement in the economy."

Taxes

Referring to proposals currently under discussion by policy makers in the EC and USA, Mrs Steeg had this to say on taxes:

"What is clear is that those taxes will not be sufficient to stabilize CO_2 emissions by 2000. There is a need for additional regulation, and at the end of the day we need comparability of the different measures which are taken by OECD countries according to the different conditions and circumstances.

I am convinced that while raising fuel prices might in the short term lead to a slight decrease of energy consumption, it will not necessarily mean that new technologies such as heat pumps will penetrate the market easily. This will only be achieved if such technologies are well adjusted to market needs - which might need more research, development and demonstration - and if information on them is more widely disseminated."

Research and Development

"Energy technology implementation on a scale sufficient to make a significant contribution is often time-consuming and may involve substantial investments. Therefore it has to be supported by governments. Private industry can only be expected to invest in technology projects that offer prospects for satisfactory capital return or business expansion.

Energy technology progress has become increasingly international, both in R&D and in application. Basic science was always a matter for the international research community, but today there is international co-operation for technological innovation more broadly. Also the national approach might not be sufficient for gaining or maintaining competitiveness on a global market. This globalization calls for international co-operation beyond the borders of single countries.

The best form to take account of these facts is to embark on collaborative R&D where costs are shared, expertise is pooled and benefits are widely dispersed throughout the marketplace. I would like to recall that the IEA is sponsoring some forty international collaborative agreements - the so-called Implementing Agreements - since R&D on advanced heat pumps is one of them, and I must add one of the most successful with regard to the aspects I have just mentioned."

Mrs Steeg stressed the importance of attracting non-member countries of the IEA to participate in Implementing Agreements such as the IEA Heat Pump Programme. She also mentioned the newest feature of the IEA technology programme - GREENTIE (the Greenhouse Gas Technology Information Exchange). Operating from the same location as the IEA Heat Pump Centre, this centre will help to give all countries of the world access to the institutions and agencies where information is available on technologies already applied and developed.

Closed Shop

"And - to come back to the free market approach - I would like to add: if there is any area where a closed shop must be avoided, it is in the field of energy technology co-operation. Competition is the healthiest and most efficient way to enhance technological innovation, but such innovations must be free to penetrate markets when they become available. We should also not be afraid to speak of broader technological co-operation which transcends the industrialized West and offers real prospects for developing countries and economies in transition to participate in and share the benefits of innovation."

Essential Elements

Mrs Steeg finished her speech by summarizing the most essential elements of a market-oriented energy efficiency strategy:

- "Given the perspective of worldwide increasing energy consumption during the next 20 years, improved energy efficiency and environmental protection are major challenges in the energy sector;
- Advanced energy-efficient technologies can promote both environmental protection and energy security in a cost-effective manner;
- Continued research, development and market deployment of new and improved energy technologies make a critical contribution to achieving energy efficiency objectives;
- Energy prices should reflect real costs and thus enable markets to work;
- A mix of measures and instruments should be applied to facilitate the exploitation of the potential new technologies have for improving energy efficiency."

Speaker:

Mrs Helga Steeg, International Energy Agency, 2 rue André-Pascal, 75775 Paris, Cédex 16, France.



Session 2 - Environmental Overview

Mike Steadman, IEA Heat Pump Centre

Global warming and ozone depletion. Describing, arguably, the most significant environmental threats perceived today, these two terms affect the development of heat pump technology. In this session, which was chaired by Mr Zegers of the Commission of European Communities, delegates heard papers on both issues. The papers relating to ozone depletion limited themselves to the current status and requirements of the CFC phase-out measures. The consequences for heat pumps and their working fluids were considered in more detail in Session 3. On global warming, various methods for assessing the impact of heat pumps were presented along with results indicating the significant potential of heat pumps.

* * *

As with any energy consuming system, no discussion on heat pump technology is complete without an examination of its environmental consequences. But for heat pumps, environmental issues play a particularly important role in their development. While the global warming issue has become a major driving force for increasing heat pump use, the ozone depletion potential of the most well-used refrigerants is holding them back. But the introduction of new measures to the Montreal Protocol means that the elimination of ozone depleting substances from heat pump systems is no longer a matter of academic discussion, but a matter of legislation.

Phase Out

Mr Reed of Environment Canada, outlined the changes to controls on CFCs and HCFCs agreed at the 4th Meeting of the Parties in Copenhagen in November 1992. For heat pumps, the most significant agreement was to freeze HCFC consumption from 1996 and to reduce consumption in steps leading to virtual elimination in 2020 (see Figure). Also significant is that the phase-out date for CFCs has been brought forward four years to 1996. Notably, Mr Reed suggested that the phase-out dates for HCFCs are likely to be brought forward in the next meeting of the Parties in 1995.

The Parties also agreed to encourage recycling by exempting trade and consumption in recycling ozone depleting substances (ODS) from the phase-out agreements. Also all practical measures must be taken to prevent the release of ODS into the atmosphere by recycling or destroying recovered ODS and minimizing refrigerant leakage.

What are the consequences of these new decisions? Perhaps surprisingly, **Mr Bivens** of Du Pont de Nemours, sees an increasing role for HCFCs in the near term. Taking chillers as an example, the estimated 90,000 units using CFC-11 globally, cannot be replaced in the near-term with new units using alternative refrigerants, when the estimated world production capacity for chillers is only 4500 units per year. Using recycled CFCs, or retrofitting with HCFCs, are the only reasonable options if the accelerated phase-out dates for CFC production are to be met.

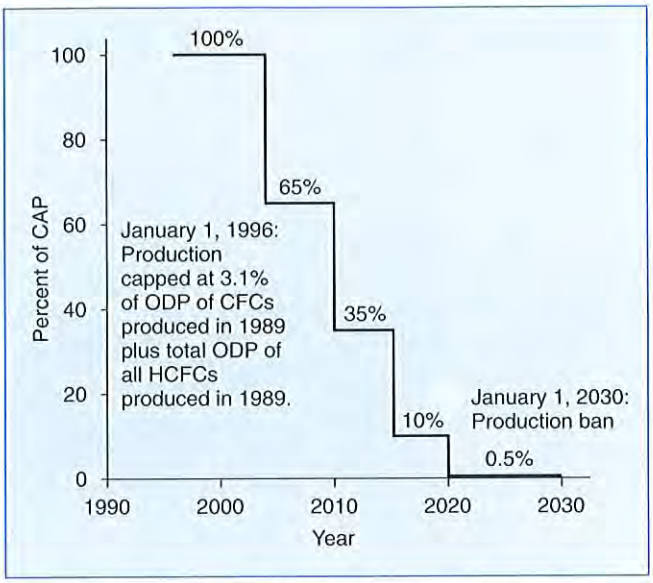
For the longer term, alternative refrigerants must be found. When deciding on alternatives, a balance must be struck between safety, environment, performance and economic issues. Both the direct (emission) and indirect (efficiency) impact of the refrigerant on global warming must be considered. Also, the atmospheric lifetime of the emitted refrigerant must be properly taken into account: the choice of the time period used (known as the Integrated Time Horizon) when assessing the Global Warming Potential of refrigerants is currently in dispute.

Fuel Cycle

With the new drive towards finding technologies for reducing global warming, it's vital that the potential of the heat pump is properly examined. **Prof. Laue** of the German Information Centre for Heat Pumps and Cooling Technology (IZW) used the concept of "Fuel Cycle Analysis" to compare heat pumps with conventional heaters. This takes account of all energy demands including those at the `front-end" such as fuel exploitation, processing and transport. These appear to add around 10% to the CO_2 emissions of boilers and heat pumps using fossil fuels. They are less significant for electric heat pumps.

Quality of Energy

Mr Kleinbloesem of the Netherlands utilities organization Sep, looked at the more wider energy system and posed the question "How should energy supply be optimized?" Urging delegates to bring essential knowledge on energy transformations to the attention of policy makers, Mr Kleinbloesem introduced the concept of exergy or "Quality of



Steps in the phaseout of HCFC refrigerants agreed upon under the Montreal Protocol (Source: EPRI Heat Pump News Exchange).

Energy". He used it to illustrate the benefits of providing low-temperature heat by the combination of a CHP (combined heat and power) system and electric heat pumps. When applied to a whole country, the concept shows that, in contrast to popular belief, an increase in electricity consumption will lead to reduced energy consumption when the waste heat from power generation is utilized, and electric heat pumps are integrated into the system.

Potential

So what is the heat pump's potential? **Mr Bouma** of the HPC summarized the findings of the HPC's Analysis Report and Workshop on "The Impact of Heat Pumps on the Greenhouse Effect." While the analysis showed a clear benefit for electric heat pumps in some countries, in others, some performance improvement in both the heat pump and power generation efficiency is needed before they can better the CO_2 emissions of the best conventional gas boilers. Also, the value of heat pumps as devices for reducing global warming will be further enhanced when they are integrated into an energy system and when they are fully utilized for heating, cooling, heat recovery and thermal storage. **Mr Okken et al.** of the Netherlands Energy Research Foundation (ECN) submitted a very thought provoking poster paper which showed results from a study made within the framework of the IEA Energy Technology Systems Analysis Programme (ETSAP). This looked at all options for reducing CO_2 emissions and showed that by 2030, heat pumps would supply more than half the heating needs for large office buildings. In the residential sector, heat pumps could supply up to 80% of the heat demand in a scenario where CO_2 emissions are reduced by 50% or more.

Convincing the Market

Once the environmental benefits of heat pumps have been established, a way must be found to convince the market to buy them. And since heat pumps are generally more expensive than the conventional technology, governments must be convinced of the value of incentive or tax systems. **Mr Jones** of the OECD Environment Directorate outlined various methods whereby environmental benefits can be given economic value. Techniques for estimating the cost of environmental damage are becoming more sophisticated and their use is increasing, especially in Germany and the USA. Mr Jones urged proponents of heat pump technology to demonstrate how much heat pumps might contribute to reducing these damage cost estimates.

Global Awareness

Poster papers by **Mr Amundsen et al.** of the Norwegian Water Resources and Energy Administration and SINTEF Refrigeration Engineering and by **Mr Srivastava et al.** of the MARA Institute of Technology in Malaysia illustrated the awareness in many different countries of heat pumps as a technology for tackling environmental problems. The Norwegian paper presented results from that country's Heat Pump Prototype and Demonstration Programme which has so-far covered around 50 projects. Future projects will focus on heat pumps using natural refrigerants. In Malaysia, heat pumps are seen as an important technology for reducing CO_2 emissions. While space heating applications are non-existent, heat pumps are being considered for combined air conditioning and hot water production. Heat pumps can also be applied in the timber, fishing, dairy and palm oil industries.

Progress for the Environment?

The environmental benefits of heat pumps are complex and vary enormously according to location, technology and application. Indeed heat pumps are not environmentally beneficial in every situation. But unlike most technologies, the environmental benefits of heat pumps will surely rise over the coming years, as heat pump efficiencies rise, as power plants become more efficient and clean, and as working fluids are better managed and are replaced by less damaging alternatives. But heat pumps also have a major role to play today, in the many applications and areas where they can significantly reduce the greenhouse effect. The analysis methods presented in this session should be used to convince a wider public of these benefits.

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Session 3 - New Refrigerant Technology Status

Bert Stuij, IEA Heat Pump Centre

The environmental benefit and safe operability of a heat pump system depends to a large extent on its life-blood: the working fluid. In the not-so-distant past, toxicity and flammability concerns lead to the massive introduction of 'safety refrigerants', as the CFCs were then called. We now know that these working fluids damage the ozone layer and aggravate the greenhouse effect. Vigorous efforts are currently ongoing to analyze, develop and stimulate the use of those working fluids that have negligible environmental drawbacks. The papers of Session 3, which was chaired by Prof. Watanabe of Keio University and Dr. Kuijpers of UNEP, addressed the potential and properties of the most promising options. These include HFCs and 'natural' fluids such as ammonia, CO_2 and air and hydrocarbons such as propane.

* * *

Working fluids have to meet a variety of possibly conflicting demands. The ideal fluid first of all allows a maximum efficiency of the employed heat pump system. This minimizes the energy consumption of the system, with the obviously associated economic and ecological benefits. Secondly, release of the ideal fluid poses no risk to either the direct or the global environment. This means that the ideal fluid is a non-toxic and non-flammable medium, with zero ozone depletion and zero global warming potential.

New Generation

Faced with these challenging demands HFCs have been identified as promising alternatives.
Mr. Fujiwara of Daikin Industries started the session with a comprehensive overview of these fluids. Most of the essential areas were covered, including thermophysical properties, toxicity, environmental impact, and material and lubricant compatibility. In view of the fact that pure HFCs rarely satisfy all demands, Mr. Fujiwara highlighted the significance of mixtures, where the defects of one component can be compensated by another.

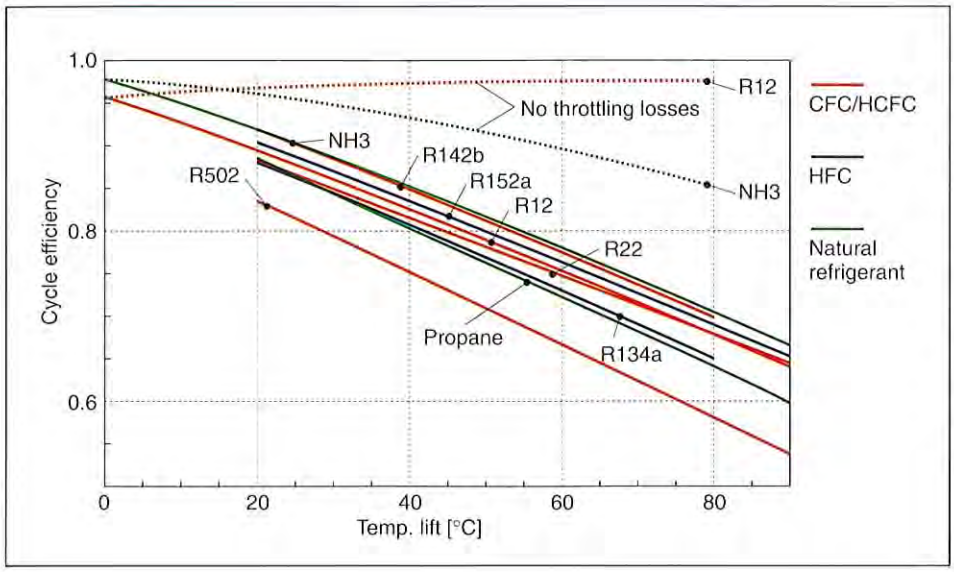
Prof. Kruse of Hannover University, Germany, discussed the perspectives for chlorine-free working fluids from a European viewpoint. In his discussion of the HFCs, he noted that for heating-only heat pumps only two pure HFCs appear to have immediate significance: HFC-134a and the propane derivative HFC-227. He supported Mr. Fujiwara's view on the advantages of mixtures, but argued that the possibilities for using HFCs in heat pumps remain limited. In Europe, hydrocarbons and other natural refrigerants such as ammonia, CO_2, and air are considered to be more promising. Prof. Kruse noted that the German Environmental Agency, UBA, has made an environmental ranking of working fluids, and found that hydrocarbons and other natural refrigerants rank better than HFCs. He urged a re-think on the flammability issue, which is currently a barrier to the use of hydrocarbons.

Conversion

A major concern is to find a replacement for the massively employed HCFC-22. Some 37 companies from North America, Europe and Japan joined forces in the Alternative Refrigerants Evaluation Program (AREP), a programme which was initiated by the Air Conditioning and Refrigeration Institute (ARI) in 1991. **Mr. Menzer** of the ARI presented an outline of the activities undertaken under this programme. He gave an overview of the first results obtained and discussed the currently perceived advantages/disadvantages of all identified potential alternatives. The results from the programme will be made public, and entered in the ARTI Refrigerant Database.

The retrofitting of existing installations with new refrigerants was discussed by **Mr Kaneshima** from the Shimizu Corporation, Tokyo. With a questionnaire to five leading manufacturers of chillers in Japan, the current use of CFCs was charted and used to develop retrofitting strategies. The current emphasis is on the replacement of CFC-11 with HCFC-123, but the longer-term perspective is replacement with non-HCFCs. Mr Kaneshima noted that the improvement of environmental performance of a heat pump system needs more than just the replacement of its working fluid. Minimum environmental impact also requires, for instance, excellent design of the heat pump for optimum efficiency, and proper design of the building energy system so that the heat pump meets cooling and heating demands with minimum energy consumption.

Prof. Granryd of the Swedish Royal Institute of Technology continued the theme of practical experiences with alternative refrigerants, focusing on the replacement of CFC-12. He showed a



Cycle efficiency for different refrigerants with basic cycles with no sub-cooling of liquid or super-heating of vapour. The condensing temperature is 40°C.

(Note: throttling loss, which is the main reason for cycle inefficiencies with organic refrigerants, can be reduced using sub-cooling or, theoretically, by using an expansion motor which assists in driving the compressor.)

comprehensive comparison of the thermodynamic characteristics of CFC-12 with those of the alternatives (see Figure). He then discussed Swedish experiences with alternatives such as HFC-134a and HFC-152a, in a variety of applications, ranging from car air conditioning to district heating and industrial heat pumps. Prof. Granryd expected a rapid rise in HFC-134a conversions as experiences from successful conversions penetrate. Finally, he emphasized the importance of the 'next step': away from the HFCs to natural refrigerants such as ammonia or propane.

Collaboration

Illustrating the benefits of international collaboration through the IEA network, **Dr. Vamling** of Chalmers University in Sweden presented highlights from Annex 13 and 18 of the IEA Heat Pump Programme. Both Annexes address the need for good data and models of basic thermodynamic and transport properties of pure compounds and mixtures of new, more environmentally friendly refrigerants. Annex 13, which closed in 1992, dealt with the state and transport properties of high-temperature working fluids. Dr. Vamling noted that Annex 13 has highlighted the need for measured property data, since prediction methods are not yet well developed enough to allow accurate heat pump performance calculations. Annex 18, which started in 1990, addresses the thermophysical properties of the environmentally acceptable refrigerants. Its final goal is the publication of a comprehensive, internationally accepted properties bulletin. Given their importance, initial efforts are concentrating on HFC-134a and HCFC-123 (see the news section, page 13, of this Newsletter, for an update on Annex 18).

A number of related topics were addressed in the **poster sessions**, such as the heat transfer of zeotropic refrigerant mixtures, practical experiences with HFC-134a, and recent results of thermodynamic research on CFC and HCFC alternatives. A US paper dealt with the modification of compressors to maintain heat pump efficiency and capacity with alternate refrigerants. A Norwegian poster illustrated a 20 kW prototype heat pump with ammonia as refrigerant.

Continued Efforts

Session 3 highlighted the aggressive worldwide drive to replace CFCs and HCFCs by refrigerants with negligible environmental impact. The pace is forced by international agreements such as the Montreal Protocol, by national legislation, and by public opinion. Furthermore, international collaboration is yielding significant results.

HFCs were presented as important medium-term alternatives, but especially in Europe, there is a growing interest in natural refrigerants including hydrocarbons. Significant hurdles remain to be overcome, such as flammability and toxicity concerns, and novel technologies may be required to use some of these refrigerants. In all cases the efficiency of the heat pump system should remain a prime concern.

There is no doubt that the continued replacement of CFCs and HCFCs will improve the standing and quality of the heat pump as an environmentally benign device. That in itself will be a stimulus for more widespread implementation.

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Session 4 - Technology Advances

Jos Bouma, IEA Heat Pump Centre

The 25 papers presented at this session reflected the enormous amount of work being carried out in the field of heat pump R&D. Chairman Mr Sellberg of the Swedish Council for Building Research and co-chairman Mr Sakamoto of Toshiba Corporation, Japan heard the six oral presentations. Broadly speaking, the papers focused on two aspects: improving the performance of heat pumps for existing applications, and widening the applicability of heat pumps to areas where their use is limited, or non-existent at present. Air-to-air heat pumps fall in to the first category - they are becoming more efficient and now offer hot water heating as well. The second category applies to heating-only heat pumps for use with hydronic type distribution systems. For industrial heat pumps, the diversity of applications offers a wide scope for fundamental heat pump R&D. Common to all industrial applications however is the concept of Process Integration which must be applied if heat pumps are going to be used in an optimal manner.

* * *

Those involved in promoting heat pumps face the dilemma of presenting heat pumps as on the one hand a mature, reliable, commercially viable technology, and on the other a technology with a huge potential for improvement in efficiency and environmental benefit. **Mr Göricke** of the major German electric utility (RWE), clearly feels that emphasis should be given to the first point. In his paper 'Heat Pumps for Widespread Use are Available Today!', he stated that technical improvements should not be emphasized in promotional campaigns since they will be implemented anyhow.

Heating-only

Mr Göricke's paper focused on heating-only heat pumps for low-temperature water-based heat distribution systems in Germany and similar regions. In these regions, there is no cooling demand in homes and reversible heat pumps would unnecessarily increase energy consumption when they are used for cooling. Instead, the heating-only heat pump should be marketed and promoted as a mature technology, commercially available today. To overcome the economic impediment of heating-only heat pumps, the first step must be to stress their energy and environmental benefits (CO_2 emission reduction) in advising the public and policy makers.

Mr Göricke reported on ongoing tests at RWE on heating-only heat pumps using propane as the working fluid. As well as being highly attractive from a global warming and ozone depletion point of view, the tests show that propane can enable higher condensation temperatures.

At present there are approximately 45,000 bivalent air-source heat pumps in operation in Germany. The majority of them supply the heat to a 'high' temperature (70/90°C) hydronic heat distribution system. These heat pumps may be disconnected from the electricity grid during winter peaks. In new homes, mainly monovalent heat pumps will be applied since a second (back-up) system is not accepted anymore for cost reasons. In addition to a considerable reduced heat demand, these new homes are equipped with low-temperature heat distribution systems (air and floor heating). Floor heating in new homes is considered by RWE to be the most promising heat distribution system in Germany, air systems being too expensive and not needed for cooling. Floor and other types of low-temperature heating systems were also examined in a poster paper by **Mr Kilkis**. The most suitable heat source gaining growing interest is the ground (groundwater can cause operational problems).

Exhaust air

Heat recovery from buildings with exhaust-air heat pumps has proved to be highly effective and energy efficient, according to **Mr Fehrm** of Elektro Standard, Sweden. In Sweden, these heat pumps have gained a 50% market share of new single-family homes. Most supply hot water for heating and domestic purposes. In some applications they heat the building structure for technical and comfort reasons. Back-up is usually provided by resistance heating, but for regions in Sweden with natural gas an integrated exhaust-air heat pump and gas boiler has been developed. By recovering heat from the boiler exhaust, high COPs (>4) are achieved leading to an overall energy efficiency of more than 130%. Another advantage is that there is no need for a conventional chimney. Exhaust-air heat pumps are also used for multi-family homes and communities in Sweden. In one case, a 4 MW system supplies 2500 flats, a school, a daycare home and small commercial buildings.

Water Heating

The theme of reducing water heating costs in homes and buildings was taken up by **Mr Reedy** of Nordyne, USA. With heating and cooling demand in new houses reduced by improved design and construction, water heating now accounts for a considerable share of a home's utility bill. Heat pumps can take advantage of this energy saving opportunity by integrating the functions of space conditioning and water heating into a single system.

Several approaches to achieving this have been tried in the USA. The Carrier/EPRI Hydrotech 2000 was the first commercialized fully integrated system to demonstrate technical feasibility. A less sophisticated but cheaper system, known as Powermiser, has recently been introduced by Nordyne/EPRI. Both these systems heat water coincident with both space heating and cooling, and in addition will provide water heating on demand without the need for space conditioning.

Control

Mr Sakamoto of Toshiba, Japan, outlined recent developments in the control technology of electric heat pumps for residential space conditioning equipment in Japan. The impact of capacity control technology on energy savings and comfort improvement contributed to the fast market growth in the 80s. High-speed inexpensive microprocessors, now employing fuzzy logic, have further improved the performance of speed-controlled reversible heat pumps. Today, all control functions such as part-load control, evaporator control, and start/stop control are carried out by a microprocessor. This has improved COP, especially at part-load conditions. A new challenge is to overcome stability problems associated with the use of some new refrigerants. Control strategies must be found to optimize the tradeoff between reliability and efficiency.

Industry

Mr Berntsson of Chalmers University of Technology, Sweden, showed that by using Process Integration, the potential for industrial heat pumps is clearly higher than has been assessed in previous studies. He showed how Pinch Technology can be used to find the proper placement for various types of heat pumps in industrial processes. Tools such as the Composite Curve and the Grand Composite Curve can be used to find the appropriate design in terms of type, size and source/sink temperatures. Methods for optimizing the main parameters in both a new design and a retrofit situation were explained.

High Temperature

Mr Linton of NRC, Canada, gave an overview of high-temperature (>80°C) heat pump technology development from a global perspective. Industrial applications of closed-cycle vapour compression systems using HCFC-142b were reported. Systems reaching condensing temperatures of 90°C have been tested. Another heat pump in Sweden uses HFC-134a and delivers 80°C heat. This temperature level is probably the highest achievable with this working fluid. Mr Linton also discussed R&D work in relation to new working fluids or mixtures capable of raising output temperatures to the 150°C range. For vapour compression heat pumps the following high-temperature working fluids are proposed: HCFC-123,

Compresssion-absorption heat pump installations.

Installation	Type of heat source	Heat source temperature	Heat sink temperature	Heat capacity (kW)	Comp. & pump power (kW)	COP
TCH No. 1	sodium carbonate	t_{in} = 95°C phase change	115°C 1.7 bar steam	1000	110	9.1
TCH No. 2	water	t_{in} = 85°C t_{out} = 80°C	138°C 3.3 bar steam	1000	275	3.6
TCH No. 3	water	t_{in} = 52°C t_{out} = 30°C	t_{in} = 60°C t_{out} = 95°C water	280	63	4.4
Bergmann	water	t_{in} = 25°C t_{out} = 5°C	t_{in} = 15°C t_{out} = 85°C water	1000	230	4.3

ethyl chloride, E-134, HCFC-124, HFC-152, HFC-143, HF-245ca and mixtures.

R&D in absorption (type I/II) heat pumps focuses on improving cycle efficiency and economic factors by developing new multi-stage cycles and using new working pairs. High temperature heat transformers show greater potential. In Japan, the New Energy and Industrial Technology Development Organization (NEDO) have bench tested a H_2O-LiBr heat transformer with a 170°C - 200°C output temperature.

The Table summarizes several compression-absorption installations, all of which use an NH_3/H_2O working pair. These systems can achieve better performance than vapour compression cycles, particularly at high temperature lifts and output temperatures. Higher temperatures and performance increases are aimed at by developing new working pairs.

Posters

While 150°C is generally considered to be an upper limit for today's heat pumps, **Mr Le Goff** of France proposed, in his poster paper, an absorption heat pump operating between 223°C and 450°C for use in an electric power plant. The separator is inserted between the combustion chamber at 1100°C and the steam evaporator super-heater at 450°C. The system uses a calogen based working pair and increases the efficiency by 22%.

Many other poster papers were presented, covering a wide range of heat pump technologies. Their titles are listed on page 38.

An Advancing Technology

While it is important to stress that heat pump technology is readily available for use in many applications, the fact that so much R&D work is underway, leads the way to increased application of heat pumps in the future. And with efficiency levels continuing to climb, heat pumps will compete more strongly with other measures for reducing energy consumption and reducing environmental damage.

With so much work in progress, it is important that engineers and researchers are well informed of R&D progress in their area of interest. The IEA Heat Pump Centre is playing a lead role in this matter by maintaining and improving communication through its network of National Teams and links with international organizations. In this way, it is hoped that progress in R&D will lead rapidly to an increased use of heat pump technology.

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Session 5 - Markets Electric Driven Heat Pumps

Mike Steadman, IEA Heat Pump Centre

With so many new developments reported, and much discussion on the potential environmental benefits of heat pumps, the casual observer may, by this stage in the conference, have been given the impression that a heat pump is a futuristic device whose relevance to the real world has yet to come. But in Japan and the USA, heat pumps are every-day objects of significant economic importance. This session, which was chaired by Mr Groff, chairman of the Advisory Board to the IEA Heat Pump Programme, and Mr Lucas of the International Institute of Refrigeration, included reports on the current market trends for electric driven heat pumps in various regions. Papers were also included on the wider issue of heat pumps in relation to the total energy market and on some application examples, where new technology has been applied to adapt heat pumps to meet specific market needs.

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European Market

With Japan and the USA leading the world in heat pump sales, Southern Europe, with its warm climate and advanced economies, has long been seen as having a high potential for heat pump sales. **Mr Wright** of Carrier Ltd. (UK) presented some new figures on the market situation in France, Italy and Spain. Taking air conditioning as a whole, a survey by BSRIA (Building Services Research and Information

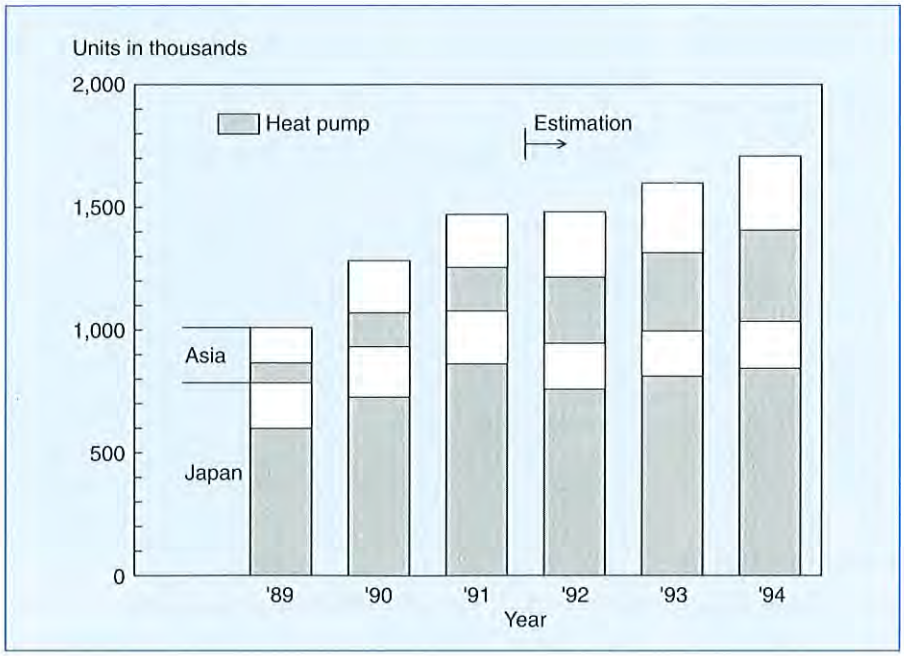


Figure: Unitary air conditioner market in Asia and Japan.

Association (UK)) shows that these countries still have the largest market potentials in Europe, although the current recession and an over-supply in office space have severely restricted growth. For heat pumps, however, an average increase in sales of 25 - 30% is predicted in the next three years. In answer to a question from Mr Groff, Mr Wright stated that manufacturers would welcome minimum efficiency ratings for heat pumps in Europe, and that this was a pre-requisite for improving COPs in a market driven more by cooling demand than by environmental concern.

In Central and Eastern Europe, heat pump sales are showing signs of a revival after several years in sharp decline. In this region, where air conditioning is of little interest, nearly all heat pumps are used to supply hydronic heating systems. **Mr Zaugg** reported that heat pump sales in Germany are still well below their peak of 1980. However, a slight revival appears to be underway, supported by 20-30% incentive schemes in some German states. In contrast to Germany, the Swiss government ranks heat pumps highly in its energy policy. In 1991, one in four new homes built in Switzerland installed a heat pump. Heat pumps also feature strongly in Austrian energy policies. Here, in contrast to Germany and Switzerland, direct-expansion ground-source heat pumps are the most common. In Poland, 200-300 heat pump systems are installed annually.

N. American Market

The air-source single-speed electric heat pump, supplemented by resistance heating remains the mainstay of the US heat pump industry according to **Mr Lannus** of EPRI, USA. This is due to the significance of the warm Southern states on heat pump sales. The efficiency of these systems has improved significantly since the late 1970s as manufacturers have strived to meet and surpass government efficiency standards. The more advanced variable-speed air-source heat pumps have still not gained widespread market acceptance, despite their high performance. And ground and water-source heat pumps represent a much smaller market than air source types. In Canada, ground-source heat pumps are equally significant to air-to-air systems with about 7,400 thought to have been installed in 1992, many of them direct-expansion systems.

Mr Lannus noted that while US heat pump shipments total about 1 million units per year, their market share has given way to the gas furnace over the last half decade. This is due, in his view, to the misguided policies of some regulatory authorities. The phase-out of HCFC-22 also appears to work against the heat pump, although the search for alternatives may act as a boost for heat pumps by leading to improved efficiencies.

Asian Market

Mr Ikomoto of Mitsubishi Heavy Industries reviewed the Asian market for room and unitary air conditioners, and chillers. Despite the current downturn in the market, the significance of Japan's room air conditioner market is remarkable, representing 44% of world demand in 1991. In 1992, 3.9 million mini-split type heat pumps were installed. 60% of these were inverter driven. In the rest of Asia, less room conditioners are installed than in Japan, although demand is rising rapidly. Nowhere more than in China, where demand rose from 800,000 in

1991, to 1.8 million units in 1992, providing a significant export market for Japanese manufacturers. Thirty per cent of these were heat pumps.

Sales of unitary air conditioners have also suffered a downturn in Japan, but as shown in the Figure, this has been compensated by increased sales in other parts of Asia. In 1992, 20% of unitary heat pumps sold in Japan were inverter type. Multi-zone systems, where one outside unit serves 2 to 8 inside units, are on the increase (16% of all unitary air conditioners in 1991) including heat recovery types which can cool one room and heat another.

Sales of reciprocating and screw chillers with capacities in the 30 to 90 kW range, are expected to remain steady at around 17,000 a year throughout Asia in the coming years. About 30% are of the heat pump type, providing heating, hot water and also snow melting on roads. Annual sales of the larger centrifugal chillers have halved since the late eighties to around 300 units. Around 30 of these are heat pumps. Absorption chillers are far more significant.

Energy Market

Mr van Wunnik of KEMA, the Netherlands, looked at how heat pumps could fit in to the total energy market in his country. Using the concept of energy quality, he demonstrated that a system based on combined-cycle power generation and district heating gave the highest exergetic efficiency for heat supply. However, in practice, a second energy supply chain is needed and the electric heat pump has several advantages over its close rival (in energy efficiency terms), the gas engine CHP (Combined Heat and Power) system. Unlike CHP, electric heat pumps only compete with combined-cycle power generators on the heating market. Also, heat pumps improve the elasticity of the electricity market by providing a market for any excess electricity produced in the district heating power plants. Another advantage of this system is that it provides the opportunity for mono-energy supply (electricity only) for buildings in difficult terrains.

Computer Control

Mr Lotz of HCF Industries, France, stressed the importance of matching heat pump designs to customer needs, and to provide tools to service people for easy and efficient maintenance. Modern computer control techniques have been applied by HCF to meet both these needs. In one project, a set of dampers are controlled to recycle air or provide fresh air according to building occupancy and outside temperature. A glycol water loop recovers heat from expelled air. Maintenance work has been significantly improved by a system which transmits diagnostic information over a modem to a central maintenance station, where remote trouble-shooting is carried out. In a separate poster paper, Mr Lotz also reported on how HCF have successfully introduced water loop heat pumps to the large-building market, most notably in the supermarket sector. Again, computer control systems have played a major role in improving efficiency, operability and serviceability.

In Norway, computer technology is being used to improve the efficiency and performance of district heating heat pump systems. **Mr Årøen** reported in his poster on the SCADA (Supervisory Control and Data Acquisition) system which monitors temperature and valve positions in all buildings and adjusts the temperature of water in the district heating grid for optimum performance. A poster by **Mr Røsvik** reported on another Norwegian project which uses river water as a thermal source for heating and cooling a complex of industrial buildings (approx. 150 years old).

Hidden Demand

In summing up this Session at the end of the conference, Mr Groff welcomed the good news from Europe, where heat pump sales are rising. But he was not convinced that the true impact of heat pumps in that region are being fairly portrayed, since unit sales are often lost in air conditioning statistics. Furthermore, the European resistance to air conditioning is holding back support for heat pump technology which can play a major role in meeting the rise in cooling demand, and in reducing environmental damage.

While actual heat pump sales are currently being hit by recession in many areas, the upward trend will continue in the future. However, a more pronounced rise in heat pump installations will only come when there is greater recognition of the benefits of heat pumps by policy makers. Measures such as incentive schemes and efficiency regulation will raise the significance of electric heat pumps in world markets.

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Session 6 - Thermally Driven Heat Pumps

Bert Stuij, IEA Heat Pump Centre

The thirteen papers (6 oral, 7 posters) of Session 6, confirmed that a great deal of research, development and commercialization of thermally driven heat pumps is ongoing. There are several good reasons for this. In the heating season, engine driven heat pumps have the potential for high efficiency since they allow utilization of the waste heat from engine cooling water and exhaust gases. In the cooling season, gas driven systems can reduce the summer peak in electricity demand, caused by electric air conditioning which is a huge problem in some areas. The CFC/HCFC issue has provided a window of opportunity for sorption heat pumps which use environmentally benign working fluids. Significant strides have been made to overcome impediments against more widespread use of thermally driven heat pumps, which in general have to do with the technical reliability of gas driven systems, and their price. Dr. Sweetser of the American Gas Cooling Center and Prof. van der Ree of the Technical University of Delft, the Netherlands, chaired the oral presentations.

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Opportunities for thermally driven heat pumps exist, because of their high potential efficiency, their ability to achieve load levelling for electric utilities, and in the case of sorption systems, their use of environmentally harmless working fluids. Challenges exist mainly in the areas of equipment reliability, NO_x emissions and costs.

Meeting the Challenge

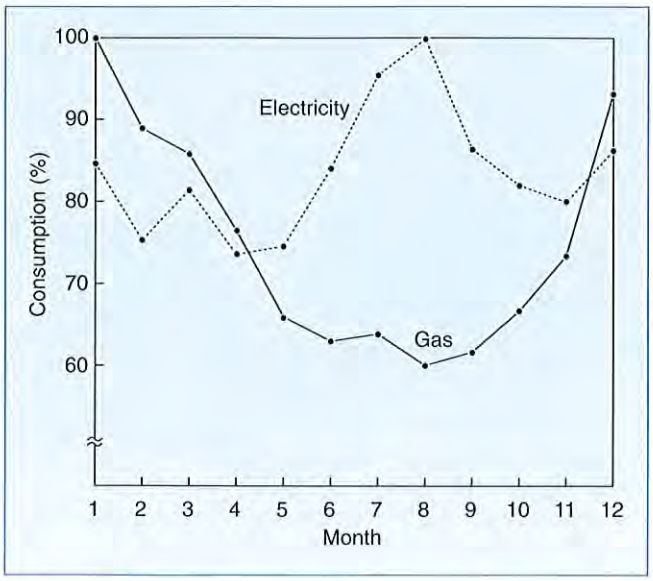
Mr Sakata of the Sanyo Electric Co., Japan, discussed the development and market penetration of the domestic gas engine driven (GEHP) heat pump in Japan. First introduced in 1985 to offer a gas-fired alternative to the electric air conditioner, annual sales of the GEHP reached 30,000 in 1992, and a continued rise is expected. The models on the market in Japan now cover a similar range of capacities and possibilities to electric heat pumps. The employment of gas engine heat pumps is in line with government and utility policies. It can reduce summer peaks in electricity demand and achieve a gas consumption which is more evenly spread over the year (see Figure). Goals for future development include reduced NO_x emissions from the gas engines, improved product reliability and a reduction of costs.

On a more fundamental level, **Prof. Steimle** of the University of Essen, Germany, reviewed both the engine driven heat pump and the absorption heat pump. He noted that the gas engine heat pump uses some 25% less primary energy than its electric equivalent, but that reliability and prices have been hurdles for a more widespread implementation. As for the absorption technology, he stated that the conventional working pairs NH_3/H_2O and H_2O/LiBr both have some problems, and that promising alternatives are still worth investigating. As an added advantage of absorption systems he highlighted the potentially very low maintenance cost, given the absence of moving parts.

National Efforts

The development and market introduction of gas fuelled space conditioning technologies is vigorously pursued in the USA. **Mr Freedman**, of the US Gas Research Institute, gave a comprehensive overview of the efforts in this field. Both engine driven and sorption systems are now close to commercialization. A residential 10 kW gas engine heat pump, developed with York, has successfully completed a 10 unit field test, and is now entering a 50 unit demonstration phase, in a concentrated endeavour to commercialize this technology. Reliability targets are exceptionally high with 50 to 60,000 hours operation hoped for (this is equivalent to a car engine running for 3 million km!). Even though no exhaust catalyst is used, NO_x emissions are kept below 2.7g/kWh. Sorption technologies, including absorption, adsorption and chemisorption of ammonia vapour are in various stages of development. An ammonia/water absorption GAX system is expected to enter a field test this year. Prototypes of the system have shown excellent efficiencies. The aim is to develop a heat pump with a size and cost to compete with existing heating and cooling systems, and a reliable operating lifetime of at least 20 years. All developments face economic trade-off issues regarding cost and performance.

Mr Yoshida, of the Japanese Gas Association, presented a Japanese R&D programme on small-sized gas driven heat pumps - in the range of 2.5 to 7 kW. The 40 million USD programme is sponsored by the Japanese government (one half), four gas utilities (one quarter), and 11 manufacturers (one quarter). It will run for four years: the first two years will be mainly



Gas and electricity consumption patterns in Japan.

devoted to the development of components; performance testing of prototypes is expected in 1994, and field tests will commence in 1995. The research efforts include H_2O/LiBr and NH_3/H_2O absorption systems, gas engine driven heat pumps, and Vuilleumier systems. Minimum efficiency targets are modest (heating COP more than 0.75, cooling COP more than 0.7). The main drive is to come to a reliable and competitive device which can find extensive market penetration. The government's first aim is to reduce the summer peak in electricity demand caused by electric air conditioners.

Encouraging

Highly encouraging operational experiences with a significantly larger system were presented by **Dr. Bassols**, of Colibri BV, the Netherlands. In the spring of 1993, an ammonia/water absorption heat pump, with a cooling capacity of 110 kW and a heating capacity of 250 kW, was installed in a government building in Maastricht. The river Maas provides the heat source together with heat recovered (30 kW) by cooling computer equipment. The heat pump uses advanced plate fin heat exchangers. Heat exchange between absorber and generator is utilized (GAX), and the design of the unit is such, that it can continuously vary between a single-stage and double-stage 'mode', depending on the operating temperatures. The single-stage mode allows relatively high temperature lifts to be achieved, while the efficiency rises rapidly if temperatures allow operation in the preferred double-stage mode. The first measurements show an excellent heating COP of 1.8, boosted by the relatively warm river water and moderate heat demand in spring. Over the entire heating season an average heating COP of 1.55 is expected. Gas consumption of the building will be reduced by one third to one half, or more than 100,000 m^3 per annum.

A distinctly different angle was covered by **Mr Bin Yassin** from the utility Tenaga Nasional Berhad, Malaysia. He discussed opportunities for large-scale thermally driven heat pumps, to be integrated in agro-based process and power plants in the tropics. Total process efficiencies in the tropics are often low because of the inherent high back-end temperatures. Large amounts of heat are currently lost to the environment. Mr Bin Yassin argued that thermally driven heat pumps are one way to make good use of this heat. Heat transformers can be integrated in processes to enhance overall efficiencies, and there are district heating or cooling opportunities which can be served by waste heat driven heat pumps. In conclusion he stated that, contrary to common belief, industries located in the tropics offer immense potential for the application of heat pumps.

The application of thermally driven heat pumps in industry was given further attention in the **poster session**. An Italian paper showed that absorption heat pumps have several advantages over compression heat pumps in industrial applications including the potential for higher temperature lifts. Experiences with a steam generating heat transformer at a steel plant in the Netherlands were also presented (see HPC Newsletter Vol.11 No.1). Another poster highlighted the latest developments with the Dutch adsorption system known as SWEAT (Salt Water Energy Accumulation and Transformation; see HPC Newsletter Vol. 10 No. 1). This low-cost system is now in a field test where it provides building cooling using heat from a district heating system. Other posters were presented on a combined absorption/compression cycle, a dynamic test rig for heat pumps, and prototype tests on an absorption heat pump with the new working pair trifluoroethanol-pyrrolidone (TFE/Pyr).

Strides and Hurdles

Session 6 made clear that a variety of thermally driven domestic heat pumps are under development or near commercialization. In particular, to reduce the summer electricity demand, gas fired space conditioner systems currently receive intense attention in the USA and Japan. Costs, reliability, size and NO_x emissions are some of the hurdles to be taken, and significant strides are reported in these areas. Large-scale absorption systems are now showing excellent performance, which increases hope for a more significant market penetration. The application of thermally driven systems in industry is beneficial in many cases, and systems which are both technically advanced and commercially attractive have been realized.

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Session 7 - Market Influences: Regulatory, Institutional and Governmental

Bert Stuij, IEA Heat Pump Centre

In previous sessions, the significant potential of heat pumps to enhance the efficiency of energy systems and thus benefit the environment was confirmed. However, these positive effects can only be realized if the market penetration of heat pumps is substantially increased: the heat pump will have to 'beat the competition' on many more occasions. Of course the competitiveness of heat pumps is greatly influenced by its economic performance compared to the alternatives. But it is clear that when governments and utilities adopt focused energy policies, they can strongly influence the market potential of energy saving technologies - including heat pumps. These market influences were surveyed in session 7 which was chaired by Prof. Frivik of SINTEF, Norway, and Mr Narita of TEPCO, Japan.

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Instruments to influence the market for heat pumps include standards and regulations, subsidies and incentives, sponsored research, and promotion. Governments, utilities and international organizations all have a role to play.

Standards

Mrs Mondot of CETIAT, France noted that, as the market for heat pumps increases, the need for standards grows with it. Standards may concern the whole product or just some of its components, for instance for safety or environmental reasons. In general, a method to determine performance will have to be standardized, to allow a harmonization and meaningful comparison of manufacturer catalogue data. Standards can be developed nationally, on a European level (CEN), or worldwide (ISO). Efforts in all these areas are ongoing. Mrs Mondot presented highlights of the main international standards (CEN and ISO) which cover performance testing, environmental quality assessment, and general and electrical safety. In conclusion she stated that standardization efforts are inevitably ongoing, in particular to cover new technologies.

Confirming the industries interest in good standards, **Mr Pritchard** of York, UK, presented the Eurovent certification programme for unitary air conditioners. Eurovent, founded in 1959, is a European association of fourteen national associations representing air handling and air conditioning equipment manufacturers. Addressing a widely shared concern about the inaccuracy of published performance data of many products marketed in Europe, the certification programme is now achieving an agreed basis of comparison between the air conditioners of all manufacturers. This will clearly benefit the image and marketing position of the industry. If products comply with Eurovent requirements they are entitled to apply the 'EUROVENT Certified Performance' label to their products. A similar programme for heat pumps does not yet exist, but the Eurovent model could be used since the market logic for heat pumps is similar.

Mr Knipscheer, chairman of the Dutch HPC National Team, stated that the traditional lack of appropriate standards and regulations for heat pumps has already had dire consequences, in particular when heat pumps are matched with a hydronic heat distribution system. In the Netherlands, the lack of adequate standards in this field has lead to a disturbing list of poorly designed heat pump systems, and has hampered further penetration. Energy savings in 17 surveyed projects were less than half of what was calculated, heat pump performance was on average 20% below the estimates, and maintenance costs were twice as high as expected. The following problems need to be addressed:

- inappropriate heat load calculations lead to massively over designed heat pumps;
- the standard heat distribution systems operate at too high a temperature to allow effective matching with a heat pump;
- 'standard' heat pump test data do not relate to actual field conditions.

Mr Knipscheer argued that wide ranging improvements to design standards for heat pumps, heat load calculations and hydronic heating systems are a pre-requisite for meaningful heat pump penetration. A proper design may well lead to the conclusion that a heat pump is not suitable in a particular situation, but that outcome is of course to be preferred above a wrongly applied and economically disastrous heat pump installation.

Programmes

In Japan, the drive of the Japanese government to accelerate the development of heat pumps for energy efficiency is typified by the 'Super Heat Pump Energy

Accumulation Systems' programme. **Mr Yoshimura** of the Japanese Ministry of International Trade and Industry highlighted the progress made in this trend-setting nine year project, which was finished in March 1993. Some of the results are shown in the Table. Innovative technologies incorporated in the Super Heat Pump include advanced screw compressors, multi-stage condensers, and plate fin heat exchangers for minimum temperature difference. Chemical heat storage units have also been developed with a performance exceeding predicted values. Now the government sponsored research is finalized, the challenge is for industry to commercialize the developed systems, so that their promise of increased efficiency and environmental benefit is realized.

In the USA and Canada, government agencies, utilities and major manufacturers are collaborating on research in both industry and government laboratories. **Mr Baxter**, of the Oak Ridge National Laboratory, USA, noted that the required phase out of CFCs and HCFCs has added new urgency to this work. These phase-out requirements are seen as an opportunity to develop advanced refrigeration and heating systems, with very high efficiencies. Zeotropic refrigerant mixtures as replacements of HCFC-22 are one way towards this goal. Thermally driven heat pumps also receive intense attention (see Session 6). Longer-term developments include work on Stirling engine driven heat pumps and solid-gas adsorption systems.

Activities to support and promote heat pumps on a multi-national level are performed under the auspices of the European Community. Highlights from these activities were presented by **Prof. Reay**, UK, chairman of the European Commission's Concerted Action Group on Heat Pumps. European initiatives have thus far mainly taken the form of sponsored RD&D work. Such activities, which include work on alternative refrigerants, heat pipe heat pumps, absorption/adsorption heat pumps, and other new technologies, take place in a variety of research establishments across Europe. Recently these activities have been supplemented with more explicitly market oriented actions such as making a market study and producing promotion material such as a multi-language brochure. The group will also be advising the European Commission on strategy, implementation and evaluation.

Mrs Steeg, executive director of the IEA, gave her keynote address in this session. She discussed the relationship between markets and the stimulation of energy efficient technologies such as heat pumps, and emphasized that innovative and bold approaches to energy efficiency programmes are needed. Extensive hightlights from her address are given on pages 19-20 of this newsletter.

A poster presented by **Mr Rivenaes** of Energy Communication Systems, Norway, highlighted the achievements of the Norwegian National Heat Pump Programme. By giving courses and developing educational material, the programme has played an important role in increasing heat pump usage in Norway. A strategy plan for 1993-2000 has been developed and includes the development of heat pumps using natural refrigerants such as ammonia, air, CO_2 and propane.

Utility Schemes

The efforts of utilities to advance heat pumps were first addressed by **Mr Narita** of the Tokyo Electric Power Co. Ltd (TEPCO). He noted that electric utilities are interested in heat pumps for two reasons: Firstly, the high efficiency of heat pumps reduces the overall energy requirement, especially if they replace resistance heaters. Secondly, they improve the load

Item		Output Temp. °C	Heat Source Temp. °C	COP
High Efficiency Type Heat Pump	for Heating	85 65	50 35	8.1 8.2
	for Heating & Cooling	45 7	10 32	6.2 7.1
High Temperature Type Heat Pump	for Low Temp. Heat Source	150 150	50 95	3.0 5.0
	for High Temp. Heat Source	300 300	150 200	3.0 6.0*
* not confirmed				

Performance experiences under Japan's Super Heat Pump Programme.

factor. Cooling demand causes an electricity peak in the summer. If heat pumps are used for heating in winter, rather than alternative energy sources, a relatively high electricity demand is achieved in winter as well. The problem of daily load fluctuations remains, and the utilities are now promoting heat pump systems combined with thermal storage. The actions of TEPCO include the distribution of free bulletins on heat pumps, free open seminars, and visits to buildings equipped with thermal storage heat pumps. Joint technical developments between utilities and manufacturers are also taking place. The utilities take active part in Japan's IEA activities in this field, coordinated through the Heat Pump Technology Center of Japan.

The efforts of American electric utilities were discussed by **Mr Taylor** of Kemper Management Service. He focused on incentive schemes, and noted that while the costs of these schemes are normally paid by the utilities, their implementation is closely guarded by the regulatory authorities. These schemes aim at load levelling, energy saving, and very often an improved market position of electricity versus alternative energy sources. Some utilities link the height of an incentive to the performance of the heat pump installed. Mr Taylor emphasized that 'threshold subsidies' (e.g. a fixed amount if a heat pump meets a minimum efficiency requirement) are clearly not stimulating technology advances. Better are schemes where the incentive continues to rise with improved performance. Touching on demand side management (DSM), Mr Taylor noted that DSM can increase rather than decrease total kWh demand. In some states DSM has the clear and stated objective to reduce energy consumption, while in others the main aim is to increase electricity sales. Mr Taylor noted some mixed feelings in the debate, caused by the realization that increased efficiencies will reduce total kWh demand, and by the fact that gas and electric utilities seek primarily to enlarge their market shares, rather than to reduce energy consumption.

A European perspective was provided by **Mr Moreau** of Electricity de France (EdF). The heat demand in France is already moderate rather than high, and it continues to fall with improving insulation. Combined with the low energy prices this hampers a widespread penetration of the heating-only heat pump. Economic possibilities remain, especially in hospitals, nursing homes, public amenities and large houses. An installed power of only 40% can cover 70% of the heat demand, and achieve significant savings - especially when compared with resistance heating which is dominant in France. Yet the economic decision remains difficult, unless use can be made of the ability of heat pumps to cool for comfort in summer. Recognizing that France, given its climate and economic development, looks rather 'under developed' with regards to comfort cooling, EdF has embarked on a promotion campaign for air conditioning with emphasis given to reversible types. If successful, this promotion should result in a significantly expanding heat pump market in France.

Joint Forces

The last speaker of Session 7 was **Mr Fleming** of The Fleming Group, USA. He argued that Demand Side Management (DSM) and heat pump programmes must result in transparent benefits to the consumer. Only then will the free market demand for heat pumps and other energy saving technologies be fast and effective. To achieve this, he urged the HVAC industry and utilities to join forces in a spirit of common interest and common sense. They should form a partnership, which in cooperation with regulators and consumers should ensure that DSM and heat pumping technologies benefit everyone. This partnership should, for instance, present accurate and relevant information to consumers, and ensure maximum benefits of the programmes to utilities, the HVAC industry and consumers. Furthermore it should continuously seek and evaluate alternative technical options to further enhance these benefits. The 'easy' DSM actions have already been implemented. The future will be more difficult, and an effective partnership will ensure that new initiatives in this field are realistic, practical and beneficial in a broad sense.

Take the Lead

The role governments and utilities can play, to accelerate the market penetration of heat pumps for energy efficiency and environmental benefits, is large and important. It is encouraging to see how much positive efforts are already undertaken around the globe, both in the national and international arena. However, much work remains to be done before the heat pump will come close to realizing its potential. Summing up the session, **Prof. Frivik** urged the IEA Heat Pump Programme to consider taking the lead in formulating internationally accepted standards for heat pumps.

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Session 8 - Plenary Closing

Bert Stuij & Mike Steadman, IEA Heat Pump Centre

The oral papers presented over the four days, and now summarized by the chairmen of the various sessions, aroused much debate. Indeed, for the uninitiated, it must have come as a surprise to witness just how many contentious issues can arise on the apparently narrow subject of the heat pump. In the final session, chaired by Mr John Ryan of the US Department of Energy, the audience took the chance to debate some of these issues. Should air conditioning be considered a necessity or an unnecessary luxury? Should power generation be made more efficient before promoting the use of heat pumps in developing countries? Why is the market for heat pumps in Europe so small? What are the prospects for natural refrigerants that are toxic or flammable? On what heat pump issues should the IEA concentrate? Some highlights from an animated debate.

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Mr Gilles, of Lennox Industries, USA, argued that the image of air conditioning as a luxury item only is unrealistic, and hampering heat pump sales. In reality, air conditioning has often important benefits which go well beyond luxury, for instance for education and people at work.

Mr Kleefkens of the Dutch Government warned against the rapid introduction of electric heat pumps in developing countries such as China, where the power plant efficiency is very low. The net result will be an increase in CO_2 emissions. He pleaded for the introduction of more efficient electricity generating equipment along with heat pumps.

Participants of the 4th IEA Heat Pump Conference.



On the observed low heat pump penetration in Europe Mr Groff, chairman of the advisory board to the HPC, noted that the European market is bigger than indicated by the statistics, since heat pump sales are often hidden in the figures for air conditioners. Both Dr Halozan of Austria and Prof Frivik of Norway argued that effective collaboration by utilities, governments and the industry is required to accelerate penetration. Mr. Bosma of NOVEM, the Netherlands, highlighted the economic opportunities for heat pumps in European industries.

On the natural refrigerant propane Mr Linton, of the National Research Council of Canada, voiced the views of many North American members of the audience when he argued that the use of flammables in North America is unlikely, due to liability concerns. Prof Frivik stated the Norwegian view, that eventually only those refrigerants should be used, which nature has proven that it can handle - such as hydrocarbons, ammonia, water, and CO_2. Dr Sellberg, from Sweden, suspected that ammonia would find increased application in Sweden. Mr Ryan observed that the working fluid issue may be soon solved in Europe, if the safety aspects of natural refrigerants are adequately controlled and then accepted.

Speaking on the role of the IEA Heat Pump Programme, Prof Frivik made a strong call to deal actively with heat pump standards, since 'standards should not become an area of competition'.

Mr John Ryan concluded the plenary session, thanking all sponsors, organizers, speakers and participants for a valuable conference. He called for comments on the conference, which will be used to make the 5th IEA Heat Pump Conference an even greater success. Closing the conference Mr Floor van Nielen, chairman of the Dutch national organizing committee, expressed gratitude and pride in an excellent conference, which will form the basis for further exchange of knowledge on heat pumps.

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Scandanavian-Style Heat Pumps - The Pre-Conference Tour

Rune Aarlien, Norway

In conjunction with the conference, a five-day tour of heat pumps in Scandinavia was organized in the previous week. Twenty participants from around the world toured the southern parts of Norway and Sweden - at a pace which exhausted even the youngest. Tour leader, Rune Aarlien reports.

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The main consideration in organizing a tour for friends and foreign colleagues, is that they will be able to experience as much as possible. This often means a very tight schedule with little relaxation and very few hours of sleep. Accordingly, this trip was no exception.

The intention of the tour was to create a good balance between sightseeing and technical visits. In Sweden, most of the time was devoted to the heat pumps. The Swedes, with many years of experience in, for instance, heat storage and district heating, offered a series of interesting presentations, and several of the highly advanced installations were thoroughly examined by the group. In addition to the visits to installations in Malmoe and Gothenburg, the group also attended a lecture about current research at the University of Lund.

Enthusiastic participants investigate a heat pump installation in Kungälv, just outside Gothenburg, Sweden.



Olympics

In Norway, the tour was centred around the sites for the 1994 Winter Olympics. The magnificent "Viking Ship" indoor speed-skating rink at Hamar and the impressive rock cavern ice hockey rink at Gjøvik were two of the places that will be well remembered - not only for the technical installations, but also for their architecture and building concepts. In addition, plants in Sarpsborg and Bærum (outside Oslo) were visited.

The participants knew, even before the tour, that heat pumping is an important subject, and upon arrival at Lillehammer the group really believed that the rest of the world had discovered this, too. The group was met by a film crew from the BBC (British Broadcasting Corporation), and most of us began exercising mental preparations for an interview about the benefits of the heat pump to the rest of the world. It is not every day you are given the chance to communicate on an international channel. However, to our disappointment, we found out that the main interest from the BBC crew was neither heat pumps nor the Conference in Maastricht, but the upcoming Winter Olympics. At any rate, the BBC crew did travel with the group while shooting scenes of pre-olympic visitors, and that in itself was fun.

Pleasure

Planning a one week programme for a group of 20 people is a large undertaking, and for a tour like this to be a success, the input of several individuals and organizations is crucial. The organizers, the Norwegian and the Swedish National Teams, would like to deeply thank all of the persons involved for their contributions: everyone from the hosts of lunches and dinners to those receiving us at their plants. Without your help the tour would have been impossible - with your help, the tour was indeed a pleasure to lead.

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Conference Programme

Session 1: Plenary Opening

- **Welcoming address** S. Dessens - Director General for Energy at the Ministry of Economic Affairs, the Netherlands
- **Welcoming address** K. Friedman, IEA, France
- **Keynote address: Environment** R. Shende - UNEP IE/PAC, France
- **Keynote address: Future vision of heat pump technology and global environment** Y. Makise - Mitsubishi Heavy Industries Ltd., Japan

Session 2: Environmental Overview

- **Thermodynamics for the uninitiated; the concept of quality as an important factor in energy policy** B. Kleinbloesem - Sep, the Netherlands
- **CFC/HCFC regulatory update** J. Reed - Evironment, Canada
- **Some key factors in phasing out ozone depleting substances** D. Bivens - DuPont Company, USA
- **Fuel cycle analysis** H. Laue - IZW, Germany
- **Global warming and heat pumps** J. Bouma - IEA Heat Pump Centre, the Netherlands
- **Incentives and the value of avoided environmental problems** T. Jones - OECD, France
- **The heat pump prototype and demonstration programme in Norway** M. Amundsen et al - Norwegian Water Resources and Energy Administration*
- **Heat Pumps in competition with other options for reducing CO_2-emissions** P. Okken et al - ECN, the Netherlands*
- **Heat pumps as means of energy recovery in developing countries** S. Ismail et al - MARA Institute of Technology, Malaysia*

Session 3: New Refrigerant Technology Status

- **Refrigerants of new generation** K. Fujiwara - Daikin Industries Ltd., Japan
- **Perspectives of chlorine-free working fluids for European residential and industrial heat pumps** H. Kruse - University of Hannover, Germany
- **North American efforts to identify replacements for HCFC-22** M. Menzer - ARI, USA
- **Retrofit with new refrigerants** M. Kaneshima - Shimuzu Corporation, Japan
- **Experiences from applications of "new" refrigerants** E. Granryd - Royal Institute of Technology, Sweden
- **The need for and availability of working fluid property data. Results from Annex 13 and Annex 18** L. Vamling - Chalmers University of Technology, Sweden
- **Operational experiences of a centrifugal chiller with heat recovery converted from R12 to R134a** P. Bailer - Sulzer Friotherm A.G., Switzerland*
- **Centrifugal compression and new refrigerant potential** F. Biancardi, United Technologies Research Centre, USA*
- **Heat transfer of zeotropic refrigerant mixtures** D. Bivens et al - Du Pont Fluor Chemicals, Wilmington, USA*
- **Experiences from a 5 MW heat pump using HFC 134a** H. Enström et al - Thermoekonomi, Sweden*
- **Alternative refrigerants to HCFC-22 in air conditioning applications** S. Kondepudi - EPRI, USA*
- **An experimental vapour compression plant for testing R502 'ozone-safe' alternative working fluids** R. Mastrullo et al - Universita of Napoli, Italy*
- **Ammonia in small and medium sized heat pumps** O. Nesje - SINTEF Refrigeration Engineering, Norway*
- **Recent progress in thermodynamic properties research on CFC and HCFC alternative refrigerants at Keio University** K. Watanabe - Keio University, Japan*

Session 4: Technology Advances

- **Heat pumps for widespread use are available today** P. Göricke - RWE Energie AG, Germany

* poster paper

- **Exhaust-air heat pump experiences** M. Fehrm - Elektro Standard, Sweden
- **Integrated heat pump advance in systems and equipment** W. Reedy - Nordyne Inc., USA
- **Advanced control. Control technology for residential air conditioners in Japan** M. Sakamoto - Toshiba Corporation, Japan
- **Process integration of industrial heat pumps** T. Berntsson - Chalmers University of Technology, Sweden
- **An overview of current high-temperature heat pump technology** J. Linton - National Research Council, Canada
- **Capability of centrifugal compressors and demonstrations of systems from 3 ton to over 1000 tons** F. Biancardi et al, United Technologies Research Centre, USA*
- **The design of heat pumps by simulation** Manuel R. Conde et al - M. Conde Engineering, Switzerland*
- **Research and development on heat pumps at DEAF** C. Dispenza et al - University of Palermo, Italy*
- **Contribution to a life cycle energy analysis of Heat Pumps with various evaporator sources** D. Favrat et al, Ecole Polytechnique Fédérale de Lausanne, Switzerland*
- **A new heat transformer operating by 'reverse rectification' for upgrading waste heat & Absorption heat pumps operating at very- high-temperatures (200 -1000°C) for improving the efficiency of power stations** P. le Goff et al - Laboratoir des Sciences du Génie Chimique, France*
- **Heat pumps performance optimization study** M. Hammad et al - University of Jordan, Jordan*
- **Enhancement of heat pumps performance by using radiant heating and cooling panels** B. Kilkis - Heatway Radiant Floors and Snowmelting, USA*
- **Future developments for heat pumps and refrigerating machines in Europe** M. Lallemand et al - INSA Centre de Thermique, France*
- **Performance measures of heat pumps based on the second law of thermodynamics** K. Ozaki et al - Ministry of International Trade and Industry, Japan*
- **A supplier's view on the future heat pump market in Norway** R. Rose - NOVAP, Norway*
- **Development of advanced heat pump for hot water supply** M. Saikawa - Central Research Institute of the Electric Power Industry, Japan*
- **Performance analysis of highly efficient advanced air/air heat pumps** S. Sami, University of Moncton, Canada*
- **Ground-coupled heat pumps with seasonal cold storage** B. Sanner - University of Giessen, Germany*
- **Field analysis of residential engine driven natural gas heat pump in an office application** M. Sasso et al - University of Napoli, Italy*
- **Heat pumps for efficient energy use in industrial processes and for process integration** A. Silva et al - University of Evora, Portugal*
- **Air to hot water heat pumping and air conditioning using thin film heat transfer** D. Stewart - University of New South Wales, Australia*
- **The application of heat pump in low-temperature drying** X. Song et al - The Norwegian Institute of Technology*
- **Test application of 'Super Heat Pump Energy Accumulation System' for new building of Kyushu Electric Power Co.** M. Hukusima et al - Super Heat Pump Energy Accumulation System, Japan*
- **Soil thermal characteristics for designing ground heat pump systems** V. Tarnawski et al - Saint Mary's University, Canada*

Session 5: Markets Electric Driven Heat Pumps

- **An update of the market in Southern Europe** B. Wright - Carrier Ltd., United Kingdom
- **Microprocessor controlled heat pumps, air handling control and remote diagnosis capabilities** R. Lotz - HCF Industries, France
- **Expanding the limits: heat pump technology and markets in North America** A. Lannus - EPRI, USA
- **Market trends and forecasts of electric driven heat pumps in Asia/Japan** Y. Ikomoto - Mitsubishi Heavy Industries Ltd., Japan
- **Electric driven heat pumps in Central and Eastern Europe** J. Zaugg - Kulmbacher Klima Geräte, Germany

* poster paper

- **Heat pumps in energy concepts** T. van Wunnik - KEMA, the Netherlands
- **Optimizing heat pump operation in a small district heating grid** A. Årøen - Ålesund og Sula Energiverk, Norway*
- **Heat pump with ice production from river water Project Seilduksfabrikken A/S** O. Flagstad et al - Det Norske Veritas Industry, Norway*
- **Water loop heat pumps development in supermarkets** R. Lotz - HCF Industries, France*

Session 6: Thermally Driven Heat Pumps

- **Development and market trend of gas engine heat pumps in Japan** S. Sakata - Sanyo Electric Co. Ltd., Japan
- **Heat-operated heat pumps** F. Steimle - University of Essen, Germany
- **Gas-fuelled space conditioning heat pump research in the United States** G. Myers - Gas Research Institute, USA
- **Thermally driven heat pumps: Opportunities in waste driven systems in the tropics** M. Bin Yassin - Tenaga Nasional Berhad, Malaysia
- **First results of the operation of a gas fired 250 kW absorption heat pump** J. Bassols - Colibri Ltd, the Netherlands
- **R&D programme of gas driven heat pumps for domestic use in Japan** S. Yoshida - Japan Gas Association, Japan
- **Steam generating heat transformer** A. Artamo - Ahlstrom Corporation, Finland*
- **Absorption refrigeration cycle aided by compression and an auxiliary fluid** A. Coronas et al - University of Tarragona, Spain*
- **Analysis of an absorption heat pump for industrial utilization** R. Lazzarin et al - University of Padova, Italy*
- **Dynamic simulation of a recuperative absorption heat pump** A. Hajji - Institut Agronomique Hassan II, Marocco*
- **S.W.E.A.T. Thermochemical heat pump storage system** J. Klein Horsman - De Beyer RTB B.V., the Netherlands*
- **Development of a dynamic test rig for heat pumps (emulator)** J. de Wit - TNO Apeldoorn, the Netherlands*
- **Design and performance of an absorption heat transformer test plant** C. Zhuo et al - University of Delft, the Netherlands*

Session 7: Market Influences: Regulatory, Institutional and Governmental

- **State of the standardization work in the field of heat pumps, air conditioning and refrigeration systems** M. Mondot - Cetiat, France
- **Regulations and standards** H. Knipscheer - Linssen Consultancy Ltd, the Netherlands
- **The emerging European certification requirements and plans for implementation of the certification programme** J. Pritchard - York International Ltd., United Kingdom
- **Utilities programme for the promotion of heat pumps** K. Narita - Tokyo Electric Power Co. Ltd., Japan
- **Electric utilities heat pump efficiency incentive programmes** E. Taylor - Kemper Management Service, USA
- **The role of the Commission of the European Communities in supporting and promotion of heat pump technology** D. Reay - David Reay and Associates, United Kingdom
- **Keynote address: Markets** H. Steeg - IEA, France
- **Current status of super heat pump energy accumulation systems** Y. Yoshimura - Ministry of International Trade and Industry, Japan
- **Heat pump technology responding to new opportunities** V. Baxter - Oak Ridge National Laboratory, USA
- **Market for the heat pump in residential and tertiary sectors** J.-P. Moreau - Electricité de France, France
- **Demand side management and heat pump technology. Can both the utility and consumer benefit?** W. Fleming - The Fleming Group, USA
- **Heat pumps in Norway** U. Rivenaes et al - Energy Communication Systems, Norway*

Session 8: Plenary Closing



* poster paper

Standard Practise - A Global Review of Heat Pump Standards

Mohammad Amalfard, Air-Conditioning and Refrigeration Institute, USA

Considering today's global market, it is extremely important to eliminate barriers to trade between countries due to non-harmonized industry standards. Fortunately, this issue has been recognized by industry leaders and standard writing organizations, and a major effort has been made to develop international standards which are acceptable to most countries.

For the heat pump industry, there is clearly a need for further harmonization of standards. This article is based on a paper presented at the joint U.S./ Canadian workshop "Heat Pump Standards for Performance Rating" held in December 1992. It reviews some existing heat pump standards and identifies the differences in terms of rating conditions, test methods, and the performance requirements among the national, regional, and international standards for air-to-air and water-to-air heat pumps.

* * *

Standards are intended for the guidance of the heat pump industry, including manufacturers, installers, purchasers/consumers, and the government. The purpose of a standard is to establish, for a given product:

- definitions and product classification;
- requirements for testing, rating, and performance.

This information will allow manufacturers to rate products on a uniform basis which enables the buyers and users to properly make selections of equipment. A major effort has been made to develop international standards for heat pumps which are acceptable to most countries.

This article covers those standards developed by the ISO (International Organization for Standardization) Technical Committee TC 86, the CEN (European Committee for Standardization) Committee TC 113, the North American bodies ARI (Air Conditioning and Refrigeration Institute (USA)) and CSA (Canadian Standards Association), and the Japanese Standards Association. Table 1 shows the national, regional, and international standards for heat pumps reviewed in this article.

Test Methods

Each region uses a different standards reference:

North America
ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 37, "Methods of Testing for Rating Unitary Air-Conditioning and Heat Pump Equipment".

Europe
SO/R 859, "Testing and Rating Room Air Conditioners".

Japan
Japanese Industrial Standard JIS B8615, "Testing Methods for Unitary Air-Conditioners".

The ISO Draft International Standard for Ducted Equipment includes test methods in its specification.

Table 2 shows the test methods specified in these standards. With the exception of the North American standards for air-to-air heat pumps, which require cyclic tests for certain types and sizes of units, the test methods specified are similar. Not all methods are applicable to all products. Only the Air-Enthalpy Method (for indoor units) is applicable to all product types and standards.

Standard Rating Conditions

All tests set standard conditions for the dry and wet bulb temperatures for the air entering and/or surrounding the indoor unit. In most cases the temperature and humidity conditions are almost identical.

ISO standards specify temperature conditions for units manufactured for "Moderate", "Cool", and "Hot" climates. The conditions for moderate climate correspond closely to North American and Japanese standards.

The North American standards (ARI and CSA) provide test conditions and test methods for Seasonal Energy Efficiency Ratio (SEER), Heating Seasonal Performance Factor (HSPF), and the Integrated Part Load Value (IPLV).

Standards	Description
Air-to-Air Heat Pumps	
ARI 210/240/89	Unitary Air-Conditioning and Air-Source Heat Pump Equipment
CSA-C656-M92	Performance Standard for Single-Package Central Air-Conditioners and Heat Pumps
Draft Standard CEN-255	
Part 4, Dec. 1988	Air/Air Heat Pump Units
JIS B8615-1984	Testing Methods for Unitary Air Conditioners
JIS B8616-1984	Unitary Air Conditioners
ISO DIS Working Draft (WD #4)	
June 16, 1992	Ducted Air-Conditioners and Air-to-Air Heat Pumps, Testing and Rating for Performance
ISO 5151	Non-Ducted Air Conditioners and Heat Pumps, Testing and Rating for Performance
Water-to-Air Heat Pumps	
ARI 320-86	Water-Source Heat Pumps
ARI 325-85	Ground Water-Source Heat Pumps
ARI 330-90	Ground-Source Closed-Loop Heat Pumps
CSA-C446-M90	Performance of Ground and Water-Source Heat Pumps
CSA-C655-M91	Performance Standard for Internal Water-Loop Heat Pumps
Abbreviations	
ARI	Air Conditioning and Refrigeration Institute
CSA	Canadian Standards Association
CEN	European Committee for Standardization
JIS	Japanese Industrial Standard
ISO	International Standard Organization
DIS	Draft International Standard

Table 1: Selected heat pump standards.

Tests

All standards require the following tests:

Cooling

- Standard Rating Conditions Test
- Maximum Operating Conditions Test
- Minimum Operating Conditions Test
- Condensate Disposal Test
- Insulation Efficiency Test

Heating

- Standard Rating Conditions Test
- Maximum Operating Conditions Test
- Frost Accumulation Test

A summary of the required tests for all standards is shown in Table 3.

Seasonal Tests

The North American standards also require cyclic tests for certain types of equipment (air-cooled, single-phase, under 19.0 kW [65,000 Btu/h] heating or cooling at standard rating conditions). The test method for the cyclic tests "Uniform Test Method for Measuring the Energy Consumption of Central Air Conditioners" was developed by the U.S. Department of Energy and mandated by the U.S. government. It provides calculation procedures for SEER and HSPF where:

- **SEER** (Seasonal Energy Efficiency Ratio) is the total cooling output (in Btu) of a central air conditioner during its normal annual usage period for cooling,

divided by the total electric power consumed (in watt-hours) during the same period [multiply by 0.34 to convert to a unitless ratio -ED.]; and

- **HSPF** (Heating Seasonal Performance Factor) is the total heating output of a heat pump (in Btu) - including supplementary electric heat - necessary to meet the building heating requirements during its normal annual usage period for heating, divided by the total electric power in watt-hours consumed during the same period [multiply by 0.34 to convert to a unitless ratio -ED.].

In addition, ARI standards provide rating procedures for part-load rating, and require a voltage tolerance test. Standards ISO 5151 and CEN 255 require a freeze-up test for cooling.

Minimum Efficiency Levels

The CSA standards contain minimum energy efficiency levels for air-to-air and water-to-air heat pumps. Although not covered in ARI standards the U.S. government has also set minimum efficiency levels for certain types of air-to-air unitary products.

New Developments

Efforts have been and continue to be made in harmonizing various standards used in the HVAC industry. For example, two important standards have been published as a result of hard work and cooperation among ARI, U.L. (Underwriters, Laboratories (USA)), HRAI (the Heating, Refrigerating and Air Conditioning Institute of Canada) and CSA (Canadian Standards Association):

- the common CSA/UL safety standard for Heating and Cooling Equipment (CSA-C22.2 No. 236-M90/ UL 1995) and
- CSA/UL standard for Hermetic Refrigerant Motor-Compressors (CSA-C22.2 No. 140.2-M91/UL984).

Table 2: Test methods specified in standards for air-to-air/water-to-air heat pumps.

	North America	Europe	Japan	ISO
Air-Enthalpy Method				
Calorimeter Room Method				
Compressor Calibration Method				
Refrigerant Enthalpy Method				
Outdoor Water Coil Method				

The CSA/UL safety standard was used in the development of a recently published international standard:

- IEC-335-2-40 "Safety of Household and Similar Electrical Appliances; Part 2: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers"

More projects of this kind are underway. Currently ARI and CSA are working to develop a joint ARI/CSA (North American) performance standard for package terminal air-conditioners and heat pumps. Another common U.S./Canadian safety standard (UL998/CSA-C22.2 No. 104-M) is being developed for electric humidifiers. The draft of this standard and a German standard are being used to develop an IEC standard.

On a larger scale ARI is actively involved in the development of international standards and has established a policy of adopting international standards for use in the United States when practical. ISO standard 5151 for non-ducted air-conditioners and heat pumps has been approved for publication and the Draft International Standard for ducted air-conditioners and air-to-air heat pumps is near completion.

Conclusions

Although there are several differences among standards, they do not present serious complications. The temperature conditions, test methods and the required tests are similar and almost identical in many areas. The scope of some standards limit the equipment covered based on capacities, although this does not apply to those considered in this article since these standards cover products rated below 19.0 kW (65,000 Btu/h). The Japanese standards classify equipment according to the function, constitution of units, cooling system of condenser, discharge air system, and the rated cooling capacity, while North American standards classifications are based on the location of the evaporator, compressor and condenser.

Only the North American standards require seasonal ratings, SEER and HSPF. Perhaps, arguments could be made both in favour and against these ratings. However, these ratings are currently mandatory in the United States and Canada. Although the ISO draft for ducted equipment does not include provisions for seasonal ratings it states that "as countries become more concerned with energy conservation and the overall efficiency of equipment, more test information may be required by the laws of a particular country. The rating test at one or two set points may be insufficient and the seasonal and part-load performances, which will give a better indication of the efficiency at actual operating conditions, may be required".

	Air-to-Air						Water-to-Air				
Test	ISO WD#4	CEN 255	ISO 5151	JIS B8615	ARI 210 /240	CSA C656	ARI 320	ARI 325	ARI 330	CSA 655	CSA 446
Cooling											
Std. Rating Conditions	■	■	■	■	■	■	■	■	■	■	■
Std. Rating Conditions (Low Temp.)								■			
Std. Rating Hot Climate	■	■	■								
Std. Rating Cool Climate	■	■	■								
Cyclic Test					■	■					
Freeze-up Conditions		■	■								
Part-Load Conditions					■						
Max. Operating Conditions	■	■	■	■	■	■	■	■	■	■	■
Minimum Operating Conditions	■	■	■	■	■	■	■	■	■		■
Condensate Disposal	■	■	■	■	■	■					
Insulation Efficiency	■	■	■	■	■	■	■	■	■	■	■
Voltage Tolerance					■		■	■	■		
Heating											
Std. Rating Conditions	■	■	■	■	■	■	■	■	■	■	■
Std. Rating Conditions (Low Temp.)								■			
Cyclic Test					■	■					
Low Temperature	■	■	■	■		■					
Extra-Low Temp. Conditions	■	■	■		■	■					
Max. Operating Conditions	■	■	■	■	■	■	■	■	■	■	■
Min. Operating Conditions	■	■	■					■	■		
Frost Accumulation	■	■	■	■	■	■					

Table 3: Standard rating and performance tests. (■ = applicable.)

Working Towards a Common Goal

Continued cooperation of the standard writing organizations from industrialized countries is essential if the common goal of harmonizing all standards used by the industry is to be reached. The harmonization of the regional and national standards must be continued. On the international level, manufacturers and the standard writing organizations alike must actively support and participate in the development of international standards.

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Bibliography

Clear Objectives, Combined Efforts: The Swiss Approach to Energy Efficiency

Federal Department of Transport, Communications and Energy, Berne Switzerland (Tel.: +41-31-615611), 16-pp, Order No. 805.071, (English, French, German, Italian) - free.

This colour brochure describes the scope and objectives of the Swiss government's action programme, Energy 2000 which includes significant measures to support heat pump technology. A summary of the annual report presenting the results of this programme is also available.

JARN HVAC & R Directory 1993

JARN Ltd. (Japan Air Conditioning and Refrigeration News) Fax: +81-3-3584-4708, March 1993, (English).

The 19th edition is now available. It lists over 450 addresses of manufacturers, import/exporters and organizations, plus industrial statistics.

Technology

The 'Peoples Heat Pump' - a Particularly Cost-Effective Absorption Heat Pump (Phase 2)

"`Volkswärmepumpe' im Sinne einer besonders kostengünstigen Absorptionswärmepumpe (Phase 2)", F.W. Diening et al, IZW (Informationszentrum Wärmepumpen+Kaltetechnik), Karlsruhe, Germany (Fax: +49-7247-808134) March 1993, 47 pp, Order No. 0328221B ISSN 0940-3442 (German) - price DEM 20.

The report describes the second phase of a research, development and demonstration programme, supported by the German government, which aims to arrive at a gas-fired absorption heat pump which can compete with an advanced gas boiler. Cost reductions of some 30% were achieved in the course of the programme, and the report concludes that if the units are mass produced (at least 1000 units per year), a unit price of less than DM 300 / kW (USD 200 / kW) can be realized. Government support is necessary to create a market demand of this size.

Compression Cycles for Environmentally Acceptable Refrigeration, Air Conditioning and Heat Pump Systems

Kruse et al, International Institute of Refrigeration, 177, Bd Malesherbes, F-75017, Paris, France (Fax: +33-1-47-631798) 1992, 173 pp (English, French) FRF 240/USD 48.

This publication gives an update on compression cycles which are in use now or which are likely to be developed to meet environmental concerns

Stirling Cycle Heat Pumps and Refrigerators

Per Lundqvist, Royal Institute of Technology, Stockholm, Sweden, April 1993, 284 pp, SKR 200, Swedish.

This thesis uses computer simulation to show that the Stirling cycle is able to compete with the compression cycle at temperature lifts greater than 60°C. The results of the computer program are compared with experimental data from a modified V160 Stirling refrigerator.

Scroll Compressors with Variable Speed

Dr. Thomas Afjei, Swiss Federal Institute of Technology, Zurich, Switzerland, 1993, 150 pp (English) - price CHF 40.

With increasing interest in the potential of variable-speed for improving heat pump performance, this report gives a timely examination of the characteristics of an inverter and hermetic scroll compressor working at various load conditions and speeds. Models are developed to describe the main losses and leakage mechanisms in the compressor, and the effect of liquid injection (wet compression process) is explained in detail. The investigations show that variable-speed heat pumps suffer a loss in efficiency during steady-state operation due to the additional inverter losses. This handicap, however, is compensated during dynamic operation due to the avoidance of the heat pump's on/off losses and the heating system's mixing losses.

The Heat Transformer - an introduction

'De warmtetransformator - een introductie', Bert Stuij (IEA Heat Pump Centre), ENERGIE CONSULENT - magazine for the Association of Energy Consultants, March 1993, 4-8, (Dutch).

Originally written as a presentation to the Dutch Association of Energy Consultants, the paper explains the thermodynamic concept of the heat transformer, and shows how this concept can be realized in practice. The state-of-the art is reviewed, and notable developments such as high-temperature working fluids and double-stage processes are highlighted. The paper concludes that the use of heat transformers is environmentally beneficial, and that its use of waste heat 'is energy efficient, exergy efficient and in a number of cases economically efficient'. The paper is currently in Dutch, but English copies can be made available by the Heat Pump Centre.

Theoretical Evaluation of R22 and R502 Alternatives

P. Domanski and D. Didion, National Institute of Standards and Technology (NIST), January 1993, Order No. RDB3305, 32 pp (English) - price USD 2.

Dr. Piotr Domanski and Dr. David Didion utilized a heat pump simulation program (CYCLE-11) and a thermodynamic properties database (REFPROP) to compare the theoretical thermodynamic performance of nine HCFC-22 and three R-502 candidate substitutes. Simulations were conducted for "drop-in" performance, performance in a modified system, and performance in a modified system with a liquid-line/suction-line heat exchanger.

The performance of the HCFC-22 alternatives evaluated in the study are compared in Figure 1. The simulations modelled a residential heat pump at four typical operating conditions (two for cooling and two for heating). Not shown are capacities, which were generally lower than HCFC-22 for those refrigerants whose COPs were higher, and higher for fluids whose COPs were lower.

The report is available from the ARTI Database, c/o James M. Calm, Engineering Consultant, 10887 Woodleaf Lane, Great Falls VA 22066, USA.

Proceedings

Heat Pumps for Energy Efficiency and Environmental Progress (4th IEA Heat Pump Conference)

600 pp, ISBN: 0 444 81534 1 (English) - price NLG 300.

A valuable record of most of the oral and poster papers presented at the 4th IEA Heat Pump Conference. Missing papers are available from the HPC.

To order the proceedings contact: van Namen and Westerlaken Congress Organization Services, P.O. Box 1558, 6501 BN Nijmegen, The Netherlands. Tel.: +31-80-234471; Fax: +31-80-601159.

Heat Pump Standards for Performance Rating

Caneta Research Inc., 6981 Millcreek Drive, Unit 28, Mississauga, Ontario, Canada L5N 6B8, January 1993, 109 pp (English) - USD 35/CAD 45.

These proceedings record the joint U.S./Canadian workshop held in December 1992. The five position papers are reproduced alongside summaries of the group discussions.

The Impact of Heat Pumps on the Greenhouse Effect

IEA HPC, 1993, Order No. HPC-WR10, 196 pp (English) - price NLG 80.

This Workshop Report includes all the papers presented at the workshop held in October 1992 on the HPC's analysis of the same name. In addition, the subsequent discussions are summarized during which participants examined possible actions to increase the use of heat pumps for environmental benefit.

IEA Heat Pump Programme

Domestic Hot Water Heat Pumps for Residential and Commercial Buildings

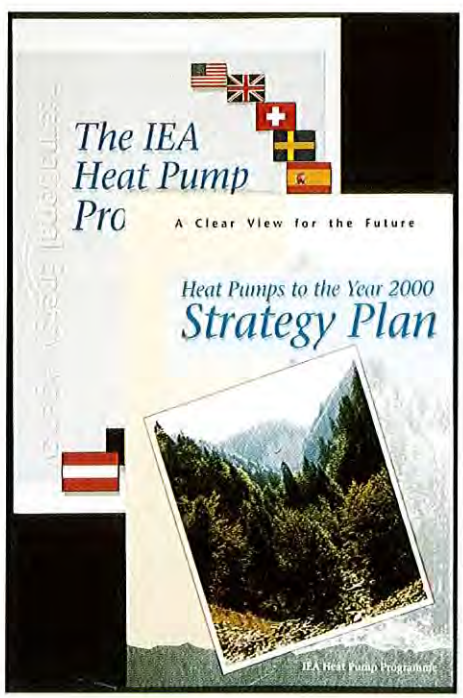
IEA HPC, April 1993, Order No. HPC-AR2, 115 pp (English) - price NLG 80.

This latest Analysis Report from the HPC reviews the current status of hot water heat pump equipment, performance, applications and manufacturers. It suggests that with some improvement in the economic conditions which restrict their use today, hot water heat pumps could become far more widespread, especially for integrated space conditioning and water heating systems.

Brochures on Programme Activities and Strategy

IEA HPC/TSSU, 1993, English - free.

In a drive to generate more interest in IEA Heat Pump Programme activities, two brochures have been released. Both brochures are available from the IEA Heat Pump Centre. **'IEA Heat Pump Programme'** gives general information on the Programme's structure, activities and accomplishments. It serves as an introduction to potential newcomers to the Programme as well as informing current participants who may not be aware of the Programme's wider activities. **'Heat Pumps to the Year 2000'** outlines the management philosophy of the Programme as has been set out in the Strategy Plan which was adopted in 1992. This brochure shows potential participants how Programme activities are guided by a set of strategies so that they serve targets and objectives.



Conferences

*Call for Papers

Chinese International Compressor Technique Conference and Exhibition
August 15-18, 1993 / Xi'an (China)
Contact: Danqing Wu, Associate Professor, Room 227, Chemical Engineering Building, Xi'an Jiatong University, 28 Xian Ning Road, Xi'an, 710049, P.R. China.
Tel.: +0086-29-335011 Ext. 3980; Fax: +0086-29-337910.

2nd International Conference on Heat Pumps in Cold Climates
August 16-17, 1993 / Moncton, New Brunswick (Canada)
Contact: Mr Douglas Cane, CANETA Research Inc., 6981 Millcreek Dr., Unit 28, Mississauga, Ontario, L5N 6B8, Canada.

ASHRAE/NIST Refrigerants Conference: R22/R502 Alternatives
August 19-20, 1993 / Gaithersburg, MD (USA)
Contact: J. Richard Wright, Director of Technology, ASHRAE, 1791 Tullie Circle, NE Atlanta, GA 30329, USA.
Tel.: +1-404-636-8400; Fax: +1-404-321-5478.

4th International Workshop on Heat Pump Reseach and Applications: Energy, Economy and Environment
August 29-31, 1993 / Prague (Czech Republic)
Organized by the European Federation of Chemical Engineering
Contact: CHISA '93, P.O. Box 857, Cs-111 21 Prague, Czech Republic.
Tel.: +422-311-61-38; Fax: +422-311-55-29.

14th AIVC Conference - Energy Impact of Ventilation and Infiltration
September 21-24, 1993 / Copenhagen (Denmark)
Contact: IEA Air Infiltration and Ventilation Centre, Barclays Venture Centre, Sir William Lyons Road, Coventry CV4 7EZ, UK.
Tel.: +44-203-692-050; Fax: +44-203-416-306.

3rd ABOK Congress
September 22-25, 1993 / Moscow (Russia)
Contact: ABOK (the Association of Engineers for Heating, Ventilation, Air-Conditioning, Heat Supply and Building Thermal Physics), at Russia, Moscow, 103754, Rozhdestvenka str. 11, MARHI. ABOK.
Tel./fax: +7-095-965-3924.

Course on Absorption Heat Pumps and Chillers: Theory and Computer Simulation
October 7-8, 1993 / College Park, MD (USA)
Contact: Gwen Saunders, University of Maryland, College Park, MD 20742, USA.
Tel.: +1-301-405-3883; Fax: +1-301-403-4105.

Energex '93 - The 5th International Energy Conference
October 18-22, 1993 / Seoul (Republic of Korea)
Contact: Energex '93 Secretariat, c/o the Korean Institute of Reseaarch, P.O. Box 77, Taedok Science Town, Taejon 305-343, Republic of Korea.
Tel.: +83-42-861-6230; Fax: +83-42-861-6231.

Meeting Customer Needs with Heat Pumps - 1993
October 20-22, 1993 / New Orleans, LA (USA)
Contact: Pam Turner, EPRI, P.O. Box 10412, Palo Alto, CA 94303, USA.
Tel.: +1-415-855-2010.

Clima 2000
November 1-3, 1993 / London (UK)
Organized on behalf of the Federation of European Heating and Ventilation Associates
Contact: Anne Gibbins, CIBSE headquarters, 222, Balham High Road, London SW12 9BS, UK.
Tel.: +44-1-81-6755211; Fax: +44-1-81-6755449.

Symposium on Heat Pump Design, Analysis and Application (1993 ASME Winter Annual Meeting).
November 28 - December 3, 1993 / New Orleans, LA (USA)
Contact: Karen R. DenBraven.
Tel.: +1-208-885-7655; Fax: +1-208-885-9031.

International Absorption Heat Pump Conference '94
January 19-21, 1994 / New Orleans, LA (USA)
Contact: IAHPC '94 Conference Secretary, Mechanical Engineering Dep't, University of Maryland, College Park, Maryland 20742-3035, USA.
Fax: +1-301-314-9477.

1994 Winter ASHRAE Meeting and Exhibition
January 22 - 26, 1994 / New Orleans, LA (USA)
Contact: ASHRAE Meetings Department, 1791 Tullie Circle, NE Atlanta, GA 30329, USA.
Tel.: +1-404-636-8400 Fax: +1-404-321-5478.

Cold Climate HVAC '94
March 15-18, 1994 / Rovaniemi (Finland)
Organized by FINVAC, the Federation of Societies of Heating, Air-Conditioning and Sanitary Engineers in Finland.
Contact: Mr Ilpo Nousiainen, FINVAC/Cold Climate HVAC '94, Sitratori 5, SF-00420 Helsinki, Finland.
Tel: +358-0-563-3600, Fax: +358-0-566-5093.

***Calorstock '94 - 6th International Conference on Thermal Energy Storage**
August 22-25, 1994 / Otaniemi, Espoo (Finland)
Deadline for Abstracts: August 15, 1993
Contact: Mr Markku Kanfas, Helsinki University of Technology, Department of Technical Physics, Otakaari 3, 02150 Espoo, Finland.
Tel.: +358-0-451-3212; Fax: +358-0-451-3195.

Annual Conference of the International District Heating and Cooling Association (IDHCA)
June 18-22, 1994 / Seattle, WA (USA)
Contact: Ms. C. Millunzi IDHCA, 1101 Connecticut Ave. N.W., Suite 700, Washington D.C., 20036, USA.

Future Issues

Vol./No.	*Topic*	*Deadlines*
11/3	Heat Pumps and the Environment	
11/4	Trends in Heat Pump Technology & Applications	**1 September 1993**
12/1	Heat Pump Working Fluids (including Alternative Refrigerants)	**1 December 1993**

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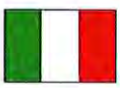
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